JOINT MONITORING PROGRAM IN THE CHUKCHI AND BEAUFORT SEAS, JULY–NOVEMBER 2006

By

Alaska Research Associates, Inc.

LGL Limited, environmental research associates
Greeneridge Sciences, Inc.
Bioacoustics Research Program, Cornell University
Bio-Wave, Inc.

FOR

Shell Offshore Inc.
ConocoPhillips Alaska, Inc.
GX Technology

and

National Marine Fisheries Service
United States Fish and Wildlife Service

November 2007

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LIST OF ACRONYMS AND ABBREVIATIONS

~	approximately
AASM	Airgun Array Source Model
AEWC	Alaska Eskimo Whaling Commission
Bf	Beaufort Wind Force
BO	Biological Opinion
CAA	Conflict Avoidance Agreement
CFR	(U.S.) Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species
cm	centimeter
CPA	Closest (Observed) Point of Approach
CPAI	ConocoPhillips Alaska, Inc.
CTD	conductivity, temperature, depth
dB	decibel
EA	Environmental Assessment
EFD	Energy Flux Density
ESA	(U.S.) Endangered Species Act
$f(0)$	sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width)
ft	feet
FRC	Fast Rescue Craft
GI	Generator Injector
GIS	Geographic Information System
GMT	Greenwich Mean Time
GPS	Global Positioning System
$g(0)$	probability of seeing a group located directly on a survey line
h	hours
hp	horse power
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under U.S. MMPA)
in^3	cubic inches
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour
kt	knots
L-DEO	Lamont-Doherty Earth Observatory (of Columbia University)
LoA	Letter of Authorization
μPa	micro Pascal
m	meters
MBB	Multibeam Bathymetric (sonar)
MCS	Multi-Channel Seismic

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

EXECUTIVE SUMMARY

Introduction and Report Objectives (Chapter 1)

This report describes the studies conducted as part of the Joint Monitoring Program (JMP) funded by Shell Offshore Inc. (SOI), ConocoPhillips Alaska Inc. (CPAI), and GX Technology (GXT) in the Chukchi and Beaufort seas in 2006. These studies were designed to monitor marine mammal abundance, distribution, and behavior and determine the potential effects of offshore seismic exploration activities on marine mammals. Studies included marine mammal monitoring and mitigation around the seismic source vessels, an acoustic program using arrays of bottom-founded recorders deployed along the Alaskan Chukchi Sea coast, dedicated vessel-based surveys with and without passive acoustic monitoring (PAM) in the Chukchi Sea Planning Area, and an aerial monitoring program over the nearshore waters and Chukchi Sea coastline between Pt. Hope and Barrow. In addition to the studies conducted in the Chukchi Sea, SOI also conducted some limited acoustic studies and aerial monitoring in the Beaufort Sea in the general area of their operations. In 2006, sea-ice conditions in the Beaufort Sea limited SOI's operations to shallow hazards surveys and other site clearance activities. Acoustic studies conducted by SOI were primarily used to test newly developed equipment for monitoring marine mammals (primarily bowhead whales) and industrial sounds in the Beaufort Sea. Aerial surveys were limited in the central Beaufort Sea to nine surveys due to weather and changes in SOI's planned seismic program.

Data from several additional sources were also taken into account when possible. The Minerals Management Service (MMS) conducts aerial surveys of bowhead whales in the Beaufort Sea on an annual basis. These data for 2006 were made available in mid-Apr. 2007 and were incorporated to the extent possible in this report. The National Science Foundation (NSF) and the Minerals Management Service (MMS) conducted bowhead whale feeding studies east of Barrow, Alaska, and the JMP participants agreed to perform aerial surveys over the study area offshore of Barrow to supplement the results of the NSF - MMS surveys. Data from these aerial surveys are presented in an appendix of this report.

Individual chapters in this report describe the various types of industry activities in the Chukchi and Beaufort seas during 2006, and provide detailed descriptions of the results of studies included in the JMP. To the extent possible this report integrates the studies conducted as part of the JMP into a broad-based assessment of industry activities and their impacts on marine mammals in the Chukchi and Beaufort seas during 2006. This report also summarizes other human activities that occurred in the region unrelated to the offshore seismic exploration including barging, drilling island construction, oil production, and subsistence whaling activities.

Industry and Other Human Activities (Chapter 2)

In the Chukchi Sea, SOI, CPAI, and GXT used towed airgun arrays which emitted sound energy into the water to collect seismic data. This sound had the potential to cause disturbance or injury to marine mammals and as part of the permitting process SOI, CPAI, and GXT requested and received Incidental Harassment Authorizations (IHAs) from the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) which authorized non-lethal "takes" of marine mammals incidental to the seismic operations. Prior to collecting seismic data the sound pressure levels (SPLs) produced by the airgun arrays for each seismic vessel were measured to determine appropriate safety radii to be used for mitigation during seismic acquisition.

SOI's seismic acquisition began on 27 July 2006 and continued through most of the field season until 19 Sept. SOI then determined that ice conditions and other operational considerations precluded continuation of the exploration program or a transition of the program into the Beaufort Sea, and seismic activities were terminated. During SOI's seismic surveys one or more airguns were firing during ~5297.4 km (3291.7 statute mi) of survey line in the Chukchi Sea in 2006.

CPAI's seismic acquisition also began on 27 July 2006 and continued through most of the field season until 6 Oct. CPAI then determined that ice conditions and other operational considerations precluded continuation of the exploration program, and seismic activities were terminated. During CPAI's seismic surveys, one or more airguns were firing during ~16,028 km (9959 statute mi) of survey line in the Chukchi Sea in 2006.

GXT's seismic acquisition began on 13 Oct. 2006 and continued through most of the period until 11 Nov. when the airguns and streamer were retrieved. During GXT's seismic surveys in the Chukchi Sea in 2006, one or more airguns were firing during ~4707 km (2924 statue mi) of survey line.

In addition to the vessel traffic associated with the seismic activities in the Chukchi Sea in 2006, other vessel traffic included barging activities in Aug. and Sept. The U.S. Coast Guard icebreaker Healy also transited the Chukchi Sea in July and on its return voyage in Aug. Subsistence whaling activities occurred at Point Lay in July, and at Wainwright in May. Limited boat activity associated with subsistence whaling also occurred off Point Hope in the fall.

In the Beaufort Sea, SOI's activities were restricted to shallow hazard and site clearance surveys using various geophysical methods and tools (including a small airgun array) to acquire graphic records of seafloor and sub-seafloor geologic conditions. The SPL produced by the airgun array was measured on 8 Aug. Site clearance survey activities occurred on ~23 days from 8 Aug. to 2 Oct. However, during that period the airgun cluster was operated only once for ~12 hr on 25 Sept. At all other times during surveys, the acoustical sources in use were lower-energy, medium- and high-frequency sources.

Other industry activities in the Beaufort Sea included construction of an offshore, gravel drilling island near the Colville River delta by Pioneer Natural Resources (PNR), oil production activities at Northstar Island by BP Exploration Alaska Inc. (BP), and barging activities at various locations between Barrow and Kaktovik. Aerial and acoustic monitoring studies were conducted in support of PNR's and BP's activities, and marine mammal observers (MMOs) were used in support of some barging activities. These studies are discussed in Chapter 11. Other monitoring activity in the Beaufort Sea included annual aerial surveys conducted by the MMS during the fall to monitor the distribution and abundance of bowhead whales. The MMS also conducted vessel based research to collect water, sediment, and biota samples for physical and chemical analyses. Subsistence whaling activities in the Beaufort Sea occurred at Barrow during both the spring and fall, and at Cross Island and Kaktovik during the fall.

Chukchi Sea Vessel-based Monitoring (Chapter 3)

This chapter describes the vessel-based monitoring tasks that were conducted to ensure that the provisions of the IHAs were satisfied. The visual monitoring methods that were implemented during the seismic programs were very similar to those used during many previous seismic cruises conducted under IHAs since 2003. Data collected during all three seismic programs for SOI, CPAI, and GXT were combined into a single data set and analyzed. In addition to data from the seismic vessels, all marine mammal observations made from support vessels were also analyzed to provide a comprehensive analysis of MMO sighting data during the 2006 open water season.

Observer effort and marine mammal sightings were divided into several analysis categories related to "useability", vessel characteristics, and environmental variables (seasonality, and proximity to shore and ice, weather conditions, and visibility). The useability of data depended on vessel-based factors including seismic activity and ship speed. Observer data were used to determine the distribution, abundance, and behavior of marine mammals in the project area. The data were also used to determine the potential effects of seismic operations on marine mammals by estimating the number of marine mammals that may have been exposed to SPLs at 190, 180, 170 and 160 dB.

The estimated numbers of cetaceans that might have been exposed to various levels of received seismic sounds and the number of exposures for per individual are summarized in Table ES.1. The estimated numbers in Table ES.1.A represent the cetaceans that would have been exposed to various SLPs had no animals shown localized avoidance of the airguns or of the seismic and support vessels. It is likely that many of the animals estimated (based on non-seismic densities) to have been within the ≥180- or ≥190-dB zones may have moved away before being exposed to sounds at those levels. That expectation was corroborated by the lower densities and lower estimated numbers of exposed individuals when the calculations were based on densities for seismic periods (Table ES.1.B).

TABLE ES.1. Estimated numbers of individual cetaceans ensonified at different SPLs, and average number of exposures per individual in both the nearshore and offshore regions, using ***(A)*** Non-seismic densities, and ***(B)*** Seismic densities, from useable[a] data recorded from chase vessels. Estimates in (A), based on non-seismic densities, undoubtedly overestimate actual numbers of cetaceans exposed to high-level sounds, given that cetaceans commonly avoid approaching seismic vessels.

	Nearshore		Offshore		Total	
Exposure level in dB re 1 µPa (rms).	Individuals	Exposures/ individual	Individuals	Exposures/ individual	Individuals	Exposures/ individual
Cetaceans						
A. Non-seismic density						
≥160	38	1.1	4144	4.2	4183	4.1
≥170	16	1.0	2296	3.7	2312	306
≥180	6	1.0	1038	2.8	1044	2.8
≥190	2	1.0	450	2.1	452	2.1
B. Seismic density[b]						
≥160	2	1.1	307	5.0	309	5.0
≥170	1	1.0	177	4.5	178	4.5
≥180	0	1.0	83	3.3	83	3.3
≥190	0	1.0	39	2.3	39	2.3

[a] See *Useability Criteria* in *Methods* section in the Chapter

[b] The offshore seismic density was used in both the nearshore and offshore calculations

Table ES.2 summarizes the number of pinnipeds potentially ensonified at different SPLs. Unlike cetacean densities, pinnipeds densities during seismic periods as recorded from the chase vessels were greater than pinnipeds densities estimated during non-seismic periods. This implies that pinnipeds may have had a localized avoidance of, or alteration in behavior near, operating seismic vessels, resulting in greater densities in the 1 to 15 km range around operating seismic vessels where the chase vessels typically operated. However, sample sizes for these analyses were small.

TABLE ES.2. Calculated numbers of pinniped individuals ensonified at different SPLs, and average number of exposures per individual in both the nearshore and offshore regions, using ***(A)*** Non-seismic densities, and ***(B)*** Seismic densities, from useable[a] data recorded from chase vessels.

	Nearshore		Offshore		Total	
Exposure level in dB re 1 µPa (rms).	Individuals	Exposures/ individual	Individuals	Exposures/ individual	Individuals	Exposures/ individual
Pinnipeds						
A. Non-seismic density						
≥160	34	1.0	14,803	5.6	14,836	5.6
≥170	14	1.0	8519	4.3	8532	4.3
≥180	5	1.0	4044	3.1	4048	3.1
≥190	2	1.0	1906	2.1	1908	2.1
B. Seismic density[b]						
≥160	110	1.0	25,053	7.2	25,163	7.2
≥170	45	1.0	14,851	5.4	14,896	5.4
≥180	16	1.0	7531	3.7	7547	3.7
≥190	6	1.0	3936	2.3	3941	2.3

[a] See *Useability Criteria* in *Methods* section in the Chapter
[b] The offshore seismic density was used in both the nearshore and offshore calculations

Dedicated Vessel-based Marine Mammal Surveys (Chapter 4)

In a joint effort by SOI, CPAI, and GXT, marine mammal distribution data were collected in the Chukchi Sea during five dedicated transect surveys, three of which also used passive acoustic monitoring (PAM) to monitor whale vocalizations during the surveys. Surveys were conducted between July and Oct. 2006. The data collected during the dedicated surveys provided baseline information on marine mammal distribution and abundance in areas unaffected by seismic activity. The dedicated surveys occurred in the Chukchi Sea MMS OCS Planning Area designated as Chukchi Sea Sale 193 (1989).

Two survey vessels, the *Torsvik* and *Gulf Provider*, were used to conduct the surveys. The vessels followed a systematic survey route composed of ten 50 n.mi. transects forming a sawtooth pattern during each of five dedicated marine mammal surveys, weather and ice permitting. Visual monitoring methods similar to NMFS protocols were used for the dedicated surveys. Standard methodologies for visual searching during ship surveys were followed in order to use line-transect methods for analysis of the data.

The PAM system was operated by two experienced bio-acousticians. They deployed the towed array, operated the acoustics processing system, and monitored sounds received by the towed array visually and aurally during survey effort. PAM operations were typically conducted from early morning to late evening coincident with visual survey effort.

The visual observers collected data on the occurrence, distribution, and abundance of marine mammals in the Chukchi Sea. Marine mammal sightings during each dedicated survey are summarized in Table ES.3. An estimated 564 individual marine mammals were seen in 432 groups in the Chukchi Sea study area.

Ice conditions during much of the 2006 field season consisted of a band of pack ice (>10% ice cover) from the shore to ~20 to 40 km offshore between Barrow and Wainwright. West and south of this band of ice the waters were open with 0% ice cover. Persistent sea ice in the Planning Area greatly affected the locations that were surveyed. This resulted in much of the survey effort occurring closer to shore and to the ice pack than was planned.

Gray whale was the most abundant cetacean species in both number of sightings and individuals (Table ES.3). Nearly as many beluga as gray whale individuals were recorded although there was only one beluga sighting which was not recorded during useable conditions. Numbers of sightings and individuals of other cetacean species were reduced compared to gray and beluga whales. Of the pinnipeds species positively identified to species, ringed seal was the most abundant in both number of sightings and individuals. Ringed seal was followed in abundance by bearded seal, spotted seal, and Pacific walrus, respectively.

The greatest estimated pinniped density (491.4/1000 km^2) was recorded on alternate transects during the mid-season when the survey vessels transited near the ice edge. The estimated pinniped density was also relatively high on transect during the late season 433.6/1000 km^2) when the survey vessels did not operate near ice. Many of the late season, on transect observations were made in open water in the southwest portion of the survey area. The relatively high pinniped density in open water during the late season may have resulted from the movement of seals toward the Bering Sea during fall migration. The overall pinniped density on transect for all seasons combined was relatively low (201.5/1000 km^2).

Passive acoustic monitoring effort was conducted for a total of ~150 h, during 19 survey days for all three surveys aboard the *Torsvik* in July, Sept., and Oct. Included in this total was transit effort from Dutch Harbor to the primary Chukchi Sea study area for the first survey and short periods of transit from coastal villages at the beginning or end of subsequent surveys. No marine mammal vocalizations were detected with PAM during any of the three surveys in 2006.

TABLE ES.3. Numbers of sightings and of individual marine mammals, ***(A)*** total and ***(B)*** useable, observed in the Chukchi Sea study area during the dedicated surveys from Jul. to Oct. 2006.

	Survey 1		Survey 2		Survey 3		Survey 4		Survey 5		*All*	
	Det.	**Indiv.**	**Det.**	**Indiv.**	**Det.**	**Indiv.**	**Det.**	**Indiv.**	**Det.**	**Indiv.**	**Det.**	**Indiv.**
A. All Sightings												
Cetaceans												
Unidentified Whale	0	0	1	1	3	5	0	0	0	0	***4***	***6***
Beluga Whale	0	0	1	30	0	0	0	0	0	0	***1***	***30***
Harbor Porpoise	0	0	0	0	1	3	0	0	2	5	***3***	***8***
Bowhead Whale	0	0	1	5	0	0	0	0	1	1	***2***	***6***
Gray Whale	1	2	1	30	3	5	1	1	0	0	***6***	***38***
Minke Whale	0	0	0	0	1	1	0	0	0	0	***1***	***1***
Total Cetaceans	***1***	***2***	***4***	***66***	***8***	***14***	***1***	***1***	***3***	***6***	**17**	**89**
Pinnipeds in Water												
Unidentified Pinniped	0	0	1	1	0	0	3	3	1	1	***5***	***5***
Pacific Walrus	1	1	6	7	0	0	10	18	2	2	***19***	***28***
Bearded Seal	0	0	17	18	17	17	6	6	9	9	***49***	***50***
Ringed Seal	0	0	0	0	37	47	0	0	25	26	***62***	***73***
Spotted Seal	1	1	12	14	1	1	14	16	2	2	***30***	***34***
Unidentified Seal	3	3	70	88	123	132	28	35	25	25	***249***	***283***
Pinnipeds on Ice												
Pacific Walrus	1	2	0	0	0	0	0	0	0	0	***1***	***2***
Total all Pinnipeds	***6***	***7***	***106***	***128***	***178***	***197***	***61***	***78***	***64***	***65***	**415**	**475**
Total Unidentified Pinnipeds	*0*	*0*	*1*	*1*	*0*	*0*	*3*	*3*	*1*	*1*	**5**	**5**
Total all Pacific Walrus	*2*	*3*	*6*	*7*	*0*	*0*	*10*	*18*	*2*	*2*	**20**	**30**
Total Seals	*4*	*4*	*99*	*120*	*178*	*197*	*48*	*57*	*61*	*62*	**390**	**440**
B. Useable[a] Sightings												
Cetaceans												
Unidentified Whale	0	0	0	0	1	2	0	0	0	0	***1***	***2***
Beluga Whale	0	0	0	0	0	0	0	0	0	0	***0***	***0***
Harbor Porpoise	0	0	0	0	1	3	0	0	1	2	***2***	***5***
Bowhead Whale	0	0	1	5	0	0	0	0	1	1	***2***	***6***
Gray Whale	1	2	1	30	3	5	1	1	0	0	***6***	***38***
Minke Whale	0	0	0	0	1	1	0	0	0	0	***1***	***1***
Total Cetaceans	***1***	***2***	***2***	***35***	***6***	***11***	***1***	***1***	***2***	***3***	**12**	**52**
Pinnipeds in Water												
Unidentified Pinniped	0	0	1	1	0	0	3	3	0	0	***4***	***4***
Pacific Walrus	0	0	5	6	0	0	7	12	1	1	***13***	***19***
Bearded Seal	0	0	17	18	13	13	6	6	8	8	***44***	***45***
Ringed Seal	0	0	0	0	30	39	0	0	21	22	***51***	***61***
Spotted Seal	0	0	11	11	1	1	11	13	2	2	***25***	***27***
Unidentified Seal	1	1	69	86	112	121	27	34	22	22	***231***	***264***
Pinnipeds on Ice												
Pacific Walrus	1	2	0	0	0	0	0	0	0	0	***1***	***2***
Total all Pinnipeds	***2***	***3***	***103***	***122***	***156***	***174***	***54***	***68***	***54***	***55***	**369**	**422**
Total Unidentified Pinnipeds	*0*	*0*	*1*	*1*	*0*	*0*	*3*	*3*	*0*	*0*	**4**	**4**
Total all Pacific Walrus	*1*	*2*	*5*	*6*	*0*	*0*	*7*	*12*	*1*	*1*	**14**	**21**
Total Seals	*1*	*1*	*97*	*115*	*156*	*174*	*44*	*53*	*53*	*54*	**351**	**397**

Chukchi Sea Nearshore Aerial Surveys (Chapter 5)

Aerial surveys of marine mammals during the open-water season in the Chukchi Sea were conducted to gather information on current marine mammal distribution and abundance. The surveys focused on beluga, bowhead, and gray whales, although other marine mammals were recorded if observed.

The aerial survey study area extended from Barrow to Point Hope and from the mainland coast to ~37 km (~20 n. mi) offshore. Within this study area two series of systematic transects were flown. The "sawtooth" surveys provided broad-scale survey coverage of the nearshore waters. The "coastline" surveys provided additional opportunities to detect mammals in the area adjacent to the coastline, including lagoons where most of the subsistence hunting occurs. The surveys were conducted twice per week from 9 July to 12 Nov. 2006 using a standard survey route, weather permitting. No surveys were flown from 26 July to 22 August due to logistical constraints. A total of 25 surveys were attempted and substantial or complete survey coverage was obtained on 18 (72%) of both the coastline and sawtooth surveys. For analysis purposes the data were divided into early (before 25 Sept.), mid- (25 Sept. to 25 Oct.), and late (after 25 Oct.) seasons.

Sighting rates and numbers of individuals were greatest for beluga whales, bowhead whales, and Pacific walrus on the coastline surveys, during the early season followed by the late and mid-seasons, respectively. Gray whale, sighting rates and numbers of individuals were greatest during the early season followed by the mid-season. No gray whales were observed during the late season. The estimated number of beluga whales within the coastline survey area ranged from zero to 508 whales (on 9 July). The estimated numbers of bowhead whales ranged from zero to 162 (on 20 July), and for gray whales from zero to 47 (on 14 Oct.).

During the sawtooth surveys, sighting rates and number of individuals for beluga and bowhead whales were greatest during late season. Sighting rates and number of individuals were greatest during the early season for gray whale and Pacific walrus during the sawtooth surveys. Based on these data the estimated number of beluga whales within the study area ranged from zero to 1131 (on 10 July). The estimated number of bowhead whales within the study area ranged from zero to 1544 (on 11-12 Nov.), and the estimated number of gray whales ranged from zero to 602 (on 10 July).

Beluga whales were sighted throughout the study area during the early, mid-, and late seasons, with most sightings occurring north of 69° N latitude. Beluga whales sighted during the study period were usually close to shore in relatively shallow water. However, there were sightings out to the 50 m depth contour. Bowhead whales were found in the northern portion of the study area during all three seasons, with all sightings occurring north of 70° N latitude. Bowheads sighted during the study period were between the 10 m and 100 m depth contours. Gray whales were sighted in the central portion of the study area during the early and mid-seasons, with most sightings occurring between Cape Lisburne (68°50' N latitude) and Icy Cape (70°20' N latitude). No gray whales were observed after 25 October. Nearly all gray whales were seen in relatively nearshore waters, between the 5 m and 20 m depth contours.

Passive Acoustic Monitoring of Marine Mammals in the Chukchi Sea (Chapter 6)

The Bioacoustics Research Program at the Cornell Laboratory of Ornithology (BRP) deployed equipment and provided technical field support to obtain acoustic recordings from representative areas of the Chukchi Sea region from Pt. Barrow to Cape Lisburne, Alaska from 15 July through 15 October 2006. The primary objectives of the field and data analysis efforts were to detect the occurrence and approximate offshore distributions of bioacoustically active beluga whales (*Delphinapterus leucas*) and bowhead whales (*Balaena mysticetus*), measure and characterize ambient noise, document the occurrences of seismic airgun array events, and measure the received levels of seismic airgun array events for 79 selected time periods from late summer to early fall.

The bioacoustic data gathered by BRP instrumentation and processed by BRP analysts were viewed as a critical piece in the overarching task of objectively documenting, as best as possible given the challenging field conditions, the potential impact of industry seismic activities upon the acoustic environment and the prevailing patterns of wildlife distribution in relation to seismic activities. The interpretation of behavioral responses by whales to seismic sounds is included elsewhere in this Comprehensive Report and is not part of this chapter.

The field effort occurred in two phases: Phase I from 15 July through 10 September 2007, when marine autonomous recording units, referred to as "pop-ups" were deployed and configured to collect beluga whale calls, and Phase II from 10-17 September through 12-15 October 2007, when pop-ups were deployed and configured to collect bowhead whale calls. For Phase I, due to extensive ice cover, only five pop-ups were deployed and recovered off Cape Lisburne, yielding a total of 2,282 recording hours covering a total of 285 pop-up recording days. In Phase II, four sets of five pop-ups were deployed off Cape Lisburne, Pt. Lay, Wainwright and Pt. Barrow, and of these 20 pop-ups 17 were recovered (three off Cape Lisburne were not recovered) yielding a total of 12,557 recording hours covering a total of 523 pop-up recording days.

To represent overall acoustic characteristics and variability, a set of analytical methods was applied to all the acoustic data. For every day of data and for every pop-up, 24-hour spectrographic images, ambient noise order statistics (5%, 25%, 50%, 75%, 95%), and 1/3 octave RMS received levels were computed at an 86 sec resolution, and all data were saved as MatLab files. In this analysis protocol, known types of sound sources (e.g., whales, vessels, seismic airgun array events) were not identified and their contributions were not removed from noise level measurements. Instead, all sounds contained in the acoustic record were considered part of the "ambient noise" habitat (i.e., the acoustic "scene"). When considering the potential impact of ambient noise on bowhead acoustic communication, noise level measurements included only the eight 1/3 octave bands covering the dominant frequency range of bowhead whale calls (70 – 450 Hz.) These ambient noise analyses resulted in a large database of Matlab-formatted measurements. Some examples of these measurements are provided in the report, and the acoustic data and measurement database are readily available for further analysis. The resultant data from these measurements were not analyzed further for such things as trends or correlations with either vessel traffic or seismic airgun array activities.

Contrary to the original plan, software for the automatic detection of whale sounds was not applied because preliminary analysis indicated that these auto-detection algorithms were significantly confounded by noise conditions from seismic survey airgun array events and by sounds from non-target species such as bearded seals, *Erignathus barbatus*, and suspected fish sounds of possibly Arctic Cod, *Arctogadus glacialis*. The inability to utilize automated detection software for bowhead calls significantly added to the timeline required to complete the bowhead detection analysis of the Pt. Barrow data.

All Phase I data were scrutinized for the occurrence of beluga and bowhead sounds at a 5-minute resolution. This analysis detected no bowhead calls, but did detect the sounds of belugas on seven of the 57 days from 15 July through 9 September, Cape Lisburne only. Belugas were never detected on the pop-up approximately 9 km from Cape Lisburne. Based on the times of day and the pop-ups on which belugas were detected, only five groups of belugas were detected out of the total of 285 days of pop-up recording data.

All Phase II data were scrutinized for the occurrence of bowhead whale sounds at a 5-minute resolution. Bowhead calls were detected off Pt. Barrow, Wainwright and Pt. Lay, with dramatically decreasing numbers of detections as one moved west from Pt. Barrow to Wainwright to Pt. Lay. For Pt. Barrow, bowhead calling occurred in a high percentage of hours (83%) throughout the 29 day recording period from 17 September to 15 October, during which bowheads were detected on 143 of the 145 total pop-up recording days. There was a slight decrease in hourly detections (70%) during the last week of monitoring from 8-15 October, but during this week bowheads were detected on every pop-up, on every day. The types of bowhead calls recorded off Pt. Barrow were remarkably variable and did not seem as dominated by the relatively simple frequency-modulated and amplitude-modulated calls so typical of the spring migration off Pt. Barrow. Sequences of highly variable sounds were recorded that were reminiscent of song as recorded in the spring migration off Pt. Barrow. Many of these sounds were detected on three of the units, raising the expectation for reliably locating calling animals. This expectation was not born out as most of the sounds were difficult to locate because they were distorted by reverberation. However, based on a conservative evaluation of bowhead call arrival times at the different recorders, there were at least three or more whales calling for the majority of time (58%) off Pt. Barrow.

Phase I and Phase II were analyzed for the occurrence of seismic airgun array sounds at daily (24-h) and 15-minute time resolutions, respectively. In Phase I, seismic airgun array activity was detected off Cape Lisburne on 35 of the total 58 calendar days (60%) over which pop-up recordings were obtained, with the highest period of detected seismic airgun array activity from 21 July through 10 August. In Phase II, using only the pop-ups 90km offshore of Pt. Lay and Wainwright, seismic airgun array activity was detected on 33 of the 37.1 calendar days (87%) of pop-up recording effort. When analyzed at 15-minute resolution, seismic airgun array activity was detected in 2715 of the 3559 15-minute time periods (76%) of pop-up recording effort in Phase II.

Seventy-nine (79) dates and time periods, totaling 119.3 h, were selected for more detailed analysis. This analysis used data from seven of the 17 pop-up recorders to measure received levels for individual seismic airgun array events and for the time periods between those events. These empirical results for received level vs. distance to the active seismic source are presented in chapter 12 of this report.

The number and received levels of seismic airgun array events during the 79 date-time sample periods varied considerably from pop-up recorder to recorder. The greatest number of seismic events (32332) was detected 90 km off of Pt. Lay while the fewest number of seismic events (5), was detected off Pt Barrow. When seismic airgun array detections per pop-up are converted into rates (events per hour), these counts translate into 268 events/h for Pt. Lay and only 0.05 events/h for Pt. Barrow. Received levels were highest at the recorders 90 km off Pt. Lay and Wainright. Maximum received levels (RMS dB re 1 µPa) for the Pt. Lay pop-up ranged from 104 – 136 dB and from 101 – 132 dB for the Wainwright pop-up. For comparison, maximum received levels for the pop-up 18 km off of Pt. Lay ranged from 100 – 118 dB and from 90 – 116 dB for the pop-up 18 km off of Wainwright. Maximum received levels for the recorder 18 km off Cape Lisburne ranged from 97 – 111 dB. Received level estimates were not possible for any of the five seismic events detected off Pt. Barrow as the signal was not sufficiently loud relative to ambient noise levels.

In summary, acoustic detections of calling beluga and bowhead whales based on passive acoustic data from Cape Lisburne for 15 July through 9 September 2006 yielded no bowhead detections and very few beluga detections. Detections of calling bowheads off Pt Barrow, Wainwright and Pt Lay for 12 September through 15 October 2006 yielded high rates of calling off Pt Barrow with decreasing detections for Wainwright to Pt. Lay. For most of this time off Pt. Barrow there were three or more calling animals.

Seismic activity in the Chukchi Sea, as evidenced by the rates of detected seismic airgun array events, occurred throughout more than half of the three month period from 15 Jul through 15 October 2006. Seismic airgun array activity was nearly continuous from 9 September through 6 October. There is insufficient evidence to evaluate whether or not beluga or bowhead distributions or relative levels of vocal activity were affected by seismic airgun array activity. The high level of bowhead calling activity off Pt. Barrow was expected. The almost total lack of seismic airgun array detections on any of the five Pt. Barrow pop-ups combined with the relatively high levels of vocal activity on these units suggests that changes in the bowhead whale call rates off Pt. Barrow were not influenced by 2006 seismic survey activities in the Chukchi Sea. Unfortunately, there is no baseline bioacoustic data for the area to the west of Barrow to compare which these 2006 Chukchi Sea data. Thus, although there is some historical aerial survey evidence indicating bowheads migrate west past Pt. Barrow in the fall, the current acoustic data also shows some bowheads moved westward across the Chukchi Sea but also that some moved southwestward along a more coastal route. Our acoustic monitoring effort ended between 12-15 October or about the time when bowhead call rates off Pt. Barrow were showing signs of decreasing and those for Wainwright had just gone through a 5-6 day crescendo, with the highest rates occurring on the Wainright pop-up 90 km offshore. This was at the same time as a lull in seismic airgun array activity. Until much more is known about the variations in the acoustic behaviors of bowhead whales and the types of natural factors influencing these variations in behaviors during the fall migration from Pt. Barrow and west into the Chukchi Sea, these types of coincidences between bowhead acoustic behavior and seismic airgun array activity remain anecdotal and speculative at best. These results underscore the critical need for a deeper understanding of bowhead acoustic communication in order to correctly interpret their responses to changes in their ambient noise habitat.

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Vessel-based Shallow Hazards Surveys—Henry Christoffersen (Chapter 7)

SOI conducted site clearance and shallow hazards surveys in the Beaufort Sea from the vessel *Henry Christoffersen* (*Henry C.*) to identify potentially hazardous or sensitive conditions and sites at or below sea level that could affect potential future drilling operations. This chapter summarizes the visual monitoring effort and marine mammal sightings from the *Henry C.* during the shallow hazards survey work. The objectives of the marine mammal monitoring and mitigation program for the shallow hazards surveys in the Beaufort Sea were the same as those discussed in Chapter 3 for seismic surveys in the Chukchi Sea. The main purpose of the mitigation program was to avoid or minimize potential effects of the surveys on marine mammals.

SOI's shallow hazards and site clearance surveys in the Beaufort Sea were conducted from 3 Aug. to 3 Oct. 2006. During the 8213 km of operations from the *Henry C.*, there were 5145 km of visual observation effort over 526 h, of which, 3152 km (61%) of effort over 284 h were classified as "useable". Airguns were operated for only 98 km (~12 h), with 57 km (~4 h) of airgun operations classified as useable for analysis purposes.

A total of 451 individual marine mammals were seen in 412 groups within the study area. Sightings during useable periods included 320 seals and 4 polar bears. No walruses were identified from the *Henry C.* Most sightings occurred in the nearshore region, where most of the visual observation effort occurred. There were no useable sightings of cetaceans, or of pinnipeds hauled out on ice.

The majority of pinniped sightings in the nearshore were of unidentified seals (63% or 180 sightings). Ringed and spotted seals combined accounted for 33% (96) of the pinnipeds sightings, and bearded seals for 4% (12 sightings).

During this project, no marine mammals were sighted within the small safety radius around the airguns while seismic operations were conducted. As no marine mammals were seen during airgun operations in the Beaufort Sea, the direct estimate of the numbers of marine mammals exposed to ≥190 dB rms was zero.

Using line transect methodologies, pinniped density was estimated to be 358 individuals/1000 km^2. This density calculation was used to estimate both the number of different *individual* pinnipeds potentially exposed to 160, 170, 180, and 190 dB rms, and the average number of *exposures* of pinnipeds to the various sound levels (Table ES.4). No cetaceans were observed from the vessel at any time during operations, and take estimates at distances equal to received levels of 160, 170, 180, and 190 dB rms for cetaceans were calculated from aerial survey data and are described in Chapter 8.

TABLE ES.4. Estimated numbers of individual pinnipeds (ringed seals, spotted seals, and bearded seals) exposed to sounds with various received levels during airgun operations from the *Henry C.*, and the average number of exposures per individual.

		Nearshore		Offshore		*Total*	
	Exposure level in dB re 1µPa (rms)	**Individuals**	**Exposures / Individual**	**Individuals**	**Exposures / Individual**	**Individuals**	**Exposures / Individual**
Based on non-seismic density [a]							
Pinnipeds	**≥ 160**	124	1.2	24	1.0	148	1.2
	≥ 170	54	1.1	9	1.0	63	1.1
	≥ 180	20	1.0	3	1.0	23	1.0
	≥ 190	7	1.1	1	1.0	8	1.0

[a] Nearshore non-seismic densities were applied to both nearshore and offshore ensonified areas.

Beaufort Sea Aerial Surveys in Support of Seismic Operations (Chapter 8)

Aerial surveys were conducted in the Beaufort Sea in support of shallow hazards and site clearance surveys conducted from the *Henry C*. The shallow hazards vessel conducted seismic activities on 25 Sept. in Camden Bay west of Kaktovik. No aerial surveys were flown on 25 Sept. due to poor weather conditions, but surveys were flown on 23–24 Sept. to monitor and clear the 120 dB zone prior to the seismic activities.

"Line Transect" methodology was used to estimate densities and numbers of animals present in the study area. The computer program "DISTANCE" was used to calculate line transect estimates of the numbers of whales present for each survey when sufficient survey effort and sightings were available to justify the use of this methodology. The distribution of whales was further examined by dividing the study area into a series of strips, each 10 km wide, oriented roughly parallel to the coast. This allowed a more detailed examination of the distribution and abundance of the whales in the study area at different distances from the shore. Seasonal patterns in distribution and abundance of whales in the study area were analyzed by 10-day periods from 26 Aug. through 24 Sept.

Total or partial aerial survey coverage was obtained on 9 surveys during the 26 Aug. through 24 Sept. study period. All or most of the surveys were completed for 6 surveys. Substantially reduced coverage of transects due to low clouds, precipitation, high sea conditions, or some combination of those factors occurred on 3 surveys. A total of 3049 km of useable transect data was collected during which 60 sightings of whales or whale groups were made.

Bowhead whales were observed on 89% (8 of 9) of the surveys, and the highest sighting rate of 4.19 bowhead whales per 100 km of survey effort occurred on 6 Sept. Bowhead whales were observed in group sizes of 1 to 4, with a group size of 1 being the most common.

Beluga whales were observed on 44% (4 of 9) of the surveys. The highest beluga whale sighting rate (8.76 beluga whales per 100 km of survey) also occurred on 6 Sept. The high beluga whale sighting rate on 6 Sept. was due primarily to the large group sizes seen on that particular survey. Beluga whales were generally seen in group sizes of 1 to 7, but on 6 Sept. a group of 17 beluga whales was observed.

Nearly all bowhead whales sighted during the surveys were found approximately 30 to 60 km from shore in waters 40–100 m deep, and four bowhead whales were sighted in waters 100-200 m deep. Only one bowhead was sighted in shallower water and it was seen in ~10 m of water just east of Kaktovik.

Beluga whale sightings were primarily concentrated at the northern end of the transect lines along the 200 m depth contour, with a few scattered sightings in shallower waters from 30 to 40 m deep. No beluga whales were observed inside the 20 m depth contour. Peak numbers of bowhead whale sightings (25) and individuals (37), and of beluga whale sightings (16) and individuals (46) were recorded during early-Sept.

Based on the results of the aerial surveys and vessel-based observations, no whales were estimated to have been exposed to SPLs ≥180 dB (rms), and it is unlikely that any whales were exposed to SPLs ≥160 dB (rms). Vessel-based observers were not able to monitor the 120 dB (rms) zone. Based on the observation of one bowhead whale during the aerial surveys on 23 and 24 Sept., ~7 bowhead whales may have been exposed to SPLs ≥120 dB (rms). Most beluga whales were likely further offshore than the extent of the 120 dB (rms) zone.

Other Beaufort Sea Aerial Surveys (Chapter 9)

The Bowhead Whale Aerial Survey Program (BWASP) is funded by MMS and the surveyed area extends from Barrow to the Canadian border. These surveys have been conducted annually since 1979.

The BWASP aerial surveys in 2006 provided good coverage of the bowhead migration in the first half of Sept. and the first half of Oct. Poor weather conditions resulted in poor coverage during the second halves of both months. The most effort, the largest numbers of sightings, and the highest sighting rates were all obtained during the first survey period from 2-15 Sept. Bowheads were scattered evenly throughout the area surveyed except for a concentration of whales near and east of Point Barrow during the 2–15 Sept period. It appears that the majority of the migration was through waters 20–100 m deep but some whales were sighted in both deeper and shallower waters. Sightings made during the first survey period (2–15 Sept) appear to be slightly farther offshore than during later periods. Only 4 of 337 transect sightings of bowhead whales were of cow/calf pairs. The cow/calf sightings were distributed throughout the survey area and all sightings were in water depths >~40 m.

Acoustics Research for Studying Bowhead Migration, 2006 (Chapter 10)

In recent years the potential for offshore oil and gas development in the Beaufort and Chukchi seas has raised concerns about the possible effects of offshore oil and gas development on marine mammals in general, and bowhead whales in particular. Recent studies have been conducted to determine underwater sound levels produced by industrial activities and the effects of industrial noise on migrating bowhead whales. Acoustical studies have been conducted to determine the amount of deflection that may result along the southern edge of the bowhead migration corridor in response to oil production activities at Northstar Island located ~10 km (6 mi) offshore of the Prudhoe Bay oil field. The approach to monitoring the bowhead migration has been to use special seafloor instruments to record the sounds of calling bowheads. The instruments, called "directional autonomous seafloor acoustic recorders" (DASARs), were configured in arrays of equilateral triangles comprising two overlapping hexagons north-northeast of Northstar Island, and whale locations were determined by triangulation.

The current study, funded by SOI in support of potential future oil and gas exploration and development in offshore locations of the Beaufort Sea, was designed to investigate the possibility of using specially designed DASARs (called DASARbs) which were better configured to remain motionless on the seafloor, in combination with vertical arrays suspended in the water column to obtain better location data on migrating bowhead whales. By using array gain an eight-element vertical array could theoretically extend the detection range of a single station by a factor of 3 to 10, depending on what degree the ocean floor attenuates sound.

There were three objectives of the acoustics research study:

- develop a new model of the DASAR (DASARb) that would use readily-available directional sensors and be configured better for remaining motionless on the bottom during periods of high currents.
- investigate the use of a vertical line array that would provide distance information to acoustic sources. Then, distance and bearing to a calling whale could be provided by a single DASAR for bearing and a vertical array for distance at any location of interest. The primary goal of the vertical array portion of this effort was to determine whether multipath modeling could be applied to bowhead whales in the Arctic environment to detect the animals out to distances of several kilometers.

- develop machine-aided whale call detection to alleviate the labor-intensive analysis of the data to detect whale calls on each DASAR, determine the bearings, and finally the locations. It was not an objective to automate the detection process, but to present detection data to an analyst for times when a call was suspected, then have him or her confirm or reject the detection.

The first two DASARbs and the modular vertical array were deployed on 10 Sept. This first installation was just northeast of West Dock in water 18 m (60 ft) deep. The modular vertical array was caught by ice and carried away within two days. Ice prevented a complete calibration transmission sequence around the units. Two other DASARbs were installed on 12 September at a site 20 km (12.4 mi) north-northeast of Cross Island in water 37 m (122 ft) deep. The standard vertical array was installed between the DASARbs with its subsurface float 6 m (20 ft) below the water surface.

Following retrieval of the DASRbs, data were analyzed beginning with data collected on 12 September until retrieval began on 1 October. A total of 16,442 calls were detected altogether, of which 13,428 were located.

The quality of the recordings from the vertical arrays was found to be contaminated by large amounts of electrical noise. Upon further investigation it was found that 90% of the non-acoustic 20 mV “spikes” typically lasted for only one sample (when sampled at 1 kHz), and had amplitudes that were far beyond any physical acoustic pressures. Thus a computer program was written to automatically replace data samples that were “spiking” with samples from a white noise distribution, improving the spectrogram quality considerably. Unfortunately this method of spike removal impacts the phase and spatial coherence of the data, which needed to be precise to permit accurate range estimates to be obtained. To improve the detection range of the array the data were also beamformed by summing all eight time series together. The combined actions of spike removal and beamforming made it possible to detect a small number of signals, including whale calls.

After preprocessing the raw binary data from one of the DASARb stations northeast of Cross Island, the public domain program ***Ishmael*** was used to detect deviations from the mean background power spectral density across four frequency bands between 50 and 500 Hz. After being stored to hard disk, these first-order detections were then run through a new MATLAB-based contour tracer, which performs the following three steps: (1) identifies the time-frequency bins in a spectrogram that may be part of a FM-modulated signal; (2) attempts to connect flagged time-frequency bins into short segments, and (3) attempts to connect segments into longer contours. If the time-duration of these contours exceeds a threshold time, the routine flags the detection and stores the time and contour shape in a log. To date the routine is detecting about 80% of all calls logged by human operators, with a tradeoff of a large number of false detections.

Despite these problems, the most expensive vertical array was safely recovered. Despite problems with electrical noise contamination, whale calls and airgun signals were detected in the data, and evidence of multipath propagation was observed. Attempts to localize the signals are continuing, although the procedure used to de-spike the data has probably disrupted the relative phase of the frequency components between the hydrophone elements, lowering the odds of an accurate ranging measurement for this data set. The electrical issues in the recording system are being addressed by a circuit board redesign, a data acquisition software review, and an adjustment in the gain of the array signals before they enter the acquisition system.

The DASARbs performed as desired. These four units proved that they are ready for whale call location monitoring in the future. The *in situ* calibration transmissions following installation and preceding retrieval were not as strong as expected and must be monitored carefully in the future.

The machine-aided call detection algorithms need further development but progress to date shows that computer analysis can be a major aid to analysts. These routines will be improved with time as more experience is gained, with a particular emphasis on reducing false detections from airgun signals and boat-generated noise.

Other Industry Studies (Chapter 11)

Acoustic Studies in Support of Barging Activities for PNR and FEX. Underwater acoustic source level measurements of vessels operating in the Alaska Beaufort Sea were conducted by JASCO Research for Pioneer Natural Resources Alaska, Inc. (Pioneer) and FEX LP (FEX) between 4 and 9 September 2006. Source level measurements were performed on eight different vessels at various sites in the Alaskan Beaufort Sea between Oliktok Point and West Dock, outside of the barrier islands. Broadband source levels produced by the vessels ranged from 172.8 to 182.9 dB at 1 m.

Acoustic Studies in Support of PNR's Ooogurak Development Project. The acoustic study which was part of an offshore monitoring program designed to address stipulations in the NSB ordinance for Pioneer's Ooogurak Development Project Area was conducted by JASCO and LGL. The goals of the acoustic study were to (1) measure underwater sounds associated with construction activities on Ooogurak Drilling Site (ODS) and the attenuation with distance and direction from the island, (2) characterize source sound levels from barging and support vessel activities and attenuation of these sounds with distance, (3) assess ambient noise levels in the vicinity of ODS, and (4) detect marine mammal vocalizations if present.

Three Ocean Bottom Hydrophones (OBH) were used to record ambient sounds and sounds produced from island construction activity. OBH deployments were 2-3 days in duration, and three separate deployments of all three systems were performed from 2-10 Sept. Five deployment locations were chosen based on the NSB stipulations in locations north and northwest of the ODS. Deployment locations were 1, 4, and 12 miles from the ODS. The closest recorder to the island (1 mi) detected intermittent noise attributed to island equipment at a maximum broadband level of 92 dB re μPa. These noises were not recorded as the OBHs located 4 and 12 miles from the island. Tug and barge traffic to the north of Thetis Island was recorded by the OBH systems deployed at 4 miles and 12 miles from the ODS.

Aerial Surveys in Support of PNR's Ooogurak Development Project. The goal of Pioneer's aerial survey program in 2006 was to determine whether bowhead whales travel near enough to the ODS to detect industrial sounds produced from the construction and operation of the facility. Working closely with NSB scientists, Pioneer developed an aerial survey program to assess the distribution of bowhead whales within 24 to 32 km (15-20 mi) of the ODS during September 2006.

Aerial surveys were flown with a Bell 412 helicopter on 3, 7, 12, and 15 Sept. and 1 Oct. 2006. The survey area was centered north of the ODS in Harrison Bay and encompassed an area approximately 580 km^2. It consisted of four north-south transects, each of which was approximately 24 km in length.

No bowhead whales were observed during the five aerial surveys. Seals were observed during the first and fourth surveys. Eight seals were observed while on-effort on 3 Sept. (~1.9

seals/100 km of effort for all surveys combined). An additional two seals were seen while traveling between transects. A single seal was observed off-effort on the 15 Sept. survey. A polar bear was observed off-effort on an ice flow approximately 8 km (5 mi) north and east of the ODS between Thetis and Spy Islands during the 3 Sept. survey.

Acoustic Studies at BP's Northstar Island. During the bowhead whale migration in Sept. 2006, Greeneridge Sciences (on behalf of BP) implemented an acoustic monitoring program north-northeast of BP's Northstar oil development. Monitoring objectives in 2006 were identical to those in 2005, but modified relative to those in earlier years. Results based on data collected in 2001–2004 had suggested that the bowhead migration corridor offshore of Northstar likely was not strongly affected by varying activities at Northstar.

The primary objectives in 2006 were two-fold: (1) monitor sounds produced by Northstar and its associated vessels, and compare the levels and frequencies to those in previous years (2001–2005), and (2) count whale calls at DASAR locations that have been used in previous years, and then compare with counts at the same locations in previous years. In addition, bearings, call locations (if available) and call types were to be compared with previous years. The 2006 monitoring program was designed to detect significant changes in sounds produced by Northstar or in number of whales (as indicated by their calls) migrating along the southern part of the bowhead migration corridor.

On 7 September 2006, four DASARs were deployed at locations 11.5–16.6 km (7.1–10.3 mi) NNE of Northstar Island. These instruments recorded low-frequency sounds continuously for ~18 days. Simultaneously, near-island recordings were obtained from three DASARs placed 410–465 m (1345–1525 ft) from Northstar over ~27 days (29 Aug. to 25 Sept. 2006). The sounds received in 2006 by one of the near-island DASARs were analyzed as broadband signals (10–450 Hz) and as one-third octave and narrowband levels. Vessel traffic to and from Northstar in 2006 increased compared to 2005, but was still below 2001–2003 values. Despite this, median broadband levels over the entire season were lower than in previous years. This is in part the result of a 45% drop in mean wind speeds in 2006 compared to 2005. Overall, industrial sounds from Northstar in 2006 were about the same as in 2004–2005, except for the increased frequency of transient high-level sounds associated with boats.

In total, 1509 bowhead whale calls were recorded in ~18 days at DASAR locations EB (2 recorders), CC, and CA. A total of 677 (38/day) of those calls were detected by DASARs EB and CC combined. This compares to 1542 calls in 2001 (110/day), 4775 calls in 2002 (208/day), 26,401 calls in 2003 (895/day), 31,903 in 2004 (1182/day), and 1020 in 2005 (35/day), based on data from the same two sites each year. The maximum call detection rate in 2006 was low, 67 calls per hour. A comparison of bearings from DASAR EB in 2001–2006 showed that the bearing directions were distributed much as in previous years (except 2005). The low call counts in 2006 are probably related to the presence of heavy nearshore ice during the 2006 season, which may have deflected the migration pathway farther offshore than in years with open water (i.e., 2001–2004).

Discussion, Conclusions, and Assessment of Potential Effects of Industry Activities in the Chukchi and Beaufort Seas (Chapter 12)

The JMP in the Chukchi and Beaufort seas in 2006 included an acoustic program using arrays of bottom-founded recorders deployed along the Alaskan Chukchi Sea coast, dedicated vessel-based surveys with and without passive acoustic monitoring (PAM) in the MMS Chukchi

Sea Planning Area, and an aerial monitoring program over the nearshore waters and coastline of the Chukchi Sea between Pt. Hope and Barrow, Alaska. In addition to the studies conducted in the Chukchi Sea, SOI also conducted some limited acoustic studies and aerial monitoring in the Beaufort Sea in the general area of their operations. In 2006, sea-ice conditions in the Beaufort Sea limited SOI's operations to shallow hazards surveys and other site clearance activities. Acoustic studies conducted by SOI in the Beaufort Sea were primarily used to test newly developed equipment for monitoring marine mammals (primarily bowhead whales) and industrial sounds. Weather and changes in SOI's planned seismic program limited the number of aerial surveys in the central Beaufort Sea to nine.

These studies contribute to the body of knowledge about marine mammals in the Chukchi and Beaufort seas and form the basis for longer term data sets to address potential disturbance of marine mammals in the area by industrial activities. There have been a number of studies on marine mammals in the Beaufort Sea over the past two decades focusing on bowhead whales, beluga whales, seals, and polar bears. Industry monitoring programs have contributed greatly to understanding of impacts to marine mammals from oil and gas exploration and production. Various government entities including the MMS and the USFWS have also funded major research programs in the Alaskan Beaufort Sea. In the Chukchi Sea, far fewer studies have been conducted in recent years. Many of the data sets were collected 20 or more years ago, making additional collection of data important for understanding the current abundance and distribution of marine mammals in the Chukchi Sea.

Vessel surveys conducted in 2006 included dedicated surveys designed to estimate densities of marine mammals in the offshore MMS Chukchi Sea Planning Area at distances from active seismic operations where the behavior and distribution of marine mammals were expected to be undisturbed. These surveys used three on-duty observers, which was not possible on other vessels. Additional data were collected during monitoring of marine mammals from the operating seismic ships and chase boats, and opportunistic sightings from the various support vessels during seismic operations. Results from all of these efforts indicated that, in general, marine mammals occur at relatively low densities in much of the Chukchi Sea during the open water period from mid-July through mid-Nov. In one case, a species uncommon to the area was documented (fin whale), but in general, the species present and their distributions and densities were similar to what has previously been reported for the area. Towed PAM systems were used on some of the dedicated vessel surveys and on one of the chase boats that accompanied the seismic vessels as an additional way to detect marine mammals, but no marine mammals were detected by the PAM systems.

Aerial surveys over the nearshore waters and along the coastline of the Chukchi Sea between Barrow and Point Hope documented the presence and movements of marine mammals along the coast. Surveys began shortly after the annual spring beluga whale hunt by the village of Pt. Lay. Surveys early in the field season documented large numbers of beluga and gray whales, and few bowhead whales. Bowhead whales seen in the Chukchi Sea early during the field season were possibly late northward migrants or could have been whales that remained in the Chukchi Sea throughout the summer. There are no known feeding areas in the Alaskan Chukchi Sea that are frequented consistently by bowhead whales in present times, but there has been speculation that some animals may remain in the area throughout the summer. Walruses were frequently sighted along survey transects early in the season and near Pt. Hope during late season surveys as they migrated back to the Bering Sea wintering ground. Numerous seals were also documented by the aerial surveys but generally were not identified to species due to the altitude of the aircraft.

In general, the numbers and distribution of marine mammals along the Alaskan coast were similar to what would be expected based on previous studies.

Bottom-founded acoustic recorders at four locations near villages from Pt. Hope to Barrow were used to conduct acoustic studies along the Chukchi Sea coast. Five recorders were deployed at each site at locations ranging from ~5 to 50 n.mi. (~9.3 to 92.6 km) offshore. Sound measurements collected by arrays of bottom-founded acoustic recorders along the Alaskan Chukchi coast indicated that sound levels reaching the offshore recorders were as high as ~130 dB re 1 μPa (rms) during periods of active seismic surveying. The received levels were highly variable depending upon the distance of the ship from the recorder and diminished to ~110 dB when the seismic ships were ~100-150 km away. Broadband levels of background sound were also variable ranging from ~90 dB to ~110 dB (Chapter 6).

Seismic sounds heard on the second recorder of each array, located 10 n.mi. (18.5 km) offshore, were distinguishable on 77% of the days off Point Lay, 59% of the days off Wainwright, 53% of the days off Cape Lisburne, and only 4% of the days near Barrow. Received sound levels at recorder #2 (10 n.mi. or 18.5 km offshore) and recorder #5 (50 n.mi. or 92.6 km offshore) of each array, plotted as a function of distance from the operating airgun array, indicated that the recorder 50 n.mi. offshore received substantially higher levels of sound than did the recorder closer to shore, as expected. All measurements of received levels at the recorders 10 n.mi. from shore were near ambient levels, ~90 to 110 dB.

In the Beaufort Sea, operations were limited by sea ice to shallow hazards surveys and general site clearance work. Airguns were only used on two days, once during sound source measurements completed early in the season and once during shallow hazards work near the end of Sept. Aerial surveys in support of SOI's operations in the Beaufort Sea were also limited by environmental conditions and by the reduced industry program, with only 9 surveys being flown over a month-long period. Marine mammals in the area of the surveys were seen in typical numbers. Acoustic studies in the Beaufort Sea were used primarily to test new bottom-founded recorders. These studies were successful in detecting whale calls but the deployment period was short. In general, there was no evidence that SOI's operations in the Beaufort Sea had any appreciable effects on the marine mammals in the area. Additionally, the whale hunts at Kaktovik, Cross Island, and Barrow were all successful, suggesting that there was likely no impact on the subsistence hunt from industry activities.

The studies conducted as part of the JMP provide a first year of data toward what is anticipated to be a long term data set. Compilation of these data will assist in later integration of these studies and will provide the basis for a broad-based assessment of industry activities and their impacts on marine mammals in the Chukchi and Alaskan Beaufort seas. Such an assessment will provide Industry and Government the data needed to better manage the resources in the area and will contribute information for assessing potential effects of cumulative increases in activity in these areas.

ACKNOWLEDGEMENTS

We thank all of the marine mammal observers (MMOs) on the seismic and support vessels, and on the aircraft who participated in the project. The captains and crews of the various vessels provided MMOs with a good working atmosphere during the course of a long field season, and the pilots and crews of ERA Aviation and Commander Northwest did their best to meet the needs of the aerial survey crews. Industry personnel provided logistical support throughout all phases of the activities from planning through completion of reporting. These included Michael Macrander, Ian Voparil, Paul Smith, Mark Kosiara, Bob Rosenbladt, Peter Littlewood, Dan Taylor, Travis Allen, Susan Childs, Jason Smith, and Rick Fox from SOI; Mike Faust, Bruce St. Pierre, Jim Darnall, Caryn Rae, and Randy Boyer from CPAI; Joe Gagliardi and Dean Kennedy from GXT; John Davis and his team at WesternGeco; Jeff Hastings and Tom Ainsworth from Fairweather. Representatives from various agencies and stakeholders provided valuable advice and comments throughout this project. These included Ken Hollingshead, Jolie Harrison, Brad Smith, Robyn Angliss, and Sue Moore from NMFS; Craig Perham and Joel Garlich-Miller from USFWS; Chuck Monnett and Pete Sloan from MMS; Robert Suydam, Craig George, and Taqulik Hepa from the NSB; Harry Brower, Maggie Ahmoagah and other whaling captains from the AEWC, and members of the walrus, beluga, nanuq, and ice seal commissions. Information on barging activities and other non-seismic industry activities was provided by representatives of FEX, Pioneer Natural Resources, BP Exploration, ARCADIS, Marsh Creek LLC, Bowhead Transportation, Crowley Marine Systems, Island Tug and Barge, Seaspan International Ltd., and ASRC. We also thank W. John Richardson, Charles Greene, Michael Macrander, Ian Voparil, Caryn Rae, Sue Moore, Robert Suydam, Craig George, and others for constructive suggestions on various chapters of this report. Danielle Savarese provided help with numerous figures and Annette Funk did final editing and formatting of the document.

1. INTRODUCTION AND REPORT OBJECTIVES[1]

Shell Offshore, Inc. (SOI), ConocoPhillips Alaska, Inc. (CPAI), and GX Technology (GXT) conducted independent vessel-based seismic exploration in the Chukchi Sea during the 2006 open-water season. Acquisition of seismic data was accomplished using industry standard airgun arrays and hydrophone streamers towed by source vessels. SOI also planned acquisition of seismic data in the central Beaufort Sea during the 2006 open-water period. Ice conditions in the Beaufort Sea during summer 2006 precluded most of the exploration activities planned by SOI. The only exploration activities in the Beaufort Sea during 2006 were shallow hazard surveys conducted by SOI on existing lease holdings. Marine mammal monitoring and mitigation around the seismic vessels, sound source modeling, and sound source measurements were conducted by all three companies prior to and/or during operations. The results from these efforts were provided in 90-day reports submitted by each company to the National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service (USFWS) after operations were completed (Patterson et al. 2007, Ireland et al. 2007a,b). In addition, SOI, CPAI, and GXT agreed to implement acoustic, vessel-based, and aerial monitoring programs in the Chukchi Sea during the seismic exploration activities in 2006 as part of a joint monitoring program (JMP).

This comprehensive report describes the research program and mitigation monitoring conducted by all three companies as part of the JMP. The research programs and mitigation monitoring were conducted in a relatively small portion of the MMS Chukchi Sea Lease Sale Area 193 and included an acoustic program using arrays of bottom-founded recorders deployed off the Alaskan coast, dedicated vessel-based surveys with and without passive acoustic monitoring (PAM), and an aerial monitoring program over the nearshore waters to ~20 mi offshore and Chukchi Sea coastline between Pt. Hope and Barrow, Alaska. In addition to the research and monitoring studies conducted in the Chukchi Sea, SOI conducted acoustic studies and vessel-based and aerial monitoring in the Beaufort Sea in the general area of their operations. Acoustic studies conducted by SOI were primarily used to test newly-developed equipment for monitoring marine mammals (primarily bowhead whales) and industrial sounds in the Beaufort Sea. Aerial surveys were limited in the central Beaufort Sea to nine surveys due to weather and changes in SOI's planned seismic program. The report describes the methods, results, conclusions and limitations of each of these data sets.

Data from several additional sources were included in the report to supplement the information described above. The National Science Foundation (NSF) and the Minerals Management Service (MMS) conducted bowhead whale feeding studies east of Barrow, Alaska, and the JMP participants agreed to perform aerial surveys over the study area offshore of Barrow to supplement the results of the NSF - MMS surveys. The data from these aerial surveys are provided as an appendix to this report. The MMS also conducts aerial surveys of bowhead whales in the Beaufort Sea on an annual basis. The MMS data for the 2006 surveys were made available in late April 2007 and are presented in this report in a limited manner. CPAI also assisted the Alaska Department of Fish and Game (ADFG) Marine Mammal division with shipment and deployment

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[1] Dale W. Funk, Robert Rodrigues, and Darren S. Ireland, LGL Alaska Research Associates, Inc., Anchorage, Alaska.

of two high frequency acoustic recorders (HARPs) in late September off the Pt. Barrow coast. The location for deployment was determined in consultation with Sue Moore of NOAA. Deployment was coordinated with the North Slope Borough (NSB) and the Alaska Eskimo Whaling Commission (AEWC) to avoid impacting the fall bowhead whale hunt. Data from these recorders are not yet available for inclusion in the report as the recorders were recently recovered during the fall of 2007.

To the extent possible, this report integrates the studies conducted as part of the JMP into a broad-based assessment of industry activities and their impacts on marine mammals in the Chukchi and Beaufort seas during 2006. As part of this integration, monitoring and mitigation data collected by the three companies to fulfill the requirements of their Incidental Harassment Authorizations (IHAs) issued by the NMFS and the USFWS were combined to allow a more comprehensive analysis of marine mammal distribution and density in the Chukchi Sea than could be conducted with each separate data set. In addition, other known industry and human activities occurring offshore in the Chukchi and Beaufort seas are summarized. These other activities included barging and vessel traffic, drilling island construction, oil production operations, and subsistence whaling. Incidental barging activities specific to NSB support are not included in this report. Industry barging activities were conducted by Island Tug and Barge, Seaspan International Ltd., Bowhead Transportation, Crowley Marine Systems, FEX LLC, Pioneer Natural Resources, Inc., Marsh Creek LLC, and BP Exploration (Alaska), Inc. Some of these companies conducted their own studies and graciously provided copies of their reports and data for us to use in describing industry activities and studies.

The NSB and the AEWC provided us with information on the subsistence whale hunts. In late spring/early summer, a beluga whale hunt occurred at Pt. Lay just prior to the start of the seismic programs. Spring bowhead whaling was also completed before the seismic programs began. Late summer and/or autumn bowhead whaling activity occurred only at Kaktovik, Cross Island (Nuiqsut), Barrow, and Wainwright.

We further attempt to integrate all of the activities that were occurring in the Beaufort and Chukchi seas during the open-water period of 2006 and assess what, if any, impacts there were on marine mammals inhabiting or migrating through these areas. However, interpretation of broad patterns in a single year of data is inherently limited, and for the Chukchi Sea the prior data available for comparison are often dated by 20 or more years.

This report focuses on the potential impacts to marine mammals from underwater sound associated with various industry activities and related vessel traffic during 2006. The report will begin to establish long-term data sets for evaluating changes in the Chukchi and Beaufort sea ecosystems by providing a regional synthesis of available data on industry activities in offshore areas of arctic Alaska that may influence marine mammal density, distribution and behavior.

Objectives and Assumptions

As described above, the primary objective of this report is to provide detailed descriptions of the studies conducted as part of the JMP, which included the following:

- deployment of arrays of bottom-founded acoustic recorders along the Alaskan Chukchi Sea coast from Pt. Hope to Barrow, Alaska;
- aerial monitoring over the nearshore waters and coastline between Pt. Hope and Barrow, Alaska;

- dedicated vessel-based surveys with and without PAM in a portion of the Chukchi Sea Planning Area; and
- analysis of a combined data set consisting of all marine mammal sightings from the three seismic vessels operating in the Chukchi Sea and all support vessels.

The objectives of these studies were to

- provide data to begin to fill current gaps in our understanding of the relative abundance and distribution of marine mammals in the Chukchi Sea; and
- assess the potential impacts of seismic activity on marine mammals.

Shell also conducted some limited operations in the Beaufort Sea during 2006. The results of the monitoring program associated with these operations are described in this report and include the following data collection efforts:

- marine mammal observations during shallow hazards work;
- aerial surveys over lease prospects in Camden Bay; and
- deployment of directional autonomous seafloor acoustic recorders, model B (DASAR-b) and vertical arrays of acoustic recorders to test equipment for monitoring marine mammals (primarily bowhead whales) and industrial sounds in the Beaufort Sea

Additionally, other human activities in the Beaufort and Chukchi seas that occurred during seismic programs but were unrelated to the JMP are also described. These activities may have influenced marine mammal responces to the seismic programs.

In preparing this report we worked under the following assumptions:

- The report primarily addresses the monitoring studies conducted as part of the JMP and the effects on marine mammals of the 2006 seismic programs conducted by SOI, CPAI and GXT;
- Marine mammals are the focus of the report, and it is not intended to address all aspects of the marine ecosystems of the Chukchi and Beaufort seas;
- The primary potential impacts addressed are those resulting from underwater sound from airguns and the vessels themselves;
- This report is intended to document the beginning of joint monitoring programs in the Alaskan Arctic and is not intended as a complete retrospective of previous work in these areas; and
- Information presented from studies conducted by other companies or organizations is usually available in reports issued by those entities. Those reports should be consulted for more detailed information on these separate studies.

Report Organization

The report describes the various types of industry and other activities in the Chukchi and Beaufort seas during 2006, summarizes the results of industry studies in these areas, and provides an initial analysis of the cumulative effects of human activities on marine mammals in 2006. The report is divided into 12 chapters and appendices.

2. INDUSTRY AND OTHER HUMAN ACTIVITIES[1]

Introduction

Seismic acquisition programs were conducted or planned in both the Chukchi and Beaufort seas in 2006. Other industry activities, monitoring studies, and subsistence harvest activities also occurred in both seas. This chapter describes the various types of human activities during the 2006 open-water period in the Chukchi Sea followed by a description of activities in Beaufort Sea. A regional timeline of activities at the end of this chapter depicts temporal aspects of the 2006 activities in the Chukchi and Beaufort seas and biweekly maps indicate the spatial extent of the described activities.

Chukchi Sea

Seismic Vessel Component

SOI, CPAI, and GXT collected offshore seismic data in the Chukchi Sea during summer and/or autumn 2006 in support of potential oil and gas exploration and development. Seismic survey data were acquired in the Chukchi Sea from seismic source vessels that towed an airgun array and hydrophone streamers to record reflected seismic data. The surveys conducted by SOI and CPAI consisted of 3-D data acquisition, whereas GXT conducted a 2-D seismic survey program.

Marine seismic surveys emit sound energy into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b), and have the potential to affect marine mammals, given the possible auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al., 2007). 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, although this has not been confirmed in the technical literature. 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).

Incidental Harassment Authorization

Seismic survey operations have the potential to "take" marine mammals by harassment. For this reason, all three companies submitted applications to the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) for Incidental Harassment Authorizations (IHAs) that contained specific monitoring and mitigation measures designed to minimize such "take." 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. No serious injuries or deaths of marine mammals were anticipated from the seismic surveys, given the nature of the operations and the mitigation measures implemented, and no injuries or deaths were attributed to these activities.

Under current NMFS guidelines (e.g., NMFS 2005; NMFS 2006a), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse

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[1] Robert Rodrigues, Darren S. Ireland, and Dale W. Funk, LGL Alaska Research Associates, Inc.

levels are ≥180 dB re 1 μPa (rms)[2] for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. Those safety radii are based on an assumption that seismic pulses at lower received levels will not injure these mammals or impair their hearing abilities, but that higher received levels *might* have some such effects. The mitigation measures required by IHAs are, in large part, designed to avoid or minimize exposure of cetaceans and pinnipeds to sound levels ≥180 and 190 dB (rms), respectively.

Disturbance to marine mammals could occur at distances beyond the safety (shut-down) radii if the mammals were exposed to moderately strong pulsed sounds generated by the airguns (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 behaviorally. That assumption is based mainly on data concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). Dolphins and pinnipeds are generally less responsive than baleen whales (e.g., Stone 2003; Gordon et al. 2004), and 170 dB (rms) may be a more appropriate criterion of potential behavioral disturbance for those groups (LGL Ltd. 2005a,b). However, this 170 dB (rms) criterion is not recognized by NMFS. In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time of disturbance, the distance from the sound source, the received level of the sound, and the associated water depth. Some individuals may exhibit behavioral responses at received levels somewhat below the nominal 160 or 170 dB (rms) criteria, but others may tolerate levels somewhat above 160 or 170 dB (rms) without reacting in any substantial manner. Marine mammal behavioral responses to seismic operations have generally been shown to be temporary and short term (Richardson et al. 1995, Richardson et al. 1999), and have not appeared to significantly affect marine mammal populations.

During late 2005 and early 2006, SOI, CPAI, and GXT requested that NMFS issue IHAs to authorize non-lethal "takes" of marine mammals incidental to the seismic operations in the Chukchi Sea (SOI 2005; CPAI 2006a; GXT 2006a) pursuant to Section 101(a)(5)(D) of the MMPA. The NMFS published notices regarding the proposed issuance of the IHAs for the surveys in the *Federal Register* on 3 May, 12 May, and 2 June 2006 for SOI, CPAI, and GXT respectively, and public comments were invited. NMFS published notices in the *Federal Register* that IHAs had been granted to SOI, CPAI, and GXT on 24 Aug., 31 July, and 23 Aug., respectively. Effective dates of the IHAs began 10 July, 7 July, and 15 Aug. for SOI, CPAI, and GXT, respectively, and all IHAs expired on 31 Dec. The IHAs authorized "potential take by harassment" of various cetaceans and pinnipeds during the marine geophysical cruises described in this report.

SOI, CPAI, and GXT also requested that the USFWS issue IHAs to authorize potential "taking" of walrus and polar bears (SOI 2006; CPAI 2006b; GXT 2006b). The USFWS published a notice regarding the proposed issuance of IHAs to all three operators (SOI, CPAI, and GXT) on 8 May 2006. IHAs for all three operators were issued by USFWS on 29 June.

The IHAs were granted to SOI, CPAI, and GXT on the following assumptions:

- 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;

[2] "rms" means "root mean square," and represents a form of average across the duration of the sound pulse as received by the animal. Received levels of airgun pulses measured on an "rms" basis are generally 10–12 dB lower than those measured on the "zero-to-peak" basis, and 16–18 dB lower than those measured on a "peak-to-peak" basis (Greene 1997; McCauley et al. 1998, 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.

- 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 IHAs issued by NMFS for the Chukchi Sea seismic surveys authorized harassment "takes" of one ESA-listed species (bowhead whale) as well as non-listed species including gray whales (*Eschrichtius robustus*), killer whales (*Orcincus orca*), and beluga whales (*Delphinapterus leucas*), harbor porpoise (*Phocoena phocoena*), and ringed seals (*Phoca hispida*), spotted seals (*Phoca largha*), and bearded seals (*Erignathus barbatus*).

The polar bear (*Ursus maritimus*) and Pacific walrus (*Odobenus rosmarus*) may also occur in the project area. These species are managed by the USFWS, unlike the other arctic marine mammals (which are managed by NMFS). The IHAs issued to SOI, CPAI, and GXT by USFWS authorized the incidental taking of walrus and polar bears in conjunction with seismic activities in the Chukchi Sea and required the applicants to observe a 190 dB (rms) safety radius for walrus and polar bears.

Dates of Operations

SOI's seismic survey was originally planned to occur in two phases. Phase one commenced in July when sea-ice conditions allowed access to the Chukchi Sea. Operations were originally planned to continue there until late summer when the source vessel *Gilavar* and the chase vessel *Kilabuk* were to transit to the Beaufort Sea to conduct seismic surveys on Shell lease-holdings in the mid- and eastern parts of the Alaskan Beaufort Sea.

SOI's source vessel, the *Gilavar*, left Dutch Harbor on 7 July to travel to the project area, and entered the Chukchi Sea on 10 July. Operations were delayed due to ice conditions in the planned operating areas and to avoid potential disruption of the Pt. Lay beluga whale hunt. SOI's seismic contractor began deploying the seismic acquisition equipment on 21 July. After airgun deployment, underwater sounds produced by the airgun array were recorded and analyzed by Greeneridge Sciences. Prior to the field season, radii had been predicted via acoustic modeling procedures, but site-specific empirical measurements were required to confirm or refine the predictions. The airgun sounds were recorded as a function of airgun configuration, distance, and aspect on 21 and 22 July, and safety and disturbance radii based on these measurements were determined within 72 hrs. Seismic acquisition began on 27 July 2006 and continued through most of the field season until 19 Sept. SOI then determined that ice conditions and other operational considerations precluded continuation of the exploration program or a transition of the program into the Beaufort Sea, and seismic activities were terminated. During SOI's seismic surveys, one or more airguns were firing over ~5297.4 km (3291.7 statute mi) of survey line in the Chukchi Sea in 2006.

CPAI's source vessel, the *Western Patriot*, left Dutch Harbor on 15 July to travel to the project area, and entered the Chukchi Sea on ~21 July. JASCO Research Ltd., under contract to CPAI, measured sound levels produced by the airgun array using methods similar to those used by SOI contractors. The airgun sounds were recorded on 24 and 25 July, and safety and disturbance radii based on these measurements were determined within 72 hrs. Seismic acquisition began on 27 July 2006 and continued through most of the field season until 6 Oct. CPAI then determined that ice conditions and other operational considerations precluded continuation of the exploration program, and seismic activities were terminated. During CPAI's seismic surveys, one or more airguns were firing over ~16,028 km (9959 statute mi) of survey line in the Chukchi Sea in 2006.

GXT's source vessel, the *Discoverer*, entered the Chukchi Sea in August to measure the sound propagation from its source array and verify the extent of sound radii to be used for mitigation purposes during the exploration activities. The methods used were similar to those used by SOI and CPAI and were performed by JASCO. The airgun sounds were recorded on 20-21 Aug., and safety and disturbance radii based on these measurements were determined within 72 h. The *Discoverer* departed from Alaskan waters after completion of the sound source measurements.

The *Discoverer* returned to the Chukchi Sea on 7 Oct. to conduct seismic exploration activities and deployed the seismic equipment on 12 Oct. Seismic acquisition began on 13 Oct. 2006 and continued through most of the period until 11 Nov. when the *Discoverer*'s airguns and streamer were retrieved. During GXT's seismic surveys in the Chukchi Sea in 2006, one or more airguns were firing over ~4707 km (2924 statue mi) of survey line.

Location of Activities

The geographic region where the seismic surveys occurred was located in the Chukchi Sea MMS OCS Planning Area designated as Chukchi Sea Sale 193 (1989) (see Figure 2.1). Since the Chukchi Sea seismic programs were conducted as pre-lease activities, the exact locations where operations occurred remain confidential for business reasons. That is, the seismic data acquired will be used by SOI and CPAI to determine leases on which they will bid in a forthcoming competitive lease sale. GXT's seismic acquisition was speculative; thus these data may be purchased by various oil companies, and the GXT tracklines are not confidential. Figure 2.2 shows the location of GXT's activities in the Chukchi Sea in 2006.

Navigation

Throughout the surveys, the source vessel position and speed were logged digitally every ~60 s. In addition, the position of each source vessel, water depth, and information on the airgun array were logged for every airgun shot while the source vessels were collecting geophysical data. Confidential vessel position data (Shell and CPAI) were used for purposes of analyses in this report. The geophysics crew kept an electronic log of events, as did the marine mammal observers (MMOs) while on duty. The MMOs also recorded the number and volume of airguns firing when the source vessels were offline (e.g., prior to shooting at full volume) or were online but not recording data (e.g., during airgun or computer problems).

Airgun Description

SOI used a WesternGeco 3147 in^3 three-string array of Bolt airguns towed approximately 245 m behind the *Gilavar* for its 3–D seismic survey operations in the Chukchi Sea. The array was composed of three identically-tuned Bolt airgun sub-arrays, each with eight airguns and a total volume of 1049 in^3, operated at an air pressure of 2000 psi. Each string was 15 m in length, 8 m from the adjacent string(s), and towed at a 6 m depth. The individual airguns ranged in volume from 30 to 235 in^3, and each string included two 235 in^3 and two 125 in^3 airguns in two-gun clusters. The system also included six hydrophone streamers 4200 m in length and spaced 100 m apart, which recorded reflected sound energy. In general, the *Gilavar* towed this system along a predetermined survey track, although adjustments were made during the field season relative to ice conditions.

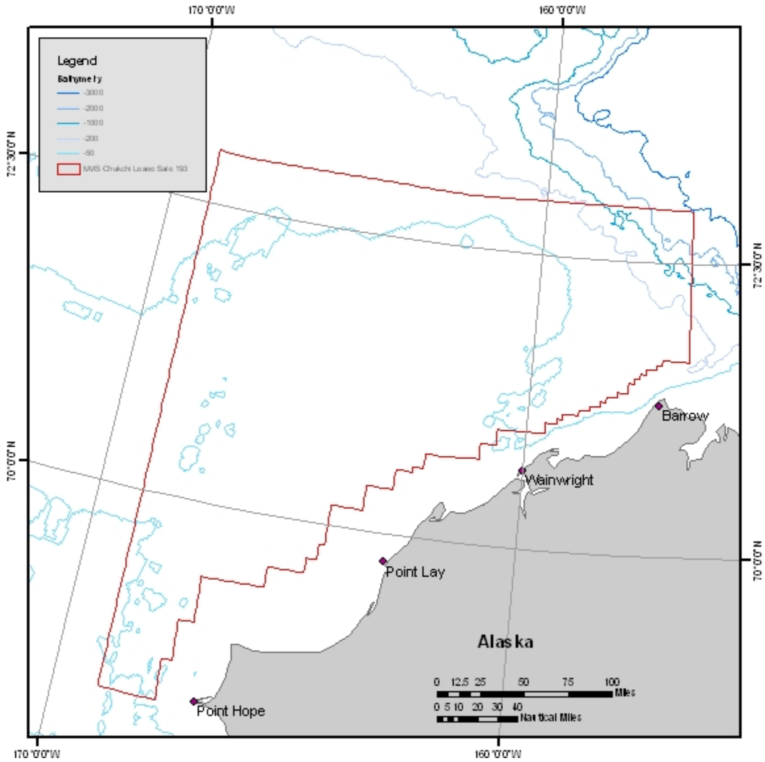

FIGURE 2.1. Location of the proposed MMS Chukchi Sea Lease Sale 193 Planning Area within which SOI, CPAI and GXT conducted seismic surveys.

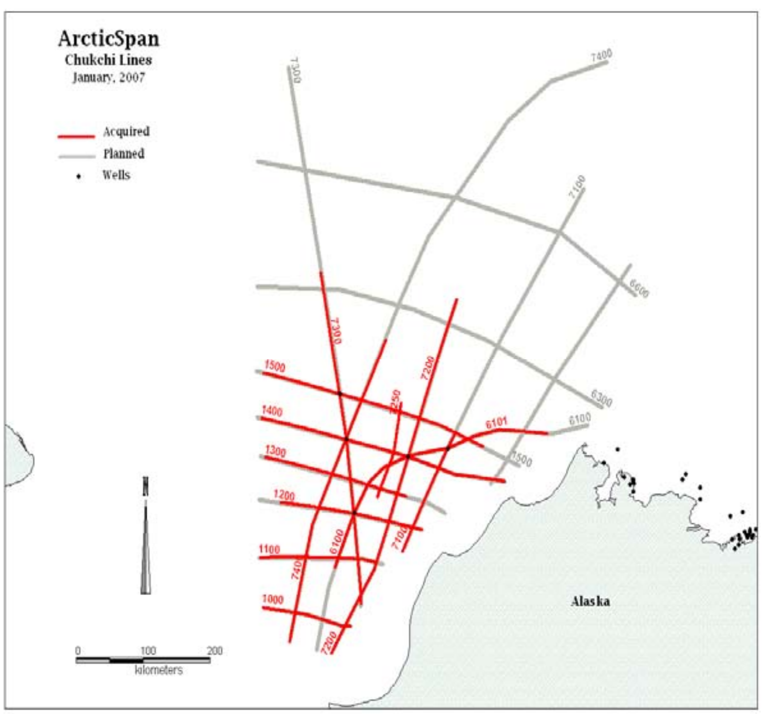

FIGURE 2.2. GXT's 2006 seismic survey tracklines in the MMS Chukchi Sea Lease Sale 193 Planning Area.

CPAI used WesternGeco 3390 in^3 arrays of Bolt airguns towed ~242 m behind the *Western Patriot* for its 3–D seismic survey operations in the Chukchi Sea. Two 3390 in^3 arrays that could be fired alternately were towed side. Each array was composed of two 1695 in^3 sub-arrays operating at 2000 psi of air pressure. Each sub-array was composed of six tuning elements: two 2-gun clusters, and four single guns. The individual airguns ranged in volume from 105 to 290 in^3. Of the two 2-gun clusters in each sub-array, one was composed of two 290 in^3 airguns, and the other was composed of two 195 in^3 airguns. Each sub-array was 15 m in length and the sub-arrays were 10 m apart and were towed at a 6 m depth. The system also included six hydrophone streamers 4000 m in length, which recorded reflected sound energy.

GXT used a hybrid Bolt/sleeve airgun array with a discharge volume of 3320 in^3 and a single hydrophone streamer for its 2-D seismic survey operations in the Chukchi Sea. The size of the airguns ranged from 40 to 150 in^3 and operated at an air pressure of 2000 psi. This energy source was towed ~50 m behind the *Discoverer* at a depth of 8.5 m. The single hydrophone streamer was 9 km in length and recorded the reflected sound energy.

Air compressors aboard the seismic vessels were the source of high pressure air used to operate the airgun arrays. Seismic pulses were emitted at intervals of ~10-25 s depending on the vessel. The source vessel traveled at 4 to 5 kt (7.4-9.3 km/h). Detailed descriptions of the airgun arrays are contained in the 90-day reports submitted to NMFS and USFWS by each operator (Patterson et al. 2007; Ireland et al. 2007a,b).

Barging and Other Vessels

In addition to the vessel traffic associated with the seismic activities in the Chukchi Sea in 2006, other vessel traffic also occurred in the Chukchi Sea during the 2006 open-water season (Table 2.1). This vessel traffic was in support of other industry activity not associated with the current seismic surveys, and with barge activity in support of villages.

Table 2.1. General Chukchi Sea vessel traffic for operations not specifically associated with seismic exploration activities in the Chukchi Sea in 2006.

Vessel or Company Name	Type	Period	Location
Seaspan	Tug and 2 barges	Mid-Aug. to mid-Sept.	1 R/T transit of Chukchi Sea
Island Monarch/ Island Trader	Tug and barge	Early to mid-Aug	Transit Chukchi Sea to Barrow
Island Monarch/ Island Trader	Tug and barge	Early Sept.	Transit Chukchi Sea south from Barrow
Island Monarch/ Island Trader	Tug and barge	Late-Sept to early Oct.	1 R/T through Chukchi Sea north to Cape Lisburne and back
Healy	USCG icebreaker	Mid-July	Transit north through Chukchi Sea
Healy	USCG icebreaker	Late Aug.	Transit south through Chukchi Sea

Whaling Activities

Subsistence whaling activities occurred in the Chukchi Sea at Point Lay and Wainwright in 2006. Point Hope has conducted spring whales during many years (Suydam and George 2004) but sea ice and weather conditions precluded the spring hunt in 2006 (Suydam et al. 2006).

Whaling activities at Barrow are discussed in the next section, which describes activities in the Beaufort Sea. Whaling activities at Point Lay were confined to the spring/early summer hunt for beluga whales, which occurred on 13 July, prior to the beginning of seismic operations. Twenty-eight whales were harvested during the 13 July hunt including 20 males and eight females (Robert Suydam, NSB, pers. comm.).

Most whaling activity at Wainwright occurred during the spring hunt for bowhead whales which was considerably before seismic operations began in the Chukchi Sea. Considerable ice coverage limited boat access from the village for hunting during this period. During the hunt, two whales were harvested, one on 10 May and one on 11 May. Some limited boat activity also occurred during the fall hunt at Wainwright, although no whales were harvested. Wainwright normally does not hunt bowhead whales in the fall, since the whales typically migrate southwestward across the Chukchi Sea considerably north of Wainwright. Beluga whales are also hunted during some years at Wainwright, although no data on beluga whaling activities is available at this time. Limited boat activity also occurred off Point Hope during the 2006 fall whaling season, although no whales were harvested there during fall 2006. Point Hope has not typically hunted bowhead whales in the fall but applied for a quota from the AEWC in 2006.

Beaufort Sea

Seismic Vessel Component

SOI planned to conduct seismic exploration activities in the Beaufort Sea in the summer of 2006. However, ice conditions precluded SOI seismic operations in the Beaufort Sea in 2006. SOI was able to conduct shallow hazards and site clearance surveys in the Beaufort Sea from the *Henry Christoffersen*. Before drilling can begin, a site clearance survey and analysis is necessary to identify and/or evaluate potentially hazardous or otherwise sensitive conditions and sites at or below the seafloor that could affect the safety or appropriateness of operations. Examples of such conditions include subsurface faults, fault scarps, shallow gas, steep-walled canyons and slopes, buried channels, current scour, migrating sedimentary bedforms, ice gouging, permafrost, gas hydrates, unstable soil conditions, pipelines, anchors, ordnance, shipwrecks, or other geophysical or man-made features. Site clearance surveys are confined to a much smaller area using much lower sound sources than seismic surveys.

Offshore site clearance surveys use various geophysical methods and tools to acquire graphic records of seafloor and sub-seafloor geologic conditions. The data acquired and the types of investigations outlined below are performed routinely for most exploratory drilling and production facilities in marine areas, and for submarine pipelines, port facilities, and other offshore projects. High-resolution geophysical data were collected using two-dimensional high-resolution multi-channel seismic, medium penetration seismic, subbottom profiler, side scan sonar, multibeam bathymetry, magnetometer, and piston core sediment sampling. These data are interpreted to define geologic, geotechnical and archeological conditions at the site and to assess the potential engineering significance of these conditions. The following section provides a brief description of the operations and instrumentation used during SOI’s 2006 Beaufort Sea site clearance program insofar as they may impact marine mammals. A more thorough discussion of SOI’s activities in the Beaufort Sea is contained in SOI’s 90-day report to NMFS (Patterson et al. 2007).

Dates of Operations

The *Henry Christoffersen* was active in the Beaufort Sea from 1 Aug. to 3 Oct. Sound measurements from the airgun array and from other acoustic sources on the *Henry Christoffersen* were conducted on 8 Aug. in the Beaufort Sea, east of Kaktovik. The sound sources (including a cluster of four airguns) were operated for 2.5 hours on this date. From 8 Aug. to 2 Oct. 2006, on an intermittent basis as allowed by ice and weather conditions, various types of site clearance surveys were conducted from the *Henry Christoffersen.* Site clearance survey activities occurred on ~23 days during this period. However, during this period the airgun cluster (now reduced to two airguns) was operated only once for ~12 h on 25 Sept. At all other times during surveys, the acoustical sources in use were lower-energy, medium- and high-frequency sources as described below. On days when surveys did not occur, the *Henry Christoffersen* was usually transiting to a new site or anchored while waiting for bad weather or ice conditions to subside.

Location of Activities

These operations were located in specific nearshore areas, ranging from east of Kaktovik west to Thetis Island near the Colville River Delta (Fig. 2.3). The site clearance surveys were confined to very small specific areas within defined OCS blocks (Fig. 2.3). Small geophysical survey sources with limited energy output were employed to measure bathymetry, topography, geohazards, and other seabed characteristics.

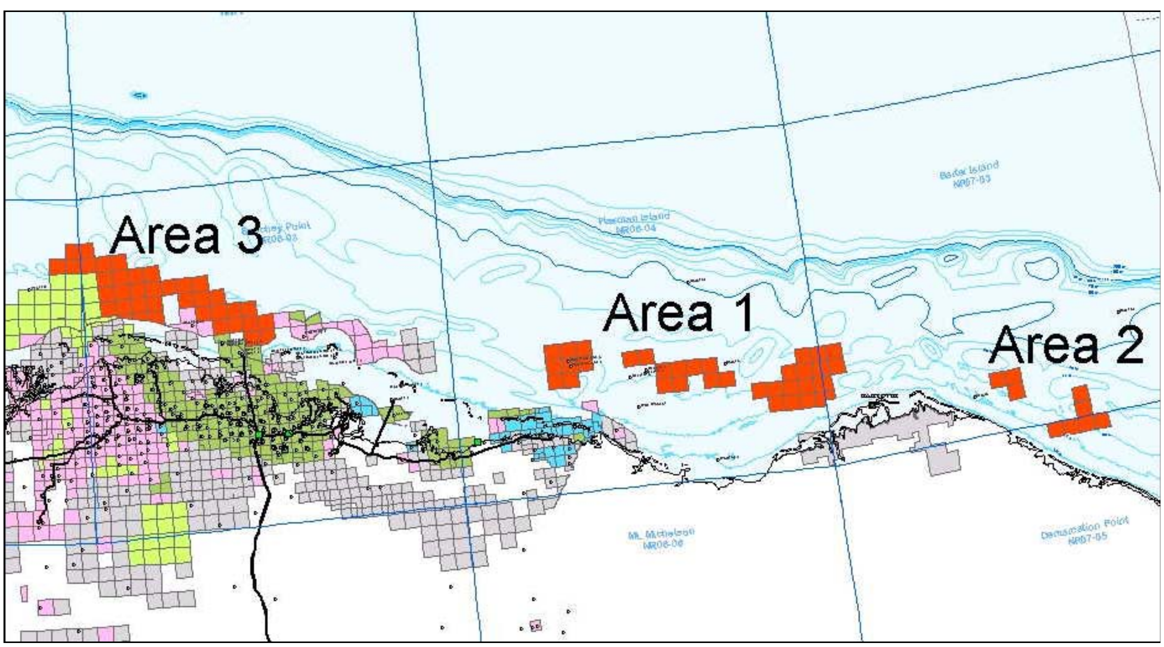

FIGURE 2.3. Location of SOI lease holdings in the Alaskan Beaufort Sea. SOI's 2006 shallow-hazards surveys were in Areas 1 and 2.

Navigation

Throughout the survey period the *Henry Christoffersen*'s position, speed, and water depth were logged digitally every ~60 s. In addition, information on the output of the airgun array or other geophysical tools was logged during all site clearance activities. The geophysics crew kept an electronic log of events, as did the MMOs while on duty.

<u>*Airgun Description and Geophysical Tools Used for Site Clearance*</u>

An airgun cluster consisting of four 70 in^3 airguns was planned for use during site clearance operations to locate potential hazards, such as gas deposits, at relatively shallow locations. The results of the source measurements on 8 Aug. with the four airguns indicated that the use of the array was excessive for their needs and only two 70 in^3 airguns were used during the ~12 h of airgun operations on 25 Sept.

Several other lower-energy acoustic sources were operated for shallow-penetration sub-bottom surveys and for mapping the bottom. A bubble pulser operating at frequencies near 400 Hz was used for medium penetration, and a chirp sonar operating at two-seven and eight–23 Hz was used for shallow penetration. Other acoustic sources used to map the seafloor included a multibeam bathymetric sonar operating at 240 kHz and a side-scan sonar operating at 190–210 kHz.

Beaufort Sea Construction (Pioneer)

Pioneer Natural Resources Alaska, Inc. (Pioneer) constructed a gravel island, the Ooog-uruk Drilling Site (ODS), in Harrison Bay near the Colville River delta for future oil drilling and production operations. The ODS is located ~6 km (4 statute mi) southwest of Thetis Island and 13 km (8 statute mi) east of Oliktok dock. Gravel was hauled to the ODS on ice roads during winter 2006 and stockpiled.

During the 2006 open-water period, construction activities on the ODS included moving sand from the stockpile to a sandbag filling station, transporting filled sandbags to a deployment location, and final placement of the sandbags on the shore perimeter. Tugs and barges were used at various times during the open-water period to haul construction equipment and supplies to the ODS. Heavy equipment used for this operation included a Deer 750J bulldozer, Caterpillar 330C and 345B excavators, a Caterpillar 966 loader, and a Terex HC275 crane. Trailers used for offices and personnel housing were also brought to the ODS during summer barging activity. Pioneer's barging activity is described below.

During Sept. 2006, Pioneer contracted JASCO and LGL to conduct an acoustic study of construction-related sounds at the ODS, and an aerial survey of bowhead whales within 24-32 km (15-20 mi) of the island. The results of those studies are reported in Chapter 11.

Oil Production Operations (BP Northstar)

BP Exploration (Alaska), Inc. (BP) has been producing crude oil from Northstar Island, a man-made island in the Beaufort Sea, since late 2001. Northstar Island is located 10 km (~6 statute mi) offshore, north of the Prudhoe Bay oil field. The gravel island serves as a work surface to support drilling and oil production facilities. Two subsea pipelines connect Northstar Island to the mainland. One pipeline transports production oil to existing facilities at Prudhoe Bay, and the other transports natural gas to the island for field injection and use in power generation.

Numerous types of activities are required to support oil production, which occurs throughout the year at Northstar. Oil field workers may live on the island for several weeks at a time, and various types of equipment are used for transport of personnel and supplies between West Dock and the island. Vessel traffic associated with transportation of personnel and equipment to and from Northstar Island is the most significant type of activity likely to affect the behavior of bowhead whales and other marine mammals during the open-water season. The vessel types include Bay class boats used as crew vessels, and tug and barge traffic between West Dock and the island. In past years crew vessels were used as the primary means of transportation to and from Northstar during the open-water season, but in recent years a Griffon 2000 TD hovercraft has been the primary means of transportation, although crew vessels are still used. Tables 2.2, 2.3 and 2.4 enumerate the number of crew vessel, hovercraft, and tug/barge round trips to Northstar Island during the 2006 open-water season (from Rodrigues and Richardson 2007).

TABLE 2.2. Number of Bay-class boat round trips to Northstar Island by month during the 2006 open-water period.

Month	Bay-Class Boat Round Trips
July 2006	1
August 2006	69
September 2006	33
October 2006	3

TABLE 2.3. Number of hovercraft round trips to Northstar Island by month during the 2006 open-water period.

Month	Hovercraft Round Trips
16-30 June 2006	47
July 2006	124
August 2006	114
September 2006	162
October 2006	113

TABLE 2.4. Number of tug and barge round trips to Northstar Island by month during the 2006 open-water period.

Month	Tug and Barge Round Trips
July 2006	10
August 2006	25
September 2006	25
October 2006	4

Helicopters (Bell 212) are also used for Northstar transportation needs during the open-water season. Table 2.5 enumerates the number of helicopter round trips to Northstar Island during the 2006 open-water season. Other vessel activity near Northstar includes oil spill response training drills conducted at various times throughout the summer, and the deployment and recovery of scientific equipment used for acoustic studies to monitor industrial sounds and calling bowhead whales. BP also has an ARKTOS evacuation vehicle stationed on Northstar

Island that can be used should evacuation of the island be necessary during an emergency. The ARKTOS is usually serviced and used during training activities during the open-water season.

TABLE 2.5. Number of Bell 212 helicopter round trips to Northstar Island by month during the 2006 open-water period.

Month	Helicopter Round Trips
16-30 June 2006	34
July 2006	26
August 2006	33
September 2006	13
October 2006	155

Most well-drilling activity has been completed at Northstar, although periodic drilling activity occurs during the open-water period for well maintenance. This work usually involves the use of cables to lower equipment into the drill hole. New wells are also occasionally drilled.

In recent years BP has conducted maintenance activities to repair the block system and fabric barrier around the perimeter of Northstar Island. This work usually begins during the ice-covered period and continues into the open-water period. The large cement blocks that form the protective barrier around the island may shift position over time. This shifting can cause the fabric barrier under the blocks to tear, which in turn allows gravel below the blocks to wash away. To repair the system the blocks are removed, sandbags are positioned at locations where gravel has washed away, a new fabric barrier is placed over the sandbags, and the blocks are repositioned and shackled together. Equipment used for these repairs include a Manitowoc 888 crane, Volvo 150D loader, John Deere 650 excavator, Ingersoll-Rand zoom-boom, air compressors, Chinook 800 and Tioga heaters, and generators.

Five gas turbines are located on Northstar Island: three Solar® generators for power generation and two GE LM-2500 high pressure compressors for gas injection. There is also a low-pressure compressor driven by a 5000 hp (3730 kW) electric motor running at a constant speed of 3600 rpm.

BP and its contractors have conducted numerous studies to monitor the effects of the Northstar development on marine mammals and the potential for Northstar activities to affect subsistence hunts for bowhead whales and seals. These studies have included pre- and post-development aerial surveys of ringed seals, and the use of trained dogs to study ringed seal use of lairs near Northstar. In addition, acoustic studies were done to determine the levels of various types of industrial sounds at Northstar Island during island construction, drilling, and production periods, and the attenuation of those sounds with distance from Northstar. Other acoustic studies focused on calling bowhead whales during the fall migration in an effort to determine what effects sounds generated from Northstar may have on the bowhead whale migration corridor. Descriptions of the various studies and their results are contained in annual and updated comprehensive reports (e.g., Richardson [ed.] 2006), annual summary reports (Richardson [ed.] 2007), and in 90-day reports submitted by BP to NMFS. In addition, a number of peer-reviewed articles and manuscripts have resulted from the Northstar marine mammal and acoustic studies program (e.g., Blackwell et al. 2004a,b, Blackwell and Greene 2005, 2006, Greene et al. 2004, Moulton et al. 2002, 2003, 2005; Williams et al. 2006). A summary of BP's 2006 acoustic program at Northstar is contained in Chapter 11.

Barging and Other Vessels

Barging activities in the Beaufort Sea in 2006 were conducted in support of industry and other activities from Cape Simpson to Kaktovik. In addition, one fuel barge transited the Beaufort Sea into Canada. The primary companies conducting barge activities in the Beaufort Sea were FEX between West Dock and Cape Simpson, Pioneer Natural Resources between Oliktok Point or West Dock and their man-made drilling island off the mouth of the Colville River, BP Exploration between West Dock and Northstar Island, and Marsh Creek between West Dock and Kaktovik and Point Lonely.

FEX conducted barge traffic between West Dock and Cape Simpson in support of exploration drilling activities in the National Petroleum Reserve Alaska (NPR-A). Barging activities occurred between 31 July and 2 Oct. In total, 30 round trips were made between West Dock and Cape Simpson (Table 2.6). Bowhead Transportation used flexi-float barges, either the M/V *Garrett* or the M/V *Stryker,* to conduct 15 of these round trips. Crowley Marine Systems conducted 14 round trips for FEX between West Dock and Cape Simpson using the tug, *Kuparuk River,* a 210 series barge or the tug *Sag River,* and a 211 series barge. One round trip was conducted by NTCL-Canada with the tugboat *Nunakput*, and 1522 and 1525 barges. MMOs were onboard many of the barge round trips and the results of their observations were reported by Green and Negri (2006).

Barge activity in support of Pioneer's ODS located off the mouth of the Colville River was conducted by Crowley Marine Systems and Bowhead Transportation. In total, 39 round trips were made from the dock at Oliktok Point to ODS, and 7½ round trips were made between West Dock and ODS (Table 2.6). The barging activities began on 28 July and ended on 13 Oct. Crowley and Bowhead used the same barges for the Pioneer work as those named above for the FEX work. The results of observations made by MMOs onboard barges for Pioneer's ODS traffic are reported by ASRC (2006).

BP Exploration conducts barge traffic annually during the open-water period in support of oil production activities at Northstar Island. During 2006, 64 round trips were made between West Dock and Northstar Island (Tables 2.4 and 2.6). Most barge activity occurred during Aug. and Sept. with reduced activity in July and Oct. In addition to barge traffic, BP also uses a hovercraft and crew vessels to transport personnel and equipment to and from Northstar Island (Tables 2.2 and 2.3). Details of activities during 2006 on Northstar Island are discussed in Rodrigues and Richardson (2007).

Marsh Creek conducted various types of construction activities at Kaktovik and Lonely that required barge activity (Table 2.6). Barges operating in support of Marsh Creek's activities made eight round trips between West Dock and Kaktovik beginning on 5 Aug. and ending on 23 Sept. In addition, an equipment backhaul on the deck of a Crowley fuel barge occurred on 3 Sept. Bowhead Transportation made eight round trips from West Dock to Lonely in support of Marsh Creek's activities from 4 through 17 Sept.

TABLE 2.6. Number of barge round trips for FEX, Pioneer, BP, and Marsh Creek in the Beaufort Sea 2006.

	FEX	Pioneer		BP	Marsh Creek	
Month		Oliktok/ODS	West Dock/ODS		Kaktovik	Lonely
July	1	9	0	10	0	0
August	24	10	3	25	4	0
Sept	5	11	2	25	4	8
October	0	9	2.5	4	0	0

A tug with two barges operated by Seaspan International Ltd. of Vancouver, B.C., transited the Beaufort Sea from Barrow into Canadian waters in late August. The tug left the barges in Canada and transited back through the Beaufort Sea in early to mid-September.

The barge M/V *Sam Taalak* operated by Bowhead Transportation made one round trip carrying general cargo from Barrow to Kaktovik in early to mid-August. The M/V *Greta Akpik*, also operated by Bowhead Transportation, made two round trips carrying general cargo between Barrow and West Dock from mid-August to early September.

The articulated tug *Island Monarch* and barge *Island Trader* transited the Beaufort Sea from Canada in early September. The *Island Monarch* and *Island Trader* arrived at Barrow on 4 Sept. and departed into the Chukchi Sea on 5 Sept.

In addition to the barge traffic, GXT's seismic vessel, the *Discoverer*, also transited the Beaufort Sea in mid- to late August and again in early October.

Other vessel activity in the Beaufort Sea not associated with seismic activities included barge activities in support of villages and transiting the Beaufort Sea to and from Canada (Table 2.7). The seismic ship *Discoverer* which conducted seismic activities in the Chukchi Sea also transited the Beaufort Sea twice although no seismic activities occurred during transit.

Table 2.7. General vessel traffic for operations not specifically assocaited with seismic exploration activities through the Beaufort Sea in 2006.

Vessel or Company Name	Type	Period	Location
Seaspan	Tug and 2 barges	Late Aug.	Beaufort Sea from Barrow to Canada
Sam Taalak	Landing craft	Early to mid-Aug.	1 R/T, Barrow to Kaktovik
Greta Akpik	Landing craft	Mid-Aug. to early Sept.	2 R/T, Barrow to West dock
Island Monarch/ Island Trader	Tug and barge	Mid-Aug.	Barrow to Canada
Island Monarch/ Island Trader	Tug and barge	Mid-Aug.	Canada to Barrow
Discoverer	Seismic vessel	Mid- to late Aug	Barrow to Canada
Discoverer	Seismic vessel	Early Oct.	Canada to Barrow

Whaling Activities

Subsistence whaling activities for bowhead whales in the Beaufort Sea occurred at Kaktovik, Cross Island (Nuiqsut), and at Barrow during 2006. Subsistence whaling at Barrow occurred in the spring during the eastward migration of bowhead whales and during their westward migration in the fall. The subsistence hunts for bowheads at Nuiqsut and Kaktovik occurred only in the fall. Bowhead whale hunts are conducted under the regulation of the International Whaling Commission (IWC) through harvest quotas. The quotas are based in part upon bowhead whale population estimates that are supplied to the IWC by the Alaska Eskimo Whaling Commission (AEWC), the North Slope Borough Department of Wildlife Management, and NOAA Fisheries. Beluga whales are also harvested during some years at Barrow, although no data were available on the beluga harvest at Barrow in 2006.

Twenty-nine bowhead whales were taken by the three villages including three during the spring and 26 during the fall (Table 2.8). The whales harvested in the Beaufort Sea combined with the two whales harvested in the Chukchi Sea at Wainwright resulted in 31 bowhead whales taken in 2006. Harvest results for Beaufort Sea villages are provided below. Detailed results of the harvest activities at Cross Island are presented in Galginaitis (2007). On average, 41.8 bowhead whales have been landed annually by Alaskan Natives during the last 10 years (1996-2005; Suydam et al. 2006). Thus, the 2006 bowhead harvest of 31 bowheads was below the most recent 10-year average.

Table 2.8. Number of bowhead whales harvested during spring and fall hunts at villages on the Beaufort Sea coast 2006. Data are from Suydam et al. 2006.

Village	Spring	Spring Period	Fall	Fall Period
Barrow	3	Mid-May	19	Late Sept. to early Oct.
Nuiqsut	N/A	N/A	4	Mid. Sept.
Kaktovik	N/A	N/A	3	Early Sept.

Area-wide Monitoring

Several other monitoring activities occurred in the Beaufort Sea during the 2006 open-water period. These were sponsored primarily by MMS, although SOI supported some of the whale monitoring activities near Barrow.

The MMS conducts the Bowhead Whale Aerial Survey Program (BWASP) annually to monitor the fall migration in the Beaufort Sea. The goals of the program are to:

- define the annual fall migration of bowhead whales, and significant inter-year differences and long-term trends in the distance from shore and water depth at which whales migrate.
- monitor temporal and spatial trends in the distribution, relative abundance, habitat, and behaviors (especially feeding) of bowhead whales in arctic waters.
- provide real-time data to MMS and NMFS on the general progress of the fall migration of bowhead whales across the Alaskan Beaufort Sea.
- provide an objective area-wide context for management interpretation of the overall fall migration of bowhead whales and site-specific study results.
- record and map beluga whale distribution and incidental sighting of other marine mammals.
- determine seasonal distribution of bowhead whales in other planning areas of interest to MMS.

The most recent report on the results of the aerial survey program includes information on the 2002-2004 fall migration (Monnett and Treacy 2005). Reports of the results for subsequent years will be forthcoming.

The MMS program entitled *Continuation of Arctic Nearshore Impact Monitoring in the Development Area* (cANIMIDA) is a vessel-based monitoring program that completed its seventh season in 2006. The survey crews collected water, sediment, and biota samples for physical and chemical analyses. Work was conducted from shore, inflatable boats, a Boston Whaler, and the MMS Vessel 1273. Sample collection activities included deployment and retrieval of mussel moorings, gravity cores, fish collection using fyke nest, towed benthic sled, small traps, plankton tows and kelp and benthic invertebrates from the Boulder Patch located in Stefansson Sound near Prudhoe Bay. The monitoring program in 2006 was conducted from 24 July to 12 Aug. in shelf waters from Harrison Bay to the Kavik River. Results of the 2006 field season were reported by Hardin (2006) and Dunton et al. 2006.

The Alaska Department of Fish and Game initiated an ongoing bowhead whale satellite tagging study during the spring migration past Barrow in 2006. Two bowheads were tagged, one in spring (May) and a second in fall (Sept.). Results of the study are available online at http://wildlife.alaska.gov/index.cfm?adfg=marinemammals.bowhead.

Regional Timeline of Activities

A Gantt chart showing the time periods during which activities described in this report took place is presented in Fig. 2.4. The Gantt chart is divided into weekly periods and provides a general overview of the timing of various activities during the 2006 open-water period. Specific dates of the various activities are contained in the relevant chapters of the report. Figures 2.5 – 2.14 are maps showing the general locations and spatial extent of activities described in this report.

ID	Task Name	Start	Finish	Text1
1	**Chukchi Sea**	**7/9/06**	**11/11/06**	
2	**Seismic**	**7/19/06**	**11/11/06**	
3	**Shell**	**7/21/06**	**9/19/06**	
4	Shell SSV	7/21/06	7/21/06	
5	Shell Seismic	7/29/06	9/19/06	
6	**CPAI**	**7/24/06**	**10/12/06**	
7	CPAI SSV	7/24/06	7/24/06	
8	CPAI Seismic	7/29/06	10/12/06	
9	**GXT**	**8/8/06**	**11/11/06**	
10	GXT SSV	8/8/06	8/8/06	
11	GXT Seismic	10/16/06	11/11/06	
12	**USS Healy near Barrow**	7/19/06	8/20/06	
13				
14	**Research**	**7/9/06**	**11/11/06**	
15	**Acoustic Recorders**	**7/15/06**	**10/16/06**	
16	**Phase I**	**7/15/06**	**9/10/06**	
17	Cape Lisburne	7/15/06	9/10/06	
18	**Phase II**	**9/10/06**	**10/16/06**	
19	Cape Lisburne	9/10/06	10/13/06	
20	Pt. Lay	9/12/06	10/12/06	
21	Wainwright	9/12/06	10/12/06	
22	Barrow	9/17/06	10/16/06	
23	**Vessel Surveys (w, w/o PAM)**	**7/15/06**	**10/22/06**	
24	1) Torsvik (PAM)	7/15/06	7/16/06	
25	2) Gulf provider (w/o PAM)	8/26/06	8/31/06	
26	3) Torsvik (PAM)	9/5/06	9/10/06	
27	4) Gulf Provider (w/o PAM)	9/30/06	10/2/06	
28	5) Torsvik (PAM)	10/18/06	10/22/06	
29	**Aerial Surveys**	**7/9/06**	**11/11/06**	
30	Coastline Aerial Surveys	7/9/06	11/11/06	
31				
32	**Beaufort Sea**	**7/10/06**	**10/31/06**	
33	**Industry Activities**	**7/10/06**	**10/31/06**	
34	**Shallow Hazards Surveys**	**8/8/06**	**10/2/06**	
35	Shallow Hazards SSV	8/8/06	8/8/06	
36	Bathymetric Surveys	8/9/06	10/2/06	
37	Shallow Hazards survey	9/25/06	9/25/06	
38	Aerial Surveys - Camden Bay	8/26/06	9/24/06	
39	**Barging**	**7/10/06**	**10/31/06**	
40	WD - Northstar	7/10/06	10/31/06	64 round trips
41	WD - Kaktovik	8/5/06	9/23/06	8 round trips
42	Barrow - Kaktovik	8/16/06	8/23/06	1 round trip
43	Barrow - WD	8/16/06	9/8/06	2 round trips
44	WD - Cape Simpson	7/31/06	10/2/06	30 round trips
45	WD - ODS/Colville R.	7/28/06	10/13/06	7.5 round trips
46	Oliktok Point - ODS/Colville	7/28/06	10/13/06	39 round trips
47	**Research**	**8/29/06**	**10/27/06**	
48	**SNACS surveys**	9/2/06	10/27/06	
49	**BWASP Surveys**	9/2/06	10/27/06	
50	**Northstar DASAR's**	8/29/06	9/25/06	
51	**DASARb's - Vertical Arrays**	9/10/06	10/1/06	

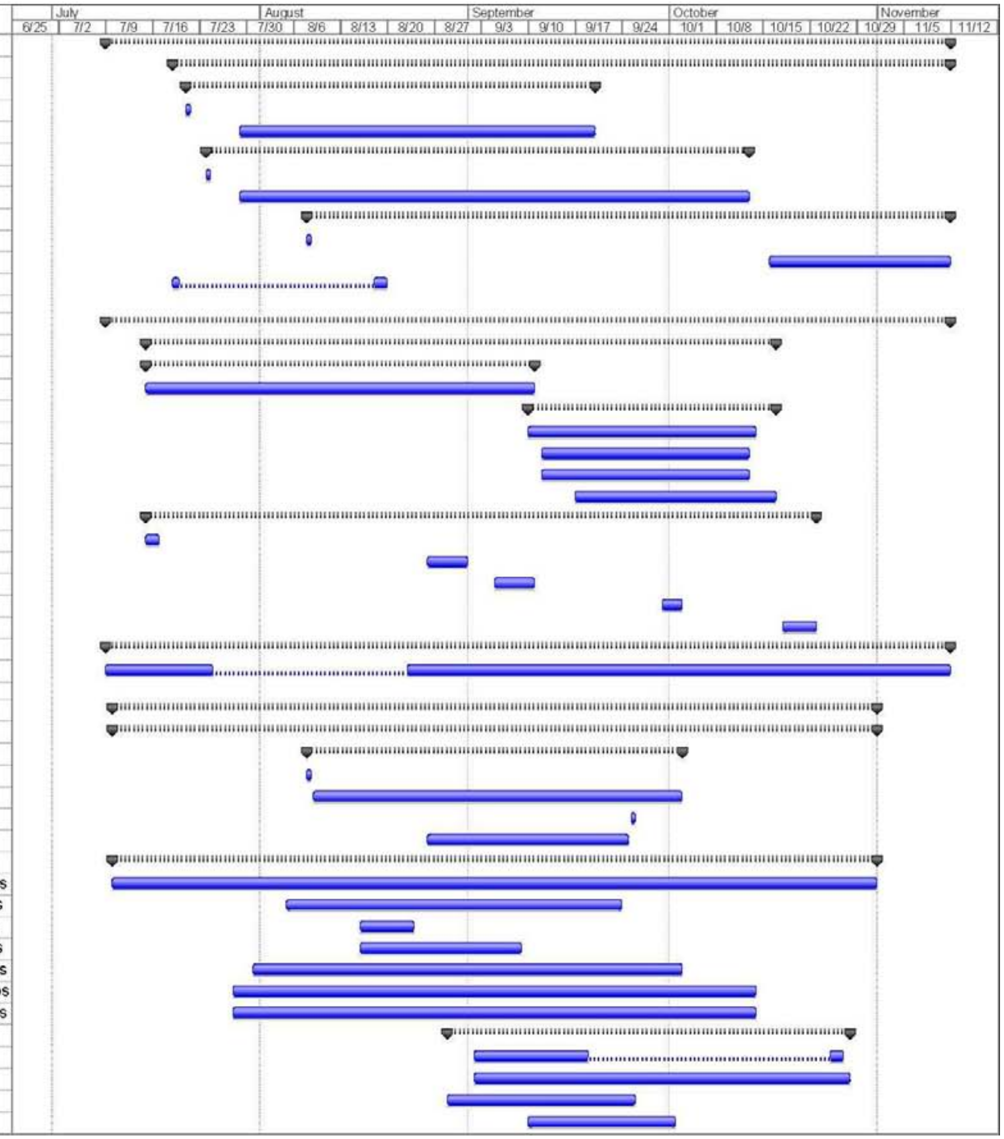

Figure 2.4. Gantt chart showing the time and duration of activities described in this report. The gray bars indicate the duration of each category of activity and the blue bars indicate the duration of specific activities that occur within each category.

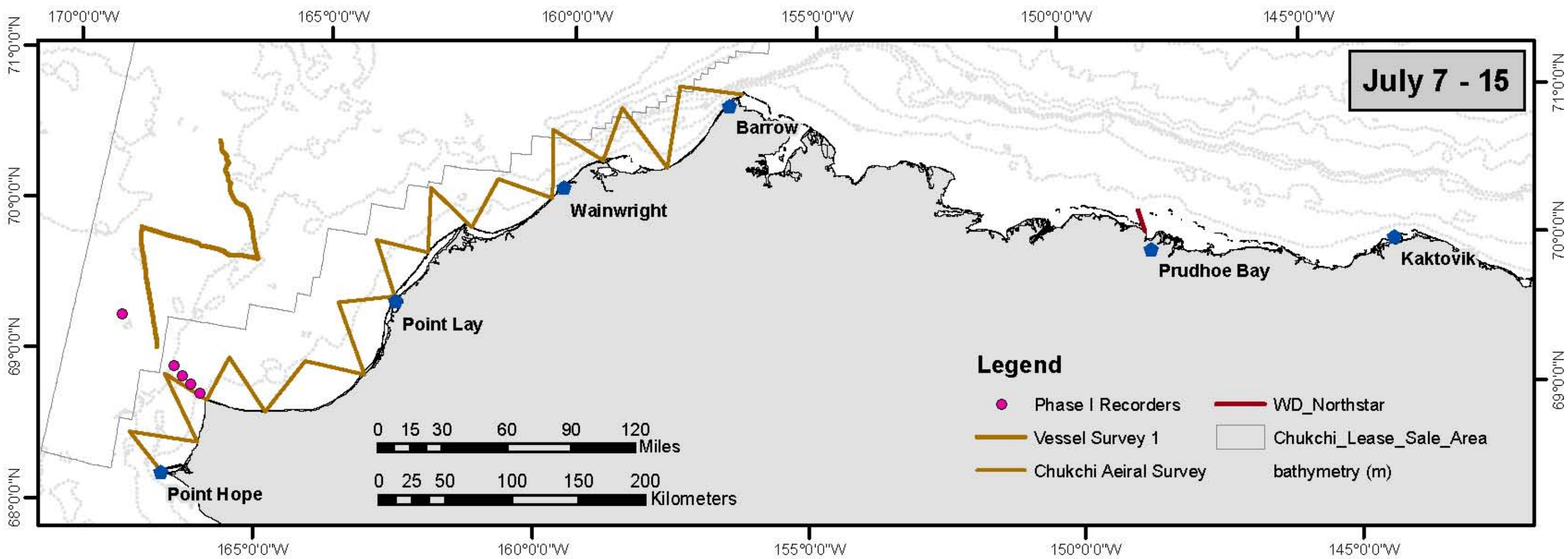

Figure 2.5. Activities that took place or were ongoing between 7July and 15 July 2006.

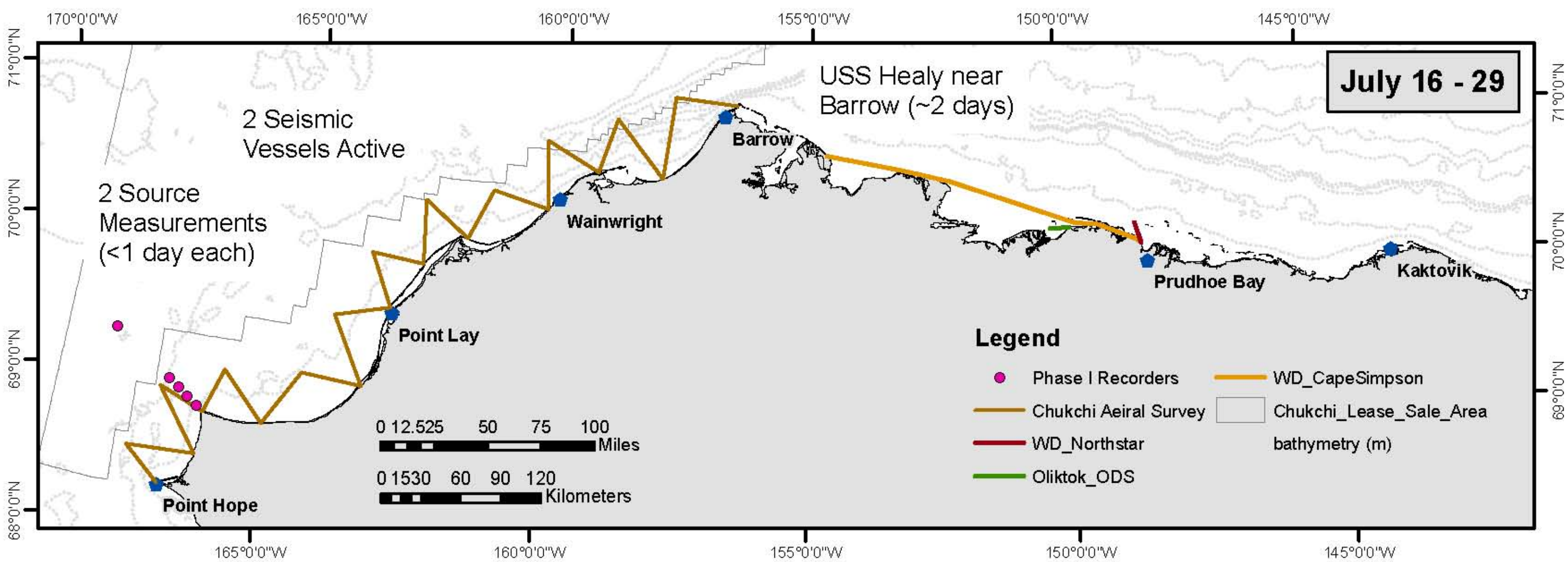

Figure 2.6. Activities that took place or were ongoing between 16July and 29 July 2006.

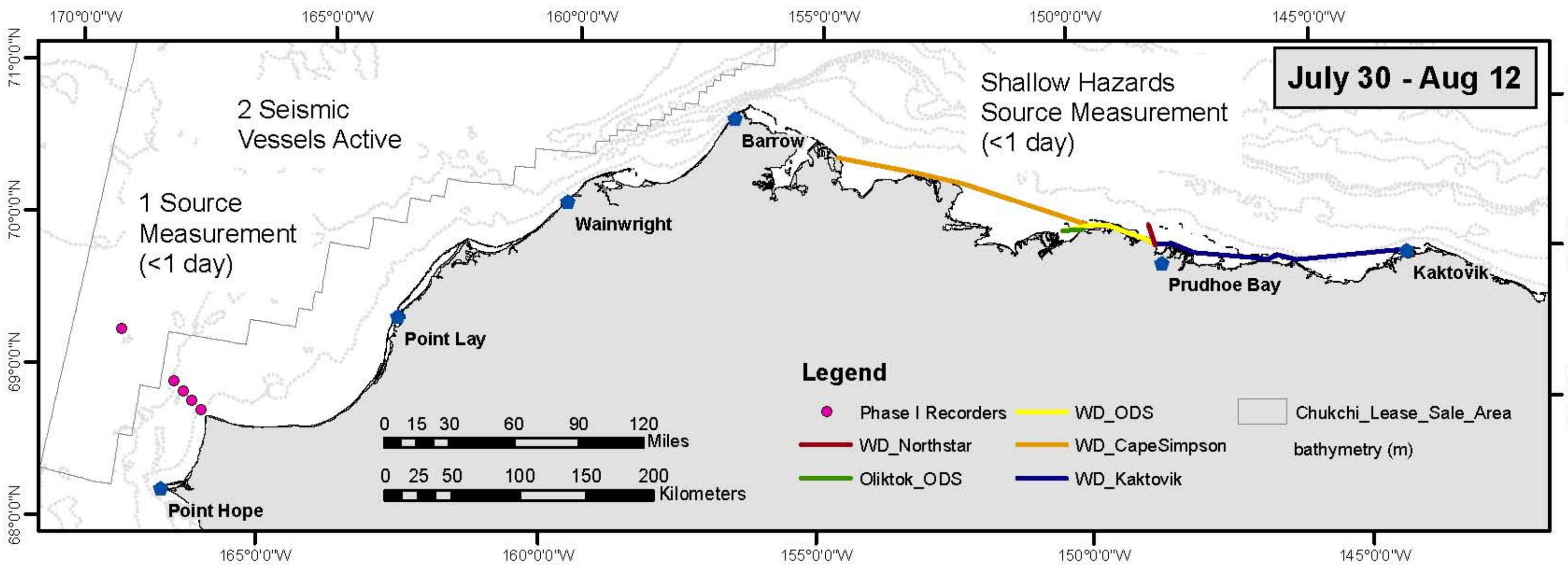

Figure 2.7. Activities that took place or were ongoing between 30 July and 12 Aug. 2006.

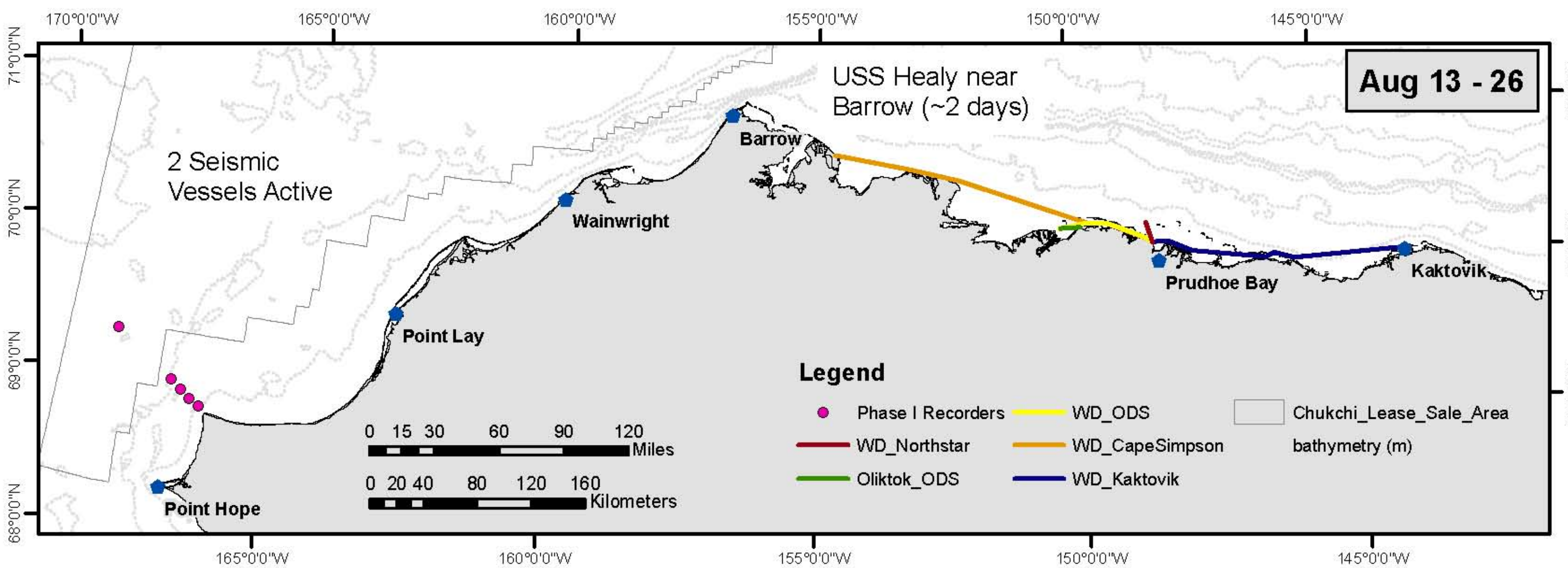

Figure 2.8. Activities that took place or were ongoing between 13 Aug. and 26 Aug. 2006.

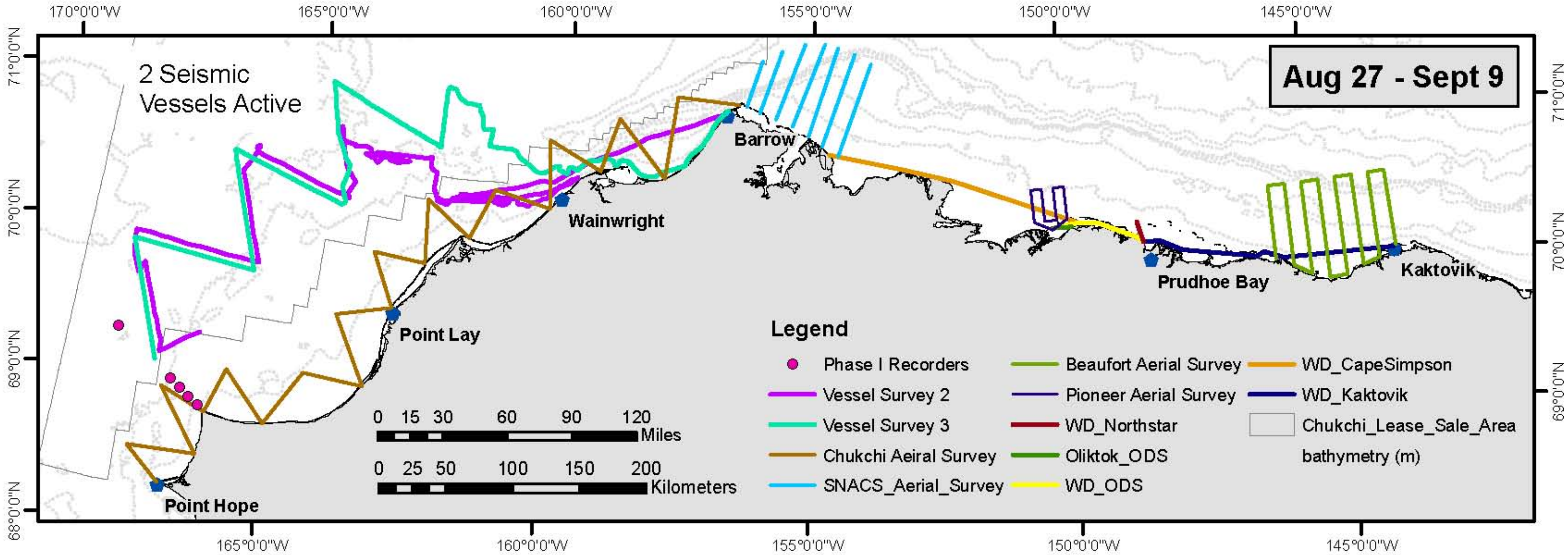

Figure 2.9. Activities that took place or were ongoing between 27 Aug. and 9 Sept. 2006.

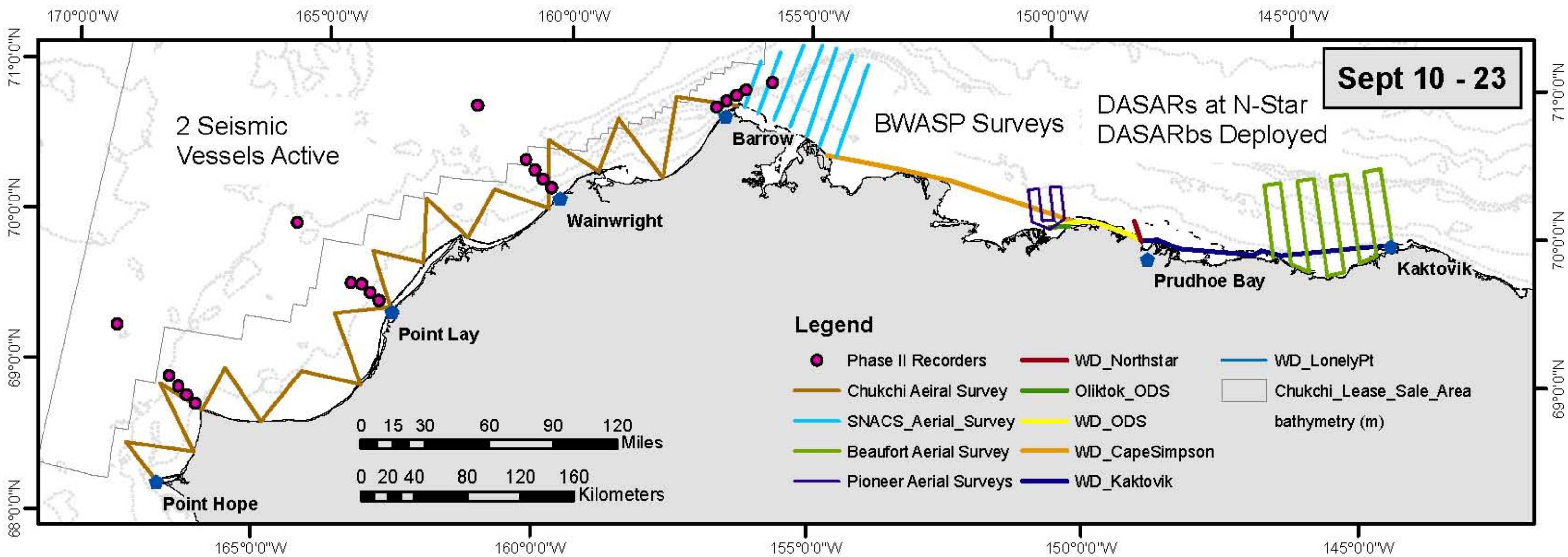

Figure 2.10. Activities that took place or were ongoing between 10 Sept. and 23 Sept. 2006.

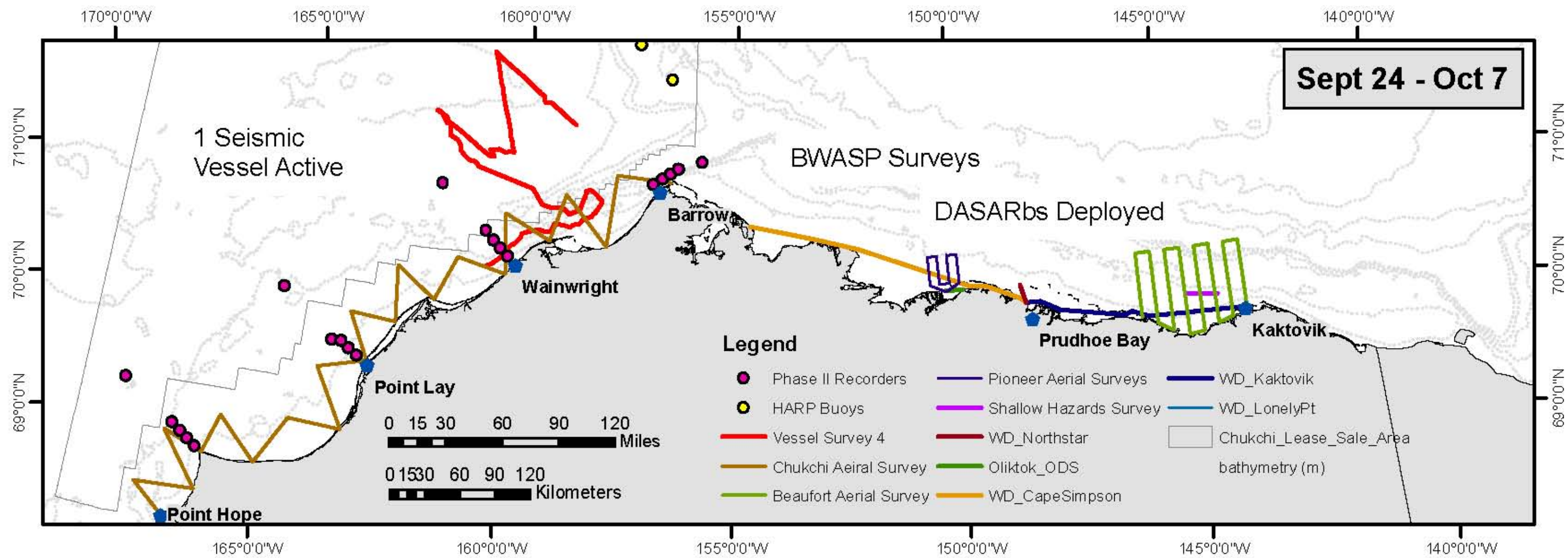

Figure 2.11. Activities that took place or were ongoing between 24 Sept. and 7 Oct. 2006.

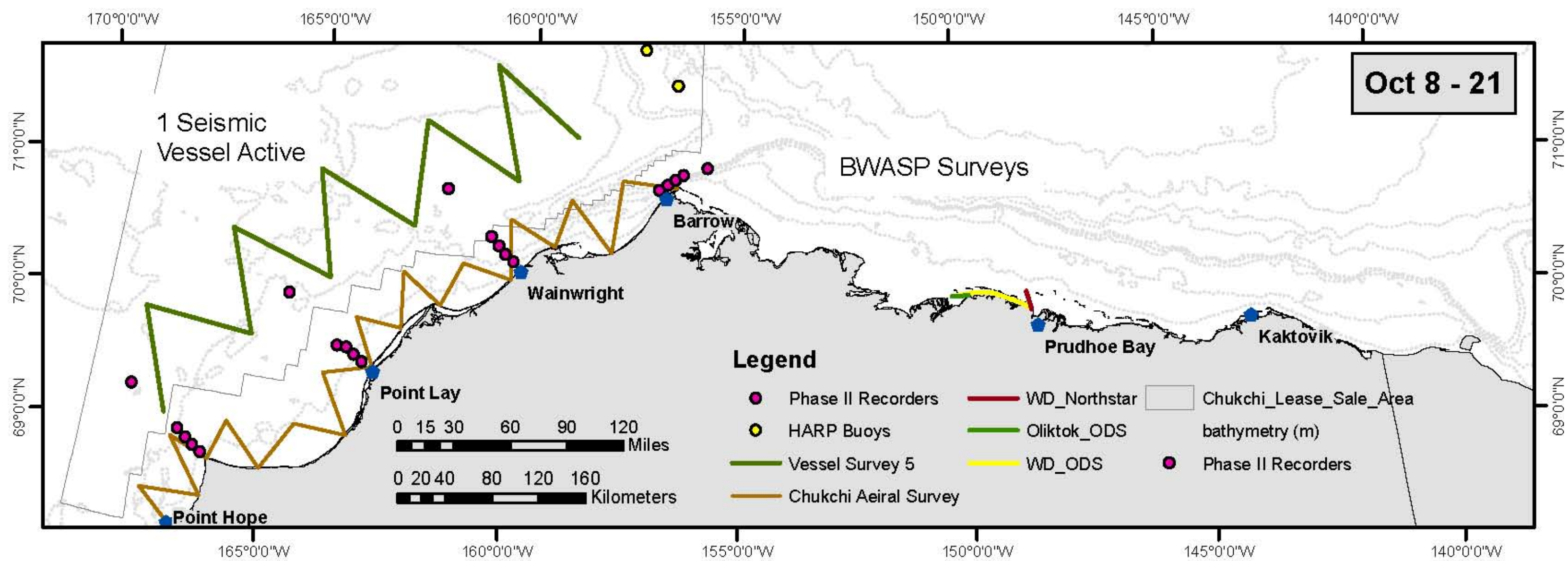

Figure 2.12. Activities that took place or were ongoing between 8 Oct. and 21 Oct. 2006.

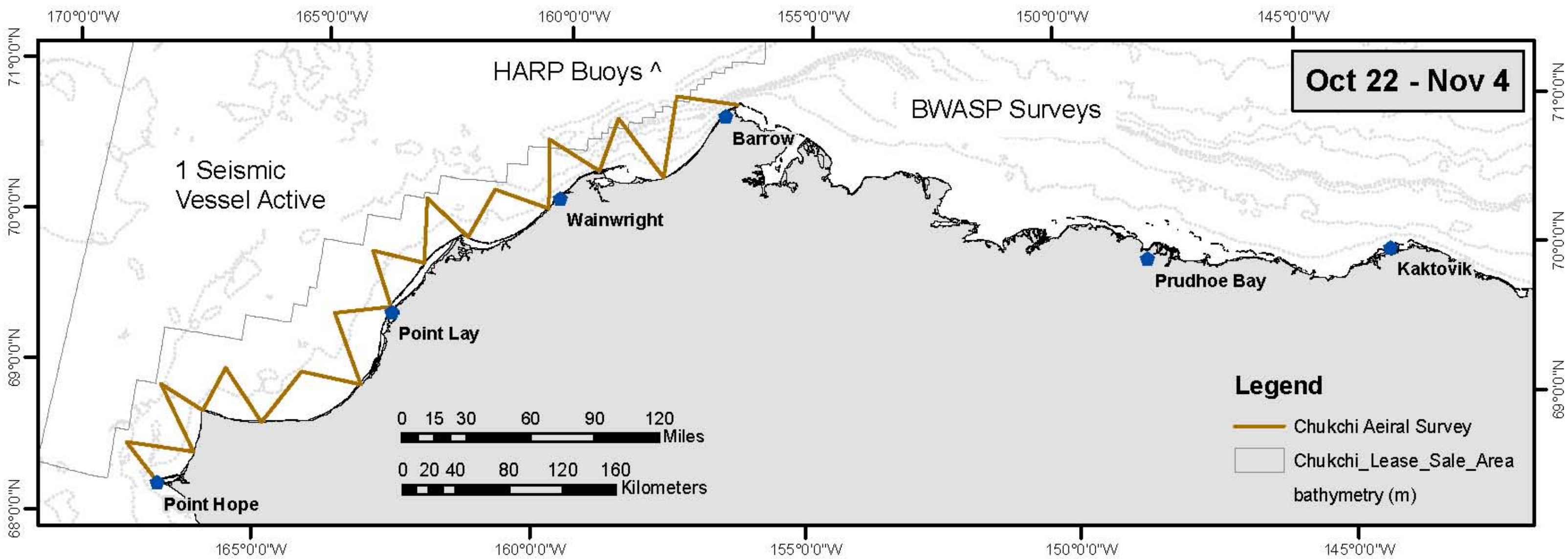

Figure 2.13. Activities that took place or were ongoing between 22 Oct. and 4 Nov. 2006.

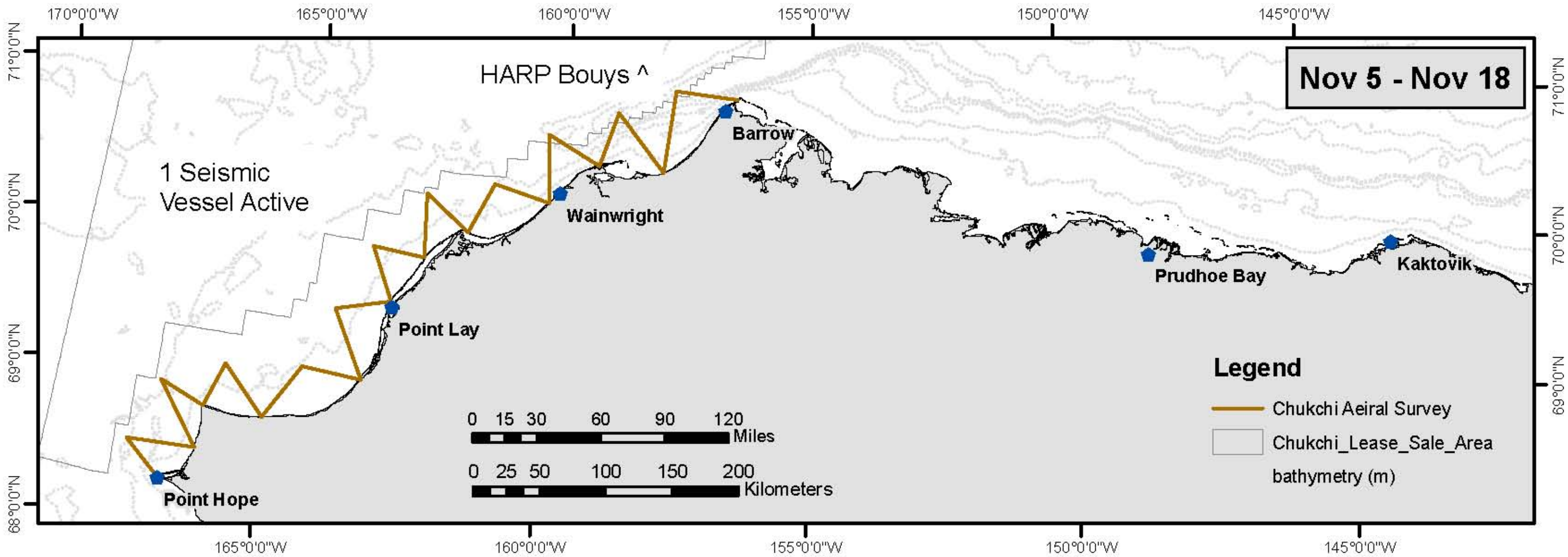

Figure 2.14. Activities that took place or were ongoing between 5 Nov. and 18 Nov. 2006.

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3. SUMMARY OF CHUKCHI SEA VESSEL-BASED MONITORING PROGRAM[1]

Introduction

This chapter describes the combined marine mammal observation data collected from all vessels involved in the seismic programs implemented in the Chukchi Sea by SOI, CPAI, and GXT during the 2006 open-water season. The data are described similarly to that in the 90-day reports submitted by each individual company as required by the IHAs (see Appendices A and B in the 90-day reports; Ireland et al. 2007a,b; Patterson et al. 2007). In addition to the usual MMO effort on the three seismic source vessels, all support vessels used in the programs had MMOs onboard. Collectively, the data from the various vessels covered a broad period of time and geographic extent and provided more information about marine mammals of the Chukchi Sea than could be obtained during vessel-based observations for any one operator.

Nine cetacean and five pinniped species are known to occur in the project area, along with the polar bear. Three species, bowhead, humpback, and fin whale are listed as endangered under the U.S. Endangered Species Act (ESA). Humpback and fin whales are uncommon in the Chukchi Sea and less likely to occur in the seismic survey area than bowhead whales. For more details on the abundance, habitat, and conservation status of the marine mammal species likely to occur in the cruise areas, see Appendix F in any of the 90-day reports for the 2006 seismic activities in the Chukchi Sea (Ireland et al. 2007a,b; Patterson et al. 2007).

Monitoring Objectives

The main purposes of the vessel-based monitoring programs were to ensure that the provisions of the IHAs issued to SOI, CPAI, and GXT by NMFS and USFWS were satisfied, and that potential effects on marine mammals were minimized and documented if they occurred. The primary objectives of the monitoring program were as follows:

- provide real-time sighting data needed to implement the mitigation requirements;
- determine the reactions (if any) of marine mammals potentially exposed to seismic sounds;
- estimate the numbers of marine mammals potentially exposed to strong seismic sounds; and
- estimate abundance and distribution of marine mammals in the Chukchi Sea.

Safety 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 IHAs issued to the companies in 2006. These safety criteria are based on an assumption that seismic pulses at lower received levels will not injure

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[1] Meaghan Jankowski, Heather Patterson, William R. Koski and Mark Fitzgerald: LGL Limited, King City, Ontario.

these animals or impair their hearing abilities, but that higher received levels *might* have some such effects. There is currently no evidence in the scientific literature that exposure to airgun pulses can cause permanent hearing loss in marine mammals, and thus the 180 and 190 dB (rms) safety criteria are considered to be precautionary. Distances from the three different airgun arrays at which received sound levels decreased to the 190–160 dB re 1 µPa (rms) levels are presented in Table 3.1.

Potential Disturbance Radii

In addition to the standard safety radii, based on the ≥190 and ≥180 dB (rms) distances for pinnipeds and cetaceans, respectively, NMFS (in the 2006 IHAs) required the ≥160 dB (rms) radius to be monitored during all airgun operations. NMFS assumes that marine mammals exposed to ≥160 dB (rms) are potentially subject to behavioral disturbance; however, for certain groups such as dolphins and pinnipeds, some available data indicate that disturbance is unlikely to occur unless received levels are higher, perhaps ≥170 dB (rms) (Richardson et al. 1995; Richardson and Würsig 1997; Stone 2003).

Mitigation Measures

Power-down or shut-down procedures were implemented on the source vessels when a marine mammal was sighted within or approaching the applicable safety radius while the airguns were operating. Briefly, a power down involved reducing the number of operating airguns from the full array to either one or two airguns when a marine mammal was observed approaching or was seen within the safety radius for the full array. A shut down involved suspending operation of all airguns. A shut down was sometimes implemented when a mammal was first sighted within or approaching its safety radius. At other times the airgun array was first powered down, and was later fully shut down if the mammal approached the smaller safety radius around the small source that operated during power downs. The development of the safety radii applied for each source vessel are explained in detail in the relevant 90-day report (Ireland et al. 2007a,b, and Patterson et al. 2007).

Additional standard mitigation measures used during seismic cruises included ramping up the airgun array. A ramp-up gradually increased the number of airguns operating and resulted in a rate of increase in received sound level of no more than 6 dB per 5 min period. Also, airgun arrays were either powered down or shut down when the source vessels were between seismic survey lines. Further, in order for seismic operations to start up during day or night, the full 180 dB (rms) safety radius had to be visible for at least 30 min. During the 2006 season, the seismic vessels were also required to power down or shut down if groups of 12 or more bowhead or gray whales were seen within the 160 dB (rms) radius while the airguns were in operation.

TABLE 3.1. Distances (m) from airgun source at which sound pressure level (SPL) decreased to various rms levels for each of the three source vessels. These distances were used in the calculation of ensonified areas. Distances are shown separately for ***(A)*** the full airgun arrays, and ***(B)*** the mitigation gun(s). These same values were used in the separate 90-day reports (Ireland et al. 2007a,b; Patterson et al. 2007), and were based on the larger of the values derived from either JASCO models or field measurements.

		Distance to RL 160-190 dB re 1µPa(rms)			
	Airgun Volume	≥160	≥170	≥180	≥190
Gilavar					
Full Aray	3147 in^3	7990	4720	1400	460
Mitigation Gun	155 in^3	1370	680	360	230
Patriot					
Full Aray	3390 in^3	11,431	4689	1628	517
Mitigation Gun	105 in^3	1449	516	179	62
Discoverer					
Full Aray	3320 in^3	10.97	5110	1770	480
Mitigation Gun	40 in^3	1475	720	400	225

Methods

Visual Monitoring

Visual monitoring methods implemented during the three seismic programs were very similar to those used during many previous seismic cruises conducted under IHAs since 2003 and, with some variation, under IHAs issued for seismic programs in the Alaskan Arctic since 1996. Standard visual observation methods are described in detail in Appendix E of each 90-day report (Ireland et al. 2007a,b; Patterson et al. 2007). To summarize, at least one MMO maintained a visual watch for marine mammals during all daylight hours onboard each of the source vessels and, to the maximum degree possible, on support vessels which included chase and resupply vessels. Observers focused their search effort forward and to either side of the vessel, searching aft of the vessel occasionally while it was underway. Watches were conducted with the naked eye, Fujinon 7 × 50 reticule binoculars, and higher powered (18× or 20×) image stabilized binoculars. MMOs on the seismic vessels instructed seismic operators to power down or shut down the airguns if marine mammals were sighted near or about to enter the appropriate safety radius. Chase vessels generally traveled ~6 km ahead of their assigned source vessel to monitor the 160 dB (rms) radius for large groups of bowhead or gray whales which would require mitigation measures.

Various factors including high sea state (determined using Beaufort wind force), poor visibility, and MMO experience can make identification of marine mammals difficult, and both cetaceans and pinnipeds could not always be identified to species. There were far more pinniped than cetacean sightings and over half of the pinnipeds could not be identified to species. Due to the large number of unidentified seals, all seals were lumped into a “pinnipeds” category for many analyses. Differentiating ringed from spotted seal was especially difficult and these two species were also lumped into one category for analyses in which pinniped species were considered. Most of the unidentified seals were probably ringed or spotted seals, and given the known densities of these two species in the Chukchi Sea, the majority of the unidentified seals was likely ringed.

Categorization of Data

Observer effort and marine mammal sightings were divided into several analysis categories related to data useability, vessel observation height, and environmental variables (seismic activity, proximity to shore, seasonality, and proximity to ice). Useability, seismic activity, and proximity to shore were categorized in ways similar to those applied in other recent seismic studies conducted under IHAs (e.g., Haley and Koski 2004; MacLean and Koski 2005; Smultea et al. 2005; Holst et al. 2005a,b; Ireland et al. 2005). However, other variables have been added to allow a more detailed investigation of the cumulative 2006 data. The data categories are defined below.

Useability Criteria

Effort and sightings were defined as “useable” when made under the following conditions: daylight periods both within the seismic survey area and during transit to and from that area, excluding:

- periods 3 min–1 h for pinnipeds, or –2 h for cetaceans and ursids, after the airguns were turned off (post-seismic), which allowed for normalization of animal distribution after periods of seismic activity;
- periods when another vessel was present within 1 km, for pinnipeds and ursids, and 5 km, for cetaceans, as the presence of another vessel may have altered the distribution of animals;
- periods when ship speed was <3.7 km/h (2 kt), as transect data collected below this speed are unreliable;
- periods when ship speed between two consecutive legs of a transect varied by >3.7 km/h (2 kt), as data collected from transect legs at different speeds cannot be pooled;
- periods when an area within 1.2 km of the ship’s previous trackline was surveyed more than once within 4 h to avoid counting single animals multiple times; and
- periods with seriously impaired sightability. This included all nighttime observations, and daytime periods with one or more of the following: visibility <3.5 km, Beaufort wind force (Bf) >5 (Bf >2 for cryptic species such as porpoises and minke whales), or >60º of severe glare between 90º left and 90º right of the bow.

Vessel Observation Height

Vessels were pooled into three categories (vessel groups A, B, and C; Table 3.2) based on “eye-height” from the water surface to the bridge, where observations were usually carried out.

TABLE 3.2. Group designations of source vessels and chase/support vessels operating during the 2006 season in the Chukchi Sea, along with observation height (m) and dates of operation.

	Observation Height (m)		Dates of Operation in Chukchi Sea	
	Bridge	**Flying Bridge**	**Start**	**End**
Vessel Group A				
Discoverer	13.3	-	9-Oct-06	12-Nov-06
Gilavar	12.5	15.5	10-Jul-06	23-Sep-06
Patriot	12.5	15.5	17-Jul-06	15-Oct-06
Vessel Group B				
Kilabuk	10.8	12.3	10-Jul-06	5-Oct-06
Gulf Provider	9.0	11.7	1-Aug-06	23-Oct-06
Torsvik	7.7	10.2	14-Jul-06	24-Oct-06
Vessel Group C				
Octopus	5.0	-	28-Sep-06	12-Nov-06

Seismic Activity

Data were categorized as seismic, non-seismic, or post-seismic. All data collected from the source vessels (*Gilavar, Patriot,* and *Discoverer*) while their airguns were operating were considered seismic. Data from support vessels (or source vessels during periods without airgun operation) were also categorized as seismic if these vessels were within 15 km of an operating airgun array. This is a conservative distance slightly greater than the largest of the 160 dB (rms) radii for the three seismic vessels. The larger 15 km radius included all of the variation in measured sound data points at the 160 dB level. The non-seismic category included all data obtained before the airguns were activated (pre-seismic) or >1 h (pinnipeds) or >2 h (cetaceans and ursids) after the airguns were deactivated. Data collected during post-seismic periods from 3 min–1 h (for pinnipeds) or –2 h (for cetaceans and ursids) after cessation of seismic activity were considered either recently exposed (3–30 min for all marine mammals) or potentially exposed (30 min–1 h for pinnipeds or –2 h for cetaceans and ursids) to seismic sound levels, and were excluded from analyses.

This categorization system was designed primarily to distinguish potential differences in behavior and distribution of marine mammals during periods with and without seismic sounds. Marine mammal responses to seismic sound likely diminish with time after seismic activity ends. The rate of recovery toward "normal" during the post-seismic period is uncertain. The end of the post-seismic period was defined as a time long enough after cessation of airgun activity to ensure that any carry-over effects of exposure to sounds from the airguns would have waned to zero or near-zero (MacLean and Koski 2005; Smultea et al. 2005 and Appendix E of Ireland et al. 2007a,b; Patterson et al. 2007).

Proximity to Shore

Data collected within 25 km of shore were classified as nearshore and those collected more than 25 km from shore as offshore. In the Chukchi Sea, this distance roughly corresponds to the

20 m depth contour. There were few data categorized as nearshore and they were not analyzed further in this chapter, but are presented in Appendix A.

Seasonality

Pinnipeds—To account for seasonal variation in pinniped abundance, useable, non-seismic, offshore, pinniped data from all vessels were pooled and divided into one-week bins (see Table 3.3 for week start and end dates). Useable effort for pinnipeds within these one-week bins (and three-week moving totals) is presented in Fig. 3.1. Some of the weekly bins had limited effort (<500 km useable pinniped effort) as opposed to the three-week moving totals which each had a greater level of useable pinniped effort (>1000 km). Fig. 3.2 shows pinniped detection rates for each weekly bin along with the three-week moving average for detection rate. Based on these data we identified breaks at weeks 8 and 13. The "early season" with lower pinniped detection rates was therefore considered to be the period before 28 Aug., the "mid-season" with high detection rates was from 28 Aug. through 8 Oct. (weeks 8 to 13, inclusive; Table 3.3), and the "late season" was from 9 Oct. onward. For detection rates by week for just Pacific walrus, see Appendix A (Fig. A.1).

TABLE 3.3. Start and end dates for the weekly bins used to determine the pinniped season categories.

Week in 2006	Start	End
1	10-Jul	16-Jul
2	17-Jul	23-Jul
3	24-Jul	30-Jul
4	31-Jul	6-Aug
5	7-Aug	13-Aug
6	14-Aug	20-Aug
7	21-Aug	27-Aug
8	28-Aug	3-Sep
9	4-Sep	10-Sep
10	11-Sep	17-Sep
11	18-Sep	24-Sep
12	25-Sep	1-Oct
13	2-Oct	8-Oct
14	9-Oct	15-Oct
15	16-Oct	22-Oct
16	23-Oct	29-Oct
17	30-Oct	5-Nov
18	6-Nov	12-Nov

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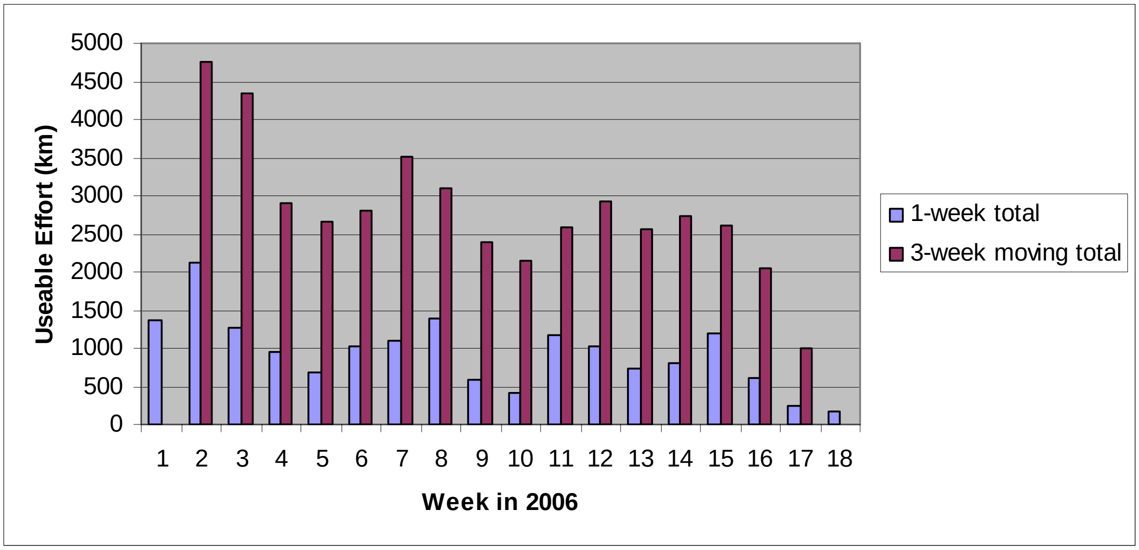


FIGURE 3.1. Pinniped effort (km) by week (and three-week moving total) in the Chukchi Sea, offshore region, during non-seismic periods, pooling useable data from all vessels.

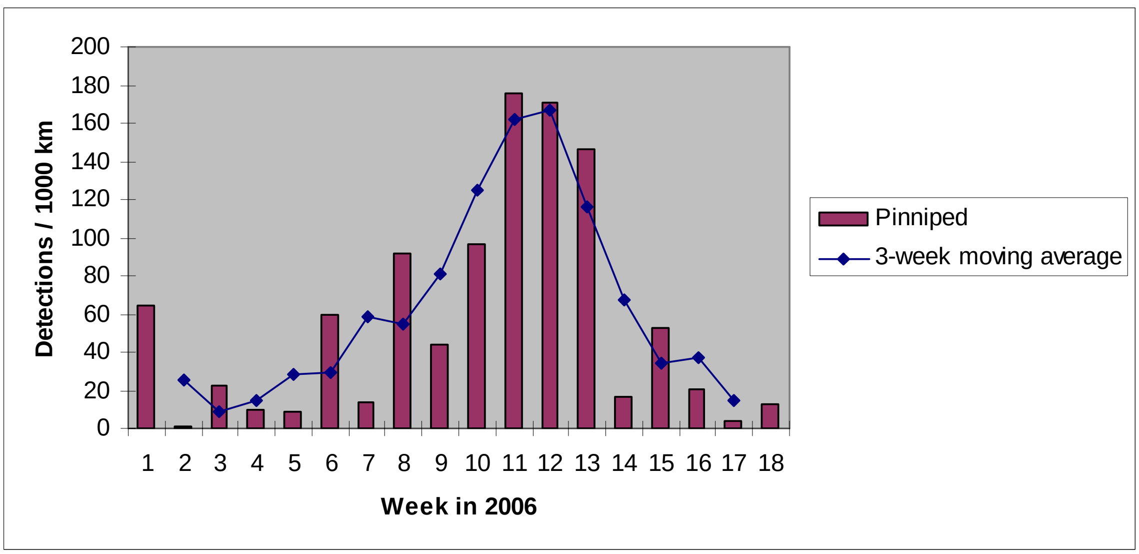


FIGURE 3.2. Pinniped detection rates (# useable sightings/1000 km) by week and three-week period in the Chukchi Sea, offshore region, during non-seismic periods, pooling useable data from all vessels.

Cetaceans—Seasonal breaks for whales in the Chukchi Sea were based on the migration patterns of bowhead whales. The typical start of the autumn bowhead migration through the Chukchi Sea as defined in the 2006 IHAs from NMFS (Appendix A in Ireland et al. 2007,a,b; Patterson et al. 2007), was 25 Sept. In 2006, the end of the main portion of the bowhead migration near Barrow, Alaska, was determined to be ~25 Oct. based on discussions with the North Slope Borough Dept. of Wildlife Management (R. Suydam and C. George, pers. comm.). Based on these dates, the early season for cetaceans was considered to be the period prior to 25 Sept., the mid-season was 25 Sept.–25 Oct., and the late season was from 26 Oct. onward.

Proximity to Ice

Pinnipeds haul out on ice and often forage near ice. Therefore, pinniped detection rates were expected to be related to the proximity of the vessels to ice. Pinniped detection rates relative to distance from ice were investigated by season (see *Seasonality* above). Ice cover and location data were obtained from the National Ice Center, NOAA (NIC 2007), and the ice edge was defined as the edge of the ≥10% ice-cover category. Useable data were pooled from all vessels within the Chukchi Sea offshore region during non-seismic periods and sub-divided into 5-km distance-from-ice bins within each pinniped season. The 3-bin (or 15 km) moving total of useable effort was marginal (around 500 km) within 45 km of the ice edge in the early season (Fig. 3.3 A), while the same moving total was marginal to poor (<500 km effort) at distances greater than 45 km in the mid-season (Fig.3.3 B). The late season had little effort within 100 km of the ice edge (Fig. 3.3 C).

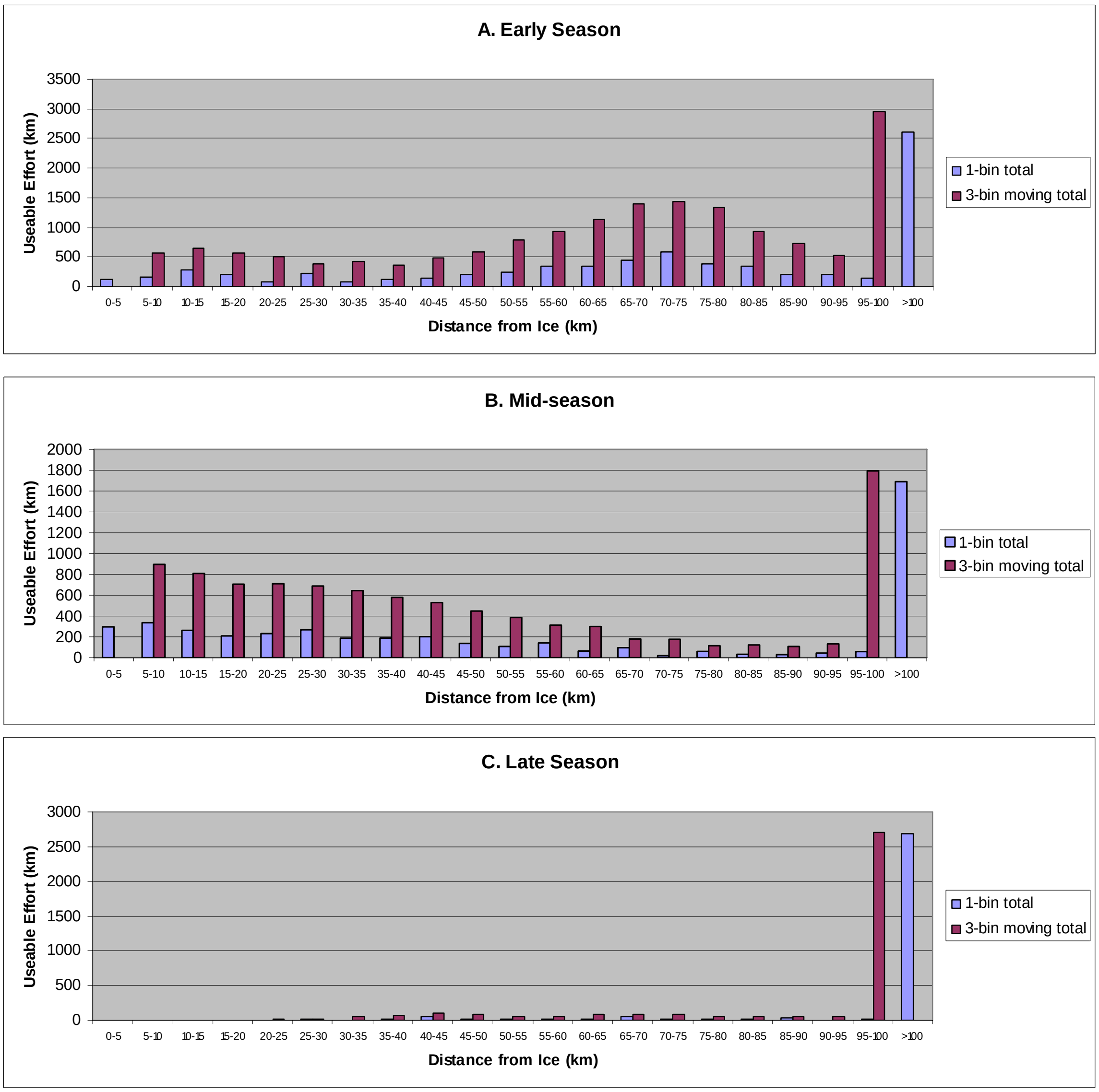
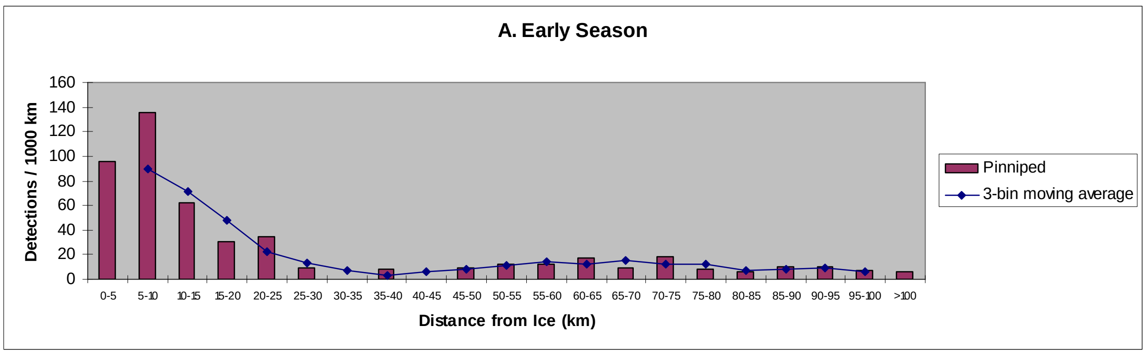


FIGURE 3.3. Pinniped effort (km) with distance from ice, subdivided by ***(A)*** early, ***(B)*** mid-, and ***(C)*** late pinniped seasons. See text for definition of pinniped seasons. Data are from the Chukchi Sea, offshore region, during non-seismic periods, pooling useable data from all vessels.

Fig. 3.4 shows the corresponding pinniped detection rates (# useable sightings/1000 km) and 3-bin moving average detection rates with distance from the ice edge, for the early and mid-seasons (the late season is not shown due to the lack of effort within 100 km of the ice edge). Even with the marginal effort near ice in the early season, there was a tendency for high detection rates near ice, falling toward low levels beyond the 20-25 km distance bin from the ice edge (Fig. 3.4 A). Therefore, data within 25 km of the ice edge in offshore areas were categorized as "near ice" in the early season. Data collected when the vessel was more than 25 km from the ice edge in the offshore region were categorized as "open water" in the early season. There was also a tendency for decreasing pinniped detection rates with increasing distance from ice in the mid-season, but it was not as well-defined as in the early season (Fig. 3.4 B). The trend was not stable past the 40-45 km bin, where detection rates varied, possibly due to low effort in these bins. Given the available data during the mid-season, it was not justifiable to identify a "near ice" versus "open water" cut-off distance. For effort and detection rates relative to distance from ice considering just the Pacific walrus, see Appendix A (Fig. A.2 and A.3). The figures for the walruses combine all seasons due to the small number of walrus sightings.



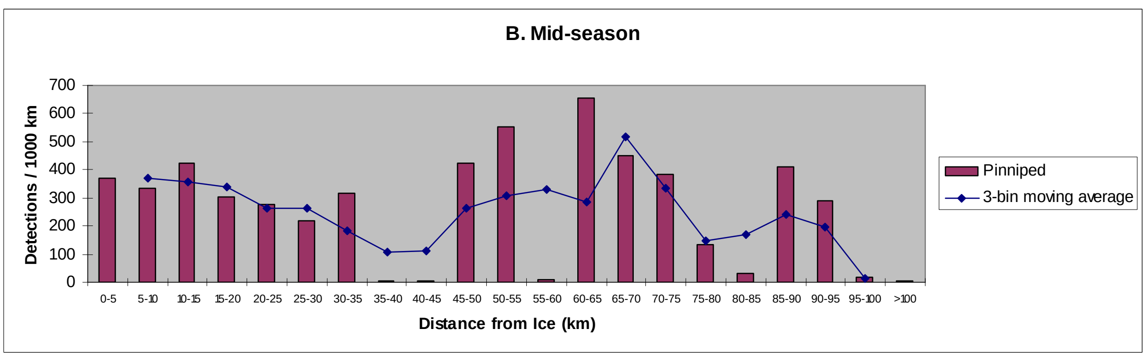


FIGURE 3.4. Detection rates for pinnipeds (# useable sightings/1000 km) with distance from ice sub-divided by ***(A)*** early and ***(B)*** mid-seasons. The late pinniped season had insufficient useable effort near ice to calculate reliable detection rates by distance from ice. See text for definition of pinniped seasons. Data are from the Chukchi Sea, offshore region, during non-seismic periods, pooling useable data from all vessels.

Marine Mammal Behavior

Marine mammal behavior is difficult to observe, especially from a seismic source vessel, because individuals and/or groups are often at the surface only briefly, and may avoid the vessel. This causes difficulties in re-sighting those animals, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Limited behavioral data were collected during this project because marine mammals were often observed at distances too far from the vessel to determine behavior, and they were typically not tracked for long distances or durations while the vessel was underway.

Data collected during visual observations provided some information about behavioral responses of marine mammals to the seismic survey and related vessel activity, however many of these data are not extensive enough to warrant statistical analysis. Relevant data included:

- bearings and distances of initial sightings of marine mammals from the MMO observation station;
- estimated closest observed points of approach (CPA) of animals relative to either the airgun array (source vessels) or the observer (support vessels);
- animal movements relative to vessel movements; and
- observed behavior of animals at the time of the initial sightings.

Within each dataset, results were compared between seismic and non-seismic periods.

Mean CPA, standard deviation, and range of distances (m) were calculated for useable sightings within each vessel group during seismic and non-seismic periods. Mean CPAs were compared between seismic and non-seismic periods for vessel groups with sufficient sample sizes using a Wilcoxon rank-sum test.

Differences in animal movements and initial observed behaviors between seismic and non-seismic periods were qualitatively compared within seasons and overall. To facilitate comparison of initial behaviors, some behavior categories were pooled. "Dive" included the front dive, fluke, sink, and thrash categories. "Look" included look and spy-hop. "Rest" included log, raft, and rest. "Swim / travel" included blow, bow-riding, mill, porpoise, surface-active travel, swim, travel, and wake-riding. "Surface active" included breach, flipper-slap, lob-tail, and surface active. "Feed" included both individual and group feeding. "Not Recorded" included blanks where no behavior was recorded. "Unknown" included none (no obvious behavior observed), and other (behaviors for which a code did not exist). For the full definitions of these variables, see Appendix E in any of the 2006 90-day reports (Ireland et al. 2007a,b; Patterson et al. 2007).

Marine Mammal Detection Rates Relative to Proximity of Seismic Source Vessels

Useable observation effort and marine mammal sightings from support vessels (vessel group B) were matched with corresponding seismic data and distance to the accompanying seismic source vessel to estimate the received level of seismic pulses in the following combinations: *Torsvik*/*Patriot*, *Kilabuk*/*Gilavar*, and *Gulf Provider*/closest of *Patriot* or *Gilavar*. Resulting data from the three support vessels were subsequently pooled, and sighting rates for exposure categories from 120 to 190 dB rms in 10 dB increments were calculated.

The vessel proximity criterion for useability precluded inclusion of any effort from vessel group B in the ≥180 dB and ≥190 dB categories for cetaceans and pinnipeds, respectively. Therefore, detection rates calculated from useable sightings and effort from vessel group A during seismic periods were used to estimate sighting rates for animals potentially exposed to seismic sounds ≥180 and ≥190 dB. The exposure categories included data from a range of seismic activities and array volumes (i.e. full array firing during data acquisition or single gun firing during turns).

Probability of Marine Mammal Detection with Distance from Vessel

The methods used to calculate density in this study depend upon the detection rate of marine mammals by MMOs. As discussed below, MMO effectiveness is dependent upon many factors including weather conditions/wind force, number of MMOs on watch, MMO fatigue and MMO ability. The impacts of several variables (e.g., wind force, number of observers) on MMO efficacy were explored using sightings data.

Beaufort wind force is known to strongly influence detection rates of marine mammals during vessel and aerial surveys (Gunnlaugsson 1991; Palka 1996; Barlow et al. 2001, 2006; DeMaster et al. 2001; Teilman 2003). The effect of wind force on an observer's ability to detect marine mammals during our study was examined using output from the DISTANCE program (Thomas et al. 2006). The "useable" data set from vessel group B during non-seismic periods was used because it contained the most sightings across wind force categories and number of observers. Seismic periods were excluded from the analysis since there may be confounding effects on animal distribution that violate the assumption that the highest probability of detection is on the trackline. Pinniped sightings within 25 km of ice during non-seismic periods were also excluded because the presence of ice affects the distribution of seals and may therefore affect the sighting distance data.

Estimation of Densities

Obtaining meaningful estimates of the number of marine mammals exposed to various levels of seismic sounds is difficult for multiple reasons:

- The relationship between numbers of marine mammals that are observed and the number actually present is uncertain.
- The most appropriate criteria for "take by harassment" are uncertain and presumably vary among species and situations.
- The distances 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) vary. Variables governing this relationship include 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).
- The sounds received by marine mammals vary depending on their depth in the water, and are considerably reduced for animals at or near the surface, (Greene and Richardson 1988; Tolstoy et al. 2004a,b) and further reduced for animals on ice.

Raw sighting data obtained from marine mammal surveys provide, at best, an index of the minimum number of animals possibly present at the time of the survey (Eberhardt et al. 1979; Best 1982; Hiby and Hammond 1989). Some animals that are present, and theoretically could be seen by observers, are not detected because of glare, haze, fog, sea conditions, ice cover, behavior of the target species, observer fatigue, abilities of the observer, obstructions to the viewing area and other factors (Holt 1987; Marsh and Sinclair 1989; DeMaster et al. 2001; Barlow et al. 2006). The proportion of animals missed due to the above factors varies depending on the severity of those factors and is specific to a particular survey. For example, Barlow et al. (2006) showed that encounter rates for small beaked whales (genera *Mesoplodon* and *Ziphius*), which are especially difficult to sight, were about 10–30× higher during Beaufort wind force 0 and 1 than during Beaufort states 4 and 5. Further complicating the estimation of densities or numbers of marine mammals present during a survey is the fact that most marine mammals dive below the surface, and therefore are out of sight for extended periods (Leatherwood et al. 1982; Martin et al. 1993; Barlow 1999; Thomas et al. 2002). The proportion of time that marine mammals are at the surface depends on their species, activity, season, weather and other factors.

Line Transect Methods

Line transect methodology (Buckland et al. 1993), often implemented using the DISTANCE program (Thomas et al. 2006, version 5.0, release 2), is the most commonly used method for estimating densities of animals from transect survey data. In theory, two correction factors, *f*(0) and *g*(0), can be computed from the raw survey data or from other observations to minimize most biases in estimates of actual numbers of marine mammals present.

Parameter *f*(0) accounts for the reduced probability of detecting an animal as its distance from the trackline increases. It is assumed that all animals directly on the trackline are seen or, if not seen, are accounted for by parameter *g*(0).

Parameter *g*(0) accounts for animals on the trackline that are not detected during the survey. In most surveys, *g*(0) accounts for animals at the surface and available to be seen but, in fact, are not seen by the primary observer; this is "detectability bias," $g_d(0)$, otherwise known as "perception bias." In some cases, *g*(0) has been calculated to account for the fact that marine mammals are often below the surface as the survey aircraft or vessel passes; this is "availability bias" $g_a(0)$. Corrections for availability bias account for the probability that an animal on the trackline will be at the surface while the surveyors are close enough to detect the animal. Failure to account for availability bias can cause significant underestimates, particularly for species that dive for long periods like bowhead whales, and/or when a rapidly-moving survey platform (such as an aircraft) is used. When there are estimates for both $g_d(0)$ and $g_a(0)$, then *g*(0) is the product of these two estimates.

Calculation of Densities

Densities were calculated separately for each cetacean species and for all pinniped species combined in each stratum. For density calculations, a separate stratum was assigned for each combination of the following factors:

- season (early, mid-, late);
- habitat (offshore open water, offshore near ice, nearshore); and
- vessel group (source vessel group A, chase vessel groups B and C).

Line transect methods (Buckland et al. 1993) were used to estimate densities using the equation:

$$D = \frac{n \times S \times f(0)}{2 \times L \times g(0)}$$

where

D	=	density of a species in number of animals/km^2,
n	=	number of sightings,
S	=	mean group size,
$f(0)$	=	sighting probability density on the trackline,
L	=	length of trackline completed (in km),
$g(0)$	=	probability of seeing a group directly on the trackline.

Densities were not calculated for strata where less than 500 km of useable survey effort was obtained. For those strata, the density used for each cetacean species or for pinnipeds when estimating the number of animals potentially affected by seismic activities was selected from data for strata with the most similar geographic, habitat, and seasonal characteristics. For more details on the calculations of *f*(0), *g*(0), and densities, including an example calculation, see Appendix B.

Estimation of Numbers of Marine Mammals Potentially Affected

Disturbance and Safety Criteria

Table 3.1 shows estimated received sound levels at various distances from the airgun arrays used during the 2006 seismic programs. The 160 and 170-dB radii were assumed behavioral disturbance criteria. The 180 and 190-dB radii were the safety radii used in determining when real-time mitigation measures were required.

Direct Observation versus Density-based Methods

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

- ***(A)*** minimum estimates based on direct observations;
- ***(B)*** estimates based on pinniped and cetacean densities derived from observations made during seismic periods; and
- ***(C)*** maximum estimates based on pinniped and cetacean densities derived from observations made during non-seismic periods.

The actual number of individuals exposed to, and potentially affected by, seismic survey sounds was likely between these minimum and maximum estimates resulting from methods ***(A)*** and ***(C)***, provided below. Calculation of densities and the correction factors used to compute densities are described in *Estimation of Densities* above and in Appendix B.

Method ***(C)*** above provides an estimate of the number of animals that would have been exposed to airgun sounds at various levels if the seismic activities did not influence the distribution of animals near the activities. However, it is known that some animals are likely to have avoided the area near the seismic vessel while the airguns were firing (see Richardson et al. 1995, 1999; Stone 2003; Gordon et al. 2004; Smultea et al. 2004). Within at least the 160–170 dB radii around the source (i.e., ~4.7–11.4 km), the distribution and behavior of cetaceans may have been altered as a result of the seismic survey. The distribution and behavior of pinnipeds may have been altered within some lesser distance. These effects could occur because of reactions to the active airgun array, or to other sound sources or other vessels working in the area. Thus method ***(B)*** may provide a more realistic estimate of the number of animals exposed to the higher sound levels of interest.

We used data from both source vessels and support vessels to investigate how far from the source vessel behavioral reactions extended. During past studies, data were typically available from only the source vessel. Here, as a refinement to method ***(B)***, we have calculated densities of marine mammals separately using data collected on the source vessel and on the support vessel when it was >1.0 km (pinnipeds) or >5.0 km (cetaceans) from the source vessel during seismic periods. During seismic periods, support vessels typically operated about 6 km from the source vessels. MMOs noted times when support vessels were required to be farther away from source vessels (e.g. when scouting for ice).

Density-based Calculation Method

The aforementioned densities were used to estimate the number of animals potentially affected by seismic operations (methods ***(B)*** and ***(C)***). This involved using two approaches to estimate the extent to which marine mammals may have been exposed to given sound levels ≥160, ≥170, ≥180, and ≥190 dB (rms):

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

For each source vessel we used the same 160, 170, 180, and 190 dB (rms) distances that were used in the separate 90-day reports (see Table 3.1). The following description of the two different methods refers only to the ≥160 dB re 1 µPa (rms) sound level, but the same method of calculation was used for ≥170, ≥180, and ≥190 dB (rms).

The first method ("individuals") involved multiplying the following three values for each airgun configuration in use and within each season:

- km of seismic survey;
- width of area assumed to be ensonified to ≥160 dB (2 × 160 dB radius), with areas ensonified on more than one occasion counted only once; and
- densities of marine mammals estimated from this study.

Counting areas of water ensonified more than one time (due to overlapping or adjacent tracklines) only once may underestimate the number of different animals exposed. This is likely to occur when the activities are conducted over a long period, as individual animals may move in and out of the ensonified area. The individuals present when an area is ensonified a second or subsequent time are not necessarily the same animals as were present when the area was first ensonified.

The second approach ("exposures") involved multiplying the same three values, except that areas ensonified to ≥160 dB on more than one occasion, due to overlapping or closely spaced tracklines, were counted as many times as they were ensonified. The area of water considered ensonified in this calculation was therefore larger than in the first calculation. During the Chukchi Sea surveys, many of the tracklines were sufficiently close to one another for there to be overlap between the ensonified areas around different lines. When there was substantial overlap, the two approaches led to very different values for the ensonified area, and the estimated number of exposures was much higher than the estimated number of individuals exposed.

Finally, the number of exposures was divided by the estimated number of individuals exposed to calculate the average number of exposures per individual. This calculation assumed that individuals did not show avoidance reactions, which could be true for some species.

This approach was originally developed to estimate the number of seals potentially affected by seismic surveys in the Alaskan Beaufort Sea conducted under IHAs (Harris et al. 2001). The approach has recently been used in estimating the numbers of seals and cetaceans potentially affected by other seismic surveys conducted under IHAs in the Arctic and elsewhere (e.g., Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b; Ireland et al. 2007a,b; Patterson et al. 2007).

The estimates provided here are based on the actual number of km of seismic survey completed during all projects in the Chukchi Sea during 2006. In contrast, the estimates provided in the 90-day reports did not consider that there may have been overlap in areas surveyed. The estimates provided here use the combined data from all surveys to compute correction factors that account for biases associated with different numbers of observers, habitats, and seasons.

Sighting distance data were entered into DISTANCE and a sighting probability detection function was fitted to the sighting data. An effective strip half-width (ESW) was calculated from the best-fit curve (determined using Akaike's Information Criterion). The ESW is the perpendicular distance from the vessel at which numbers of animals sighted beyond ESW are equal to those missed within ESW. The ESW is the inverse of *f*(0), which is the sightability correction factor for the reduced probability of detecting animals with increasing distance from the trackline. Sample sizes of less than 15 sightings were considered insufficient to warrant calculating ESW, while 15 to 25 sightings were considered a marginal sample size. If fewer than nine sightings were obtained for a category, sighting distances were not plotted. The DISTANCE program chooses the optimal bin sizes in order to describe the best-fit curve for a data set. For presentation purposes, the bin sizes were decreased in some plots when DISTANCE compressed sightings into a few wide bins, but the best-fit curve is still presented.

Results

Visual Survey Effort

This section summarizes the visual monitoring effort from the various seismic survey vessels and support or chase vessels that operated in the Chukchi Sea, 10 July–12 Nov. 2006. Of 113,563.7 km (11,893.7 h) of trackline covered within the Chukchi Sea, visual observations by MMOs were conducted over 77,420.2 km (7352.6 h), of which 72,281.7 km occurred during daylight. Average visibility during daytime periods was 5.7 km (range 0 to 10 km, n = 18,076 records where visibility value entered), and average Beaufort wind force was 3.5 (range 0 to 10, n = 19,387 wind force records). Of the 5138.5 km (567.6 h) of effort conducted during periods of darkness, the majority occurred during seismic periods (91.5% or 4702.1 km). Most nighttime observations were recorded from vessel group A (92.2% or 4740.3 km), with the remaining nighttime observation effort carried out by vessel group B. No nighttime observations were conducted from vessel group C. During periods of darkness no marine mammal observations were recorded. Wind force, fog, and precipitation also contributed to poor visibility during nighttime observations. Average Beaufort wind force during nighttime observations was 4.2. Effort carried out during darkness was not considered useable in later analyses.

Actual amounts of useable effort were different for cetaceans, pinnipeds, and ursids (see *Useability Criteria* in *Methods*). Based on these usability criteria, 30,010–38,266 km (2496–3281 h) of trackline, or 39–49% of the visual effort, was considered useable (ranges of useable effort presented here and in the following sections are for all species groups). The following analyses include only useable visual effort divided into Beaufort wind force categories, presented in Table 3.4 (effort in km) and Appendix Table A.1 (effort in h). The effort was also categorized by the total number of observers on watch, presented in Table 3.5 (effort in km) and Appendix Table A.2 (effort in h). Overall, vessel group B had the most useable non-seismic effort in the nearshore and offshore regions (Tables 3.4 and 3.5). Within the offshore region, vessel group B had the most useable seismic effort for pinnipeds and ursids, but vessel group A had the most useable seismic effort for cetaceans.

<u>*Vessel Group A*</u>

This data set combined the tracklines from the source vessels *Gilavar*, *Patriot*, and *Discoverer*, for a total of 9120–11,282 km (991–1215 h; Table 3.4 and Appendix Table A.1) of useable visual observations. Of the useable 2770–3047 km of non-seismic effort, most was conducted in the offshore region (96%) as opposed to the nearshore region (Table 3.4). Similarly, almost all useable seismic effort was carried out in the offshore region (Table 3.4). There were negligible amounts of useable effort during Beaufort wind force (Bf) zero (Table 3.4). The majority of useable non-seismic observation effort in the offshore region was conducted in Bf 3–4 (62%; Table 3.4). The majority of useable seismic effort in the offshore region occurred during Bf 4–5 (~67%; Table 3.4).

TABLE 3.4. Useable[a] visual observation effort, in kilometers, from the different vessel groups within the Chukchi Sea, offshore and nearshore, subdivided by Beaufort wind force[b], seismic activity, and the different species groups. Note that effort is different for cetaceans, pinnipeds, and ursids (polar bear) due to differences in useability definitions (see *Methods* above). For effort in hours, see Appendix Table A.1.

	Nearshore								Offshore							
Beaufort Wind Force	**0**	**1**	**2**	**3**	**4**	**5**	**blank**	***Total***	**0**	**1**	**2**	**3**	**4**	**5**	**blank**	***Total***
Effort in km																
Vessel Group A																
Non-seismic																
Cetaceans	0	5.5	40.9	72.5	0	6.7	0	***125.6***	0	166.7	353.6	802.9	843.1	437.8	40.6	***2644.7***
Pinnipeds	0	5.5	40.9	72.5	0	6.7	0	***125.6***	0	190.8	387.1	912.3	906.8	483.5	40.6	***2921.2***
Ursids	0	5.5	40.9	72.5	0	6.7	0	***125.6***	0	182.2	378.0	903.2	884.1	476.1	40.6	***2864.2***
Seismic																
Cetaceans	0	0	0	0	2.5	0	0	***2.5***	7.2	158.0	572.8	1406.4	2406.8	1875.8	0.0	***6427.0***
Pinnipeds	0	0	0	0	2.5	0	0	***2.5***	9.2	169.5	690.2	1809.0	3139.4	2415.6	0.0	***8232.8***
Ursids	0	0	0	0	2.5	0	0	***2.5***	9.2	169.5	690.2	1809.0	3139.4	2415.6	0.0	***8232.8***
Vessel Group B																
Non-seismic																
Cetaceans	51.8	343.9	535.6	560.6	225.3	152.2	0	***1869.4***	467.1	2036.3	4091.2	2486.0	2001.2	1377.3	0	***12459.1***
Pinnipeds	51.8	383.8	551.7	568.4	225.3	183.6	0	***1964.6***	500.7	2436.0	4613.6	2978.7	2222.7	1535.0	0	***14286.7***
Ursids	51.8	383.8	551.7	568.4	225.3	183.6	0	***1964.6***	500.7	2180.9	4155.5	2523.7	2172.5	1435.0	0	***12968.3***
Seismic																
Cetaceans	0	0	0	0	0	0	0	***0***	30.6	656.1	1203.9	1214.7	1222.8	656.9	0	***4985.1***
Pinnipeds	0	0	0	0	0	0	0	***0***	107.6	1112.8	2132.0	2388.1	2375.7	1026.0	0	***9142.2***
Ursids	0	0	0	0	0	0	0	***0***	107.6	1112.8	2132.0	2388.1	2375.7	1026.0	0	***9142.2***
Vessel Group C																
Non-seismic																
Cetaceans	0	0	0	0	20.0	6.8	0	***26.8***	0	37.3	214.6	319.6	203.3	231.6	0	***1006.4***
Pinnipeds	0	0	0	0	20.0	6.8	0	***26.8***	0	42.9	246.0	319.6	206.5	244.2	0	***1059.2***
Ursids	0	0	0	0	20.0	6.8	0	***26.8***	0	37.3	220.5	319.6	203.3	231.6	0	***1012.3***
Seismic																
Cetaceans	0	0	0	0	0	0	0	***0***	0	73.0	94.3	154.8	73.4	67.9	0	***463.3***
Pinnipeds	0	0	0	0	0	0	0	***0***	0	87.3	114.5	160.1	73.4	69.4	0	***504.8***
Ursids	0	0	0	0	0	0	0	***0***	0	87.3	114.5	160.1	73.4	69.4	0	***504.8***

Note: Totals are of unrounded values.
[a] See *Useability Criteria* in *Methods* in this Chapter.
[b] Beaufort Wind Force scale: 0 is < 1 knot (<1 mph); 1 is 1-3 knots (1-3 mph); 2 is 4-6 knots (4-7 mph); 3 is 7-10 knots (8-12 mph); 4 is 11-16 knots (13-18 mph); 5 is 17-21 knots (19-24 mph).

Within the offshore region, the majority of visual observations were conducted by one MMO at a time (~72% of non-seismic effort, ~62% of seismic effort; Table 3.5). Periods with two MMOs on watch were proportionally more common during seismic periods than non-seismic periods (~37% compared to 27%; Table 3.5). Periods with three MMOs on watch accounted for less than 1% of the effort during both non-seismic and seismic periods in the offshore region (Table 3.5).

Vessel Group B

Vessel group B data consisted of the pooled useable, visual observation data from the support vessels *Kilabuk*, *Torsvik*, and *Gulf Provider*. Most useable non-seismic effort was conducted in the offshore region (~87%). Useable non-seismic effort in the nearshore region was greater for group B vessels than for vessel groups A or C (1869–1965 km; Table 3.4). However, there were no useable seismic observations from group B vessels in the nearshore region (i.e., when in nearshore waters, these vessels did not come within 15 km of an operating seismic vessel). In the offshore region, useable non-seismic effort was greater than useable seismic effort (Table 3.4). The majority of useable non-seismic effort was in conditions of Bf 1–3 (77% in nearshore region, ~70% in offshore), while most useable seismic effort was during Bf 2–4 (~74% in offshore region; Table 3.4).

TABLE 3.5. Useable[a] visual observation effort in kilometers from the different vessel groups within the Chukchi Sea, offshore and nearshore, subdivided by total number of observers and seismic activity. Note that effort is different for cetaceans, pinnipeds and ursids due to differences in useability definitions (see *Methods* above). For effort in hours, see Appendix Table A.2.

	Nearshore				Offshore			
Total number observers	**1**	**2**	**3**	***Total***	**1**	**2**	**3**	***Total***
Effort in km								
Vessel Group A								
Non-seismic								
Cetaceans	94.4	31.2	0	***125.6***	1912.0	720.4	12.3	***2644.7***
Pinnipeds	94.4	31.2	0	***125.6***	2111.2	797.6	12.3	***2921.2***
Ursids	94.4	31.2	0	***125.6***	2084.2	767.7	12.3	***2864.2***
Seismic								
Cetaceans	<0.1	2.5	0	***2.5***	3909.0	2464.6	53.3	***6427.0***
Pinnipeds	<0.1	2.5	0	***2.5***	5116.3	3049.6	66.9	***8232.8***
Ursids	<0.1	2.5	0	***2.5***	5116.3	3049.6	66.9	***8232.8***
Vessel Group B								
Non-seismic								
Cetaceans	928.5	496.9	443.9	***1869.4***	8217.6	1720.8	2520.7	***12459.1***
Pinnipeds	998.1	522.6	443.9	***1964.6***	9871.3	1867.1	2548.2	***14286.7***
Ursids	998.1	522.6	443.9	***1964.6***	8689.4	1753.5	2525.4	***12968.3***
Seismic								
Cetaceans	0	0	0	***0***	3765.0	1148.6	71.4	***4985.1***
Pinnipeds	0	0	0	***0***	7596.7	1443.3	102.2	***9142.2***
Ursids	0	0	0	***0***	7596.7	1443.3	102.2	***9142.2***
Vessel Group C								
Non-seismic								
Cetaceans	26.8	0	0	***26.8***	1006.4	0	0	***1006.4***
Pinnipeds	26.8	0	0	***26.8***	1059.2	0	0	***1059.2***
Ursids	26.8	0	0	***26.8***	1012.3	0	0	***1012.3***
Seismic								
Cetaceans	0	0	0	***0***	463.3	0	0	***463.3***
Pinnipeds	0	0	0	***0***	504.8	0	0	***504.8***
Ursids	0	0	0	***0***	504.8	0	0	***504.8***

Note: Totals are of unrounded values.
[a] See *Useability Criteria* in *Methods* in this chapter.

One MMO was on watch for the majority of useable effort in both the nearshore and offshore regions, and during non-seismic and seismic periods (Table 3.5). The remaining useable non-seismic effort was obtained in the nearshore region almost equally during two- and three-person MMO watches (27% and ~23%, respectively; Table 3.5). In the offshore region, more useable non-seismic effort was collected with three MMOs on watch than with two (18–20% and ~13%, respectively; Table 3.5). This occurred because the *Torsvik* and *Gulf Provider* participated in the dedicated vessel surveys (described in detail in Chapter 4) where almost all effort included three MMOs on duty. Finally, most of the remaining useable effort (16-23%) in the offshore region during seismic periods occurred with two MMOs on watch simultaneously. Three MMOs were on watch for 1% of the useable offshore effort during seismic periods (Table 3.5).

Vessel Group C

This vessel group was composed of a single support vessel, the *Octopus*, because of its unique observation platform height. Virtually all of its useable effort was obtained in the offshore region. Of the useable offshore effort, there was about twice as much non-seismic effort as seismic effort (Table 3.4). No useable effort was collected when Bf was zero. The majority of the useable offshore effort was collected in Bf 3–5 during non-seismic periods (73–75%), and Bf 2–4 during seismic periods (~70%; Table 3.4). All visual observations were conducted by one MMO at a time (see Table 3.5).

Visual Sightings of Marine Mammals

Details on all sightings within the Chukchi Sea during 2006 seismic programs can be found in Appendix G of the three 90-day reports (Ireland et al. 2007a,b; Patterson et al. 2007). Given the small amount of useable nearshore effort and that the seismic surveys were conducted in the offshore region, the useable nearshore sightings are presented in Appendix A (Table A.3). The observed distributions of pinnipeds and cetaceans were largely dependent on where source and support vessels operated during the different seasons. However, specific sighting locations are not presented given the sensitivity of information surrounding the exact locations where seismic surveys were conducted. This section focuses on the useable offshore sightings, subdivided by seismic activity, season, and proximity to ice (where applicable) for each vessel group.

Vessel Group A

Cetaceans—Useable cetacean sightings from vessel group A occurred solely during the early cetacean season, July to 25 Sept. Most of the 55 useable, non-seismic, early season sightings were of gray whales (56%, or 31 sightings), which also had the largest estimated number of individuals (61 whales; Table 3.6). There were six sightings of bowhead whales, followed by unidentified whales and unidentified mysticete whales (five sightings each), harbor porpoises (four sightings), minke whales (three sightings), and fin whales (one sighting; Table 3.6). In contrast, there were only three useable cetacean sightings during seismic periods, including two bowhead whale sightings, and a harbor porpoise sighting (Table 3.6).

Pinnipeds In Water—Useable pinniped sightings in water occurred in the early and mid-seasons during both seismic and non-seismic periods. The few useable pinniped sightings during the late season occurred during seismic periods (Table 3.7). There were 213 sightings of an estimated 235 individual pinnipeds (across all seasons, seismic and non-seismic). The most commonly sighted pinnipeds were ringed/spotted seals with 33 sightings (15%), followed by Pacific walrus (11% or 23 sightings), and the bearded seal (5% or 11 sightings; Table 3.7). Most pinniped sightings were classified as unidentified seals (62% or 133 sightings), with some classified as unidentified pinnipeds (6% or 13 sightings; Table 3.7).

Pinnipeds On Ice—Useable sightings of pinnipeds on ice occurred only in the early season during non-seismic periods. This was expected since there was more ice in the early season and seismic activities were less likely to occur near ice due to the possibility of damaging the towed seismic equipment. Most sightings were of ringed/spotted seals (38% or five sightings), followed by Pacific walrus (23% or three sightings), but the most individuals observed hauled out were Pacific walruses (35 individuals; Table 3.7). There were also four sightings of unidentified seals hauled out and one sighting of an unidentified pinniped.

TABLE 3.6. Numbers of useable[a] cetacean sightings (number of individual cetaceans) in the Chukchi Sea, offshore, from vessel group A between 10 July and 12 Nov., 2006. Sightings are sub-divided by season. See *Methods* for definitions of these data categories. For a similar breakdown of nearshore data, see Appendix Table A.3.

	Non-Seismic			**Seismic**		
Species	**Early**	**Mid**	**Late**	**Early**	**Mid**	**Late**
Cetaceans						
Unidentified Whale	5(9)	0	0	0	0	0
Odontocetes						
Harbor Porpoise	4(7)	0	0	1(1)	0	0
Mysticetes						
Bowhead Whale	6(11)	0	0	2(2)	0	0
Fin Whale	1(3)	0	0	0	0	0
Gray Whale	31(61)	0	0	0	0	0
Minke Whale	3(3)	0	0	0	0	0
Unidentified Mysticete Whale	5(5)	0	0	0	0	0
Total Cetaceans	***55(99)***	***0***	***0***	***3(3)***	***0***	***0***

[a] See *Useability Criteria* in *Methods* in this chapter.

Vessel Group B

Cetaceans—Useable sightings of cetaceans by vessel group B occurred in the early and mid-cetacean seasons, July to 25 Sept. and 26 Sept. to 25 Oct., respectively. During non-seismic periods in the early season, the most commonly sighted and most numerous cetacean species was the gray whale (43% or 12 sightings of 85 whales), followed by harbor porpoise (five sightings), and bowhead whale and killer whale (one sighting each; Table 3.8). There were also three sightings each of unidentified whales and unidentified mysticete whales in the early season. In mid-season, the most commonly sighted and most numerous cetacean was the bowhead whale (52% or 16 sightings of 21 whales), followed by harbor porpoise (nine sightings), gray whale (five sightings), and minke whale (one sighting; Table 3.8). The only useable seismic period sightings were in the early season, and they consisted of a single harbor porpoise sighting and two unidentified whale sightings (Table 3.8).

TABLE 3.7 Numbers of useable[a] pinniped sightings (number of individual pinnipeds) in the Chukchi Sea, offshore, from vessel group A between 10 July and 12 Nov. 2006. Sightings are sub-divided by season (early, mid-, late). The early pinniped season data are further subdivided by proximity to ice. See *Methods* for definitions of these data categories. For a similar breakdown of nearshore data, see Appendix Table A.3.

	Non-Seismic				Seismic			
	Early		Mid	Late	Early		Mid	Late
Species	Near Ice	Open Water			Near Ice	Open Water		
Pinnipeds in Water								
Unidentified Pinniped	6(7)	0	0	0	1(1)	2(2)	4(4)	0
Odobenids								
Pacific Walrus	7(11)	3(3)	1(1)	0	1(1)	4(7)	7(9)	0
Phocids								
Bearded Seal	3(5)	0	1(1)	0	2(5)	4(4)	1(1)	0
Ringed/SpottedSeal	3(3)	3(3)	0	0	2(2)	19(20)	6(7)	0
Unidentified Seal	31(34)	11(11)	2(2)	0	1(1)	37(38)	49(50)	2(2)
Total Pinnipeds in Water	***50(60)***	***17(17)***	***4(4)***	***0***	***7(10)***	***66(71)***	***67(71)***	***2(2)***
Pinnipeds on Ice								
Unidentified Pinniped	1(1)	0	0	0	0	0	0	0
Odobenids								
Pacific Walrus	3(35)	0	0	0	0	0	0	0
Phocids								
Ringed/SpottedSeal	5(6)	0	0	0	0	0	0	0
Unidentified Seal	4(5)	0	0	0	0	0	0	0
Total Pinnipeds on Ice	***13(47)***	***0***	***0***	***0***	***0***	***0***	***0***	***0***

[a] See *Useability Criteria* in *Methods* in this chapter.

Pinnipeds In Water—Useable pinniped sightings (both near ice and open water regions) were obtained in the early, mid-, and late pinniped seasons during non-seismic and seismic periods. Across all seasons as well as non-seismic and seismic periods, there were 1396 sightings of an estimated 1659 individual pinnipeds. The most commonly identified pinnipeds were ringed/spotted seals (42% or 592 sightings), followed by bearded seal (11% or 154 sightings), and Pacific walrus (6% or 87 sightings; Table 3.9). The most numerous pinniped was also ringed/spotted seal (41% or 678 individuals), followed by Pacific walrus (11% or 185 individuals) and bearded seal (10% or 165 individuals; Table 3.9). There were also large numbers of unidentified seal sightings (40% or 558 sightings) and some unidentified pinniped sightings (< 1% or five sightings; Table 3.9).

TABLE 3.8. Numbers of useable[a] cetacean sightings (number of individual cetaceans) in the Chukchi Sea, offshore, from vessel group B between 10 July and 24 Oct. 2006. Sightings are sub-divided by season (early, mid-, late). See *Methods* for definitions of these data categories. For a similar breakdown of nearshore data, see Appendix Table A.3.

	Non-Seismic			Seismic		
Species	**Early**	**Mid**	**Late**	**Early**	**Mid**	**Late**
Cetaceans						
Unidentified Whale	3(3)	0	-	2(2)	0	-
Odontocetes						
Harbor Porpoise	5(7)	9(15)	-	1(1)	0	-
Killer Whale	1(2)	0	-	0	0	-
Unidentified Dolphin	3(4)	0	-	0	0	-
Mysticetes						
Bowhead Whale	1(5)	16(21)	-	0	0	-
Gray Whale	12(85)	5(9)	-	0	0	-
Minke Whale	0	1(1)	-	0	0	-
Unidentified Mysticete Whale	3(4)	0	-	0	0	-
Total Cetaceans	***28(110)***	***31(46)***	***-***	***3(3)***	***0***	***-***

- denotes no operations during the indicated season.

[a] See *Useability Criteria* in *Methods* in this chapter.

TABLE 3.9. Numbers of useable[a] pinniped sightings (number of individual pinnipeds) in the Chukchi Sea, offshore, from the support vessel group B between 10 July and 24 Oct. 2006. Sightings are sub-divided by season (early, mid-, late), and for the early pinniped season, data are further subdivided by proximity to ice. See *Methods* for definitions of these data categories. For a similar breakdown of nearshore data, see Appendix Table A.3.

	Non-Seismic				Seismic			
	Early		Mid	Late	Early		Mid	Late
Species	**Near Ice**	**Open Water**			**Near Ice**	**Open Water**		
Pinnipeds in Water								
Unidentified Pinniped	1(1)	1(1)	3(3)	0	0	0	0	0
Odobenids								
Pacific Walrus	6(10)	5(7)	53(125)	2(2)	1(1)	6(9)	14(32)	0
Phocids								
Bearded Seal	18(18)	3(3)	88(99)	12(12)	8(8)	10(10)	15(15)	0
Ringed/Spotted Seal	21(22)	13(24)	267(316)	44(45)	12(13)	66(75)	168(182)	1(1)
Unidentified Seal	36(36)	30(50)	259(294)	28(28)	15(15)	93(95)	97(107)	0
Total Pinnipeds in Water	***82(87)***	***52(85)***	***670(837)***	***86(87)***	***36(37)***	***175(189)***	***294(336)***	***1(1)***
Pinnipeds on Ice								
Odobenids								
Pacific Walrus	5(57)	0	7(780)	0	0	0	0	0
Phocids								
Unidentified Seal	2(3)	0	0	0	0	0	0	0
Total Pinnipeds on Ice	***7(60)***	***0***	***7(780)***	***0***	***0***	***0***	***0***	***0***

[a] See *Useability Criteria* in *Methods* in this chapter.

Pinnipeds On Ice—Useable pinniped sightings on ice occurred during non-seismic periods in the early and mid- seasons. Of the useable sightings of pinnipeds hauled out, 12 of 14 were of Pacific walruses, and these 12 sightings accounted for almost all of the hauled-out individuals

(99.6% or 837 estimated individuals; Table 3.9). Group sizes for Pacific walrus hauled-out on ice were, on average, an order of magnitude larger in the mid-season than in the early season (average group size of 111 versus 11, data not tabulated).

Polar Bears—There were four useable sightings of single polar bears during non-seismic periods. Seismic activities generally do occur near ice and polar bears were seen during seismic periods.

Vessel Group C

Cetaceans—Useable cetacean sightings for vessel group C occurred infrequently during non-seismic periods in the mid- and late cetacean seasons. During the mid-season, the gray whale was the most commonly sighted and most numerous cetacean (50% or four sightings, 10 whales), followed by bowhead whale (two sightings), and harbor porpoise (one sighting; Table 3.10). There was also one unidentified whale sighting. There were two useable cetacean sightings in the late season: one gray whale and one unidentified mysticete whale (Table 3.10).

TABLE 3.10. Numbers of useable[a] cetacean sightings (number of individual cetaceans) in the Chukchi Sea, offshore, from the support vessel group C between 28 Sept. and 12 Nov., 2006. Sightings are sub-divided by season (early, mid-, late). See *Methods* for definitions of these data categories. For a similar breakdown of nearshore data, see Appendix Table A.3.

	Non-Seismic			Seismic		
Species	**Early**	**Mid**	**Late**	**Early**	**Mid**	**Late**
Cetaceans						
Unidentified Whale	-	1(1)	0	-	0	0
Odontocetes						
Harbor Porpoise	-	1(2)	0	-	0	0
Killer Whale	-	0	0	-	0	0
Unidentified Dolphin	-	0	0	-	0	0
Mysticetes						
Bowhead Whale	-	2(4)	0	-	0	0
Gray Whale	-	4(10)	1(2)	-	0	0
Minke Whale	-	0	0	-	0	0
Unidentified Mysticete Whale	-	0	1(1)	-	0	0
Total Cetaceans	***-***	***8(17)***	***2(3)***	***-***	***0***	***0***

\- denotes no operations during the indicated season.

[a] See *Useability Criteria* in *Methods* in this chapter.

Pinnipeds In Water—Useable pinniped sightings during non-seismic periods occurred in the mid- and late pinniped seasons, while useable sightings during seismic periods were obtained only in the late season. Overall, the most commonly sighted and most numerous pinniped species was the bearded seal (30% or 12 sightings of 24 seals), followed by ringed/spotted seal (10% or four sightings), and Pacific walrus (one sighting; Table 3.11). There were also many unidentified seal sightings (55% or 22 sightings of 28 seals), and one unidentified pinniped sighting (Table 3.11).

TABLE 3.11. Numbers of useable[a] pinniped sightings (number of individual pinnipeds) in the Chukchi Sea, offshore, from the support vessel group C between 28 Sept. and 12 Nov. 2006. Sightings are sub-divided by season (early, mid-, late). See *Methods* for definitions of these data categories. For a similar breakdown of nearshore data, see Appendix Table A.3.

	Non-Seismic		Seismic	
Species	**Mid**	**Late**	**Mid**	**Late**
Pinnipeds in Water				
Unidentified Pinniped	0	0	-	1(1)
Odobenids				
Pacific Walrus	0	0	-	1(2)
Phocids				
Bearded Seal	9(21)	2(2)	-	1(1)
Ringed/Spotted Seal	0	1(1)	-	3(3)
Unidentified Seal	14(19)	3(3)	-	5(6)
Total Pinnipeds in Water	***23(40)***	***6(6)***	***-***	***11(13)***
Pinnipeds on Ice				
Odobenids				
Pacific Walrus	0	0	-	0
Phocids				
Unidentified Seal	0	0	-	0
Total Pinnipeds on Ice	***0***	***0***	***-***	***0***

- denotes no operations during the indicated season.
[a] See *Useability Criteria* in *Methods* in this chapter.

Marine Mammal Behavior

Distance to Initial Sighting

The bearing and distance from the observer station on the bridge of the three seismic vessels to initial sighting locations were determined for all useable sightings of cetaceans and pinnipeds (Fig. 3.5). Most sightings were forward of the vessels or lateral to the vessel trackline although a few initial sightings were recorded aft of the vessels. Initial sightings of cetaceans were generally further from the source vessels than pinniped initial sightings (Table 3.12). Initial sightings of some cetaceans were over four km from the source vessel. The furthest pinnipeds sightings were over two km from the vessels (Table 3.12).

The bearing and distance from the observer stations on the *Gilavar* and the *Western Patriot* to initial sighting locations for pinnipeds were determined for all useable sightings of pinnipeds within the 180 dB safety zone (Fig. 3.6). Initial pinniped sighting distances from the *Gilavar* and the *Western Patriot* were compared during periods with and without seismic activity (Table 3.13). The initial sighting distance was greater during non-seismic than seismic periods for the *Gilavar* (Table 3.13). The reverse was true for the *Western Patriot* although the sample size was low during non-seismic periods. However, there was little difference in the initial pinniped sighting distance during seismic activities for the two vessels (388 m vs. 325 m; Table 3.13). There was also little difference in the distribution of initial pinniped sightings within the 180 dB safety zone during seismic vs. non-seismic periods for the *Gilavar* (Fig. 3.6). The number of pinniped sightings from the *Western Patriot* was insufficient to make any comparisons of pinniped distribution with airgun status.

TABLE 3.12. Mean initial sighting distances from observations with useable data for cetaceans and pinnipeds from the bridge of the *Gilivar, Discoverer,* and *Western Patriot* in the Chukchi Sea 2007.

Initial sighting distance (m)							
Cetaceans	s.d.	Range	n	Pinnipeds	s.d.	Range	n
1837	1251	150-4440	64	430	385	1-2292	211

TABLE 3.13. Comparison of mean initial sighting distances from observations with useable data for pinnipeds from the *Gilivar* and *Western Patriot* within the 180 dB safety zone during seismic and non-seismic periods, and for all sightings.

Vessel	Seismic Status	Initial Sighting Distance (m)	s.d.	Range (m)	n
Gilivar	All sightings	440	305	2-1362	119
Gilivar	Guns off	490	355	2-1362	60
Gilivar	Guns on	388	237	1-1362	59
Patriot	All sightings	321	297	1-1362	84
Patriot	Guns off	217	116	150-350	3
Patriot	Guns on	325	301	25-1074	81

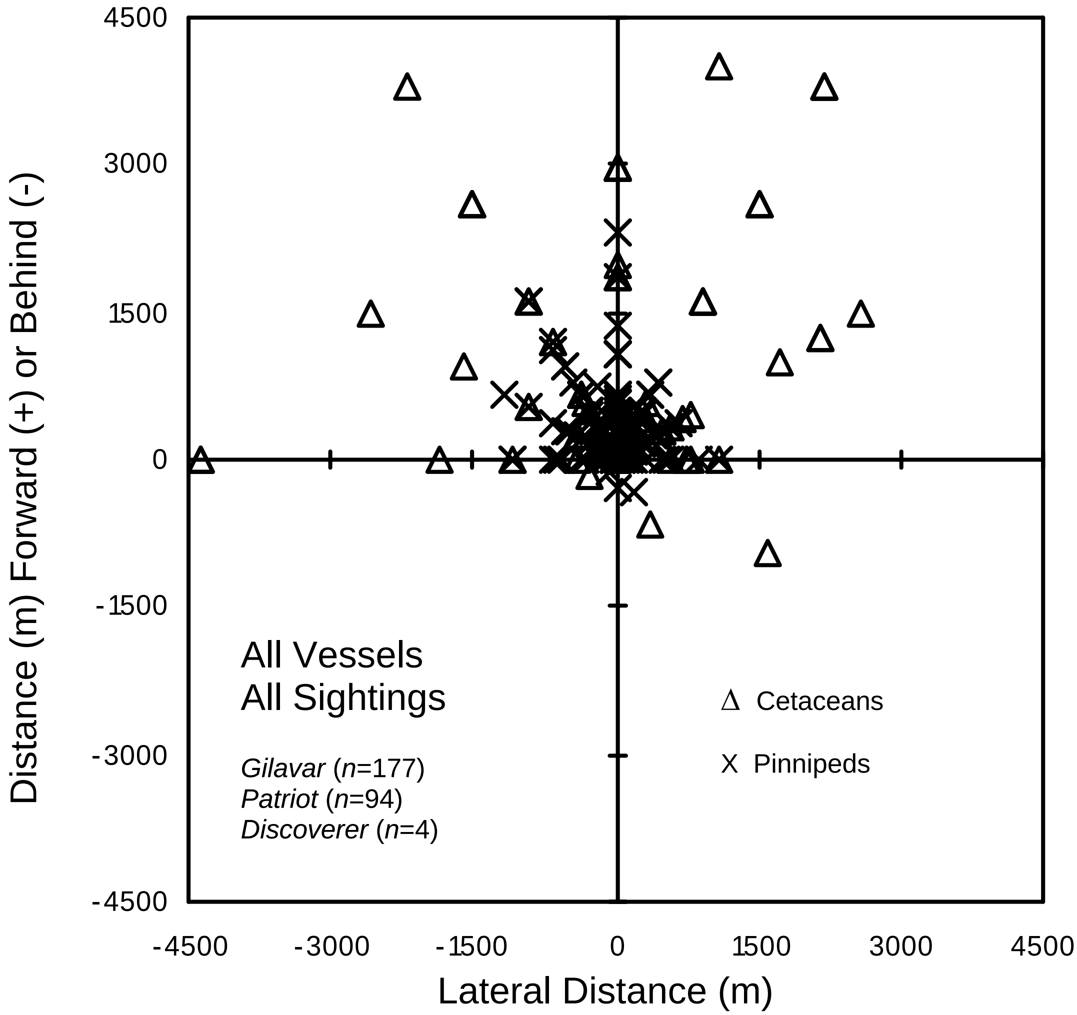


FIGURE 3.5. Relative bearings and distances of all useable marine mammal sightings during the 2006 seismic operations from the *Gilavar, Patriot,* and *Discoverer* (not including sightings of mammals on ice). Bearings and distances are measured relative to the observation site on the bridge of each vessel. The airgun arrays were ~315, 300, and 144 m behind the observers on the *Gilavar*. *Patriot* and *Discoverer, respectively*.

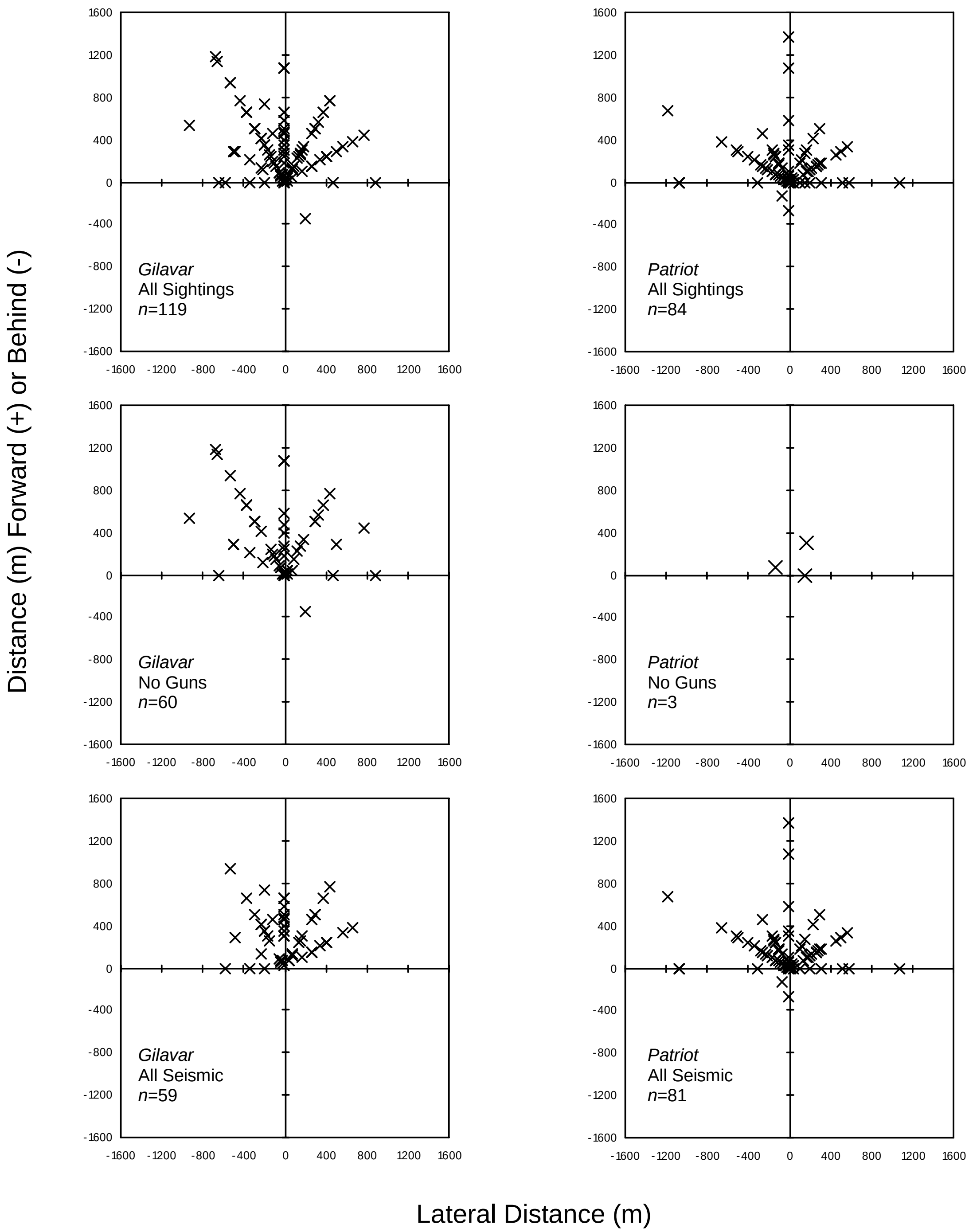


FIGURE 3.6. Relative bearings and distances of pinniped sightings within the 180 dB sound level radius during the 2006 seismic operations from the *Gilavar* and *Patriot* (not including sightings of pinnipeds on ice). The 180 dB radius was 1400 m for the *Gilavar* and 1628 m for the *Patriot*. Bearings and distances are measured relative to the observation site on the bridge. The airgun arrays were ~315 and 300 m behind the observers on the *Gilavar* and *Patriot*, respectively.

Closest Observed Point of Approach (CPA)

During non-seismic periods the mean cetacean and pinniped CPAs to the airgun array of the source vessels (vessel group A) was greater than the mean CPAs to the observers on the support vessels (vessel groups B and C; Table 3.14). The CPA to the airgun array would be expected to be at least ~250 m greater than the CPA to the observer because airgun arrays were located about that distance behind observers on the source vessels. Overall, the mean CPA for cetaceans was farther than the mean CPA for pinnipeds within all vessel groups and during both non-seismic and seismic periods (Table 3.14).

The mean cetacean CPA differed between vessel groups B and C during non-seismic periods (612.9 m versus 384.2 m; Table 3.14). It is not clear why such a large difference occurred between these ships.

For cetaceans, CPA distances during seismic and non-seismic periods could not be compared meaningfully because of the very low numbers of sightings during seismic periods (Table 3.14). The range in CPA distances was larger for vessel group A, followed by vessel group B and then C, during non-seismic periods. Differences in the ranges of recorded CPA may be partially explained by the relative distance to which observers on each vessel can see, which is related to eye-height (see Table 3.2).

TABLE 3.14. Closest observed point of approach (CPA) calculated to the seismic array (vessel group A), or to the observer (vessel groups B and C) for ***(A)*** cetacean sightings, and ***(B)*** pinniped in water sightings, during seismic and non-seismic periods in the Chukchi Sea, using only useable[a] data. Note that nearshore and offshore region data as well as seasons are pooled.

		Non-seismic				**Seismic**			
Vessel Group	**# Sightings**	**Mean CPA (m)**	**s.d.**	***n***	**Range (m)**	**Mean CPA (m)**	**s.d.**	***n***	**Range (m)**
A. Cetaceans									
Vessel Group A	58	1674.1	1032.8	55	4039	714.7	179.9	3	317
Vessel Group B	88	612.9	577.6	85	2964	862.3	1234.8	3	2187
Vessel Group C	10	384.2	310.3	10	745	-	-	-	-
B. Pinnipeds in Water									
Vessel Group A	216	728.5	460.9	74	2011	564.0	298.0	142	2592
Vessel Group B	1640	215.8	240.9	1134	2498	124.9	149.5	506	1009
Vessel Group C	41	186.5	159.5	30	790	103.5	111.2	11	311

- denotes no operations in the indicated category.
[a] See *Useability Criteria* in *Methods* in this chapter.

Pinniped sightings tended to occur closer to the airgun array (vessel group A) or observer (vessel groups B and C) during seismic periods than during non-seismic periods. This difference was statistically significant for vessel groups A and B (Wilcoxon Z = -2.4 and -8.5, respectively, P = 0.0188 and P < 0.0001). The pinnipeds CPA range was greater during seismic periods compared to non-seismic periods for source vessels (2592 m versus 2011 m), but was greater during non-seismic periods for support vessel groups B and C (1009 m versus 2498 m, 311 m versus 790 m, respectively; Table 3.14).

Animal Movement Relative to Vessel Movement

Movement was observed and recorded for 156 sightings of cetaceans (150 during non-seismic periods and six during seismic periods; Table 3.15). Of the 156 sightings, 105 occurred during the early season, 49 during the mid-season, and two during the late season (Table 3.15). For 35 sightings, it was not possible to determine the direction of the animal's movement. During non-seismic periods within the early and mid-seasons, when almost all sightings were recorded, the most commonly observed movement was swimming parallel to the vessel (Table 3.15). Overall, there were no observations of cetaceans "fleeing" during either seismic or non-seismic periods.

TABLE 3.15. Numbers of useable[a] sightings of cetaceans within the Chukchi Sea by movement category, distinguishing seismic and non-seismic periods, vessel groups, and cetacean seasons (nearshore and offshore regions combined). See Table 3.2 for details of vessel groups.

	Movement Relative to Vessel									
	Mill	Swim Perpen-dicular	Swim Away	Swim Parallel	Swim Toward	Flee	No Movement	Unknown	Not Recorded	*Total*
Cetaceans										
A. Early season										
Vessel Group A										
Non-seismic	0	10	4	19	6	0	0	16	0	***55***
Seismic	0	0	2	0	0	0	0	1	0	***3***
Vessel Group B										
Non-seismic	4	3	5	16	0	0	1	15	0	***44***
Seismic	0	1	0	2	0	0	0	0	0	***3***
Vessel Group C										
Non-seismic	-	-	-	-	-	-	-	-	-	***0***
Seismic	-	-	-	-	-	-	-	-	-	***0***
B. Mid-season										
Vessel Group A										
Non-seismic	0	0	0	0	0	0	0	0	0	***0***
Seismic	0	0	0	0	0	0	0	0	0	***0***
Vessel Group B										
Non-seismic	0	4	10	17	6	0	2	2	0	***41***
Seismic	0	0	0	0	0	0	0	0	0	***0***
Vessel Group C										
Non-seismic	1	1	1	3	1	0	1	0	0	***8***
Seismic	0	0	0	0	0	0	0	0	0	***0***
C. Late season										
Vessel Group A										
Non-seismic	0	0	0	0	0	0	0	0	0	***0***
Seismic	0	0	0	0	0	0	0	0	0	***0***
Vessel Group B										
Non-seismic	-	-	-	-	-	-	-	-	-	***0***
Seismic	-	-	-	-	-	-	-	-	-	***0***
Vessel Group C										
Non-seismic	1	0	0	0	0	0	0	1	0	***2***
Seismic	0	0	0	0	0	0	0	0	0	***0***
D. All seasons										
All Vessels										
Non-seismic	***6***	***18***	***20***	***55***	***13***	***0***	***4***	***34***	***0***	***150***
Seismic	***0***	***1***	***2***	***2***	***0***	***0***	***0***	***1***	***0***	***6***

- denotes no operations during the indicated season.

[a] See *Useability Criteria* in *Methods* in this chapter.

For pinnipeds, the direction of movement (or lack thereof) relative to the vessel was recorded for 1926 sightings, of which 1267 were during non-seismic periods and 659 sightings during seismic periods (Table 3.16). Most sightings occurred in the mid-season (1289), followed by the early and late seasons (523 and 114 sightings; Table 3.16). Considering all data combined across seismic state, season and vessels, no clear direction of movement, or "no movement," was the most frequently recorded category for seals in the water, followed by swimming away (Table

3.16). Swimming parallel was the next most frequently-observed movement. However, during non-seismic periods, pooling all seasons and vessels, the most common movement was "swim away," while during seismic periods, it was "no movement" (Table 3.16).

Within vessel groups, the most common pinniped movement observed for vessel group A was swimming away during both non-seismic and seismic periods in the early and mid-seasons (Table 3.16). Within vessel group B the most common movement was also swimming away during non-seismic periods, but switched to "no movement" during seismic periods (Table 3.16). In the late season, the most commonly observed movement was "no movement" for support vessel groups B and C (Table 3.16).

TABLE 3.16. Numbers of useable[a] sightings of pinnipeds within the Chukchi Sea by movement category, distinguishing seismic and non-seismic periods, vessel groups, and pinniped seasons (nearshore and offshore regions combined). Note that the early season includes offshore near ice, offshore open water, and nearshore region data. See Table 3.2 for details of vessel groups.

	Movement Relative to Vessel										
	Mill	Swim Perpen-dicular	Swim Away	Swim Parallel	Swim Toward	Hauled Out	Flee	No Movement	Unknown	Not Recorded	*Total*
Pinnipeds											
A. Early season											
Vessel Group A											
Non-seismic	11	17	19	8	2	13	0	3	10	0	***83***
Seismic	6	7	34	10	1	0	0	4	9	2	***73***
Vessel Group B											
Non-seismic	2	10	40	27	11	9	0	37	20	0	***156***
Seismic	3	16	39	46	18	0	1	76	12	0	***211***
Vessel Group C											
Non-seismic	-	-	-	-	-	-	-	-	-	-	***0***
Seismic	-	-	-	-	-	-	-	-	-	-	***0***
B. Mid-season											
Vessel Group A											
Non-seismic	0	0	1	2	0	0	0	0	1	0	***4***
Seismic	1	5	29	9	5	0	0	7	11	0	***67***
Vessel Group B											
Non-seismic	84	31	266	138	66	7	12	224	69	4	***901***
Seismic	12	5	60	29	32	0	0	148	8	0	***294***
Vessel Group C											
Non-seismic	0	0	4	5	1	0	0	13	0	0	***23***
Seismic	-	-	-	-	-	-	-	-	-	-	***0***
C. Late season											
Vessel Group A											
Non-seismic	0	0	0	0	0	0	0	0	0	0	***0***
Seismic	1	0	0	1	0	0	0	0	0	0	***2***
Vessel Group B											
Non-seismic	3	4	9	16	14	0	0	40	7	0	***93***
Seismic	0	0	0	1	0	0	0	0	0	0	***1***
Vessel Group C											
Non-seismic	1	0	0	2	0	0	1	3	0	0	***7***
Seismic	0	1	3	1	0	0	0	6	0	0	***11***
D. All seasons											
All Vessels											
Non-seismic	***101***	***62***	***339***	***198***	***94***	***29***	***13***	***320***	***107***	***4***	***1267***
Seismic	***23***	***34***	***165***	***97***	***56***	***0***	***1***	***241***	***40***	***2***	***659***

- denotes no operations during the indicated season.

[a] See *Useability Criteria* in *Methods* in this chapter.

There were four useable polar bear sightings, all of which occurred during non-seismic periods. Polar bears would be less likely to be recorded during seismic activities which have less potential to occur near ice than non-seismic activities. The first sighting was recorded as "milling" (walking on ice), the second was movement unknown (but walking), the third was swimming away from the vessel, and the fourth was no movement.

First Observed Behavior

For cetaceans, when data were pooled across seasons, seismic state, and vessels, the most common "first observed behavior" was "swim / travel," followed by "dive" (Table 3.17). This was also true during the early and mid-seasons, when almost all the cetacean sightings were recorded. "Surface active" and "feeding" behaviors were also recorded during non-seismic periods.

For pinnipeds in water, pooling all seasons, vessels, and seismic states, "swim / travel" was the most frequently observed first behavior (40%, or 752 sightings), closely followed by "look" (38%, or 730 sightings; Table 3.18). The next most common behaviors were "dive" (252 sightings) and "rest" (122 sightings; Table 3.18).

During the early and mid- seasons, "swim / travel" was the predominant pinniped activity for vessel group A regardless of seismic state. However, for vessel group B during the same periods the predominant pinniped activity during seismic periods was "look" (Table 3.18). In the late season, the most common behavior during non-seismic periods changed to "look" for both vessel groups B and C, which was also the most common behavior during seismic periods for vessel group C (Table 3.18).

There were 29 useable sightings of pinnipeds hauled out, or "on ice," with most sightings occurring in the early season (76%, or 22 sightings), followed by the mid-season (seven sightings; Table 3.19). There were no sightings of pinnipeds on ice in the late season. The majority of pinnipeds on ice were recorded as "resting" (79%, or 23 sightings), with the remaining sightings having no recorded behavior, or "unknown" behavior (Table 3.19). All sightings occurred during non-seismic periods, likely due to the operating source vessels avoiding areas with significant ice cover. Four useable polar bear sightings were recorded. The initial behavior was "unknown" for two of the sightings, while the other two sightings were "swim/travel" and "look."

TABLE 3.17. Numbers of useable[a] sightings of cetaceans in the Chukchi Sea by pooled behavior category, distinguishing seismic state and non-seismic periods from all vessel groups, within each cetacean season (nearshore and offshore regions combined). See Table 3.2 for details of vessel groups.

	Dive	Look	Rest	Swim / Travel	Surface Active	Feeding	Unknown	Not Recorded	*Total*
Cetaceans									
A. Early season									
Vessel Group A									
Non-seismic	0	0	0	55	0	0	0	0	***55***
Seismic	0	0	0	3	0	0	0	0	***3***
Vessel Group B									
Non-seismic	5	0	0	32	3	4	0	0	***44***
Seismic	1	0	0	2	0	0	0	0	***3***
Vessel Group C									
Non-seismic	-	-	-	-	-	-	-	-	***0***
Seismic	-	-	-	-	-	-	-	-	***0***
B. Mid-season									
Vessel Group A									
Non-seismic	0	0	0	0	0	0	0	0	***0***
Seismic	0	0	0	0	0	0	0	0	***0***
Vessel Group B									
Non-seismic	6	0	0	35	0	0	0	0	***41***
Seismic	0	0	0	0	0	0	0	0	***0***
Vessel Group C									
Non-seismic	1	0	0	7	0	0	0	0	***8***
Seismic	0	0	0	0	0	0	0	0	***0***
C. Late season									
Vessel Group A									
Non-seismic	0	0	0	0	0	0	0	0	***0***
Seismic	0	0	0	0	0	0	0	0	***0***
Vessel Group B									
Non-seismic	-	-	-	-	-	-	-	-	***0***
Seismic	-	-	-	-	-	-	-	-	***0***
Vessel Group C									
Non-seismic	0	0	0	2	0	0	0	0	***2***
Seismic	0	0	0	0	0	0	0	0	***0***
D. All seasons									
All Vessels									
Non-seismic	***12***	***0***	***0***	***131***	***3***	***4***	***0***	***0***	***150***
Seismic	***1***	***0***	***0***	***5***	***0***	***0***	***0***	***0***	***6***

- denotes no operations during the indicated season.

[a] See *Useability Criteria* in *Methods* in this chapter.

TABLE 3.18. Numbers of useable[a] sightings of pinnipeds in water in the Chukchi Sea by behavior category, distinguishing seismic state, vessel groups, and pinniped season (nearshore and offshore regions combined). Note that the early season includes offshore near ice, offshore open water, and nearshore region data. See Table 3.2 for details of vessel groups.

	Dive	Look	Rest	Swim / Travel	Surface Active	Feeding	Unknown	Not Recorded	*Total*
Pinnipeds in Water									
A. Early season									
Vessel Group A									
Non-seismic	5	5	1	53	1	0	5	0	***70***
Seismic	8	22	0	43	0	0	0	0	***73***
Vessel Group B									
Non-seismic	28	52	2	62	2	1	0	0	***147***
Seismic	21	104	6	78	0	0	2	0	***211***
Vessel Group C									
Non-seismic	-	-	-	-	-	-	-	-	***0***
Seismic	-	-	-	-	-	-	-	-	***0***
B. Mid-season									
Vessel Group A									
Non-seismic	0	0	0	3	0	0	0	1	***4***
Seismic	3	14	1	44	0	0	5	0	***67***
Vessel Group B									
Non-seismic	133	277	91	378	3	4	4	4	***894***
Seismic	36	177	13	63	1	0	4	0	***294***
Vessel Group C									
Non-seismic	4	17	0	2	0	0	0	0	***23***
Seismic	-	-	-	-	-	-	-	-	***0***
C. Late season									
Vessel Group A									
Non-seismic	0	0	0	0	0	0	0	0	***0***
Seismic	1	1	0	0	0	0	0	0	***2***
Vessel Group B									
Non-seismic	12	48	7	24	1	1	0	0	***93***
Seismic	0	0	1	0	0	0	0	0	***1***
Vessel Group C									
Non-seismic	1	5	0	0	0	0	1	0	***7***
Seismic	0	8	0	2	0	0	1	0	***11***
D. All seasons									
All Vessels									
Non-seismic	***183***	***404***	***101***	***522***	***7***	***6***	***10***	***5***	***1238***
Seismic	***69***	***326***	***21***	***230***	***1***	***0***	***12***	***0***	***659***

- denotes no operations during the indicated season.

[a] See *Useability Criteria* in *Methods* in this chapter.

TABLE 3.19. Numbers of useable[a] sightings of pinnipeds on ice in the Chukchi Sea by pooled behavior category, distinguishing seismic state, vessel groups, and pinniped seasons (nearshore and offshore regions combined). Note that the early season includes offshore near ice, offshore open water, and nearshore region data. See Table 3.2 for details of vessel groups.

	Dive	Look	Rest	Swim / Travel	Surface Active	Feeding	Unknown	Not Recorded	*Total*
Pinnipeds on Ice									
A. Early season									
Vessel Group A									
Non-seismic	0	0	12	0	0	0	1	0	***13***
Seismic	0	0	0	0	0	0	0	0	***0***
Vessel Group B									
Non-seismic	0	0	5	0	0	0	0	4	***9***
Seismic	0	0	0	0	0	0	0	0	***0***
Vessel Group C									
Non-seismic	-	-	-	-	-	-	-	-	***0***
Seismic	-	-	-	-	-	-	-	-	***0***
B. Mid-season									
Vessel Group A									
Non-seismic	0	0	0	0	0	0	0	0	***0***
Seismic	0	0	0	0	0	0	0	0	***0***
Vessel Group B									
Non-seismic	0	0	6	0	0	0	1	0	***7***
Seismic	0	0	0	0	0	0	0	0	***0***
Vessel Group C									
Non-seismic	0	0	0	0	0	0	0	0	***0***
Seismic	-	-	-	-	-	-	-	-	***0***
C. Late season									
Vessel Group A									
Non-seismic	0	0	0	0	0	0	0	0	***0***
Seismic	0	0	0	0	0	0	0	0	***0***
Vessel Group B									
Non-seismic	0	0	0	0	0	0	0	0	***0***
Seismic	0	0	0	0	0	0	0	0	***0***
Vessel Group C									
Non-seismic	0	0	0	0	0	0	0	0	***0***
Seismic	0	0	0	0	0	0	0	0	***0***
D. All seasons									
All Vessels									
Non-seismic	***0***	***0***	***23***	***0***	***0***	***0***	***2***	***4***	***29***
Seismic	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***

- denotes no operations during the indicated season.

[a] See *Useability Criteria* in *Methods* in this chapter.

Detection Rates of Marine Mammals

Detection rates (number of useable sightings/unit of useable effort) were calculated to evaluate potential changes in the frequency of observations between non-seismic and seismic periods. Tables 3.20 and 3.21 show the detection rates for cetaceans and pinnipeds, respectively, from the different vessel groups in the offshore region, divided by seismic activity, season, and proximity to ice (where applicable). For detection rates in the nearshore region, see Appendix A (Table A.4). Detection rates based on >1000 km of effort were considered more reliable, and detection rates based on 500–1000 km were considered "marginal". Detection rates based on <500 km of effort were considered unreliable.

Marginal and reliable detection rates were compared between non-seismic and seismic periods both within and between vessel groups. Cetacean detection rates in the early season were higher in vessel group A than in vessel group B (21.3 versus 3.2/1000 km, respectively; Table 3.20) during non-seismic periods. This difference could reflect the greater area that could be observed from the higher source vessel platforms (eye-height 12.5–13.3 m), compared to the support vessel platforms in group B (eye-height 7.7–10.8 m; Table 3.2).

Conversely, useable pinniped detection rates in open water during non-seismic periods in the early season were similar for vessel groups A and B (8.8 versus 9.4/1000 km; Table 3.21). In general, pinnipeds tend to be detected at much closer distances than do cetaceans, so the difference in eye-height should not affect the sighting rate as much. In higher seas, however, observers at lower heights may have more difficulty sighting pinnipeds, even close to the vessel. As discussed previously, vessel group C operated primarily during the late pinniped season, and collected the majority of its useable effort in Bf 3–5 (Table 3.4). During the late pinniped season, pinniped detection rates were higher for vessel group B than for group C (40.0 versus 7.1/1000 km; Table 3.9b). It is not possible to say whether the lower pinniped detection rates for vessel group C were a result of a lower observation platform or a true reflection of lower numbers of pinnipeds present in the operating location of vessel group C.

However, differences in eye-height do not adequately explain the differences between vessel group detection rates during seismic periods. Useable pinniped detection rates during seismic periods were much lower from group A vessels than from group B vessels in the early season, both near ice and in open water, and in the mid-pinniped season (Table 3.21). Since support vessels had to be 1 – 15 km from an operating source vessel for the useable data to be considered "seismic," the MMOs on support vessels were farther from the operating airgun array than were those on the seismic vessel. (The average distance between an observer on the seismic vessel and the airgun array was ~250 m.) Therefore, the differences in detection rates of pinnipeds between the source vessels (vessel group A) and the support vessels (vessel group B) may be due to localized avoidance of the operating airgun array. On the other hand, for cetaceans, useable detection rates during seismic periods were only slightly lower for group A than group B in the early cetacean season (Table 3.20) though relatively few cetaceans were seen from any of the source vessels during seismic periods.

Potential avoidance of seismic activities by cetaceans was suggested by the much lower cetacean detection rates in the early season from both vessel groups A and B during seismic periods than during non-seismic periods (0.5 versus 21.3/1000 km for vessel group A; 0.7 versus 3.2/1000 km for vessel group B; Table 3.20). No such pattern was apparent in pinniped detection rates in the early and late pinniped seasons, but in the mid-season, pinniped detection rates were lower during seismic periods compared to non-seismic periods (75.3 versus 132.5/1000 km for vessel group B; Table 3.21).

Polar bears (ursids) were sighted solely by vessel group B, and only during non-seismic periods. Vessel group B had the most useable effort near ice, and polar bears are known to associate closely with ice.

TABLE 3.20. Number of useable[a] cetacean detections (sightings), useable[a] effort in km and calculated useable detection rate (number of detections per 1000 km) for all vessel groups in the Chukchi Sea, offshore, divided by ***(A)*** Non-seismic, and ***(B)*** Seismic periods. Entries in bold are associated with levels of useable effort > 1000 km, while entries in gray are associated with levels of useable effort < 500 km. For a similar treatment of nearshore data, see Appendix Table A.4.

	Early			Mid			Late		
	# Det.	Effort (km)	Det. rate/ 1000km	# Det.	Effort (km)	Det. rate/ 1000km	# Det.	Effort (km)	Det. rate/ 1000km
Cetaceans									
A. Non-seismic									
Vessel Group A	**55**	**2585.2**	**21.3**	0	59.4	0.0	0	<0.1	0.0
Vessel Group B	**28**	**8825.6**	**3.2**	**31**	**3633.4**	**8.5**	-	-	-
Vessel Group C	-	-	-	8	309.3	25.9	2	697.1	2.9
B. Seismic									
Vessel Group A	**3**	**5684.7**	**0.5**	0	587.6	0.0	0	154.6	0.0
Vessel Group B	**3**	**4513.9**	**0.7**	0	471.1	0.0	-	-	-
Vessel Group C	-	-	-	0	417.6	0	0	45.8	0

- denotes no operations during the indicated season.

[a] See *Useability Criteria* in *Methods* in this chapter.

Marine Mammal Sighting Rates Relative to Proximity of Seismic Source Vessels

Useable sightings, effort, and detection rates of cetaceans are summarized in Table 3.22. The ≥ 170 dB category had very little useable effort and no sightings. The overall limited numbers of cetacean sightings within these categories do not permit meaningful interpretation of the data. As data accumulate from similar studies in this area, this type of analysis may provide further insight into cetacean distributions relative to received sound levels.

Useable sightings, effort, and detection rates of pinnipeds are summarized in Fig. 3.7 and Table 3.23. The detection rates for both seals and walruses were estimated to be relatively high in the ≥180 dB category compared to nearby sound level categories. However, there was very little effort in the ≥180 dB category (Table 3.23), so these results should be interpreted with caution.

TABLE 3.21. Number of useable[a] pinniped detections (sightings), useable[a] effort in km and calculated useable detection rate (number of detections per 1000 km) for all vessel groups in the Chukchi Sea, offshore, divided by ***(A)*** Non-seismic, and ***(B)*** Seismic periods. Entries in bold are associated with levels of useable effort > 1000 km, while entries in gray are associated with levels of useable effort < 500 km. For a similar treatment of nearshore data, see Appendix Table A.4.

	Early						Mid			Late		
	Near Ice			Open Water								
	# Det.	Effort (km)	Det. rate/ 1000km	# Det.	Effort (km)	Det. rate/ 1000km	# Det.	Effort (km)	Det. rate/ 1000km	# Det.	Effort (km)	Det. rate/ 1000km
A. Non-seismic												
Vessel Group A												
Pinnipeds in Water	50	422.0	118.5	**17**	**1928.7**	**8.8**	4	493.9	8.1	0	76.6	0.0
Pacific Walrus in water	7	422.0	16.6	**3**	**1928.7**	**1.6**	1	493.9	2.0	0	76.6	0.0
Pinnipeds on Ice	13	422.0	30.8	**0**	**1928.7**	**0.0**	0	493.9	0.0	0	76.6	0.0
Pacific Walrus on ice	3	422.0	7.1	**0**	**1928.7**	**0.0**	0	493.9	0.0	0	76.6	0.0
Vessel Group B												
Pinnipeds in Water	**82**	**1517.3**	**54.0**	**52**	**5561.1**	**9.4**	**670**	**5056.4**	**132.5**	**86**	**2151.9**	**40.0**
Pacific Walrus in water	**6**	**1517.3**	**4.0**	**5**	**5561.1**	**0.9**	**53**	**5056.4**	**10.5**	**2**	**2151.9**	**0.9**
Pinnipeds on Ice	**7**	**1517.3**	**4.6**	**0**	**5561.1**	**0.0**	**7**	**5056.4**	**1.4**	**0**	**2151.9**	**0.0**
Pacific Walrus on ice	**5**	**1517.3**	**3.3**	**0**	**5561.1**	**0.0**	**7**	**5056.4**	**1.4**	**0**	**2151.9**	**0.0**
Vessel Group C												
Pinnipeds in Water	-	-	-	-	-	-	23	219.4	104.8	6	839.8	7.1
Pacific Walrus in water	-	-	-	-	-	-	0	219.4	0.0	0	839.8	0.0
Pinnipeds on Ice	-	-	-	-	-	-	0	219.4	0.0	0	839.8	0.0
Pacific Walrus on ice	-	-	-	-	-	-	0	219.4	0.0	0	839.8	0.0
B. Seismic												
Vessel Group A												
Pinnipeds in Water	**7**	**1141.0**	**6.1**	**66**	**4387.0**	**15.0**	**67**	**2342.0**	**28.6**	2	362.4	5.5
Pacific Walrus in water	**1**	**1141.0**	**0.9**	**4**	**4387.0**	**0.9**	**7**	**2342.0**	**3.0**	0	362.4	0.0
Pinnipeds on Ice	**0**	**1141.0**	**0.0**	**0**	**4387.0**	**0.0**	**0**	**2342.0**	**0.0**	0	362.4	0.0
Pacific Walrus on ice	**0**	**1141.0**	**0.0**	**0**	**4387.0**	**0.0**	**0**	**2342.0**	**0.0**	0	362.4	0.0
Vessel Group B												
Pinnipeds in Water	36	949.0	37.9	**175**	**4227.8**	**41.4**	**294**	**3902.0**	**75.3**	1	63.3	15.8
Pacific Walrus in water	1	949.0	1.1	**6**	**4227.8**	**1.4**	**14**	**3902.0**	**3.6**	0	63.3	0.0
Pinnipeds on Ice	0	949.0	0.0	**0**	**4227.8**	**0.0**	**0**	**3902.0**	**0.0**	0	63.3	0.0
Pacific Walrus on ice	0	949.0	0.0	**0**	**4227.8**	**0.0**	**0**	**3902.0**	**0.0**	0	63.3	0.0
Vessel Group C												
Pinnipeds in Water	-	-	-	-	-	-	-	-	-	11	504.8	21.8
Pacific Walrus in water	-	-	-	-	-	-	-	-	-	1	504.8	2.0
Pinnipeds on Ice	-	-	-	-	-	-	-	-	-	0	504.8	0.0
Pacific Walrus on ice	-	-	-	-	-	-	-	-	-	0	504.8	0.0

- denotes no operations during the indicated season.

[a] See *Useability Criteria* in *Methods* in this chapter.

TABLE 3.22. Number of useable detections, useable effort (km), and detection rates (detections/1000 km) for cetaceans exposed to various sound levels sighted from the *Torsvik*, *Gulf Provider*, and *Kilabuk* in the Chukchi Sea during the 2006 open water season. NOTE: Data for the ≥180 dB category were taken from source vessel sightings (*Patriot*, *Gilavar*, and *Discoverer*) during seismic periods.

Received Sound Exposure Level (dB re1 μPa rms)	Number of Detections	Effort (km)	Detections / 1000 km
≥ 120	0	768.1	0
≥ 130	0	1696.8	0
≥ 140	0	1237.9	0
≥ 150	0	815.7	0
≥ 160	4	4912.6	0.8
≥ 170	0	165.5	0
≥ 180	3	6426.9	0.5

Detection rates for seals were similar between the ≥ 120 dB and ≥ 160 dB categories and appeared to have increased somewhat in the ≥ 170 and ≥ 180 dB levels. Increased detection rates just outside of the ≥ 190 dB zone may reflect a displacement of seals from areas very close to the operating airgun(s). Excluding the ≥ 180 dB category due to the very low amount of effort within it, walrus detection rates were similar throughout with a slight trend towards increased detections at lower received sound levels.

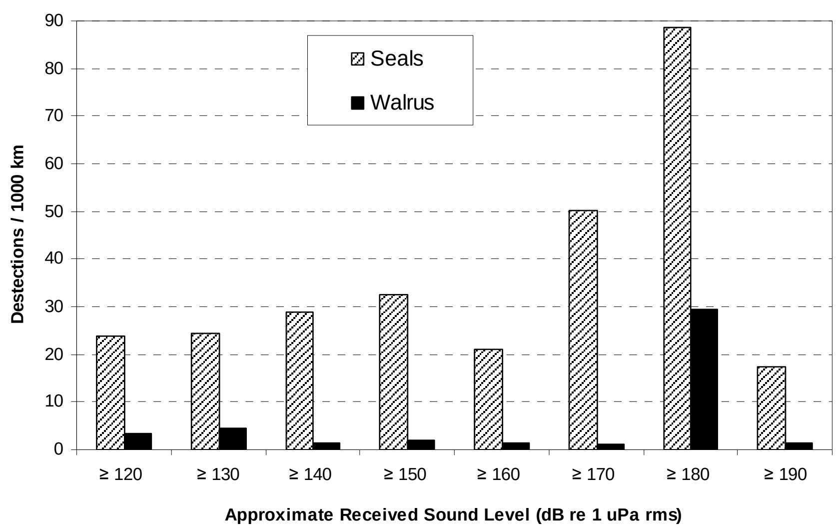


FIGURE 3.7. Detection rates (detections / 1000 km) for pinnipeds exposed to various sound levels sighted from vessel group B (*Torsvik*, *Gulf Provider*, and *Kilabuk*) in the Chukchi Sea during the 2006 open water season. Data for the ≥190 dB category were taken from source vessel sightings (*Patriot*, *Gilavar*, and *Discoverer*) during seismic periods and may include some animals exposed to sound levels ranging between 180 dB and 190 dB. Data for the ≥180 dB category are based on very little effort (chase boats usually operated at somewhat greater distances than the ≥180 dB zone) and should be considered with caution.

TABLE 3.23. Number of useable detections, useable effort (km), and detection rates (detections/1000 km) for pinnipeds exposed to various sound levels sighted from the *Torsvik*, *Gulf Provider*, and *Kilabuk* in the Chukchi Sea during the 2006 open water season. Data for the ≥190 dB category were taken from source vessels (*Patriot*, *Gilavar*, and *Discoverer*) during seismic periods and may include some animals exposed to sound levels ranging between 180 dB and 190 dB.

Received Sound Exposure Level (dB re1 µPa rms)	Number of Detections		Effort (km)	Detections / 1000 km	
	Seals	Pacific Walrus		Seals	Pacific Walrus
≥ 120	28	4	1168.9	24.0	3.4
≥ 130	55	10	2265.9	24.3	4.4
≥ 140	89	4	3068.2	29.0	1.3
≥ 150	48	3	1480.1	32.4	2.0
≥ 160	162	10	7670.3	21.1	1.3
≥ 170	200	5	3975.6	50.3	1.3
≥ 180	6	2	67.8	88.5	29.5
≥ 190	142	12	8232.4	17.2	1.5

Probability of Marine Mammal Detection with Distance from Vessel

The effective strip half-width (ESW) for cetaceans during periods of low sea conditions (Bf 0–2) ranged from 706 m (one observer, n = 19) to 778 m (three observers, n = 21; Fig. 3.8). There were insufficient numbers of cetacean sightings with two observers on watch during periods with low wind force to calculate the ESW (n = 9); however, one sighting did occur out to a perpendicular distance of ~2000 m. With high wind force (Bf 3–5), the ESW decreased to 544 m for one observer (n = 15), but the ESW for two observers was 984 m (n = 17; Fig. 3.8). There were only two cetacean sightings by three observers during higher wind force conditions, so there were not enough data to compare to the three-observer data during periods of low wind force. Overall, there was a general trend toward increasing ESW with an increasing number of observers and decreasing ESW with higher wind force (Fig. 3.8). Sample sizes were generally poor or marginal, ranging from 9–21 sightings for all categories examined, so it was not possible to draw any firm conclusions.

Overall, ESW for cetaceans was similar to that of pinnipeds, decreasing as wind force increased. During periods of low wind force (Bf 0–1), the ESW for pinnipeds in water ranged from 157 m (one observer, n = 49) to 243 m (three observers, n = 39; Fig. 3.9). As with cetaceans, ESW increased with the numbers of observers. The same trend was not apparent during periods of moderate wind force (Bf 2–3), likely due to the occurrence of one sighting at a perpendicular distance of 1299 m made by one observer (not shown on Fig. 3.9 due to the truncation of the x-axis for presentation purposes), which affected fitting of the sighting probability curve and which increased the ESW estimate to 281 m. The ESW for two and three observers during periods of medium wind force ranged from 147 m to 205 m, which was shorter than estimates during periods of low wind force (Fig. 3.9). During periods of high wind force, the ESW for all observers was greatly shortened, ranging from 48–68 m (Fig. 3.9). Overall, similar to cetaceans, ESW decreased for pinnipeds as wind force increased.

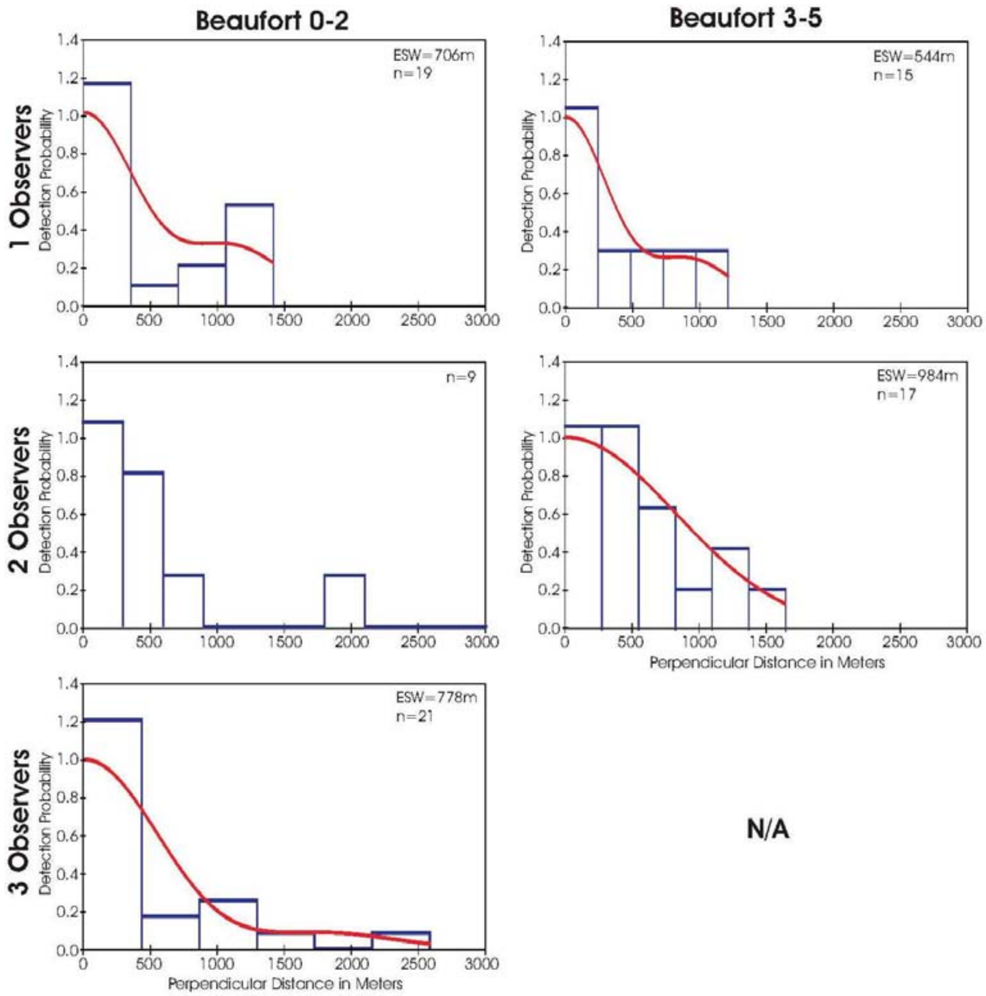


FIGURE 3.8. Frequency distributions of sighting distances (m) and sighting probability curves for useable cetacean sightings from vessel group B during non-seismic periods, divided by low and high wind force (Bf 0–2 vs. Bf 3–5), and number of observers (1, 2 and 3).

There were insufficient data to conduct a similar analysis using vessel group A data, but it is likely that the ESWs would have been somewhat larger because the source vessels have a higher observation platform, which allowed observers to effectively monitor a greater area. There were also insufficient data for vessel group C, but its ESWs would likely have been shorter, due to its lower observation platform.

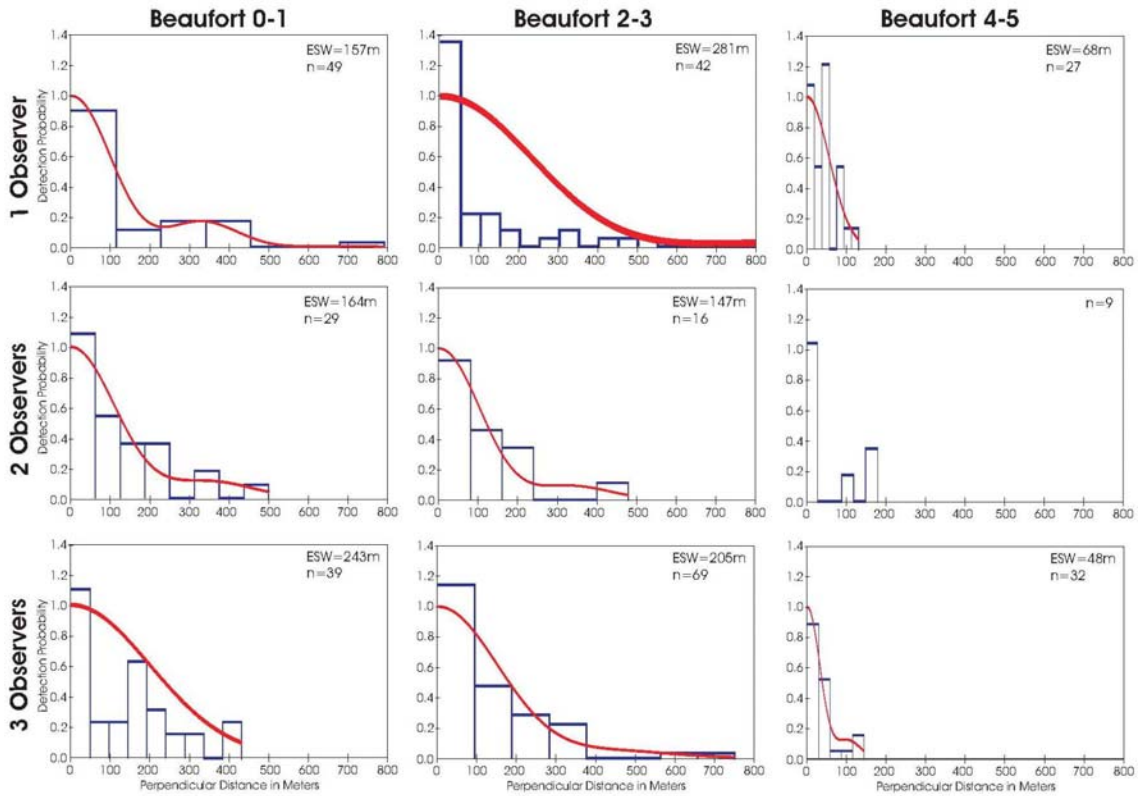


FIGURE 3.9. Frequency distributions of sighting distances (m) and sighting probability curves for useable pinniped sightings from Vessel Group B during non-seismic periods, divided by low (Bf 0–1), medium (Bf 2–3), and high (Bf 4–5) wind force, and number of observers (one, two and three).

Estimated Number of Marine Mammals Potentially Ensonified

Estimates from Direct Observations

The number of marine mammals directly observed within the established dB (rms) distances around the three source vessels (*Gilavar*, *Patriot*, and *Discoverer*) during the Chukchi Sea 2006 surveys provided a minimum estimate of the numbers of marine mammals potentially affected by seismic sounds. Table 3.24 shows the total number of individual marine mammals observed within each of the established sound level distances. The numbers of individuals listed in Table 3.24 are likely underestimates of the actual numbers of animals exposed to the specified sound levels. Some animals probably moved away before coming within visual range, and not all of those that remained would have been detected by observers.

TABLE 3.24. Total number of individuals directly observed within the ≥160, ≥170, ≥180, or ≥190 dB re 1µPa (rms) distances during 2006 seismic activities in the Chukchi Sea.

	Exposure level in dB re 1µPa (rms)	Individuals
Cetaceans	**≥160**	9
	≥180	4
Pinnipeds	**≥160**	252
	≥170	235
	≥190	89

Estimates Extrapolated from Density

Density estimates (Table 3.25) were derived from the data collected by the *Kilabuk*, *Torsvik*, and *Gulf Provider* (vessel group B) during operations in the Chukchi Sea in the 10 July–24 Oct. 2006 period. These densities were corrected for sightability biases and the number of observers as described in Appendix B. The estimated areas ensonified to ≥160, ≥170, ≥180, and ≥190 dB (rms), are shown in Tables 3.26 and 3.27. Area calculations in Tables 3.26 and 3.27 were categorized according to the cetacean seasons and pinniped seasons, respectively. The total ensonified area for pinnipeds and cetaceans was not the same because the cetacean seasons were defined differently than the pinniped seasons.

The number of marine mammal *individuals* and average number of *exposures* per individual potentially affected by seismic operations in the Chukchi Sea were estimated by multiplying densities by the corresponding ensonified area (e.g., mid-season pinniped densities were multiplied by mid-season pinniped ensonified areas). In the event that a particular area was ensonified during more than one season, the higher seasonal density was used. When density estimates were not possible for a particular season, area or seismic state, the largest of the applicable densities was used for the calculation. For example, during non-seismic periods, there were no available cetacean density estimates for the late season. The early season density estimates were substituted in these cases. During seismic periods, there was only an early-season density estimate within the offshore region for some cetacean species; therefore, this estimate was applied to the other seasons and the nearshore region. For pinnipeds in water, the early open-water seismic density estimate was applied to the late pinniped season, and offshore estimates were also applied to the nearshore region. The following analyses are based on densities calculated for non-seismic and seismic periods based on “useable” data from vessel group B.

TABLE 3.25. Density estimates (individuals/1000 km^2) for the different cetacean species and pinniped species groups in the Chukchi Sea, nearshore and offshore regions, during ***(A)*** non-seismic periods, and ***(B)*** seismic periods, based on vessel group B useable[a] data.

	Nearshore			Offshore				
	Early	Mid	Late	Early			Mid	Late
				Near Ice	Open Water	All		
A. Non-seismic								
Cetaceans								
Unidentified Whale	8.40	4.54	-			1.10	0.00	-
Harbor Porpoise	19.83	0.00	-			5.59	34.03	-
Killer Whale	0.00	0.00	-			1.70	0.00	-
Unidentified Dolphin	0.00	0.00	-			1.41	0.00	-
Bowhead Whale	0.00	68.91	-			3.09	31.56	-
Gray Whale	53.81	6.46	-			16.06	5.71	-
Minke Whale	7.46	0.00	-			0.00	2.56	-
Unidentified Mysticete Whale	0.00	0.00	-			1.47	0.00	-
Pinnipeds in Water	69.66	484.71	I	120.57	74.34		262.32	169.89
Pinnipeds on Ice	21.74	0.00	I	19.78	0.00		77.14	0.00
B. Seismic								
Cetaceans								
Unidentified Whale	I	I	-			1.43	I	-
Harbor Porpoise	I	I	-			2.19	I	-
Pinnipeds in Water	I	I	I	246.99	228.08		610.53	I
Pinnipeds on Ice	I	I	I	0.00	0.00		0.00	I

Note: I indicates insufficient effort to warrant calculating a density.
- denotes no operations during the indicated season.
[a] See *Useability Criteria* in *Methods* section in this chapter.

TABLE 3.26. Areas (km^2) potentially ensonified to various levels by the three source vessels (*Gilavar, Patriot,* and *Discoverer*) operating within the Chukchi Sea study area, 10 July−12 Nov. 2006, subdivided by cetacean season. ***(A)*** Maximum area ensonified, with overlapping areas counted each time they overlapped. ***(B)*** Total area ensonified, with overlapping areas counted only once.

	Nearshore				Offshore			
	Level of ensonification (dB re1µPa (rms))				Level of ensonification (dB re1µPa (rms))			
Area (km^2)	**≥160**	**≥170**	**≥180**	**≥190**	**≥160**	**≥170**	**≥180**	**≥190**
Early cetacean season								
A. Including Overlap Area	0	0	0	0	289,948	158,634	55,698	18,890
B. Excluding Overlap Area	0	0	0	0	20,149	13,942	8481	6061
Mid- cetacean season								
A. Including Overlap Area	520	207	72	25	98,310	40,595	13,629	4040
B. Excluding Overlap Area	481	199	71	25	36,028	18,622	7876	2764
Late cetacean season								
A. Including Overlap Area	0	0	0	0	37,750	19,181	7172	2158
B. Excluding Overlap Area	0	0	0	0	28,637	16,335	6525	2013
All seasons								
A. Including Overlap Area	***520***	***207***	***72***	***25***	***426,008***	***218,411***	***76,499***	***25,089***
B. Excluding Overlap Area	***481***	***199***	***71***	***25***	***84,814***	***48,900***	***22,883***	***10,838***

Note: Totals are of unrounded values.

TABLE 3.27. Areas (km^2) potentially ensonified to various levels by the three source vessels (*Gilavar, Patriot,* and *Discoverer*) operating within the Chukchi Sea study area, 10 July−12 Nov. 2006, subdivided by pinniped season. ***(A)*** Maximum area ensonified, with overlapping areas counted each time they overlapped. ***(B)*** Total area ensonified, with overlapping areas counted only once.

	Nearshore				Offshore			
	Level of ensonification (dB re1µPa (rms))				Level of ensonification (dB re1µPa (rms))			
Area (km^2)	**≥160**	**≥170**	**≥180**	**≥190**	**≥160**	**≥170**	**≥180**	**≥190**
Early pinniped season								
A. Including Overlap Area	0	0	0	0	77,411	40,117	21,479	9918
B. Excluding Overlap Area	0	0	0	0	12,909	7416	4184	3295
Mid- pinniped season								
A. Including Overlap Area	0	0	0	0	234,399	101,667	32,420	9738
B. Excluding Overlap Area	0	0	0	0	14,143	9,821	6222	3819
Late pinniped season								
A. Including Overlap Area	520	207	72	25	90,269	40,213	13,818	3998
B. Excluding Overlap Area	481	199	71	25	58,892	31,300	12,118	3690
All seasons								
A. Including Overlap Area	***520***	***207***	***72***	***25***	***402,079***	***181,997***	***67,717***	***23,654***
B. Excluding Overlap Area	***481***	***199***	***71***	***25***	***85,944***	***48,537***	***22,525***	***10,804***

Note: Totals are of unrounded values.

Cetaceans—The estimated numbers of cetaceans that might have been exposed to various levels of received seismic sounds are summarized in Table 3.28. The density data used to calculate these numbers for non-seismic and seismic periods are presented in Table 3.25. The estimated numbers in Table 3.28A represent the cetaceans that would have been exposed had no animals shown localized avoidance of the airguns or of the seismic and support vessels. Many of the animals estimated (based on non-seismic densities) to have been within the ≥180- or ≥190-dB zones likely moved away before being exposed to sounds that strong. That expectation was corroborated by the lower densities and lower estimated numbers of exposed individuals when the calculations were based on densities for seismic periods (Table 3.28B).

(A) ≥160 dB (rms): We estimated that 4183 individual cetaceans would each have been exposed ~4.1 times (on average) to airgun pulses with received levels ≥160 dB re 1 µPa (rms) during the 2006 surveys if cetaceans showed no avoidance of the airguns (Table 3.28 A). Based on the available densities, 1499 of the individuals would have been harbor porpoises, 1321 bowhead whales, 992 gray whales, and 371 other cetaceans (minke whale, killer whale, unidentified dolphin, and unidentified whales).

TABLE 3.28. Estimated numbers of individual cetacean ensonified at different levels, and average number of exposures per individual in both the nearshore and offshore regions, using ***(A)*** Non-seismic densities, and ***(B)*** Seismic densities, from useable[a] vessel group B data. Estimates in ***(A)***, based on non-seismic densities, undoubtedly overestimate actual numbers of cetaceans exposed to high-level sounds, given that cetaceans commonly avoid approaching seismic vessels.

	Nearshore		Offshore		***Total***	
Exposure level in dB re 1µPa (rms)	**Individuals**	**Exposures / Individual**	**Individuals**	**Exposures / Individual**	**Individuals**	**Exposures / Individual**
Cetaceans						
A. Non-seismic density						
Early season						
≥160	0	0.0	613	14.4	613	14.4
≥170	0	0.0	424	11.4	424	11.4
≥180	0	0.0	258	6.6	258	6.6
≥190	0	0.0	184	3.1	184	3.1
Mid-season						
≥160	38	1.1	2661	2.7	2699	2.7
≥170	16	1.0	1375	2.2	1391	2.2
≥180	6	1.0	582	1.7	587	1.7
≥190	2	1.0	204	1.5	206	1.5
Late season						
≥160	0	0.0	871	1.3	871	1.3
≥170	0	0.0	497	1.2	497	1.2
≥180	0	0.0	198	1.1	198	1.1
≥190	0	0.0	61	1.1	61	1.1
All seasons						
≥160	38	1.1	4144	4.2	***4183***	***4.1***
≥170	16	1.0	2296	3.7	***2312***	***3.6***
≥180	6	1.0	1038	2.8	***1044***	***2.8***
≥190	2	1.0	450	2.1	***452***	***2.1***
B. Seismic density[b]						
Early season						
≥160	0	0.0	73	14.4	73	14.4
≥170	0	0.0	51	11.4	51	11.4
≥180	0	0.0	31	6.6	31	6.6
≥190	0	0.0	22	3.1	22	3.1
Mid-season						
≥160	2	1.1	131	2.7	132	2.7
≥170	1	1.0	67	2.2	68	2.2
≥180	0	1.0	29	1.7	29	1.7
≥190	0	1.0	10	1.5	10	1.5
Late season						
≥160	0	0.0	104	1.3	104	1.3
≥170	0	0.0	59	1.2	59	1.2
≥180	0	0.0	24	1.1	24	1.1
≥190	0	0.0	7	1.1	7	1.1
All seasons						
≥160	2	1.1	307	5.0	***309***	***5.0***
≥170	1	1.0	177	4.5	***178***	***4.5***
≥180	0	1.0	83	3.3	***83***	***3.3***
≥190	0	1.0	39	2.3	***39***	***2.3***

[a] See *Useability Criteria* in *Methods* in this chapter.

[b] The offshore seismic density was used in both the nearshore and offshore calculations.

Seismic activities ensonified the largest area, including overlap area, within the early cetacean season (289,948 km^2; Table 3.26 A), but the mid-cetacean season had the largest ensonified area, excluding overlap areas (36,028 km^2; Table 3.26 B). Correspondingly, there were fewer individuals estimated to have been ensonified in the early season than in the mid-season (613 versus 2699), but individuals in the early season were exposed more times on average than in the late season (14.4 times versus 2.7 times, respectively; Table 3.28 A). The relatively high number of multiple exposures per individual reflects the high degree of overlap in ensonified areas around adjacent seismic lines in the early cetacean season.

(B) ≥170 dB (rms): On average, some odontocete species may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 μPa (rms). If so, then the estimated number of exposures would be ~55% of the corresponding estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB (Table 3.26). The ~2312 individual cetaceans exposed ~3.6 times each (on average) to seismic sounds ≥170 dB (Table 3.28 A), would include ~803 harbor porpoises, ~52 killer whales, and ~43 unidentified dolphins, assuming no avoidance of the ≥170 dB zone. Harbor porpoises are generally acknowledged to be relatively sensitive to sound, so the ≥170 dB (rms) criterion may not be appropriate for them. The number of other odontocetes that might have been exposed to ≥170 dB was small.

(C) ≥180 dB (rms): If there were no avoidance of airgun noise by cetaceans, we estimated that ~1044 individual cetaceans would have been exposed an average of ~2.8 times to airgun sounds with received levels ≥180 dB rms (Table 3.28 A). This would include ~352 harbor porpoises, ~300 bowhead whales, ~286 gray whales, and ~106 other cetaceans (minke whale, killer whale, unidentified dolphin, and unidentified whales). However, cetaceans tend to avoid approaching seismic survey vessels (and often avoid other vessels as well). Thus, most of these cetaceans probably moved away before the airguns were close enough to create a received level ≥180 dB (as corroborated by the much lower estimates based on density data acquired during seismic periods; see Table 3.28 B).

Estimates Based on Densities during Seismic Periods: Few cetaceans were sighted from the support vessels during seismic periods even though these vessels typically traveled ahead of their assigned source vessel. Only one species, the harbor porpoise, was identified from the support vessel during periods of seismic activity, but two other sightings of unidentified cetaceans were made. The density of harbor porpoises based on observations during seismic periods was much lower than that based on observations during non-seismic periods. Based on the corrected densities recorded from the support vessels when they were between 5 and 15 km from the operating source vessel, 309 cetaceans (most or all harbor porpoises) were estimated to be exposed an average of ~5.0 times each to seismic sounds ≥160 dB (rms). Similar results for other sound levels are summarized in Table 3.28 B. As noted above, few of these estimated individuals would actually have been exposed to the higher sound levels as they would likely move away before coming that close to the operating source vessel.

Pinnipeds—Table 3.29 summarizes the number of pinniped *individuals* potentially ensonified at different levels within each pinniped season, and overall, based on densities estimated from observations during non-seismic and seismic periods (Table 3.29 A and B). As with cetaceans, the estimated numbers of pinniped individuals exposed to the different levels of seismic sound, shown in Table 3.29, are likely overestimates given the method’s assumption that animals do not show localized avoidance of the operating seismic array or vessels.

TABLE 3.29. Calculated numbers of pinniped individuals ensonified at different levels, and average number of exposures per individual in both the nearshore and offshore regions, using ***(A)*** Non-seismic densities, and ***(B)*** Seismic densities, from useable[a] vessel group B data.

	Nearshore		Offshore		*Total*	
Exposure level in dB re 1µPa (rms)	**Individuals**	**Exposures / Individual**	**Individuals**	**Exposures / Individual**	**Individuals**	**Exposures / Individual**
Pinnipeds in Water						
A. Non-seismic density						
Early season						
≥160	0	0.0	1088	6.0	1088	6.0
≥170	0	0.0	625	5.4	625	5.4
≥180	0	0.0	353	5.1	353	5.1
≥190	0	0.0	278	3.0	278	3.0
Mid-season						
≥160	0	0.0	3710	16.6	3710	16.6
≥170	0	0.0	2576	10.4	2576	10.4
≥180	0	0.0	1632	5.2	1632	5.2
≥190	0	0.0	1002	2.5	1002	2.5
Late season						
≥160	34	1.0	10,005	1.5	10,039	1.5
≥170	14	1.0	5317	1.3	5331	1.3
≥180	5	1.0	2059	1.1	2064	1.1
≥190	2	1.0	627	1.1	629	1.1
All seasons						
≥160	34	1.0	14,803	5.6	***14,836***	***5.6***
≥170	14	1.0	8519	4.3	***8532***	***4.3***
≥180	5	1.0	4044	3.1	***4048***	***3.1***
≥190	2	1.0	1906	2.1	***1908***	***2.1***
B. Seismic density[b]						
Early season						
≥160	0	0.0	2986	6.0	2986	6.0
≥170	0	0.0	1715	5.4	1715	5.4
≥180	0	0.0	968	5.1	968	5.1
≥190	0	0.0	762	3.0	762	3.0
Mid-season						
≥160	0	0.0	8635	16.6	8635	16.6
≥170	0	0.0	5996	10.4	5996	10.4
≥180	0	0.0	3799	5.2	3799	5.2
≥190	0	0.0	2332	2.5	2332	2.5
Late season						
≥160	110	1.0	13,432	1.5	13,542	1.5
≥170	45	1.0	7139	1.3	7184	1.3
≥180	16	1.0	2764	1.1	2780	1.1
≥190	6	1.0	842	1.1	847	1.1
All seasons						
≥160	110	1.0	25,053	7.2	***25,163***	***7.2***
≥170	45	1.0	14,851	5.4	***14,896***	***5.4***
≥180	16	1.0	7531	3.7	***7547***	***3.7***
≥190	6	1.0	3936	2.3	***3941***	***2.3***

[a] See *Useability Criteria* in *Methods* in this chapter.

[b] The offshore seismic density was used in both the nearshore and offshore calculations.

(A) ≥160 dB (rms): We estimated that 14,836 individual pinnipeds would each have been exposed ~5.6 times (on average) to airgun pulses with received levels ≥160 dB re 1 μPa (rms) during the 2006 surveys (Table 3.29 A). Since the definition of pinniped and cetacean seasons differed, most seismic activities occurred in the mid-season (Table 3.27 A), but the late season had the largest extent of area ensonified to 160 dB (rms) (Table 3.27 B). Correspondingly, fewer individuals were estimated to have been ensonified to ≥160 dB (rms) in the mid-season than in the late season (3710 versus 10,039), but in the mid-season individuals were exposed many more times, on average, than individuals in the late season (~16.6 times versus ~1.5 times, respectively; Table 3.29 A).

(B) ≥170 dB (rms): Studies of the reactions of pinnipeds to seismic activities have suggested that at times, pinnipeds do not alter their distribution or behavior when exposed to seismic sounds <170 dB (rms) (Thompson et al. 1998; Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005; this project). We estimated that 8532 pinniped individuals (with an average of ~4.3 exposures each) were exposed to seismic sounds ≥170 dB (Table 3.29 A). The numbers of individuals estimated to be ensonified at this level were again fewer in the mid-season compared to the late season (2576 versus 5331, respectively), with numbers again much lower in the early season (625 individuals; Table 3.29 A).

(C) ≥190 dB (rms): The number of animals estimated to be exposed at the ≥190 dB level included 1908 individual pinnipeds, which were each exposed to ≥190 dB (rms) an average of ~2.1 times (Table 3.29 A). This estimate assumes that pinnipeds did not avoid the operating seismic vessel. At this level of sound exposure, there were more individuals potentially exposed to ≥190 dB (rms) in the mid-season compared to the late season (1002 versus 629 individuals), but as before, many fewer individuals were potentially exposed in the early season (278 individuals; Table 3.29 A).

Estimates Based on Densities during Seismic Periods: Unlike the cetacean densities, the pinniped densities during seismic periods, as recorded from vessel group B, were higher than the pinniped density estimates during non-seismic periods (Table 3.25). Therefore, the estimated number of pinniped individuals potentially exposed to ≥160 dB (rms) using the seismic density estimates was 25,163 (each exposed an average of ~7.2 times; Table 3.29 B), which was 70% more individuals than were estimated using the non-seismic densities (Table 3.29 A). As discussed previously under *Detection Rates of Marine Mammals*, detection rates for pinnipeds in water were higher from vessel group B than from vessel group A during seismic periods (Table 3.20). This suggests that pinnipeds might be showing a very localized avoidance of, or alteration in behavior near, the operating seismic vessel, producing higher density estimates in the 1–15 km range around the operating source vessel (which is the range from the source vessel at which chase vessels typically operated during useable seismic periods).

Summary

During the 2006 season, 10 July – 12 Nov., visual observations took place over 77,420.2 km of trackline, or 7352.6 hours. Between 39 and 49 percent of this visual effort was considered useable for analyses, depending on the species group.

Cetacean sightings, the majority of which were of gray whales, were most numerous during the early season. Most bowhead whales had likely passed through the Chukchi Sea during spring migration prior to the start of the 2006 seismic activities. Bowhead whales sighted during the mid-season may have been late migrating bowheads or bowheads that may have remained in the Chukchi Sea during the summer. Based on summer sightings of bowhead whales, Moore (1992) suggested that summer bowhead use of the Chukchi Sea may be more regular than is commonly believed. Although there were no useable sightings of beluga whales from the vessels, beluga whales were observed during aerial surveys in 2006 (Chapter 5) and were recorded acoustically in the project area (Chapter 6). Most of the vessel-based activities were at locations further offshore than the aerial surveys where beluga whales may have been more dispersed. No cetaceans were observed during the late season.

Cetacean sighting rates were higher during seismic activities than non-seismic periods for both source and chase vessels, although the overall number of sightings was greater during non-seismic periods. This suggested that localized avoidance of seismic activity may have occurred. Comparison of cetacean CPA between seismic and non-seismic periods could not be made due to the low number of sightings during seismic periods.

The most frequently observed pinnipeds were ringed and spotted seals. Sightings of all pinnipeds combined were greatest during the mid-season and the number of sightings did not vary consistently by seismic activity. Pinniped detection rates were generally higher during non-seismic activity during the mid-season, and during seismic activity during the early season. The pinniped CPA was generally smaller during non-seismic than seismic periods for both source and chase vessels. Looking was the most common pinniped behavior observed from source and support vessels. Most pinnipeds did not appear to be moving either toward or away from vessels during seismic activities and most appeared to be moving away from vessels during non-seismic periods. Polar bears were sighted on five occasions throughout the course of the project, and all sightings occurred during non-seismic periods which would be expected since polar bears are generally associated with ice which is avoided by seismic vessels.

It was estimated that 4183 cetaceans were ensonified 4.1 times each to ≥160 dB and 1044 were ensonified 2.8 times each to ≥180dB. It was estimated that 14,836 pinnipeds were ensonified 5.6 times each to ≥160 dB and 1908 were ensonified 2.1 times each to ≥190dB. These estimates assume no avoidance of seismic activities by animals within the area and are very likely higher than the actual numbers of animals that were ensonified to these levels.

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4. DEDICATED VESSEL-BASED MARINE MAMMAL SURVEYS[1]

Introduction

In a joint effort by Shell Offshore, Inc. (SOI), ConocoPhillips Alaska, Inc. (CPAI), and GX Technology (GXT), marine mammal distribution data were collected in the Chukchi Sea during five dedicated vessel transect surveys, three of which also used passive acoustic monitoring (PAM). Surveys began in July and continued into October 2006 on an intermittent basis. The dedicated surveys were intended to provide baseline data to assess the potential impacts of seismic activities in the Chukchi Sea over time. The surveys occurred in the Chukchi Sea MMS OCS Program Area designated as Chukchi Sea Sale 193 (1989). For the purposes of marine mammal data analyses, the study area included the actual survey transects and transit areas within the Chukchi Sea (Fig. 4.1).

The marine mammals known to occur in the Chukchi Sea study area belong to four taxonomic groups: odontocete and mysticete cetaceans (nine species), pinnipeds (five species), and polar bear. Of these, three cetaceans are listed under the U.S. Endangered Species Act (ESA) as endangered: bowhead, humpback, and fin whales. The abundance, habitat, and conservation status of the marine mammal species likely to occur in the study area are summarized in Appendix F of Ireland et al. (2007a,b) and Patterson et al. (2007).

The distribution and abundance of marine mammals in the offshore waters of the Chukchi Sea have not been surveyed extensively, especially in recent years. The bowhead whale population that migrates through the Chukchi Sea in spring and fall has increased during the past 30 years (George et al. 2004; Zeh and Punt 2005), but there is little information on the status of bowhead whales in the Chukchi Sea during the summer months. In addition, there are few current estimates of the numbers of most other marine mammal species in this area, and population estimates generated from earlier surveys may no longer be representative (Bengtson et al. 2005; Rugh 2004; Cooper et al. 2006). Changes in sea temperature and ice-extent in recent years may also have influenced the distribution of many species of marine mammals in the region (Tynan and DeMaster 1997; Johannessen et al. 1999; Ferguson et al. 2001; Stirling and Parkinson 2006; Treacy et al. 2006) and may continue to impact marine mammal distribution in the future.

Objectives

The primary objective of the dedicated vessel-based marine mammal surveys was to collect systematic visual and acoustic data on the distribution and abundance of marine mammals in the Chukchi Sea in areas removed from seismic activity during the 2006 open-water season.

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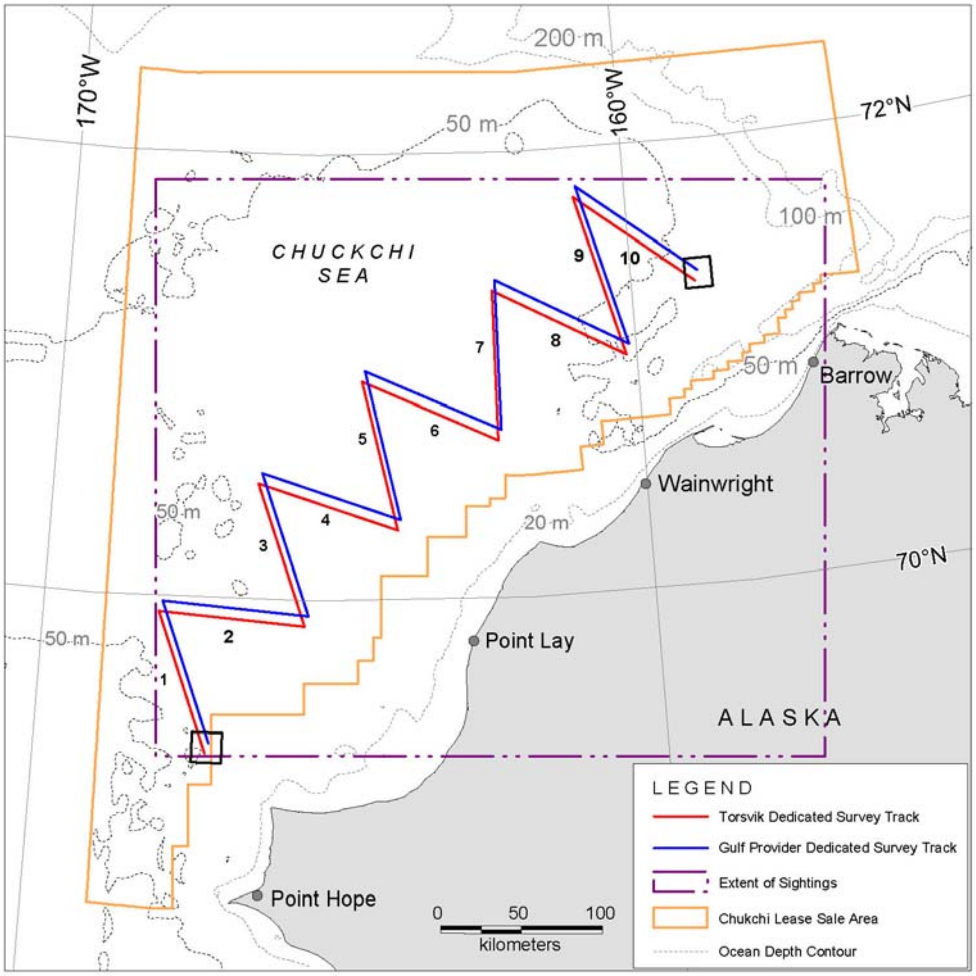

FIGURE 4.1. The proposed routes for dedicated vessel surveys to estimate marine mammal densities in the Chukchi Sea OCS lease sale area. Each proposed route consisted of ten 50 n.mi. transects and was surveyed by the *Torsvik* and *Gulf Provider*. The squares at the southwest and northeast ends of the survey route represent 100 n.mi.^{2} areas within which the start of each survey could be randomly selected.

Methods

Survey Considerations

The Chukchi Sea is a highly variable environment, especially during the spring and fall when the pack ice is changing rapidly in concentration and extent. Marine mammals in the region tend to move northward in spring and early summer along cracks and leads or with receding ice, while in fall, they travel southward ahead of or with the advancing ice edge. Distributions and abundances of marine mammals vary substantially over the course of a year, and often from year to year, due to these migratory movements and changes in the amount of ice at a given location. For example, walrus densities were much higher near the ice-edge margin than in open water or areas with heavy ice during surveys conducted in the Chukchi Sea OCS lease area during late June and early July of 1988-1990 (Brueggeman et al. 1990, 1991, 1992).

The floor of the Chukchi Sea is a relatively broad, shallow, plain, except for the extreme northeast corner where Barrow Canyon and several smaller features connect to the Canada Basin.

The relative homogeneity of the seafloor allows for survey transects to cover a wide geographical area but remain in a similar habitat type. However, variability in habitat may result from currents that move through the Chukchi Sea and from inter- and intra-year variability in ice conditions.

Survey Design and Procedures

Two support vessels, the *Torsvik* and *Gulf Provider*, were used to conduct five dedicated marine mammal surveys in the Chukchi Sea during 2006. During the dedicated surveys, the *Torsvik* and the *Gulf Provider* generally operated at distances far enough from seismic vessels where it was assumed that seismic surveys would not appreciably affect marine mammal distribution and behavior. Occasionally, a dedicated survey vessel was located near a seismic vessel, and during these periods, marine mammal sighting and effort data were not considered "useable" (see discussion in *Analysis of Survey Data* below).

Each vessel followed a systematic survey route composed of ten 50 n.mi. transects forming a sawtooth pattern during each of five dedicated marine mammal surveys, weather and ice permitting (Fig. 4.1). The start location of each survey was randomly selected within a designated 100 n.mi.^{2} area at either the southwest or northeast end of the survey route; the entire survey shifted based on the start location. Average survey speed was ~7-10 kt. On the *Torsvik*, where PAM was in use during the surveys, vessel speed was reduced to ~3 kt for 5-min periods every half hour to reduce engine and flow noise to increase the potential for detecting marine mammal vocalizations. The survey route was designed to cover a large portion of the OCS Chukchi Sea lease sale area while remaining in waters of similar depth. The repeated surveys over nearly the same route were designed to detect differences in detection rates and densities of marine mammals during summer and fall.

Three surveys were originally scheduled from July through October 2006 from the *Torsvik*. Due to the presence of ice, portions of some surveys could not be completed and, consequently, two additional surveys were conducted during the field season using the *Gulf Provider*. The location of the ice edge had a significant influence on what portion of the survey route could be completed, and all ten transect lines were completed for only one of the dedicated surveys. When the presence of the ice pack precluded following pre-planned transect lines, the survey vessel followed the edge of the ice pack, as near to the survey route as possible.

The *Torsvik* (Fig. 4.2) was used as the platform for the dedicated marine mammal surveys conducted on 15-17 July, 5-10 Sept., and 18-23 Oct. 2006. Marine mammal observations were conducted from the bridge of the *Torsvik*, ~7.7 m eye-height above the mean water line. Acoustic data were systematically acquired and monitored from the *Torsvik* during these surveys using a towed hydrophone PAM system. This system was monitored in real time by an acoustician, and continuous recordings were made during all on-effort periods. The information collected from the PAM system was intended to supplement the visual data, potentially providing data at distances beyond visual range, and providing a method to monitor marine mammals when conditions for visual surveys were poor, e.g., during high sea-state, low light, rain, or other similar conditions.

The *Gulf Provider* (Fig. 4.3) was used as the platform for the dedicated marine mammal surveys on 28-31 Aug., and on 30 Sept.-3 Oct. 2006. The *Gulf Provider* was the primary supply vessel for transfer of personnel, equipment, and supplies to the seismic vessels *Western Patriot* and *Gilavar*. The *Gulf Provider* also occasionally served as the *Western Patriot's* chase boat.

Marine mammal observations were conducted from the bridge of the *Gulf Provider*, ~9.0 m eye-height above the mean water line. No PAM data were collected from the *Gulf Provider*.

FIGURE 4.2. M/V *Torsvik*.

FIGURE 4.3. M/V *Gulf Provider*.

Visual Vessel-Based Monitoring

Visual monitoring methods similar to those used on research vessels (Barlow 1995) and, insofar as practicable, to NMFS protocols for vessel-based surveys (see Chapter 3; Ireland et al. 2007a,b; Patterson et al. 2007). Visual observers rotated among observation stations (port, center, and starboard) for ~3-hr shifts using the naked eye and 7×50 binoculars equipped with reticles to systematically search for marine mammals from the bridge of the survey vessels. Two observers were positioned at the port and starboard sides of the bridge, respectively, and scanned the area directly in front of and to 90° on either side of the vessel. The third observer recorded data and scanned the area nearer to the vessel with the naked eye or 7× magnification binoculars, if needed. When a sighting occurred, all observers were made aware of the animal(s) and assisted in species identification if necessary. MMOs recorded time, vessel longitude and latitude, environmental factors including Beaufort wind force, visibility, and glare, as well as various behavioral and location data for each sighting. In addition, the presence of any other vessels or potential sources of disturbance was recorded.

During the dedicated surveys, three visual observers were on duty for 89.3% and two observers for 9.5% of the watch time. The remainder of the combined watch time on both vessels (1.2%) involved a single observer during "in transit" periods when the vessel was underway toward the start of the designated transect. Surveying ranged from a maximum of 17 h 28 min to a minimum of 9 h per day as daylight periods shortened. Observers were on watch up to ~5.5 h (average ~2.7 h) without a break to a maximum of ~10 h per day.

Survey Data Analysis

Detection rates and, where possible, densities of marine mammals in the survey area were estimated collectively among the five dedicated surveys. Effort and visual sightings were defined as useable when observations were made during daylight periods within the survey area. Useable effort and visual sightings excluded periods with the following conditions:

- poor visibility (<3.5 km or extensive glare in the forward direction)
- Beaufort wind force >5 (Bf >2 for porpoises, minke and beluga whales)
- ship speed <3.7 km/h (2 kt)
- periods when vessel speed between two consecutive data records varied by >3.7 km/h (2 kt)
- periods during which other vessels were sighted within 1 km (pinnipeds) or 5 km (cetaceans) of the survey vessel were also excluded

The specific distances of the dedicated survey vessels from active seismic vessels were calculated from post-season comparison of vessel track logs. Survey data were categorized as seismic if the survey vessel was within 15 km of a source vessel while the airguns were firing (e.g., during ramp up, mitigation power-down, and seismic line shooting). The break at 15 km was a conservative distance that was slightly greater than the largest 160 dB disturbance radius (~11.5 km; Fig. 3.1). Survey data were categorized as post-seismic if the survey vessel was within 15 km from a source vessel 3 min to 1 h (for pinnipeds) or 2 h (for cetaceans) after the airguns were turned off. Seismic and post-seismic data were not used for analyses. Effort and visual sightings were considered duplicated, and were excluded from analysis, if the survey vessel came within 1.2 km (2/greatest $f(0)$) of its own track in a 4 h period. Data were also considered "non-useable" if greater than 45 min elapsed between sequential MMO records. Pinnipeds hauled out on the ice were considered "useable" for analyses.

Data Categorization—Observer effort and marine mammal sightings were divided into analysis categories similar to those used during other recent seismic studies conducted under IHAs (e.g., Haley and Koski 2004; MacLean and Koski 2005; Smultea et al. 2005; Holst et al. 2005a,b; Ireland et al. 2005; Chapter 3). All data collected from the survey vessels were categorized as in transit, on transect, off transect, or alternate transect. "In transit" included all data collected from the survey vessel while traveling to the first waypoint of each survey. The "on transect" category included data collected when the survey vessel was on the designated transect lines. Temporary deviations from the designated transects when ice was encountered were categorized as "off transect." Data classified as "alternate transect" were collected when the survey vessel was unable to maintain course along the transect lines due to ice. During such periods the survey vessel followed the pack-ice edge as close to the designated transect lines as possible. Data were categorized as "nearshore" if the vessel was within 25 km of shore, or "offshore" if the vessel was farther than 25 km from shore when data were collected.

The location of the pack-ice margin, a factor known to affect the distribution of marine mammals, varied among the surveys. Distance of the survey vessels to the ice edge was estimated using U.S. National Ice Service Maps from the National Snow and Ice Data Center (NSIDC; www.natice.noaa.gov). Data were further partitioned based on season, as the distribution of marine mammals over the season was anticipated to be influenced by ice formation. Early, mid-, and late cetacean and pinniped seasons were the same as those described in Chapter 3.

Line Transect Estimation of Densities—Useable marine mammal sightings during in transit, on transect, off transect, and alternate transect periods were used to calculate detection rates (# sightings/ km). Detection rates were then used to estimate the corresponding densities (# animals/1000 km^2) of marine mammals along the survey routes. Density estimates were based on line-transect principles (Buckland et al. 2001) and were calculated as described in Chapter 3. Because of assumptions associated with line-transect surveys [sightability, $f(0)$, $g(0)$, etc.], only useable effort and sightings were included in density calculations. Density estimates were also only calculated for 3-person monitoring periods where $f(0)$ values met the shape criterion for model robustness ($n \geq 20$) and useable effort was >500 km. This included “on transect” and “alternate transect” observations during some seasons. Surveys conducted in the early pinniped season had too few sightings to calculate correction factors and therefore densities. Estimates of cetacean densities in the Chukchi Sea study area could not be calculated when subdivided by species, season, or transect type due to insufficient effort or sighting sample size.

When estimating densities, $f(0)$ was calculated independently for “on transect” and “alternate transect” periods of each season. Correction factors for missed animals, $f(0)$ and $g(0)$, during 3-person offshore monitoring were calculated for pinnipeds sighted “on transect” in the mid- and late pinniped seasons (see *Categorization of Data* in Chapter 3). Pinniped $f(0)$ values were also calculated across all transect types and seasons. Pinniped $f(0)$ values were also calculated across all transect types and seasons. Pinnipeds hauled out on ice were considered useable for analyses and assigned a $f(0)$ value of 1.000 (as done in Haley 2006).

Passive Acoustic Monitoring (PAM)

The PAM system was operated by a team of two experienced bio-acousticians during the dedicated surveys from the *Torsvik* on 10-16 July, 5-10 Sept., and 17-22 Oct. 2006. The main roles of the acoustics team were to deploy the towed array, operate the acoustics processing system, and monitor sounds from the towed array visually and aurally during survey effort. PAM operations were typically conducted during daylight periods when visual monitoring was conducted by MMOs to correlate observations with sound detection. During the last survey, some PAM was conducted after dark when visual monitoring could not be conducted. Limitations of PAM include its inability to detect presence of non-calling whales, and it is likely limited to detection distances of 1-2 km.

Real-time monitoring occurred throughout the “on effort” periods during the three surveys when PAM was applied. However, low-frequency (<1 kHz) ship noise and water flow noise can be excessive at the speeds at which the surveys were conducted. Therefore, a “listening station” protocol was used to allow the bio-acousticians to monitor the array under lower noise conditions than would be possible at typical survey speeds. Listening station protocols were conducted every ~30 min, at the top and bottom of every hour. Before each listening station was initiated, the ship was slowed to ~2-3 kt. The array was monitored for a period of 5 min, after which the ship resumed survey speed.

Towed Array System—The towed array system consisted of a 2-element hydrophone array. The 2-element array rather than a larger array was used due to the short amount of time available prior to the field season for fabrication of the recording equipment. The hydrophone elements were spaced ~3 m apart with ~500 m of lead-in cable. Both elements had an effective (i.e., flat +/- 5 dB) frequency response from ~100 Hz to 45 kHz capable of detecting most marine mammals in the area. Approximately 4 lbs of lead weight was attached ~180 m from the end of the array to sink it to a suitable depth during towing. The monitoring station was located in the aft section of the wheelhouse so the array cable could be visually monitored and to allow for quick access for retrieval.

Signal Processing and Recording Systems**—**Two channels of analog acoustic data from the hydrophone array were sent to a PC digital audio interface (MOTU Traveler). This digitized both channels of hydrophone signals and sent them to a desktop computer via a fire-wire cable. A low-pass filter system (Alligator Technologies, AAF-1), which was intended to be used for anti-aliasing prior to digitization, was not functioning properly. Instead, data were over-sampled at 192 kHz (~4x the effective frequency range), thereby eliminating concern about aliasing.

A desktop PC computer was dedicated to running ISHMAEL sound localization and digital recording software (developed by D. Mellinger, OSU-NOAA/PMEL, Newport, OR). A second (laptop) computer was dedicated to running Whaletrack II geographic plotting and data-logging software (developed by G. Gailey, TAMUG, TX). These two computers were connected via an ethernet network used to pass information, such as bearings, from the ISHMAEL to the Whaletrack II computer (Fig. 4.4).

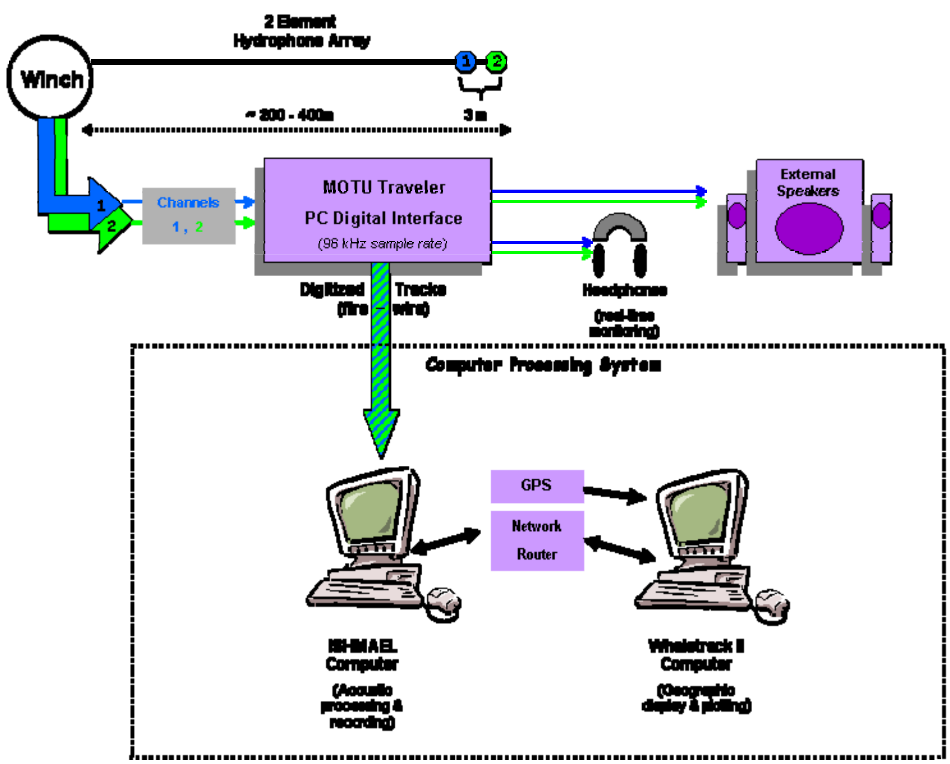

FIGURE 4.4. Schematic of passive acoustic monitoring (PAM) system.

ISHMAEL was used to process, record, and estimate acoustic data bearings. Both channels were recorded whenever on effort. Recordings were made continuously with 10-min recording periods. The times and dates of each file were saved in the filename. ISHMAEL software is designed to calculate the bearing to a signal (e.g., a whale call) that is manually selected by an operator who "windows" it with a mouse. All bearings are estimated relative to the ship's bearing and location. If the operator chooses, the bearing and other relevant information are then passed to Whaletrack II via the ethernet connection.

Whaletrack II was used to plot bearings and/or animal call location estimates passed from ISHMAEL. Whaletrack II also acquired and plotted ship position via a serial GPS connection. Ship track history, current heading and speed, and an estimated position of the array were calculated and stored in an MS Access database created by Whaletrack II. Information about effort, acoustic contacts, settings of acoustic equipment (e.g., gain and filter cutoffs), and general comments were also entered into Whaletrack II by the operator.

Bearings plotted in Whaletrack II can be used to estimate an animal's location, with or without a left-right ambiguity, using a "sequential-bearing fix" technique. This technique involves sequentially plotting several bearings to the acoustic source while steadily moving past it (Fig. 4.5). The location of the animal(s) can be estimated visually by the computer operator by subjectively assessing the point where the bearing lines intersect. If the PAM vessel remains on a straight course, there is a left-right ambiguity in determining the point of intersection. This ambiguity can be resolved if the PAM vessel can temporarily change course (Fig. 4.5).

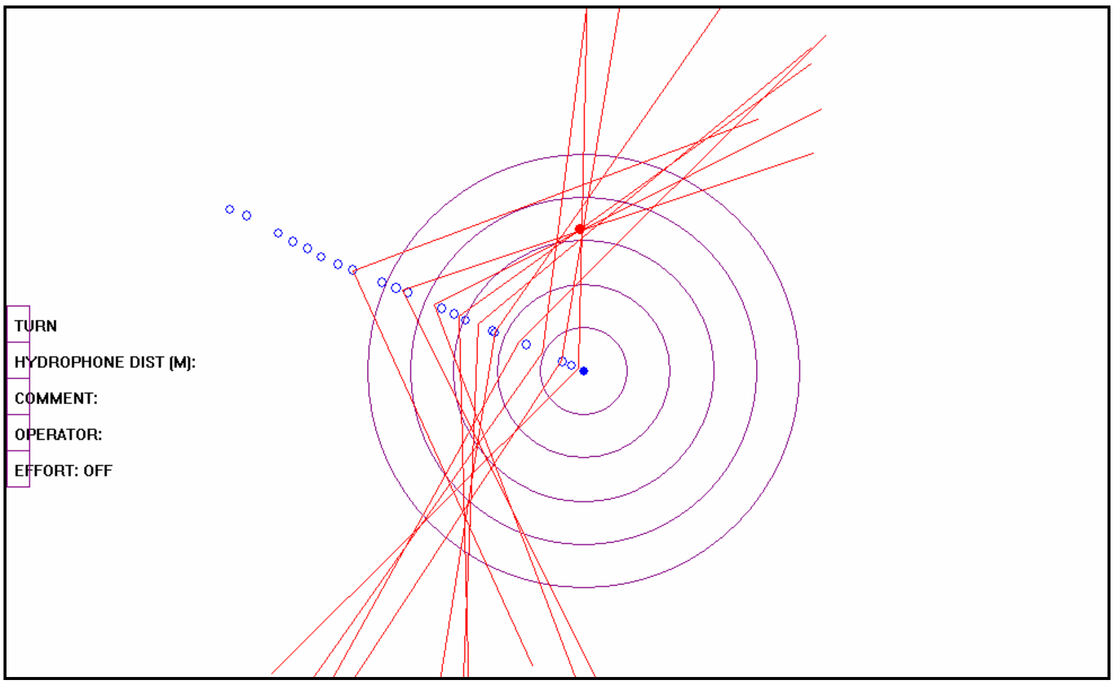

FIGURE 4.5. Example of sound localization using sequential bearings. The vessel (sequence of blue dots) is moving along a transect line from left to right, with associated bearings (red lines) to acoustic signals (e.g., whale calls) as the vessel maintains course. The location where bearings are estimated (by the operator) to converge is the location of the sound source (red dots). Note the left/right ambiguity evident here can be resolved by turning the vessel 20-30º to either side to determine the side on which the bearings converge.

Array Deployment Procedure—The hydrophone array was deployed at the beginning of each survey day and was retrieved at the end of the day's effort. The array was retrieved early only during periods of severe weather conditions (usually winds >30 kt and/or seas >10 ft) or dense sea-ice conditions. The hydrophones were towed 200-300 m behind the vessel, depending on water depths, ice conditions, and other constraints.

Results

Observers collected data on the occurrence, distribution, and abundance of marine mammals in the Chukchi Sea, an area where few systematic survey data had been collected in recent years. In total, 2944 km and 171 h of visual observations were conducted within the Chukchi Sea lease sale area. Due to ice the remaining 779 km and 39 hr of visual effort occurred outside of the lease sale area.

Visual Survey Effort

MMOs observed exclusively from the bridge aboard the *Torsvik* and *Gulf Provider*. During dedicated visual surveys within the Chukchi Sea study area, there were 3723 km of visual observation effort over 210 h; of that, 2747 km of effort over 154 h were classified as useable (Table 4.1; Fig. 4.6). Three observers were on visual watch aboard the dedicated survey vessels during 187 h (3309 km), with two observers on watch for 20 h (306 km), and one observer on watch during the remaining time. The majority of effort was "on transect" (2090 km, 127 h), followed by "alternate transect" effort (1071 km, 58 h), with the remaining effort roughly evenly distributed between "in transit" (295 km, 10 h) and "off transect" (265 km, 14 h) periods (Fig. 4.6). Non-seismic periods made up 98.3% of total effort, with the remaining post-seismic and seismic periods classified as non-useable.

Reduced visibility due to fog (visibility <3.5 km) was the most common reason that sightings and effort were considered non-useable (60.1% of non-useable data), followed by high Beaufort wind force (Bf >5, 13.1% of non-useable data). During non-useable periods, the detection rate was about 3/8 that for useable periods (excluding cryptic cetaceans; Table 4.2). The proportionately lower detection rates during non-useable periods relative to useable periods was similar to that of other 2006 Chukchi Sea monitoring tasks (see Chapter 3).

Visual Sightings of Marine Mammals

Details on all marine mammal sightings during the dedicated surveys within the Chukchi Sea study area are provided in Appendix C. An estimated 564 individual marine mammals were recorded in 432 groups in the Chukchi Sea study area (Table 4.3). Nine marine mammal species were identified, with ringed seal being the most frequently identified species, followed by bearded and spotted seals (Table 4.3). Ringed seals comprised 46% of the seals identified to species, although many seal sightings were recorded as unidentified. Twenty sightings of 30 individual Pacific walruses were recorded, including one group of two individuals on ice (Table 4.3). No polar bears were observed during the monitoring effort despite 28.8% (in km) of all survey tracks occurring during alternate transect periods located near the ice edge. Numbers of cetaceans recorded during dedicated surveys were far less than numbers of pinnipeds. Gray whale was the most abundant species of cetacean, followed by beluga whale (Table 4.3). Bowhead whales and unidentified whales were seen on multiple occasions, and there was one sighting of a minke whale.

No deaths or injuries of animals were observed during the dedicated surveys. One carcass of an unidentified pinniped was sighted and was included as non-useable in the summary of marine mammal sightings. The carcass was approached at close range by the survey vessel *Torsvik*, observed in detail, and documented as having signs of advanced decomposition (i.e., a gray underside).

TABLE 4.1. Survey effort in hours and kilometers for marine mammal groups during dedicated vessel-based surveys in the Chukchi Sea, 2006.

	Survey 1 15-17 July Torsvik		Survey 2 28-31 Aug. Gulf Provider		Survey 3 5-10 Sept. Torsvik		Survey 4 30 Sept.-3 Oct. Gulf Provider		Survey 5 18-23 Oct. Torsvik		*Total Effort*	
	Effort (h)	**Effort (km)**	**Effort (h)**	**Effort (km)**	**Effort (h)**	**Effort (km)**	**Effort (h)**	**Effort (km)**	**Effort (h)**	**Effort (km)**	**Effort (h)**	**Effort (km)**
Useable[a]												
Cetaceans	13.13	200.24	33.15	775.40	45.35	671.45	27.58	547.38	34.46	552.63	***153.67***	***2747.09***
Cryptic Cetaceans	2.74	42.64	12.91	364.93	13.30	182.41	17.30	315.87	8.51	137.08	***54.77***	***1042.93***
Pinnipeds	13.13	200.24	33.15	775.40	45.35	671.45	27.58	547.38	34.46	552.63	***153.67***	***2747.09***
Pacific Walruses	13.13	200.24	33.15	775.40	45.35	671.45	27.58	547.38	34.46	552.63	***153.67***	***2747.09***
Ursids	13.13	200.24	33.15	775.40	45.35	671.45	27.58	547.38	34.46	552.63	***153.67***	***2747.09***
Non-useable[b]												
Cetaceans	5.22	80.41	7.94	203.57	20.33	281.97	9.61	197.41	13.22	212.28	***56.33***	***975.64***
Cryptic Cetaceans	15.61	238.01	28.18	614.04	52.38	771.01	19.89	428.91	39.18	627.83	***155.23***	***2679.80***
Pinnipeds	5.22	80.41	7.94	203.57	20.33	281.97	9.61	197.41	13.22	212.28	***56.33***	***975.64***
Pacific Walruses	5.22	80.41	7.94	203.57	20.33	281.97	9.61	197.41	13.22	212.28	***56.33***	***975.64***
Ursids	5.22	80.41	7.94	203.57	20.33	281.97	9.61	197.41	13.22	212.28	***56.33***	***975.64***
Totals												
All Groups	18.35	280.64	41.09	978.97	65.68	953.42	37.19	744.78	47.69	764.91	**210.00**	**3722.73**

[a] Useable sightings were those made during useable daylight periods of visual observation, as defined in *Survey Data Analysis.*.
[b] Non-useable sightings were classified according to the criteria described in *Analysis of Survey Data Analysis*.

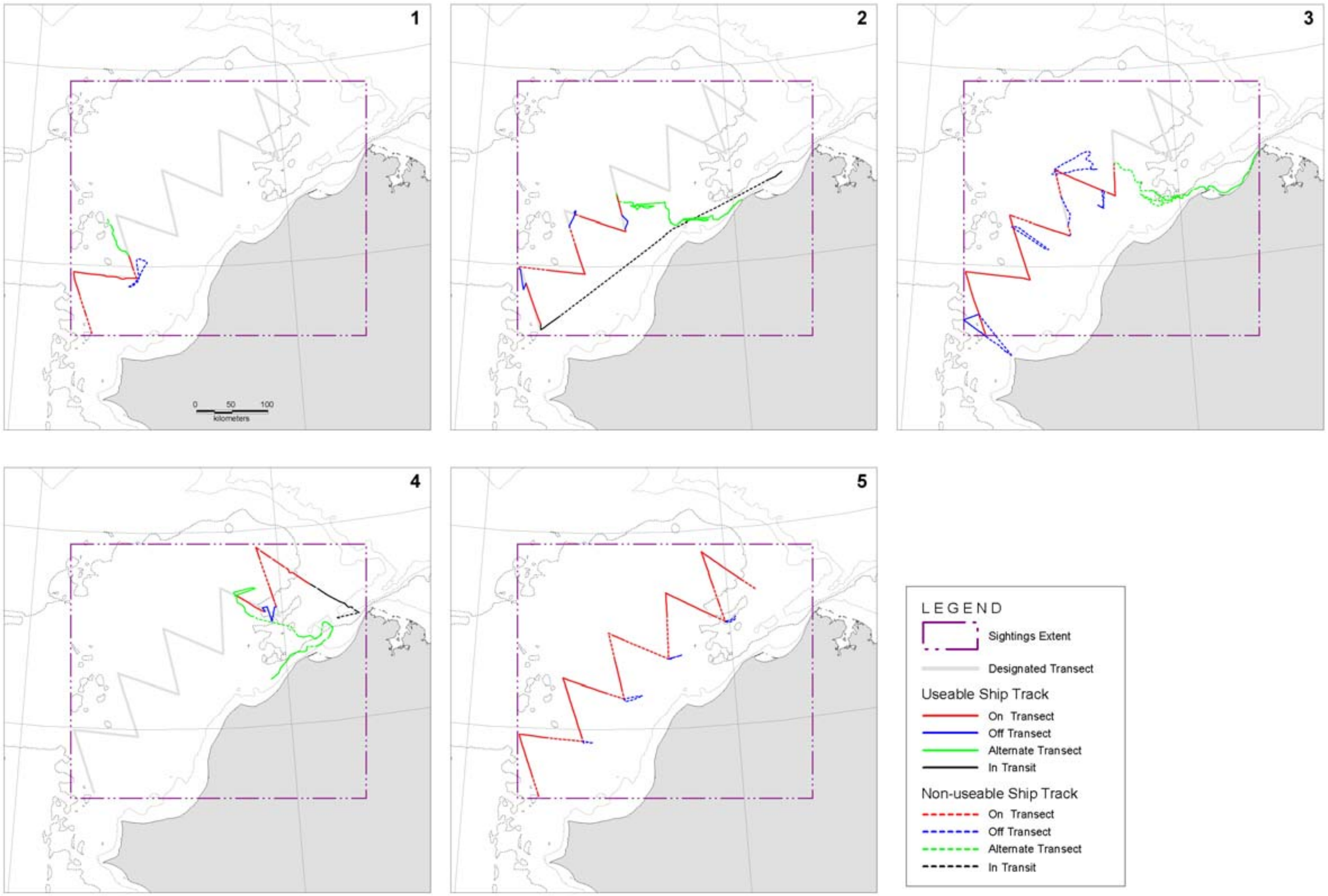

FIGURE 4.6. Survey tracks during each dedicated survey in the Chukchi Sea: (1) 15-17 July, (2) 28-31 Aug., (3) 5-10 Sept., (4) 30 Sept.-3 Oct., and (5) 18-23 Oct. Survey periods and data useability are categorized as identified in the legend.

TABLE 4.2. Number of detections and detection rate (sightings/1000 km of effort) for marine mammal groups during vessel-based surveys in the Chukchi Sea, 2006.

	Survey 1		Survey 2		Survey 3		Survey 4		Survey 5		*Totals*	
	No. Det.	Det. Rate	No. Det.	Det. Rate	No. Det.	Det. Rate	No. Det.	Det. Rate	No. Det.	Det. Rate	No. Det.	Det. Rate
Useable [a]												
Cetaceans	1	4.99	2	2.58	6	8.94	1	1.83	2	3.62	***12***	***4.37***
Cryptic Cetaceans	0	0.00	0	0.00	2	10.96	0	0.00	1	7.29	***3***	***2.88***
Pinnipeds in Water	1	4.99	103	132.83	156	232.33	54	98.65	54	97.72	***368***	***133.96***
Pacific Walrus	0	0.00	5	6.45	0	0.00	7	12.79	1	1.81	***13***	***4.73***
Pinnipeds on Ice	1	4.99	0	0.00	0	0.00	0	0.00	0	0.00	***1***	***0.36***
Pacific Walrus	1	4.99	0	0.00	0	0.00	0	0.00	0	0.00	***1***	***0.36***
Total all Pinnipeds	*2*	*9.99*	*103*	*132.83*	*156*	*232.33*	*54*	*98.65*	*54*	*97.72*	**369**	**134.32**
Total Unidentified Pinnipeds	*0*	*0.00*	*1*	*1.29*	*0*	*0.00*	*3*	*5.48*	*0*	*0.00*	**4**	**1.46**
Total all Pacific Walrus	*1*	*4.99*	*5*	*6.45*	*0*	*0.00*	*7*	*12.79*	*1*	*1.81*	**14**	**5.10**
Total Seals	*1*	*4.99*	*97*	*125.10*	*156*	*232.33*	*44*	*80.38*	*53*	*95.91*	**351**	**127.77**
Non-useable [b]												
Cetaceans	0	0.00	2	9.82	2	7.09	0	0.00	1	4.71	***5***	***5.12***
Cryptic Cetaceans	0	0.00	1	1.63	0	0.00	0	0.00	1	1.59	***2***	***0.75***
Pinnipeds in Water	4	49.75	3	14.74	22	78.02	7	35.46	10	47.11	***46***	***47.15***
Pacific Walrus	1	12.44	1	4.91	0	0.00	3	15.20	1	4.71	***6***	***6.15***
Pinnipeds on Ice	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	***0***	***0.00***
Pacific Walrus	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	***0***	***0.00***
Total all Pinnipeds	*4*	*49.75*	*3*	*14.74*	*22*	*78.02*	*7*	*35.46*	*10*	*47.11*	**46**	**47.15**
Total Unidentified Pinnipeds	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*0*	*0.00*	*1*	*4.71*	**1**	**1.02**
Total all Pacific Walrus	*1*	*12.44*	*1*	*4.91*	*0*	*0.00*	*3*	*15.20*	*1*	*4.71*	**6**	**6.15**
Total Seals	*3*	*37.31*	*2*	*9.82*	*22*	*78.02*	*4*	*20.26*	*8*	*37.69*	**39**	**39.97**
Totals												
Cetaceans	*1*	*3.56*	*4*	*4.09*	*8*	*8.39*	*1*	*1.34*	*3*	*3.92*	**17**	**4.57**
Cryptic Cetaceans	*0*	*0.00*	*1*	*1.02*	*2*	*2.10*	*0*	*0.00*	*2*	*2.61*	**5**	**1.34**
Total all Pinnipeds	*6*	*21.38*	*106*	*108.28*	*178*	*186.70*	*61*	*81.90*	*64*	*83.67*	**415**	**111.48**
Total Unidentified Pinnipeds	*0*	*0.00*	*1*	*1.02*	*0*	*0.00*	*3*	*4.03*	*1*	*1.31*	**5**	**1.34**
Total all Pacific Walrus	*2*	*7.13*	*6*	*6.13*	*0*	*0.00*	*10*	*13.43*	*2*	*2.61*	**20**	**5.37**
Total Seals	*4*	*14.25*	*99*	*101.13*	*178*	*186.70*	*48*	*64.45*	*61*	*79.75*	**390**	**104.76**

[a] Useable sightings were those made during useable daylight periods of visual observation, as defined in *Survey Data Analysis*.
[b] Non-useable sightings were classified according to the criteria described in *Survey Data Analysis*.

TABLE 4.3. Number of detections (or groups) and number of individual marine mammals, including (A) all sightings and (B) only useable data, recorded during dedicated vessel-based surveys in the Chukchi Sea, 2006.

	Survey 1		Survey 2		Survey 3		Survey 4		Survey 5		*All*	
	Det.	Indiv.	Det.	Indiv.	Det.	Indiv.	Det.	Indiv.	Det.	Indiv.	Det.	Indiv.
A. All Sightings												
Cetaceans												
Unidentified Whale	0	0	1	1	3	5	0	0	0	0	***4***	***6***
Beluga Whale	0	0	1	30	0	0	0	0	0	0	***1***	***30***
Harbor Porpoise	0	0	0	0	1	3	0	0	2	5	***3***	***8***
Bowhead Whale	0	0	1	5	0	0	0	0	1	1	***2***	***6***
Gray Whale	1	2	1	30	3	5	1	1	0	0	***6***	***38***
Minke Whale	0	0	0	0	1	1	0	0	0	0	***1***	***1***
Total Cetaceans	***1***	***2***	***4***	***66***	***8***	***14***	***1***	***1***	***3***	***6***	**17**	**89**
Pinnipeds in Water												
Unidentified Pinniped	0	0	1	1	0	0	3	3	1	1	***5***	***5***
Pacific Walrus	1	1	6	7	0	0	10	18	2	2	***19***	***28***
Bearded Seal	0	0	17	18	17	17	6	6	9	9	***49***	***50***
Ringed Seal	0	0	0	0	37	47	0	0	25	26	***62***	***73***
Spotted Seal	1	1	12	14	1	1	14	16	2	2	***30***	***34***
Unidentified Seal	3	3	70	88	123	132	28	35	25	25	***249***	***283***
Pinnipeds on Ice												
Pacific Walrus	1	2	0	0	0	0	0	0	0	0	***1***	***2***
Total all Pinnipeds	***6***	***7***	***106***	***128***	***178***	***197***	***61***	***78***	***64***	***65***	**415**	**475**
Total Unidentified Pinnipeds	*0*	*0*	*1*	*1*	*0*	*0*	*3*	*3*	*1*	*1*	**5**	**5**
Total all Pacific Walrus	*2*	*3*	*6*	*7*	*0*	*0*	*10*	*18*	*2*	*2*	**20**	**30**
Total Seals	*4*	*4*	*99*	*120*	*178*	*197*	*48*	*57*	*61*	*62*	**390**	**440**
B. Useable[a] Sightings												
Cetaceans												
Unidentified Whale	0	0	0	0	1	2	0	0	0	0	***1***	***2***
Beluga Whale	0	0	0	0	0	0	0	0	0	0	***0***	***0***
Harbor Porpoise	0	0	0	0	1	3	0	0	1	2	***2***	***5***
Bowhead Whale	0	0	1	5	0	0	0	0	1	1	***2***	***6***
Gray Whale	1	2	1	30	3	5	1	1	0	0	***6***	***38***
Minke Whale	0	0	0	0	1	1	0	0	0	0	***1***	***1***
Total Cetaceans	***1***	***2***	***2***	***35***	***6***	***11***	***1***	***1***	***2***	***3***	**12**	**52**
Pinnipeds in Water												
Unidentified Pinniped	0	0	1	1	0	0	3	3	0	0	***4***	***4***
Pacific Walrus	0	0	5	6	0	0	7	12	1	1	***13***	***19***
Bearded Seal	0	0	17	18	13	13	6	6	8	8	***44***	***45***
Ringed Seal	0	0	0	0	30	39	0	0	21	22	***51***	***61***
Spotted Seal	0	0	11	11	1	1	11	13	2	2	***25***	***27***
Unidentified Seal	1	1	69	86	112	121	27	34	22	22	***231***	***264***
Pinnipeds on Ice												
Pacific Walrus	1	2	0	0	0	0	0	0	0	0	***1***	***2***
Total all Pinnipeds	***2***	***3***	***103***	***122***	***156***	***174***	***54***	***68***	***54***	***55***	**369**	**422**
Total Unidentified Pinnipeds	*0*	*0*	*1*	*1*	*0*	*0*	*3*	*3*	*0*	*0*	**4**	**4**
Total all Pacific Walrus	*1*	*2*	*5*	*6*	*0*	*0*	*7*	*12*	*1*	*1*	**14**	**21**
Total Seals	*1*	*1*	*97*	*115*	*156*	*174*	*44*	*53*	*53*	*54*	**351**	**397**

Detection rates—When considering all surveys, the detection rate for cetaceans during offshore periods was ~1/10 that during nearshore monitoring periods (Table 4.4). Cetacean detection rates were highest during "in transit" and "alternate transect" periods, and lower during "off transect" and "on transect" periods. These results were skewed by a large number of sightings made from the *Gulf Provider* on 28 Aug. when the vessel was "in transit" along the coast toward the beginning of the designated survey transects. If these sightings are not considered, the detection rate was greater during "alternate transect" periods, when the vessel was near ice, than "in transit" periods. The detection rate decreased between early and mid-cetacean seasons for mysticetes and for all cetacean species pooled (Table 4.4).

As with cetaceans, detection rates for pinnipeds were also greater in nearshore compared to offshore areas (Table 4.4). Pinniped detection rates were much greater during alternate transects than other transect types. Detections of Pacific walruses in water were most frequent during "alternate transect" periods, which were generally conducted closer to ice. Unlike detection rates for cetaceans, pinniped detection rates increased from the early to mid-seasons although detection rates decreased from mid- to late pinniped seasons (Table 4.4).

TABLE 4.4. Detection rates (sightings/1000 km) calculated using all and useable observation effort, subdivided for all cetaceans and pinnipeds by distance from shore, season, and transect type during dedicated vessel-based surveys in the Chukchi Sea, 2006.

	Cetacean Detection Rate		Pinniped Detection Rate	
	All Effort	Useable Effort	All Effort	Useable Effort
Nearshore	22.54	18.83	521.22	555.42
Offshore	2.67	2.47	68.29	79.06
In transit	10.16	15.02	40.65	75.11
On transect	1.91	1.32	48.32	54.81
Off transect	0.00	0.00	33.90	23.12
Alternate transect	9.33	9.06	273.35	306.78
Early season	5.89	5.48	21.38	9.99
Mid-season	2.64	2.71	128.87	156.95
Late season	N/A	N/A	83.67	97.72

Other Vessels—There were few vessels near the *Torsvik* or *Gulf Provider* during the 2006 dedicated survey periods. Most vessels were >5 km, including two non-seismic vessels sighted at ~10 km from the survey vessels. No marine mammals were sighted while another vessel was <5 km from the survey vessel, and therefore no obvious reactions by marine mammals to other vessels were observed.

Marine Mammal Distribution

Ice conditions during much of the 2006 field season consisted of a band of pack ice (>10% ice cover) from the shore out to ~20 to 40 km between Barrow and Wainwright. Ice lingered and remained closer to shore in 2006 than in recent years. West and south of this band of ice the waters were open with no ice cover. The majority of all marine mammal sightings occurred in the northern latitudes of the areas surveyed (Fig. 4.7).

Two bowhead whale sightings were recorded, with one sighting of five bowhead whales on 28 Aug., and one sighting of a single whale on 18 Oct. Other cetacean sightings were distributed with respect to season, survey period, and proximity to ice and shore. The only beluga whale sighting was a group of 30 individuals seen "in transit" between the 20-50 m depth contour with no ice cover on 28 Aug. (Fig. 4.7). Gray whales were seen on five occasions while the vessel surveyed in close proximity to ice during "alternate transect" periods.

Heavy ice conditions precluded access to most of the study area during the first survey, and few pinnipeds were observed (Table 4.3; Fig. 4.7a), though some pinnipeds were observed relatively close to the ice near the southwestern edge of the survey area (Fig. 4.7a).

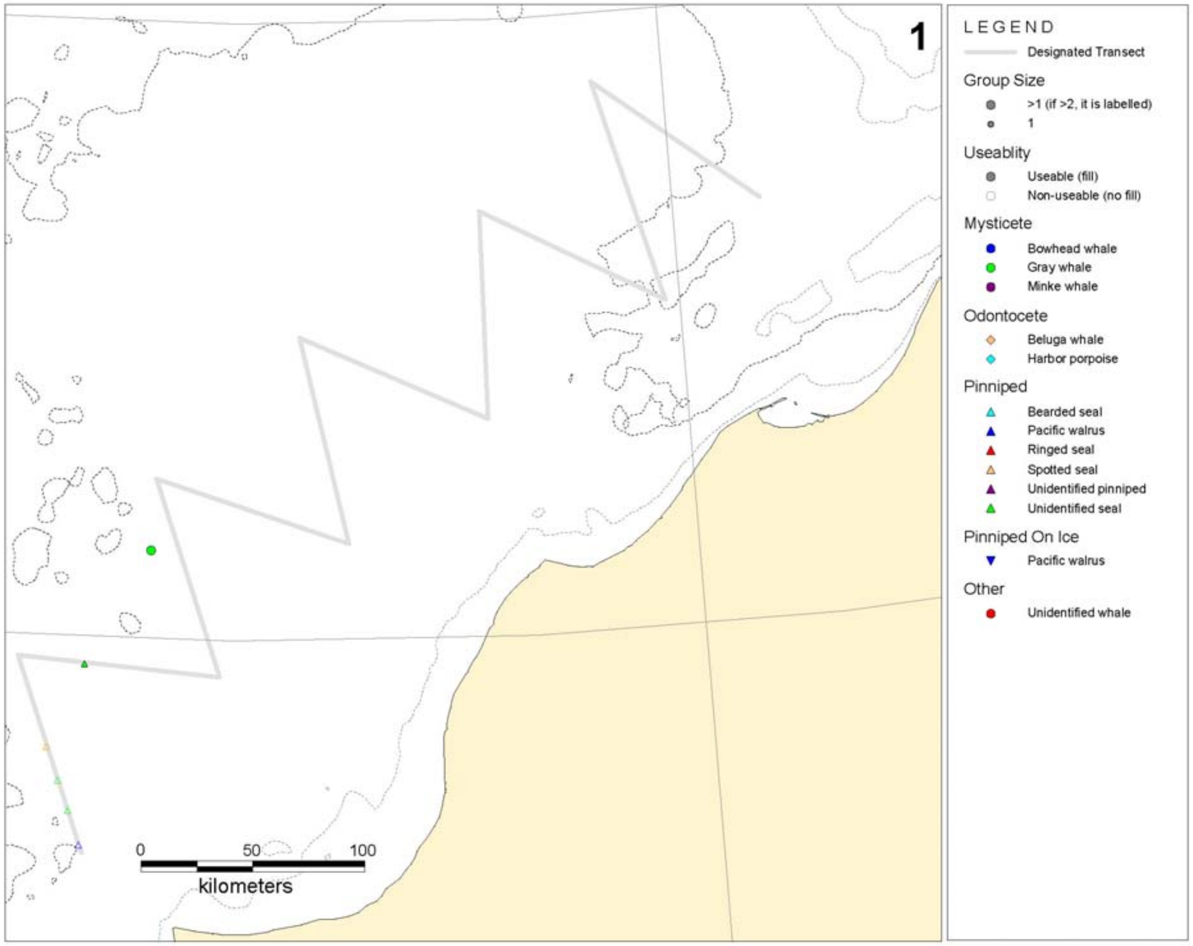

FIGURE 4.7a. All sightings during the first dedicated survey on 15-17 July from the *Torsvik*. Species, group size, and useability of sightings are labeled according to the legend. Maps are scaled according to Figure 4.1.

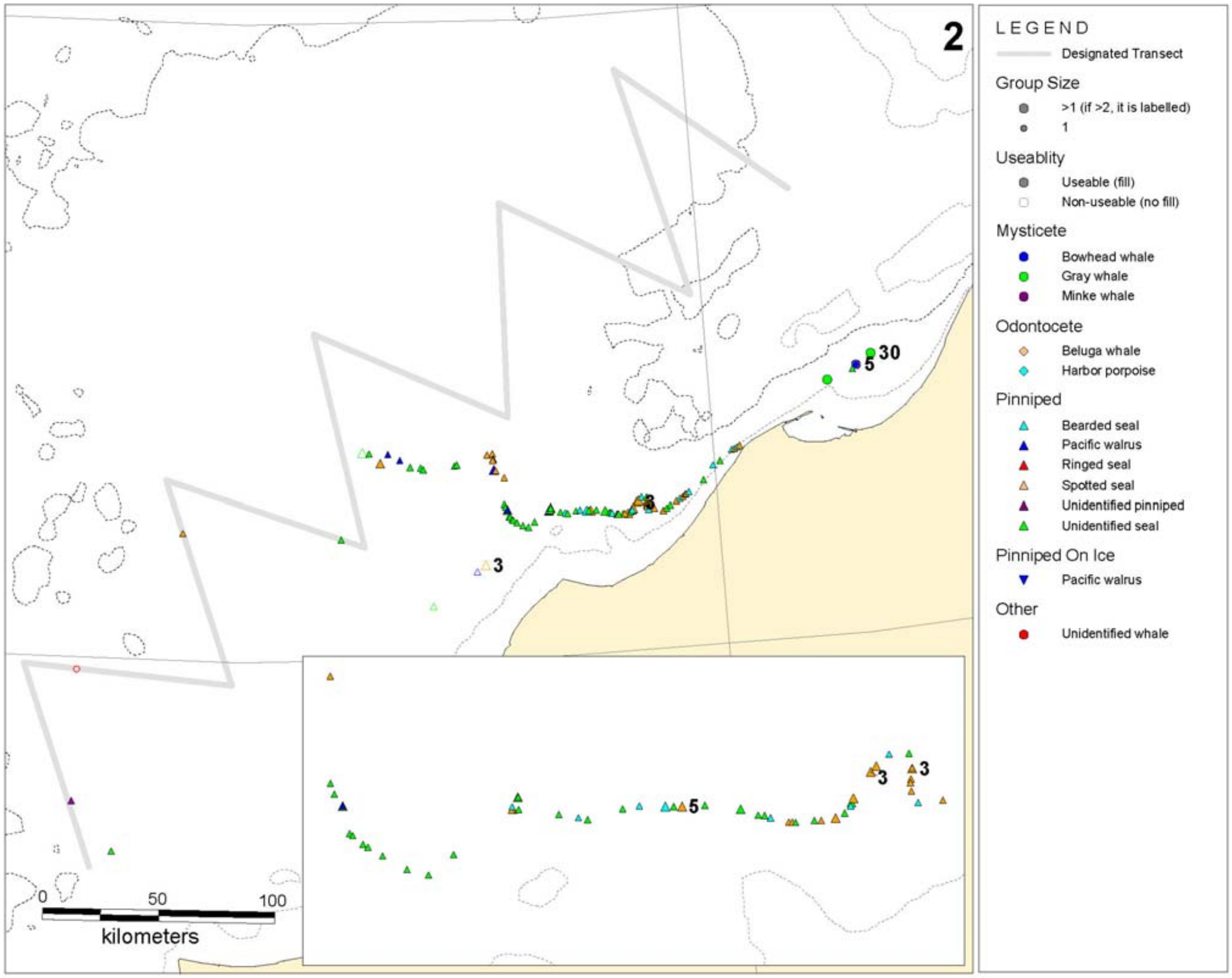

FIGURE 4.7b. All sightings during the second dedicated survey on 28-31 Aug. from the *Gulf Provider*.

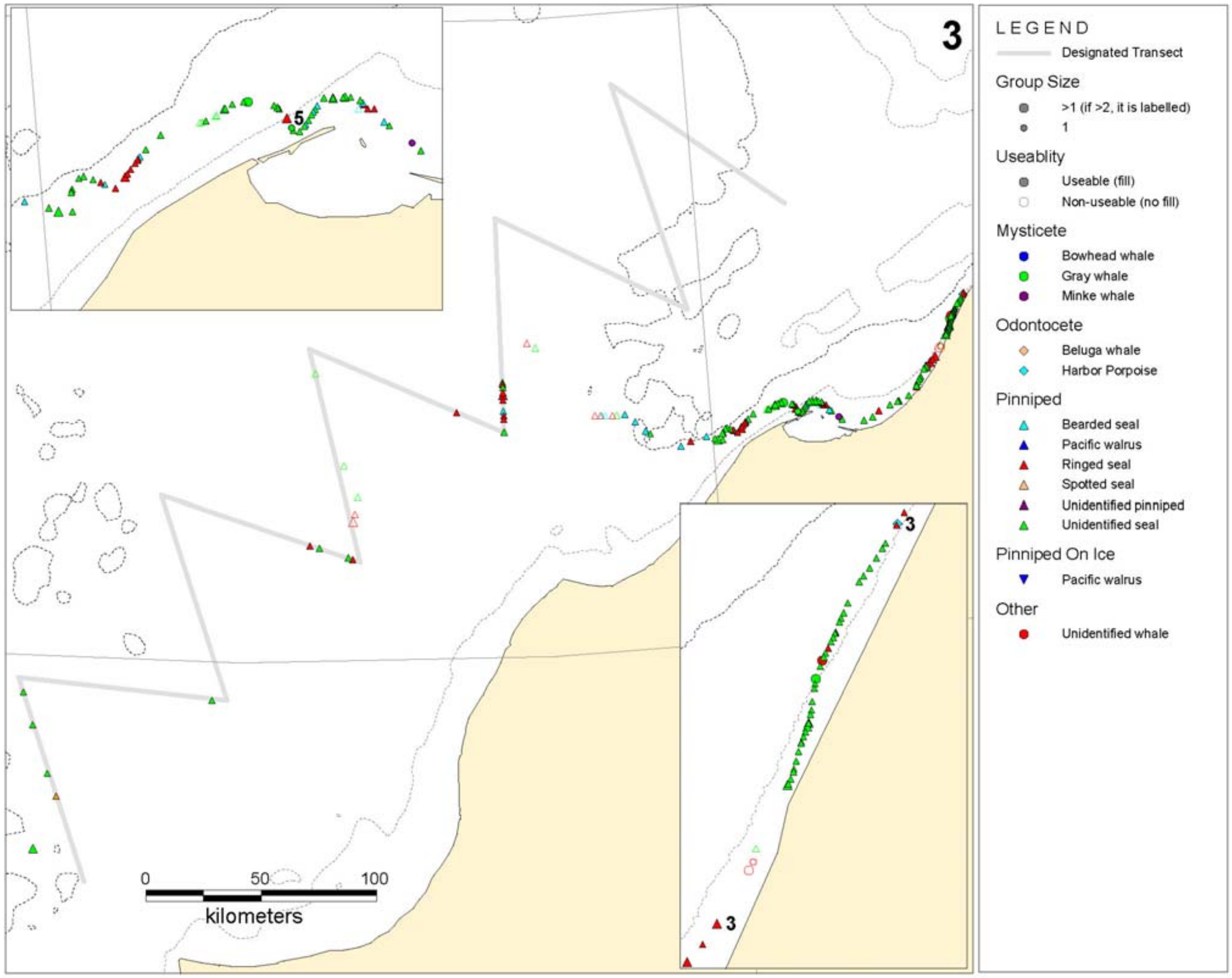

FIGURE 4.7c. All sightings during the third dedicated survey on 5-10 Sept. from the *Torsvik*.

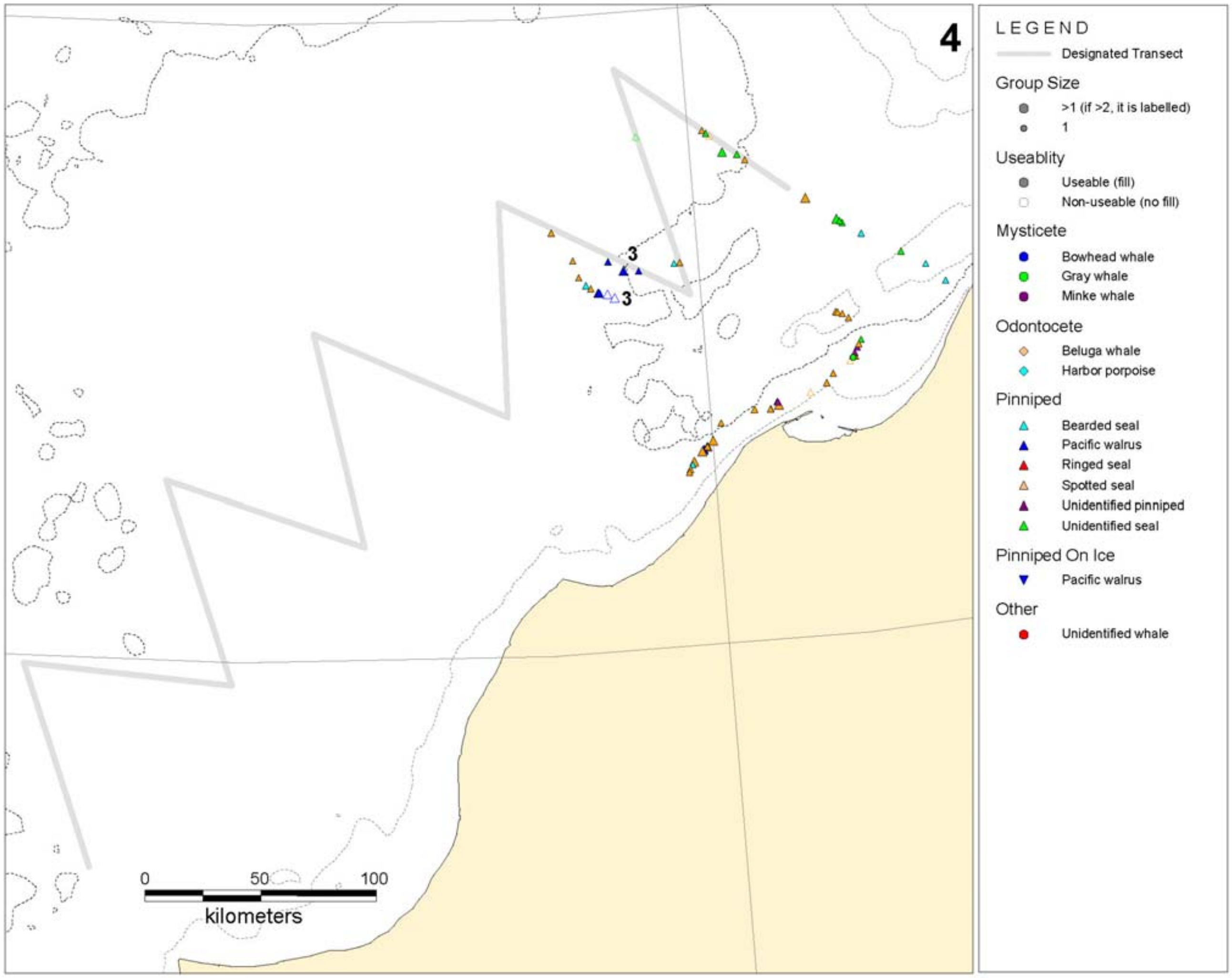

FIGURE 4.7d. All sightings during the fourth dedicated survey on 30 Sept.-3 Oct. from the *Gulf Provider*.

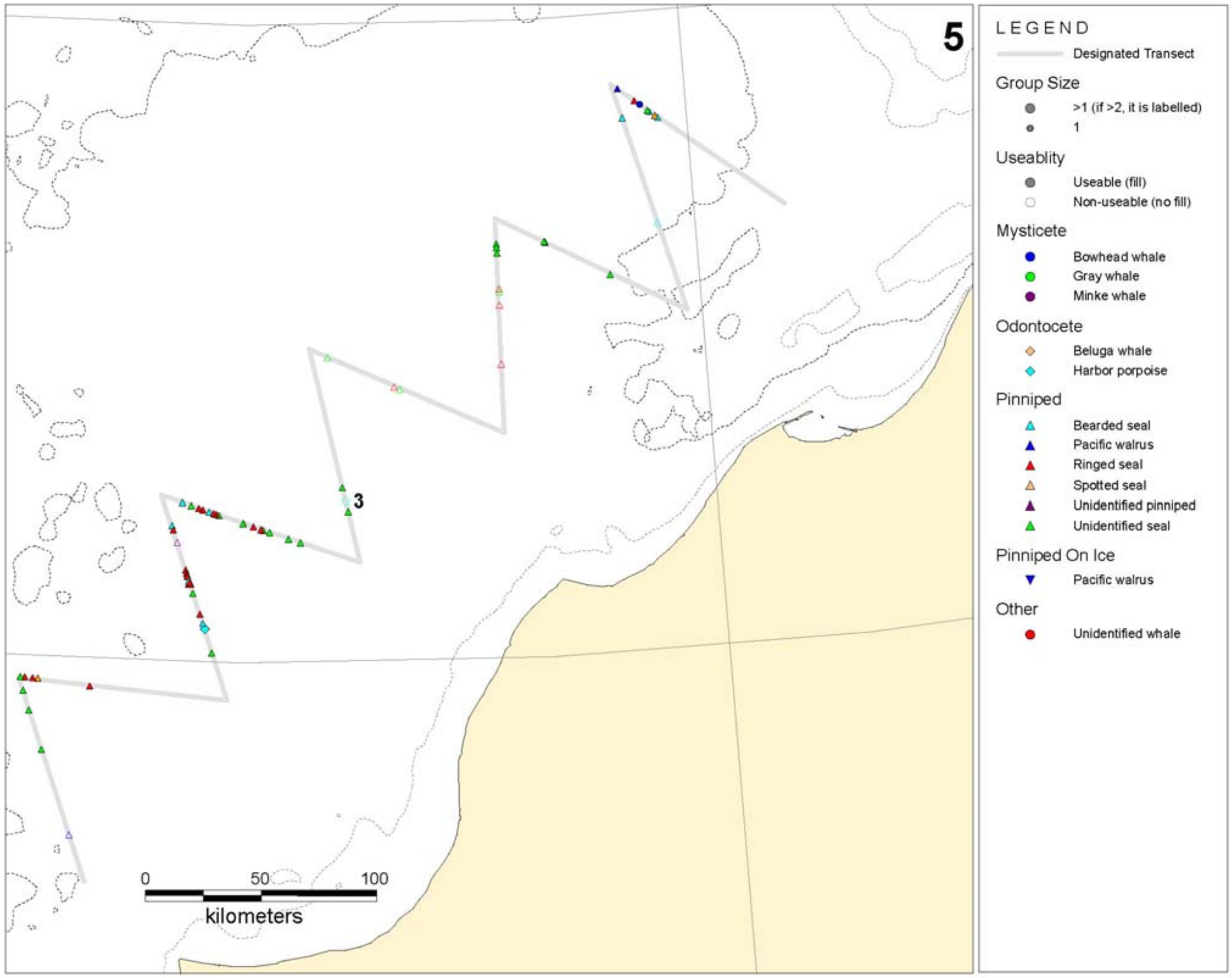

FIGURE 4.7e. All sightings during the fifth dedicated survey on 18-23 Oct. from the *Torsvik*.

Most pinniped sightings were also recorded relatively close to ice during the second, third, and fourth surveys primarily in the northern portion of the survey area and at locations near the shore (Fig. 4.7b,c,d). During the last survey, pinnipeds were recorded farther from ice than in previous surveys, and more pinnipeds were recorded along the southwestern portion of the study area than in the northeast (Fig. 4.7e). The highest concentrations of pinnipeds were recorded in areas between the shore and the edge of the ice pack during the second and third surveys (Fig. 4.7 b,c,d).

Marine Mammal Behavior

The data collected during visual observations provide information about behavioral responses of marine mammals to the non-seismic dedicated survey vessel. The relevant data collected from the *Torsvik* and *Gulf Provider* included estimated closest observed points of approach (CPA) to the vessel, movement relative to the vessel, and observed behavior of animals at the time of the initial sightings.

Closest Observed Point of Approach (CPA)

The mean CPA for pinnipeds in water, independent of season, was 265 m ($n = 368$) which was about 1/3 of that for cetaceans (771 m; $n = 12$; Table 4.5). The difference in CPA between pinnipeds and cetaceans was significant (Wilcoxon rank sum test: $n = 368$ vs. 12, $Z = 24.827$, $p < 0.001$). Within the pinnipeds, mean CPA was lower for seals than for Pacific walrus ($n = 13$ vs. 351, $Z = 24.701$, $p < 0.001$). In all cases where effort was >500 km, CPA decreased significantly ($p < 0.001$) as the seasons progressed. The seasonal decrease in CPA matched the seasonal decline in detection rates in cases with sufficient effort (effort >500 km; Table 4.5). The difference in CPA between cetaceans and pinnipeds may be related to differences in sightability of the two groups. A cetacean blow could be visible to MMOs at several km, whereas sighting a seal at that distance would be unlikely under most conditions.

Behavior Categories

Marine mammal behavior is difficult to observe because individuals and/or groups are often at the surface only briefly, and may exhibit avoidance behavior. This causes difficulties in re-sighting those animals, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Only limited behavioral data were collected during the dedicated surveys because marine mammals were often seen at a distance from the vessel, and were not typically tracked for long distances or durations while the vessel was underway. Two variables that were examined quantitatively to assess potential behavioral effects were the categories of movement and behavior when the animal(s) were first observed (see Chapter 3 for variables and definitions).

Movement—Movement was observed and recorded for 12 sightings of cetaceans (Table 4.6). Most cetaceans were observed swimming parallel to the vessel (75%) or swimming away (~17%). Movement categories were recorded for 332 (94.6%) sightings of seals in water. During "useable" periods, ~34% of seals in water were observed swimming away from the vessel (Table 4.6). Swimming parallel (~25%) and no movement (16%) were the next most frequently-observed movement categories in relation to the vessel. Approximately 9% of seal sightings in the water involved individuals swimming toward the vessel. Of the 13 in-water walrus sightings, ~69% were of animals swimming away and ~23% were of animals swimming parallel to the vessel (Table 4.6).

First Observed Behavior—The most common first observed behavior of cetaceans and pinnipeds was swim/travel (75% and 43.5%; Table 4.7). Other common pinnipeds behaviors included diving (~25.4%) and looking (~24.9%). The first observed behavior of all pinniped sub-categories (seals and Pacific walruses) followed a similar pattern; swim/travel was recorded most frequently, followed by look and dive.

TABLE 4.5. Seasonal mean closest observed points of approach (CPA) and detection rates of useable marine mammal sightings during dedicated survey cruises in the Chukchi Sea, from July to Oct. 2006. Data are pooled for nearshore and offshore areas, and the number of observers on watch. Values are presented for cetacean and pinniped taxonomic categories.

Taxonomic Group		Detections	Effort (km)	Detection Rate (no./1000 km)	Mean CPA (m)	s.d.	Range (m)
All Cetaceans							
	Early	9	1641.85	5.48	961.00	963.65	100-2979
	Mid	3	1105.24	2.71	200.00	50.00	150-250
	Late	N/A	N/A	N/A	N/A	N/A	N/A
	All Seasons	12	2747.09	4.37	770.75	891.22	100-2979
Cryptic Cetaceans							
	Early	2	584.73	3.42	283.00	258.80	100-466
	Mid	1	458.19	2.18	150.00	N/A	N/A
	Late	N/A	N/A	N/A	N/A	N/A	N/A
	All Seasons	3	1042.93	2.88	238.67	198.46	100-466
Odontocetes (Cyptic)							
	Early	1	584.73	1.71	100.00	N/A	N/A
	Mid	1	458.19	2.18	150.00	N/A	N/A
	Late	N/A	N/A	N/A	N/A	N/A	N/A
	All Seasons	2	1042.93	1.92	125.00	35.36	100-150
Mysticetes (Non-Cryptic)							
	Early	6	1641.85	3.65	1149.17	1111.63	150-2979
	Mid	2	1105.24	1.81	225.00	35.36	200-250
	Late	N/A	N/A	N/A	N/A	N/A	N/A
	All Seasons	8	2747.09	2.91	918.13	1032.40	150-2979
All Pinnipeds							
	Early	1	200.24	4.99	50.00	N/A	N/A
	Mid	313	1994.23	156.95	289.23	235.80	5-1188
	Late	54	552.63	97.72	126.57	137.68	10-750
	All Seasons	368	2747.09	133.96	264.71	231.19	5-1188
Unidentified Pinnipeds							
	Early	0	200.24	0.00	N/A	N/A	N/A
	Mid	4	1994.23	2.01	362.50	354.44	50-800
	Late	0	552.63	0.00	0.00	0.00	N/A
	All Seasons	4	2747.09	1.46	362.50	354.44	50-800
Pacific Walrus							
	Early	0	200.24	0.00	N/A	N/A	N/A
	Mid	12	1994.23	6.02	440.67	270.39	100-1000
	Late	1	552.63	1.81	100.00	N/A	N/A
	All Seasons	13	2747.09	4.73	414.46	275.58	100-1000
Seals							
	Early	1	200.24	4.99	50.00	N/A	N/A
	Mid	297	1994.23	148.93	282.13	231.43	5-1188
	Late	53	552.63	95.91	127.08	138.95	10-750
	All Seasons	351	2747.09	127.77	258.05	226.67	5-1188

TABLE 4.6. Movement categories recorded for useable marine mammal sightings in water during all dedicated surveys combined in the Chukchi Sea, from July to Oct. 2006. Results are presented as sample size (*n*) and percent of total (*%*). Numbers in parentheses are numbers of individuals. See Chapter 3 for definitions of movement categories.

		Movement Relative to Vessel[a]												
Taxonomic Group		**Flee**	**Swim Away**	**Swim Parallel**	**Swim Across Bow**	**Swim Toward**	**Mill**	**No Movement**	**Hauled Out**	**Unknown**	**Not Recorded (blank)**	***Total Known / Recorded***	***Total Unknown / Not Recorded***	***Total***
Cetaceans	**n**	0 (0)	2 (3)	9 (47)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	*12 (51)*	*0 (0)*	**12 (51)**
	%	0 (0)	16.7 (5.9)	75 (92.2)	0 (0)	0 (0)	0 (0)	8.3 (2)	0 (0)	0 (0)	0 (0)	*100 (100)*	*0 (0)*	
Cryptic Cetaceans	**n**	0 (0)	1 (2)	2 (4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	*3 (6)*	*0 (0)*	**3 (6)**
	%	0 (0)	33.3 (33.3)	66.7 (66.7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	*100 (100)*	*0 (0)*	
Pinnipeds (All)	**n**	10 (10)	131 (152)	89 (94)	18 (25)	31 (36)	14 (18)	56 (65)	1 (2)	16 (17)	3 (3)	*350 (402)*	*19 (20)*	**369 (422)**
	%	2.7 (2.4)	35.5 (36)	24.1 (22.3)	4.9 (5.9)	8.4 (8.5)	3.8 (4.3)	15.2 (15.4)	0.3 (0.5)	4.3 (4)	0.8 (0.7)	*94.9 (95.3)*	*5.1 (4.7)*	
Pinnipeds in Water	**n**	10 (10)	131 (152)	89 (94)	18 (25)	31 (36)	14 (18)	56 (65)	0 (0)	16 (17)	3 (3)	*349 (400)*	*19 (20)*	**368 (420)**
	%	2.7 (2.4)	35.6 (36.2)	24.2 (22.4)	4.9 (6)	8.4 (8.6)	3.8 (4.3)	15.2 (15.5)	0 (0)	4.3 (4)	0.8 (0.7)	*94.8 (95.2)*	*5.2 (4.8)*	
Seals in Water	**n**	9 (9)	119 (136)	86 (89)	17 (24)	31 (36)	14 (18)	56 (65)	0 (0)	16 (17)	3 (3)	*332 (377)*	*19 (20)*	**351 (397)**
	%	2.6 (2.3)	33.9 (34.3)	24.5 (22.4)	4.8 (6)	8.8 (9.1)	4 (4.5)	16 (16.4)	0 (0)	4.6 (4.3)	0.9 (0.8)	*94.6 (95)*	*5.4 (5)*	
Pacific Walrus in Water	**n**	0 (0)	9 (13)	3 (5)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	*13 (19)*	*0 (0)*	**13 (19)**
	%	0 (0)	69.2 (68.4)	23.1 (26.3)	7.7 (5.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	*100 (100)*	*0 (0)*	
Pacific Walrus on Ice	**n**	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2)	0 (0)	0 (0)	*1 (2)*	*0 (0)*	**1 (2)**
	%	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (100)	0 (0)	0 (0)	*100 (100)*	*0 (0)*	
Total	**n**	10 (10)	133 (155)	98 (141)	18 (25)	31 (36)	14 (18)	57 (66)	1 (2)	16 (17)	3 (3)	*362 (453)*	*19 (20)*	**381 (473)**
	%	2.6 (2.1)	34.9 (32.8)	25.7 (29.8)	4.7 (5.3)	8.1 (7.6)	3.7 (3.8)	15 (14)	0.3 (0.4)	4.2 (3.6)	0.8 (0.6)	*95 (95.8)*	*5 (4.2)*	

[a] Includes only useable sightings as defined in *Survey Data Analysis*.

TABLE 4.7. First observed behavior of useable marine mammal sightings during all dedicated surveys combined in the Chukchi Sea, from July to Oct. 2006. Results are presented as sample size (*n*) and percent of total (*%*). Numbers in parentheses are numbers of individuals. See Chapter 3 for definitions of behavior categories.

		First-observed Behavior[a]										
Taxonomic Group		**Dive**	**Look**	**Rest**	**Swim / Travel**	**Surface / Active**	**Feeding**	**Unknown**	**Not Recorded (blank)**	***Total Known / Recorded***	***Total Unknown / Not Recorded***	***Total***
Cetaceans	**n**	3 (4)	0 (0)	0 (0)	9 (48)	0 (0)	0 (0)	0 (0)	0 (0)	*12 (52)*	*0 (0)*	**12 (52)**
	%	25 (7.7)	0 (0)	0 (0)	75 (92.3)	0 (0)	0 (0)	0 (0)	0 (0)	*100 (100)*	*0 (0)*	
Cryptic Cetaceans	**n**	1 (1)	0 (0)	0 (0)	2 (5)	0 (0)	0 (0)	0 (0)	0 (0)	*3 (6)*	*0 (0)*	**3 (6)**
	%	33.3 (16.7)	0 (0)	0 (0)	66.7 (83.3)	0 (0)	0 (0)	0 (0)	0 (0)	*100 (100)*	*0 (0)*	
Pinnipeds (All)	**n**	93 (106)	92 (99)	17 (18)	160 (190)	2 (2)	1 (3)	1 (1)	3 (3)	*365 (418)*	*4 (4)*	**369 (422)**
	%	25.2 (25.1)	24.9 (23.5)	4.6 (4.3)	43.4 (45)	0.5 (0.5)	0.3 (0.7)	0.3 (0.2)	0.8 (0.7)	*98.9 (99.1)*	*1.1 (0.9)*	
Pinnipeds in Water	**n**	93 (106)	92 (99)	16 (16)	160 (190)	2 (2)	1 (3)	1 (1)	3 (3)	*364 (416)*	*4 (4)*	**368 (420)**
	%	25.3 (25.2)	25 (23.6)	4.3 (3.8)	43.5 (45.2)	0.5 (0.5)	0.3 (0.7)	0.3 (0.2)	0.8 (0.7)	*98.9 (99)*	*1.1 (1)*	
Seals in Water	**n**	89 (101)	92 (99)	16 (16)	147 (172)	2 (2)	1 (3)	1 (1)	3 (3)	*347 (393)*	*4 (4)*	**351 (397)**
	%	25.4 (25.4)	26.2 (24.9)	4.6 (4)	41.9 (43.3)	0.6 (0.5)	0.3 (0.8)	0.3 (0.3)	0.9 (0.8)	*98.9 (99)*	*1.1 (1)*	
Pacific Walrus in Water	**n**	2 (3)	0 (0)	0 (0)	11 (16)	0 (0)	0 (0)	0 (0)	0 (0)	*13 (19)*	*0 (0)*	**13 (19)**
	%	15.4 (15.8)	0 (0)	0 (0)	84.6 (84.2)	0 (0)	0 (0)	0 (0)	0 (0)	*100 (100)*	*0 (0)*	
Pacific Walrus on Ice	**n**	0 (0)	0 (0)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	*1 (2)*	*0 (0)*	**1 (2)**
	%	0 (0)	0 (0)	100 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	*100 (100)*	*0 (0)*	
Total	**n**	96 (110)	92 (99)	17 (18)	169 (238)	2 (2)	1 (3)	1 (1)	3 (3)	*377 (470)*	*4 (4)*	**381 (474)**
	%	25.2 (23.2)	24.1 (20.9)	4.5 (3.8)	44.4 (50.2)	0.5 (0.4)	0.3 (0.6)	0.3 (0.2)	0.8 (0.6)	*99 (99.2)*	*1 (0.8)*	

[a] Includes only useable sightings as defined in *Survey Data Analysis.*

Estimated Density of Marine Mammals

The number of marine mammals observed close to the survey vessels during the dedicated surveys provides a minimum estimate of the number present in the absence of seismic sounds. Animals are missed if they are below the surface when the ship is nearby. Some mammals, even if they surface near the vessel, are missed because of environmental factors limiting sightability. High Beaufort wind force and fog were significant factors limiting visibility during some periods of these surveys. The proportion of animals missed due to these biases is dependent on the magnitude and type of influence, but the presence of these biases likely resulted in an underestimation of the actual number of animals present in the survey area.

Pinnipeds— Pinniped densities, subdivided by transect type and season, were estimated where data showed good model robustness ($n \geq 20$), > 500 km of useable effort, and represented 3-person offshore monitoring (Table 4.8). The effort and/or sample size were insufficient to estimate pinnipeds densities during ”in transit” and ”off transect” periods, and for ”on transect” and ”alternate transect” during some seasons.

Densities of pinnipeds doubled from mid- to late seasons in offshore areas (Table 4.8). The greatest estimated pinniped density occurred on alternate transects during the mid-season (Table 4.8) when the survey vessels transited near the ice edge as close to the original transect lines as possible (Figs. 4.7b,c, and d). The estimated late-season pinniped density was also relatively high during on transect periods, when survey vessels did not operate near ice. However, overall pinniped density on transect for all seasons combined was relatively low (Table 4.8). Many of the late season, on transect observations were made in open water in the southwest portion of the survey area (Fig. 4.7e). The relatively high pinniped density in open water during late season may have resulted from movement of seals toward the Bering Sea during fall migration.

TABLE 4.8. Pinniped densities subdivided by season and transect type. Densities were calculated where $f(0)$ values showed good model robustness ($n \geq 20$) and >500 km effort. Values presented represent offshore periods with 3-person visual monitoring effort. All transects include On Transect, Alternate Transect, Off Transect, and In Transit periods. Densities were corrected for $f(0)$ and $g(0)$ biases (see Chapter 3).

Transect Type	Season	Effort (km)	Detections	Individuals	$f(0)$	$g(0)$	Density (# / 1000 km^2)
All	All	2594.27	349	396	4.202	1.0	319.5
All	Mid-	1522.73	116	137	4.764	1.0	214.3
All	Late	552.63	54	55	8.719	1.0	433.6
On	All	1446.31	71	75	8.446	1.0	201.5
On	Late	552.63	54	55	8.719	1.0	433.6
Alternate	All	558.55	89	106	4.654	1.0	293.2
Alternate	Mid-	506.18	88	104	4.654	1.0	491.4

Cetaceans—Estimates of cetacean densities in the Chukchi Sea study area could not be calculated due to insufficient effort or sighting sample size to meet the shape criterion for model robustness.

Passive Acoustic Monitoring (PAM) Effort

Passive acoustic monitoring effort spanned ~150 h, over 19 survey days, aboard the *Torsvik* in July, Sept., and Oct. 2006 (Fig. 4.8). This included transit effort from Dutch Harbor to the primary Chukchi Sea study area for the first survey and short periods of transit from coastal villages at the beginning or end of subsequent surveys. No marine mammal vocalizations were detected with PAM during any of the three surveys in 2006.

During the July survey, the hydrophone array was deployed for ~19 h 35 min during transit to the study site, and ~18 h and 42 min while the *Torsvik* conducted surveys along the pre-determined transect lines (10-16 Jul. 2006; 5.47 h/day average effort). During Sept. and Oct. surveys the hydrophone array was deployed for a total of 53 h 35 min and 57 h 56 min, respectively, over six days of surveys for both periods (8.93 h/day and 9.66 h/day average effort, respectively). During the last survey (Oct.), the array was deployed for short periods after dark for much of the survey period. There were no extended periods (>1 h) in which the PAM system had to be shut down due to equipment failures or maintenance in 2006.

Passive Acoustic Detections

The lack of detections during the surveys precludes further analysis of the acoustic data. It should be noted that absence of acoustic detections is not necessarily indicative of absence of animals, as vocalizing is not an obligatory behavior for most marine mammals. Furthermore, detection ranges were probably limited by ship noise, ice noise, and sound propagation conditions of the study area. However, the lack of acoustic detections was corroborated by the visual data in which there were only 12 sightings of cetaceans during all dedicated survey periods with PAM effort. Results of other studies in which acoustic and visual surveys were conducted usually resulted in greater detection rates for the acoustic component when compared to visual detections, which did not occur in this case.

Technical and Logistical Issues—The PAM hardware and software performed satisfactorily. One concern was an intermittent and rapid onset of static (electrical noise) that occurred on the hydrophone array every ~20-30 min. The source of this static could not be determined. The problem was easily rectified by switching the array power off and back on (this took only ~1-2 s to complete). We do not think this affected data quality or the monitoring effort.

A problem was encountered with signal digitization using ISHMAEL software. Upon review of the recordings, it was determined that ISHMAEL software was writing files in 16-bit instead of the 24-bit format generated by the MOTU digitization board as it was passed to the ISHAMEL computer. We resolved this by limiting recording levels to below 1 V, which manually limited the dynamic range of recording. The only instance in which this could cause clipping would be when received levels were extremely high (e.g., when animals are very close to the array). Limiting the recording levels also had no effect on the real-time monitoring effort.

The *Torsvik* was not an ideal acoustic survey platform. The 220 V power presented some obstacles in obtaining clean, regulated, 110 V power. Several 220-110 transformers were used to overcome this problem; however, these introduced some noise into the acoustic system. Electrical noise can be a significant problem, as the processing system uses cross-correlation functions to estimate the time delays of signals arriving at the two hydrophones to obtain bearings. Electrical noise is typically present on both channels and can make obtaining a time-delay to a signal of interest difficult, if not impossible. Clean power using power conditioners, high-end inverters running off DC power, or a good quality power generator (which was provided by Fairweather Leasing, Inc., but was not used used in this project for logistical reasons) would help limit electrical noise. Masking due to self-noise from the survey vessel is a common problem for towed array research, especially for monitoring baleen whales, which tend to produce sounds in the same frequency band as noise produced by small to medium-sized research vessels.

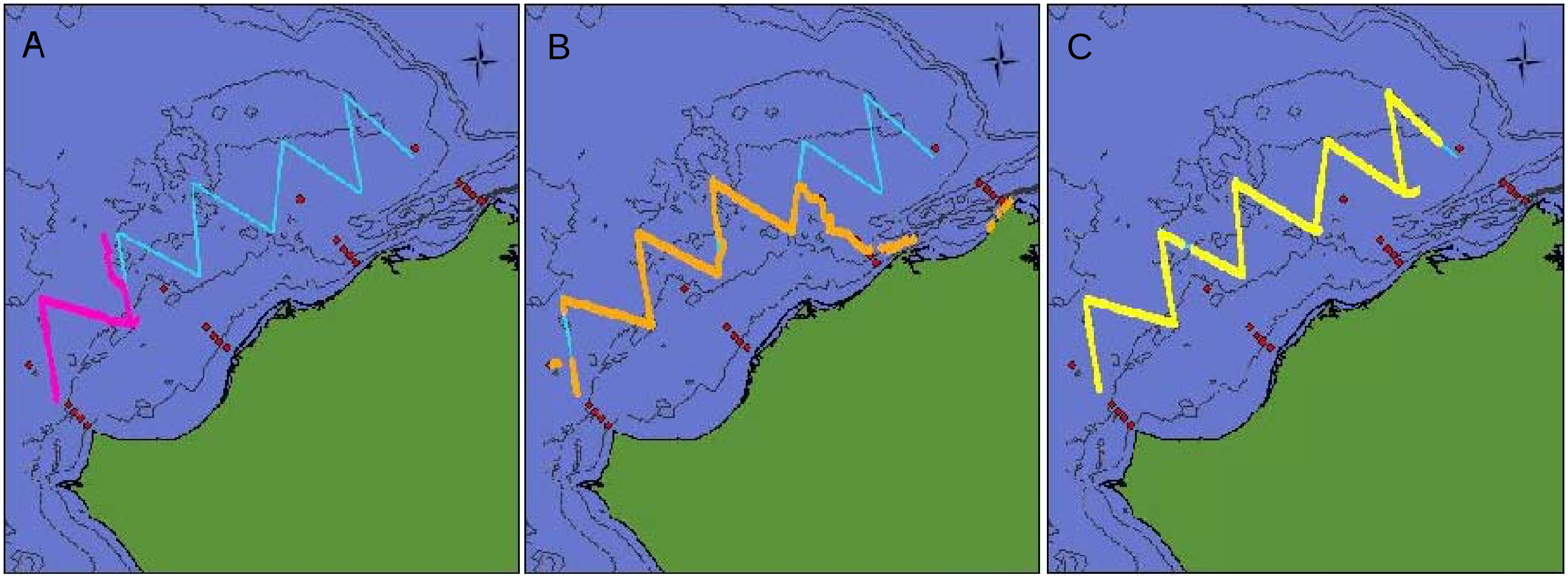

FIGURE 4.8. Map of the Chukchi Sea study area with PAM effort in (a) July, (b) Sept., and (c) Oct. 2006. Designated survey transects (blue lines), pop-up locations (red diamonds), and 0-100 m bathymetry (black lines) are indicated on each panel.

Summary

The 2006 dedicated surveys in the Chukchi Sea provide baseline data to assess the potential effects of seismic activities in the Chukchi Sea. Cetacean species observed within the survey area included two odontocetes (harbor porpoise and beluga whale) and three mysticetes (bowhead, gray and Minke whales). Four pinniped species including ringed, bearded, and spotted seals and Pacific walrus were also recorded in the survey area. No polar bears were detected during the dedicated surveys. Marine mammal detection rates for both cetaceans and pinnipeds were generally greater nearshore and around ice floes than in offshore ice-free conditions.

Relatively few useable sightings of cetaceans were recorded compared to pinniped sightings. Cetacean detection rates during the early season were approximately twice as high as during the mid-season. No surveys were conducted during the late cetacean season. The most frequently observed cetacean was gray whale. There were six gray whale sightings that comprised ~38 individuals. Only two sightings of bowhead whales and one beluga whale sighting were recorded during the dedicated surveys. Few bowheads would be expected to occur in the area prior to fall migration in late Sept. or early Oct. (Miller et al. 1986; Moore et al. 1986; Angliss and Outlaw 2007). However, some evidence suggests that small numbers of bowheads may remain in the Chukchi Sea during the summer (Moore 1992). During fall migration bowheads would likely be dispersed over a relatively wide area that could extend across the Chukchi Sea to the Russian coast (Miller et al. 1986; Moore et al. 1995). Similarly, most beluga whales likely move out of the survey area during the summer and would not be expected to return until fall migration (Suydam et al. 2001, 2005). Although beluga whales often occur in nearshore habitats during the spring (e.g., coastal lagoons), their distribution during fall migration through the Chukchi Sea is dispersed in low densities over a larger area (Clarke et al. 1993). Harbor porpoise (two sightings) and Minke whale (one sighting) were also recorded.

Pinniped detection rates were greatest during the mid-season (surveys 2 through 4) followed by the late season (survey 5). The low detection rate during the early pinniped season may have resulted in part from the reduced amount of effort during the first survey. Approximately three legs of the ten survey transects were completed during the first survey, and this survey did not include any of the nearshore habitats surveyed during the mid-season. Ringed seal was the most frequently recorded pinniped species followed by bearded and spotted seals and Pacific walrus, although the preponderance of unidentified seals limits any species-specific conclusions that can be drawn from the data. Pinniped detection rates were greater in nearshore vs. offshore areas and at locations near ice than locations farther away from ice.

The greatest estimated pinniped density occurred on alternate transects during the mid-season when the survey vessels transited near the ice edge as close to the original transect lines as possible. The estimated pinniped density was also relatively high “on transect” during the late season when the survey vessels did not operate near ice, while the overall pinniped density on transect for all seasons combined was relatively low. Many of the late season, on transect observations were made in open water in the southwest portion of the survey area. The relatively high pinniped density in open water during the late season may have resulted from the movement of seals toward the Bering Sea during fall migration.

A passive acoustic monitoring program using a towed array was employed to record marine mammal vocalizations during three of the five dedicated surveys. No marine mammal vocalizations were recorded during the surveys.

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5. CHUKCHI SEA NEARSHORE AERIAL SURVEYS[1]

Introduction

Aerial surveys of marine mammals during the open-water season in the Chukchi Sea have not been conducted in recent years. Distribution and abundance of marine mammal species may have changed since earlier surveys in the 1980s and early 1990s (George et al. 2004; Rugh 2004; Cooper et al. 2006). Changes could result from differences in habitats used by some marine mammal species related to global warming and changing ice conditions (Tynan and DeMaster 1997; Johannessen et al. 1999; Ferguson et al. 2001; Stirling and Parkinson 2006; Treacy et al. 2006). SOI, CPAI, and GXT conducted nearshore aerial surveys to gather information on current marine mammal distribution and abundance in the eastern Chukchi Sea. The surveys focused on beluga whales, bowhead whales, and gray whales, although other marine mammals were recorded if observed. Sightings of pinnipeds were collected during the surveys, but these data should be interpreted with caution as flight altitude and speed limited the ability of observers to collect consistent and reliable data on those species. Distribution and sightings rate data for walruses are presented in this chapter. Additional data for cetacean species and other pinniped species are presented in Appendices D and E.

The eastern Chukchi Sea stock of beluga whales was estimated to contain ~3,710 individuals (based on 1989-91 aerial surveys), and the population size was considered stable (Angliss and Outlaw 2007). More recent estimates are not available. During June-July the Chukchi stock of beluga whales is typically found in nearshore waters and in lagoons along the Alaskan Chukchi Sea coast. The coastal villages, most notably Pt. Lay, conduct subsistence hunts for beluga whales during this period. By August most Chukchi Sea beluga whales have moved into the northern Chukchi Sea, the Arctic Ocean, or into the western Beaufort Sea, where they spend the rest of the summer (Suydam et al. 2001; NMFS 2006). These whales return to the southern Chukchi Sea during their fall migration in October (NMFS 2006). The much larger Beaufort Sea stock of beluga whales (39,258; Angliss and Outlaw 2007) also migrates through the eastern Chukchi Sea during spring (April - early June) and fall migrations (Oct.).

The Bering/Chukchi/Beaufort Sea (BCB) stock of bowhead whales was estimated to contain about 10,545 animals as of 2001, with lower and upper 95% confidence bounds of 8,200 and 13,500 animals (Zeh and Punt 2005). Between 1978 and 2001 this bowhead population was estimated to have increased at a rate of 3.4% per year (95% confidence interval 1.7 to 5.0%) with an annual subsistence harvest averaging 38.4 whales during 2000-2004 (Angliss and Outlaw 2007). If a 3.4% annual rate of increase continued after 2001, the 2006 population size would be ~12,500 bowhead whales.

In the spring (April to mid-June) bowhead whales migrate north from the Bering Sea through the open leads in the Chukchi Sea along the west coast of Alaska. They continue across the Alaskan Beaufort Sea and into the Canadian Beaufort Sea and Amundsen Gulf arriving there in June and July (Moore and Reeves 1993). Although most bowheads appear to migrate to the Canadian Beaufort Sea for the summer, there is evidence that small numbers of bowheads may remain in the northeastern Chukchi Sea (Moore 1992). In the fall, most bowhead whales migrate west through the central Alaskan Beaufort Sea during September and October, but after reaching Barrow, their autumn migration route back to the Bering Sea remains largely unknown (Moore et al. 1995). Some whales are thought to migrate southwest from Barrow (Moore 1993) while others migrate westward from Barrow, before heading south along the

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[1] Tannis Thomas, William R. Koski, and Ted Elliot, LGL Limited, King City, Ontario.

Chukotka coast. This migration route has been observed for satellite-tagged bowheads in fall (Mate et al. 2000; Quakenbush et al. 2007). Moore et al. (1995) observed bowhead whales along the Chukotka Coast during opportunistic mammal/seabird search surveys in the Chukchi Sea in autumn 1992 and 1993, and a satellite-tagged bowhead spent at least a month, probably feeding (Schell et al. 1989; Thompson et al. 2002; Lee et al. 2005), along the Chukotka coast during the autumn of 2006 before migrating into the Bering Sea wintering area (Quakenbush et al. 2007).

The Eastern North Pacific stock of gray whales was estimated to contain 29,758 animals in 1997-1998, but estimates were lower for 2000-01 (19,448), and 2001-02 (18,178; Rugh et al. 2005). Rugh et al. (2005) also estimated the carrying capacity (*K*) to be 26,290 (CV=0.059) animals for this stock of gray whales. During the 1980s, some of this stock migrated to the Chukchi Sea to feed, arriving in mid-June (Braham 1984; Moore et al. 1986; Moore 2000), but in recent years, several tens of gray whales have been seen near Barrow by early June (W. Koski survey data from 2003 and 2004). Some gray whales continue east into the Beaufort Sea (Reeves et al. 2002; Angliss and Outlaw 2007; Appendix D, Figure D.4A), but most remain in the Chukchi Sea until October, when they migrate south to wintering areas in northern Mexico and southern California (Moore et al. 1986). Recent evidence from acoustical data suggest that some gray whales may overwinter in the Barrow area (Stafford et al. 2007).

Alaskan Natives from several villages along the east coast of the Chukchi Sea hunt marine mammals during the summer, and there is concern that offshore oil and gas development activities may negatively impact their ability to harvest marine mammals. Of particular concern for summer activities are potential impacts on the early summer beluga harvest at Point Lay and on fall bowhead harvests at Point Hope, Wainwright and Barrow. Native hunters at Point Hope and Wainwright have traditionally hunted bowheads in the spring, when the whales pass through leads relatively close to shore, but these villages have not traditionally hunted bowheads during the fall. The spring bowhead harvests at Point Hope and Wainwright occur while sea ice is still present in high concentrations, and industry seismic vessels are not able to operate. Members of the coastal communities also hunt seals and walruses for subsistence purposes.

Objectives

An aerial survey program was conducted as part of the Joint Monitoring Program (JMP) during seismic activities in the Chukchi Sea in the summer and fall of 2006. The objective of the aerial surveys was to update data on distribution and relative abundance of marine mammals in coastal areas of the eastern Chukchi Sea during the open-water season.

Methods

Aerial surveys for marine mammals in the eastern Chukchi Sea were conducted twice weekly from 9 July to 12 Nov. 2006 using a standard survey route, weather permitting. No surveys were flown from 26 July to 22 Aug. due to unavailability of aircraft. A total of 25 surveys was attempted, and substantial or complete survey coverage was obtained on 18 (72%) of the surveys.

Survey Area

The aerial survey area extended from Barrow to Point Hope, Alaska and from the mainland coast to ~37 km (~20 n. mi) offshore (Fig. 5.1). Within this survey area, two series of systematic transects were flown. The “sawtooth” surveys provided broad-scale survey coverage of the entire survey area. The “coastline” surveys provided additional opportunities to detect marine mammals in nearshore areas, including lagoons, where most subsistence hunting occurs.

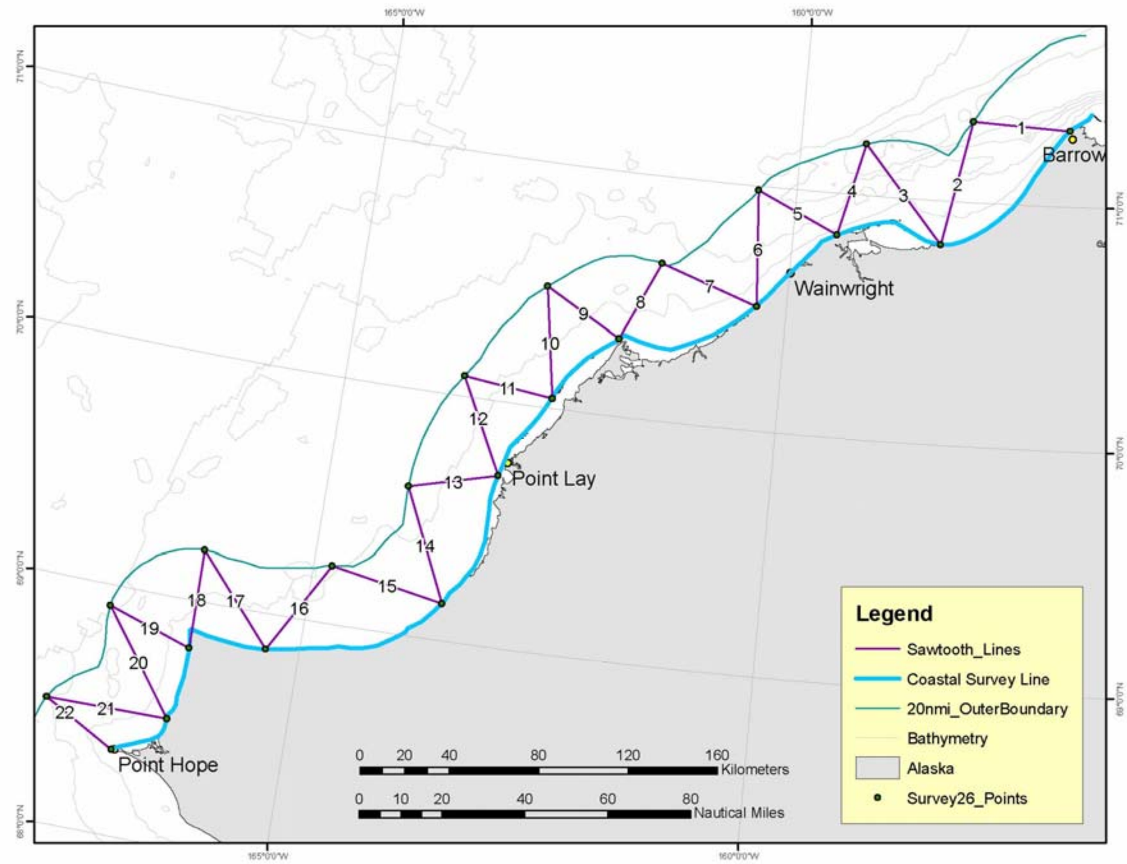

FIGURE 5.1. Aerial survey transect locations and general survey patterns for the eastern Chukchi Sea, summer 2006.

Sawtooth Survey

The "sawtooth" survey grid flown in 2006 nominally consisted of 22 transect lines (total length ~1015 km) in a sawtooth pattern. The survey pattern was developed in consultation with scientists from the National Marine Fisheries Service (NMFS) and the North Slope Borough (NSB). Survey transects were determined by placing transect start/end points every 55 km (30 n.mi) along the offshore boundary of the survey area and at points along the shore midway between the offshore points. The transect line start/end points were shifted along both the coast and the offshore boundary for each survey based upon a randomized starting point. Overall, distance did not vary substantially among surveys. This design permitted near completion of the survey in one day and provided representative coverage of the nearshore area from the shore to ~37 km (20 miles) offshore. The Aero Commander aircraft used prior to 26 June allowed the survey to be completed in one day, weather permitting. After 26 July the surveys were flown in a Twin Otter aircraft, which was slower and had less fuel capacity than the Aero Commander, and required two days to complete a survey. Transects 19 to 22 at the southwestern end of the survey area were not flown until after 22 Aug., at which point permission was granted by the village of Point Hope to fly in the area.

Coastline Survey

The shorter "coastline" survey (total length ~560 km) was flown either on the return trip to Barrow after completion of the sawtooth survey, or en route to the southwestern end of the survey area on days when the survey began near Point Hope. The coastline survey was designed to determine the distribution and abundance of beluga and gray whales in coastal areas and lagoons.

Survey Procedures

From 9 to 25 July 2006, aerial surveys were flown in a twin-engine, high-wing Aero Commander N222ME aircraft specially modified for survey work. The plane was operated by Commander Northwest of Anchorage, Alaska. Special features included upgraded engines, STOL modifications to allow safer flight at low speeds, long-range fuel tanks, multiple GPS navigation systems, bubble windows at all observer positions, 110 V AC power for survey equipment, and a camera port for taking photos. Two pilots were present for takeoffs, landings, and ferry flights. For the remainder of the field season, from 22 Aug. to 12 Nov., the aerial surveys were flown in a Twin Otter EA320 operated by ERA Aviation, Inc. of Anchorage, Alaska. This twin-engine, high-wing aircraft was also specially modified for survey work similar to the Aero Commander, although without a camera port and with a shorter flight duration.

When conditions permitted, both the sawtooth and the coastline surveys were flown. Fuel capacity of the Twin Otter aircraft precluded completion of the entire sawtooth portion of the survey without refueling. In general, the coastline was flown first from Barrow to transect 9, and then the sawtooth portion was flown from transects 9 to 22. The aircraft was refueled in Kotzebue to fly the coastline survey from Point Hope to transect 8, and then complete the sawtooth portion from transects 8 to 1, time and weather permitting. If the survey could not be completed in one day, the survey was finished the next day, which usually included transects 1 to 4. However, on several occasions the sequence was modified because of weather restrictions.

Surveys were conducted at altitudes of 1000 to 1500 ft (305-457 m) above sea level (ASL) and a groundspeed of 120 knots (222 km/h). An altitude of 1500 ft ASL (457 m) was maintained in the Ledyard Bay spectacled eider critical habitat area, as required by USFWS regulation. This critical habitat area extended from Icy Cape to Cape Lisburne, which generally included the sawtooth transects 9 to 18. The preferred altitude outside the critical habitat area was 1000 ft ASL (305 m), but some surveys were conducted at higher altitudes during periods when there was concern about potential aircraft disturbance to whaling activities based at Barrow, Wainwright, Point Lay and Point Hope. "No-fly" zones around coastal villages or other hunting areas established during communications with village representatives were in place during hunting seasons. For example, during the summer beluga whaling season (July), transects 19 to 22 were not surveyed to avoid the potential aircraft disturbance to whaling by Point Hope (as per their request). Also, during the fall whaling season in Barrow (25 Sept. to 2 Oct.), transects 1 and 2 of the sawtooth survey were flown at 1500 ft. These procedures were implemented to provide as much coverage of the survey area as possible while

- minimizing the potential for aircraft disturbance to whales in the whaling area; and
- maximizing the probability that the aircraft would be at high altitude (1500 ft) where bowheads generally do not react to aircraft overflights (Patenaude et al. 2002) if the aircraft did fly over or near whalers.

The two primary observers occupied the front right (Aero Commander) or the back right (Twin Otter) seat and a seat on the left side of the aircraft, immediately behind the pilot. A third observer, who also operated a laptop computer, was positioned behind the co-pilot's seat (Twin Otter), or at the rear of the plane (Aero Commander). The third observer surveyed when not occupied with other duties. All observers sat at bubble windows that allowed greater downward visibility than standard windows.

Data Recording Procedures

A laptop computer using Garmin NRoute software automatically recorded time and aircraft position (latitude and longitude) at 2-s intervals throughout the flights. The electronics system consisted of a portable computer, GPS unit (Garmin GPSmap 76CSx), and NRoute data-logging software. In addition to the automated flight-track recording, locations were recorded through keystrokes initiated by the computer operator at various times, including when animals were sighted by one of the observers, transect starts and ends, ends of 2-minute time periods, marine mammal sightings, and other observations or comments.

The two primary observers recorded the time, sightability (subjectively classified as excellent, good, moderately impaired, seriously impaired, or impossible), sea state (Beaufort wind force), ice cover (in 10ths) and sun glare (none, up to 10% glare, 10-30% glare, >30% and <70% glare, and >70% glare) onto digital recorders at the end of each 2-minute (~7.4 km) period. The time and position of the aircraft were automatically logged by the NRoute software when the time period data were entered.

For each whale sighting, the observer notified the computer operator of the species and number seen and then dictated details of the sighting into a portable digital recorder, including the species, number, ice conditions, size/age/sex class when determinable, activity, heading, swimming speed category, sighting cue, inclinometer angle (taken when the animal's location was 90° to the side of the aircraft track), and altitude. In conjunction with aircraft altitude, inclinometer readings allowed calculation of lateral distances of whales from the transect line. Non-transect sightings were identified as being recorded along “Connect” segments (between transect lines) and “Search” segments (seen while circling). (For pinnipeds and polar bears, only the species, number, and ice conditions were routinely dictated.) In addition to recording sighting data on the digital recorder, marine mammal sighting data, time and position were recorded in the NRoute software. The whale sighting information entered into the software in real time was cross-checked against the recorded dictation after each survey to correct any data entry errors.

Analyses of Aerial Survey Data

Mapping—This report includes maps showing the sighting locations of whales and walruses during the surveys. These maps show the sawtooth and coastline surveys encompassing the 156°42’-167°39' W (approx.) and 68°21’-71°22' N (approx.) region. The sightings were divided into early, mid-, and late seasons for cetaceans and for pinnipeds. For cetacean sightings, the early season was defined as before 25 Sept., the mid-season was 25 Sept. through 25 Oct., and the late season was after 25 Oct. For the pinniped sightings, the early season was defined as before 29 Aug., the mid-season was 29 Aug. through 8 Oct., and the late season was after 8 Oct. as defined in Chapter 3 of this report.

Each sighting symbol on these maps represents a sighting of one or more individuals. Sightings along formal transects (regardless of distance from trackline) are shown as filled (useable data) or ‘dotted’ (non-useable data) symbols. Useable data refers to sightings and effort collected under good sighting conditions, i.e. Beaufort Scale 4 or less for whales, and Beaufort Scale 2 or less for pinnipeds, or sightability moderately impaired or better. Non-useable data refers to sightings and effort collected under poor conditions, i.e. Beaufort Scale 5 or more for whales, and Beaufort Scale 3 or more for pinnipeds, or sightability seriously impaired or impossible. These sightings, and the associated survey effort under poor conditions, were excluded from analyses of sightings per unit effort. Incidental sightings, including sightings during "Connect" legs between transects and during non-systematic "Search" legs, are shown as open symbols, and were not used in the analyses.

Whales and Walruses per Unit Effort (Relative Abundance)—The maps also illustrate much of the distributional information. However, the maps are difficult to interpret because survey effort varied considerably within the survey area. To account for this variability, we computed sightings and whales per unit effort for both the Coastline and the Sawtooth surveys.

We used NRoute, supplemented by MapBASIC computer code, to determine the number of sightings and individuals, and the numbers of kilometers of transect coverage within the survey area. These analyses excluded survey effort and sightings during non-systematic "Connect" and "Search" segments, as well as non-useable data segments (described above) flown during periods with poor sighting conditions. Sightings or individuals per unit effort were determined by dividing the number of sightings (or individuals) seen during the survey by the number of kilometers of "Transect" coverage. We then categorized the surveys into the early, mid-, and late season periods (as described above), and calculated a mean sighting rate for each species within each season.

Estimated Number of Whales Present—Line transect methodology (Buckland et al. 2001) was used to estimate densities and numbers of animals present in the survey area. We used the DISTANCE program to estimate numbers of whales present for each survey when there was sufficient survey effort to meet assumptions of this methodology (Thomas et al. 2006, version 5.0, release 2). When beluga whale sightings included clusters of animals, a cluster analysis was performed in the DISTANCE program to estimate the number of animals. The lateral distance factor, $f(0)$, accounts for the reduced probability of detecting an animal at the surface of the water as its distance from the trackline increases. For $f(0)$, we calculated inner truncation distances according to aircraft type and altitude (as in Thomas et al. 2002). For a Twin Otter aircraft, the inner truncation distances were 100 m from the centerline at 1000 ft and 300 m at 1500 ft. For the Aero Commander aircraft, the inner truncation distance was 450 m at 1000 ft and 1500 ft. The outer truncation distances were calculated for each whale species using data during good sighting conditions (sea conditions between 0-4 and ice-cover between 0-5%; Thomas et al. 2002). For beluga, gray, and bowhead whales the outer truncation distances were calculated at 1000, 1500, and 2000 m, respectively. The availability bias factor, $g_a(0)$, which takes into account the effects of surfacing and dive behavior on the probability that an animal on or near the trackline will be at the surface while the surveyors are close enough to have a chance of detecting the animal, was calculated for each whale species (as in Thomas et al. 2002). For beluga whales, the $g_a(0)$=0.58 was calculated from data in Martin and Smith (1992), and for bowhead whales, the $g_a(0)$=0.144 was taken from Thomas et al. (2002). The $g_a(0)$=0.32 for migrating gray whales was taken from Forney and Barlow (1998), and $g_a(0)$=0.292 for feeding gray whales was calculated from data in Würsig et al. (1986).

The number of cetaceans present was estimated for each survey. For the coastline surveys, we calculated the number of cetaceans within an area of 2240 km^2, which covered the coastline out to 4 km, to determine how many whales were close to shore. For the sawtooth surveys, we calculated the number of whales within an area of 19,022 km^2, which encompassed the entire survey area. A weighted mean, confidence intervals and standard error were calculated for the early, mid- and late season surveys to estimate abundance for the three cetacean species in the survey area during each season. Confidence intervals and standard error were calculated using a "bootstrap" resampling method. However, sample sizes were low and estimates of cetacean numbers within the survey area should be viewed with caution.

Distances from Shore and Seasonal Occurrence—We further examined the distribution of whales by dividing the survey area into a series of strips, each 10 km wide, oriented roughly parallel to the coast. This allowed a more detailed examination of the distribution and abundance of the whales in the survey area relative to the shore. We combined the two regions (coastline and sawtooth) to get a better overall view of the whale distribution. These analyses were restricted to useable data to allow meaningful calculations of sightings and individuals per unit effort during different parts of the season. Thus, "zero" sightings or individuals in a particular strip signifies that there were no sightings during conditions suitable for systematic aerial surveys, not necessarily that there were no sightings in those strips. Given the irregularities in the coastline, and the presence of islands along some parts of the coast, a "0 km from shore" reference point was established. Waters inshore of the "0 km" line are shallow nearshore waters, in some cases inside lagoons. Thus the first distance-from-shore band (also referred to as –5 km band) represented the area inshore of the "0 km" line out to 5 km offshore, resulting in this band being less than 10 km wide at times. The last distance-from-shore band located 35-40 km offshore was only 5 km wide, resulting in limited survey effort in this band. Similarly, we examined the relative abundance of whales in the survey area by monthly periods from July to November to determine seasonal changes in abundance.

Behavior— Marine mammal habitat use and movement in the survey area were assessed by the behavior, swimming speeds, and headings of the whales during all surveys, including useable and non-useable data, and off-transect sightings. To calculate the angular deviations of the heading, we used the Methods of Batschelet (1981) were used to calculate angular deviations of headings.

Results

Coastline Surveys

Ice Cover—From July to mid-Sept. 2006, pack ice was always present within some portion of the survey area. The southern portion of the survey area from Wainwright to Point Hope was ice free by 22 Aug., and by 21 Sept. the entire survey area was ice free, except for a few areas which had < 5 % ice cover. By 25 Oct. ice had started to form along the coast in the northern portion of the survey area around Barrow, and by 12 Nov. shore ice was present from Barrow to south of Point Lay.

Survey Effort—Table 5.1 summarizes the aerial survey effort and whale sightings for each coastal survey that produced useable data. A total of 8781 km of coastline transects were flown in useable conditions (Table 5.1, Appendix Table D.1). This included 14, 7, and 4 surveys in the early, mid-, and late seasons, respectively. Daily aerial survey effort and whale sightings during the aerial surveys are summarized in Appendix Table D.1 (all surveys, including useable and non-useable data). Appendix D contains daily aerial survey maps showing the coastline transects surveyed each day and the whale sightings (Fig. D.1 – D.13).

Total or partial aerial survey coverage of the coastline was obtained on 25 surveys (during 37 days) during the 9 July to 12 Nov. study period. All or most of the survey was completed on 18 occasions. Substantially reduced coverage of the survey area was obtained during seven surveys due to low clouds, precipitation, high sea conditions, or some combination of those factors.

Sighting Rates—Seasonal sighting rates were determined for each species, using useable data (Table 5.1, 5.2). Useable sightings of beluga whales were made on 20% (five of 25 surveys) of the coastline surveys. The lowest beluga whale sighting rate occurred during the mid-season (0.05 sightings/100 km of survey), and the sighting rate was similar during the early (0.18 sightings/100 km) and late (0.20 sightings/100 km) seasons; Table 5.1). Although the number of individual beluga whales during the early season (6.13 whales/100 km) was greater than that of other species (Table 5.1), this was almost entirely due to a single group of 295 beluga whales (320 individuals) seen on the first day of surveying. Beluga whales were generally seen in small groups.

TABLE 5.1. Whale sightings and sighting rates during coastline aerial surveys in the eastern Chukchi Sea, 2006, divided into early, mid-, and late season (non-useable data excluded).

			Beluga Whale				Bowhead Whale				Gray Whale			
Date in 2006	Survey No.	Transect km	Sightings	Individuals	Sight. /100 km	Indiv. /100 km	Sightings	Individuals	Sight. /100 km	Indiv. /100 km	Sightings	Individuals	Sight. /100 km	Indiv. /100 km
Early Season														
9-10 Jul	1	378	8	320	2.12	84.65	0	0	0.00	0.00	0	0	0.00	0.00
15-Jul	2	346	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
18-Jul	3	292	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
20-Jul	4	172	0	0	0.00	0.00	4	4	2.33	2.33	0	0	0.00	0.00
23-24 Jul	5	674	3	8	0.45	1.19	0	0	0.00	0.00	3	3	0.45	0.45
25-Jul	6	522	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.19	0.19
No Surveys	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Aug	7	264	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.38	0.38
28-30 Aug	8	140	0	0	0.00	0.00	0	0	0.00	0.00	2	2	1.43	1.43
31 Aug-1 Sept	9	534	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.19	0.19
3-Sep	10	300	0	0	0.00	0.00	1	1	0.33	0.33	0	0	0.00	0.00
5-6 Sept	11	390	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
11-12 Sept	12	350	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.29	0.29
14-15 Sept	13	570	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
21-23 Sept	14	252	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
Mean					**0.18**	**6.13**			**0.19**	**0.19**			**0.21**	**0.21**
Mid Season														
25-Sep	15	436	0	0	0.00	0.00	0	0	0.00	0.00	3	3	0.69	0.69
30 Sept-2 Oct	16	343	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.29	0.29
6-Oct	17	277	1	1	0.36	0.36	0	0	0.00	0.00	0	0	0.00	0.00
11-Oct	18	230	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
14-15 Oct	19	287	0	0	0.00	0.00	0	0	0.00	0.00	1	2	0.35	0.70
18-20 Oct	20	500	0	0	0.00	0.00	1	1	0.20	0.20	2	2	0.40	0.40
21-23 Oct	21	353	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.28	0.28
Mean					**0.05**	**0.05**			**0.03**	**0.03**			**0.29**	**0.34**
Late Season														
25-26 Oct	22	355	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
29-31 Oct	23	287	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
7-9 Nov	24	338	1	1	0.30	0.30	0	0	0.00	0.00	0	0	0.00	0.00
11-12 Nov	25	194	1	2	0.52	1.03	1	1	0.52	0.52	0	0	0.00	0.00
Mean					**0.20**	**0.33**			**0.13**	**0.13**			**0.00**	**0.00**

Useable sightings of bowhead whales were made on 16% (four of 25 surveys) of the coastline surveys. The lowest bowhead whale sighting rate occurred during the mid-season (0.03 sightings/100 km of survey) and their highest sighting rate occurred during the early season (0.19 sightings/100 km of survey; Table 5.1). Bowheads were generally seen singly or in pairs, but on 25 Oct. a group of 26 feeding bowhead whales was seen off transect east of Point Barrow.

Gray whales were the most consistently observed whale species, and useable sightings were made on 44% (11 of 25 surveys) of the coastline surveys. The lowest gray whale sighting rate occurred during the late season (0.00 gray whales/100 km of survey), and their highest sighting rate occurred during the mid-season (0.29 sightings/100 km of survey; Table 5.1). Gray whales were generally seen as single animals.

Useable sightings of walruses were made on 20% (five of 25 surveys) of the coastline surveys. The highest walrus sighting rate occurred during the early season (0.26 sightings/100 km, and 0.91 individuals/100 km of survey; Table 5.2). Sighting rates dropped to zero during the mid-season, and then increased by the late season to 0.07 sightings/100 km of survey (Table 5.2). Walruses were generally seen in small groups along the coastline, with the largest group seen on 9 July (9 individuals).

TABLE 5.2. Walrus sightings and sighting rates during coastline and sawtooth aerial surveys in the eastern Chukchi Sea, 2006, divided into early, mid-, and late season (non-useable data excluded).

		A. Walrus Coastline Surveys					B. Walrus Sawtooth Surveys				
Date in 2006	Survey No.	Transect km	Sightings	Individuals	Sight. /100 km	Indiv. /100 km	Transect km	Sightings	Individuals	Sight. /100 km	Indiv. /100 km
Early Season											
9-10 Jul	1	350	1	9	0.29	2.57	538	16	305	2.97	56.66
15-Jul	2	340	0	0	0.00	0.00	492	19	321	3.86	65.20
18-Jul	3	194	0	0	0.00	0.00	138	2	4	1.45	2.89
20-Jul	4	172	1	4	0.58	2.33	419	12	955	2.86	227.67
23-24 Jul	5	551	4	7	0.73	1.27	644	47	114	7.29	17.69
25-Jul	6	470	1	1	0.21	0.21	745	14	21	1.88	2.82
No Surveys	-	-	-	-	-	-	-	-	-	-	-
23-Aug	7	260	0	0	0.00	0.00	391	0	0	0.00	0.00
Mean					**0.26**	**0.91**				**2.90**	**53.28**
Mid Season											
28-30 Aug	8	59	0	0	0.00	0.00	438	2	2	0.46	0.46
31 Aug-1 Sept	9	195	0	0	0.00	0.00	227	0	0	0.00	0.00
3-Sep	10	169	0	0	0.00	0.00	217	0	0	0.00	0.00
5-6 Sept	11	342	0	0	0.00	0.00	423	2	22	0.47	5.20
11-12 Sept	12	251	0	0	0.00	0.00	200	0	0	0.00	0.00
14-15 Sept	13	559	0	0	0.00	0.00	772	0	0	0.00	0.00
21-23 Sept	14	120	0	0	0.00	0.00	272	1	1	0.37	0.37
24-25 Sept	15	118	0	0	0.00	0.00	505	2	13	0.40	2.57
30 Sept-2 Oct	16	287	0	0	0.00	0.00	806	2	12	0.25	1.49
6-Oct	17	217	0	0	0.00	0.00	329	0	0	0.00	0.00
Mean					**0.00**	**0.00**				**0.19**	**1.01**
Late Season											
11-Oct	18	42	0	0	0.00	0.00	14	0	0	0.00	0.00
14-15 Oct	19	104	0	0	0.00	0.00	200	0	0	0.00	0.00
18-20 Oct	20	374	2	2	0.54	0.54	376	1	2	0.27	0.53
21-23 Oct	21	232	0	0	0.00	0.00	267	0	0	0.00	0.00
25-26 Oct	22	205	0	0	0.00	0.00	180	0	0	0.00	0.00
29-31 Oct	23	140	0	0	0.00	0.00	87	0	0	0.00	0.00
7-9 Nov	24	229	0	0	0.00	0.00	227	0	0	0.00	0.00
11-12 Nov	25	99	0	0	0.00	0.00	445	0	0	0.00	0.00
Mean					**0.07**	**0.07**				**0.03**	**0.07**

Abundance—The numbers of whales present during the early, mid-, and late season surveys were estimated for the coastal area consisting of a 4-km band adjacent to the coastline. The estimates were based on all surveys, each of which was flown on one or two consecutive days during the 2006 field season (Table

5.3). The estimates were calculated at the request of some stakeholders. Sample sizes used to calculate abundance estimates were low and the abundance estimates should be viewed with caution.

TABLE 5.3. Estimated numbers of whales near the coastline in the eastern Chukchi Sea survey area, based on Jul.-Nov. surveys, including allowance for $f(0)$, and $g_a(0)$ correction factors.

			Beluga Whale					Bowhead Whale					Gray Whale				
Date in 2006	Survey No.	Effort (km)	Individuals[a]	Est. No. /100 km[b]	S.E.[b]	Est. No. Whales[b]	S.E.[b]	Individuals[a]	Est. No. /100 km[b]	S.E.[b]	Est. No. Whales[b]	S.E.[b]	Individuals[a]	Est. No. /100 km[b]	S.E.[b]	Est. No. Whales[b]	S.E.[b]
Early Season																	
9-Jul	1	378	307	9.49	3.39	508[c]	-	0			0		0			0	
15-Jul	2	346	0			0		0			0		0			0	
18-Jul	3	292	0			0		0			0		0			0	
20-Jul	4	172	0			0		3	7.25	7.27	162	162	0			0	
23-24 Jul	5	674	1	0.74	0.75	17	17	0			0		2	0.99	1.00	22	22
25-Jul	6	522	0			0		0			0		1	0.64	0.64	14	14
23-Aug	7	263	0			0		0			0		1	1.03	1.03	23	23
28-30 Aug	8	139	0			0		0			0		0			0	
31-Aug	9	534	0			0		0			0		0			0	
3-Sep	10	300	0			0		1	1.21	1.21	27	27	0			0	
5-6 Sept	11	390	0			0		0			0		0			0	
11-12 Sept	12	350	0			0		0			0		0			0	
14-Sep	13	570	0			0		0			0		0			0	
21-23 Sept	14	251	0			0		0			0		0			0	
Weighted Mean		(n=14)				**47**	**9**				**8**	**2**				**6**	**1**
Mid Season																	
25-Sep	15	436	0			0		0			0		3	1.87	0.66	42	15
30 Sept-2 Oct	16	343	0			0		0			0		0			0	
6-Oct	17	277	1	0.44	0.45	10	10	0			0		0			0	
11-Oct	18	230	0			0		0			0		0			0	
14-Oct	19	287	0			0		0			0		2	2.11	2.13	47	47
18-20 Oct	20	500	0			0		1	0.73	0.73	16	16	0			0	
21-23 Oct	21	353	0			0		0			0		0			0	
Weighted Mean		(n=7)				**1**	**0**				**4**	**1**				**14**	**3**
Late Season																	
25-26 Oct	22	355	0			0		0			0		0			0	
29-31 Oct	23	287	0			0		0			0		0			0	
7-Nov	24	338	1	0.36	0.37	8	8	0			0		0			0	
11-12 Nov	25	193	2	1.25	1.29	28	29	1	1.87	1.87	42	42	0			0	
Weighted Mean		(n=4)				**8**	**2**				**8**	**4**				**0**	**0**

[a] Excludes sightings between trackline and inner truncation distance (100-450 m, depending on aircraft altitude and type); also excludes sightings beyond outer truncation distance (1000-2000 m, depending on aircraft altitude, sea conditions, ice cover and species).
[b] Calculated by the DISTANCE program including use of $f(0)$ and $ga(0)$ correction factors to correct for submerged whales.
[c] This includes one sighting of 295 belugas. Other large groups of this size along the coast likely would not have been missed; therefore, this sighting of 295 belugas was added to the estimate produced from the other 12 scattered sightings (213 belugas as determined from the DISTANCE program) to give an estimate of 508 belugas for coastal areas on 9 Jul.

During the early season, the estimated numbers of beluga whales in the coastal area ranged from zero (on twelve surveys) to 508 (on 9 July 2006), with a weighted mean of 47 beluga whales (CV = 0.75; 95% CI = 0 to 120). In the mid-season, the estimated numbers of beluga whales in the coastal area ranged from zero (on six surveys) to 10 (on 6 Oct. 2006), with a mean of 1 beluga whale (CV = 0.90; 95% CI = 0 to 4). During the late-season, the estimated numbers of beluga whales in the coastal area ranged from zero (on two surveys) to 28 (on 11-12 Nov. 2006), with a mean of 8 beluga whales (CV = 0.57; 95% CI = 0 to 19).

The estimated number of bowhead whales in the coastal area in the early season ranged from 0 (on 12 surveys) to 162 (on 20 Jul. 2006), with a mean of 8 bowhead whales (CV = 0.69; 95% CI = 0 to 20). In the mid-season, bowhead whale abundance estimates ranged from 0 (on six surveys) to 16 (on 18-20 Oct. 2006), with a mean of 4 bowhead whales (CV = 0.75; 95% CI = 0 to 9). During the late-season, the estimated numbers of bowhead whales in the coastal area ranged from zero (on three surveys) to 42 (on 11-12 Nov. 2006), with a mean of 8 bowhead whales (CV = 0.89; 95% CI = 0 to 27).

The estimated number of gray whales in the coastal area during the early season ranged from 0 (on 11 surveys) to 23 (on 23 Aug. 2006), with a mean of 6 gray whales (CV = 0.43; 95% CI = 0 to 11). In the mid-season, the estimated numbers of gray whales within the coastal area ranged from 0 (on five surveys) to 47 (on 14 Oct. 2006), with a mean of 14 gray whales (CV = 0.53; 95% CI = 0 to 30). During the late season, the estimated number of gray whales within the coastal area was 0 for all four of the surveys.

Sawtooth Surveys

Ice Cover—Ice-cover conditions are described above in the section on coastline surveys.

Survey Effort—Table 5.4 summarizes the useable effort and whale sightings for each sawtooth aerial survey. A total of 14,385 km of sawtooth transects was flown in useable conditions. Daily aerial survey effort and whale sightings are summarized in Appendix Table D.2 (all surveys, including useable and non-useable data). Appendix D contains aerial survey maps showing the whale sightings and transects covered for each survey, and the locations of useable and non-useable coverage and sightings (Fig. D.1 – D.13).

Sighting Rates— Useable sightings of beluga whales were made on 36% (nine of 25 surveys) of the sawtooth surveys. The lowest mean sighting rates of beluga whales occurred during the mid- and early seasons (Table 5.4), and the highest mean sighting rate occurred during the late season (0.27 signtings/100 km; Table 5.4). The highest single-survey sighting rate occurred during the early season (0.72 sightings/100 km; Table 5.4). Beluga whales were seen in group sizes of 1 to 5, with a group size of one being the most common.

Bowhead whales were observed under useable conditions on 32% (eight of 25 surveys) of the sawtooth surveys. The lowest mean sighting rate of bowhead whales occurred during the early season (0.04 sightings/100 km of survey), and the highest occurred during the late season (0.54 sightings/100 km; Table 5.4). The highest single-survey sighting rate occurred during the late season (1.43 sightings/100 km; Table 5.4). Bowhead whales were seen in group sizes of 1 to 5, with a group size of one being the most common.

Gray whales were the most consistently observed whale species, and useable sightings were made on 44% (11 of 25 surveys) of the sawtooth surveys. The lowest mean sighting rate of gray whales occurred during the late season when no gray whales were seen, and the highest sighting rate occurred during the early season (0.18 sightings/100 km of survey; Table 5.4). The highest single survey sighting rate occurred during the early season (0.72 signtings/100 km of survey; Table 5.4). Gray whales were seen in group sizes of 1 to 3, with a group size of one being the most common.

Useable sightings of walruses were made on 48% (12 of 25 surveys) of the sawtooth surveys. The lowest mean sighting rate of walruses occurred during the late season (0.03 sightings/100 km of survey), and the highest sighting rate occurred during the early season (2.90 sightings/100 km; Table 5.2). The highest single-survey sighting rate occurred during the early season (7.29 sightings/100 km; Table 5.2). Walruses were generally seen in large groups, with the largest group seen on 20 July (444 individuals), and the mean group size during the sawtooth surveys was 15 individuals.

TABLE 5.4. Whale sightings and sighting rates during sawtooth aerial surveys, 2006, divided into early, mid-, and late season (non-useable data excluded).

			Beluga Whale				Bowhead Whale				Gray Whale			
Date in 2006	Survey No.	Transect km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km
Early Season														
9-10 Jul	1	552	4	10	0.72	1.81	0	0	0.00	0.00	4	6	0.72	1.09
15-Jul	2	611	3	8	0.49	1.31	1	1	0.16	0.16	1	1	0.16	0.16
18-Jul	3	236	0	0	0.00	0.00	0	0	0.00	0.00	1	2	0.42	0.85
20-Jul	4	476	0	0	0.00	0.00	1	1	0.21	0.21	1	1	0.21	0.21
23-24 Jul	5	786	0	0	0.00	0.00	0	0	0.00	0.00	2	4	0.25	0.51
25-Jul	6	760	0	0	0.00	0.00	0	0	0.00	0.00	3	4	0.39	0.53
No Surveys	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Aug	7	448	0	0	0.00	0.00	0	0	0.00	0.00	1	3	0.22	0.67
28-30 Aug	8	505	1	1	0.20	0.20	0	0	0.00	0.00	0	0	0.00	0.00
31 Aug-1 Sept	9	598	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
3-Sep	10	302	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
5-6 Sept	11	509	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
11-12 Sept	12	405	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
14-15 Sept	13	861	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
21-23 Sept	14	666	1	1	0.15	0.15	2	2	0.30	0.30	1	2	0.15	0.30
24-25 Sept	15	894	4	4	0.45	0.45	0	0	0.00	0.00	2	2	0.22	0.22
Mean					**0.13**	**0.26**			**0.04**	**0.04**			**0.18**	**0.30**
Mid Season														
30 Sept-2 Oct	16	840	0	0	0.00	0.00	1	1	0.12	0.12	0	0	0.00	0.00
6-Oct	17	596	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.17	0.17
11-Oct	18	217	1	1	0.46	0.46	1	1	0.46	0.46	0	0	0.00	0.00
14-15 Oct	19	598	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
18-20 Oct	20	658	1	5	0.15	0.76	0	0	0.00	0.00	0	0	0.00	0.00
21-23 Oct	21	751	0	0	0.00	0.00	1	1	0.13	0.13	1	1	0.13	0.13
Mean					**0.10**	**0.20**			**0.12**	**0.12**			**0.05**	**0.05**
Late Season														
25-26 Oct	22	529	5	5	0.95	0.95	0	0	0.00	0.00	0	0	0.00	0.00
29-31 Oct	23	621	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
7-9 Nov	24	268	0	0	0.00	0.00	2	2	0.75	0.75	0	0	0.00	0.00
11-12 Nov	25	700	1	5	0.14	0.71	10	16	1.43	2.29	0	0	0.00	0.00
Mean					**0.27**	**0.42**			**0.54**	**0.76**			**0.00**	**0.00**

Abundance—The numbers of whales present in the Chukchi Sea survey area during the early, mid-, and late season surveys were estimated for the 19,022 km^2 of nearshore waters covered by the sawtooth surveys. The estimates were based on all surveys, each of which was flown on one to three consecutive days during the 2006 field season (Table 5.5).

During the early season, the estimated number of beluga whales within the survey area ranged from 0 (on ten surveys) to 1131 (on 10 July 2006), with a mean of 158 beluga whales (CV = 0.47; 95% CI = 13 to 312). In the mid-season, the estimated number of beluga whales within the survey area ranged from 0 (on five surveys) to 413 (on 18-20 Oct. 2006), with a mean of 79 beluga whales (CV = 0.87; 95% CI = 0 to 230). During the late season, the estimated number of beluga whales ranged from 0 (on two surveys) to 389 (on 11-12 Nov. 2006), with a mean of 251 beluga whales (CV = 0.39; 95% CI = 0 to 378).

The estimated number of bowhead whales within the survey area in the early season ranged from 0 (on 13 surveys) to 216 (on 21-23 Sept. 2006), with a mean of 31 bowhead whales (CV = 0.59; 95% CI = 0 to 67). In the mid-season, bowhead whale abundance estimates ranged from 0 (on four surveys) to 318 (on 11 Oct. 2006), with a mean of 40 bowhead whales (CV = 0.67; 95% CI = 0 to 104). During the late season, the estimated number of bowhead whales ranged from 0 (on two surveys) to 1544 (on 11-12 Nov. 2006), with a mean of 662 bowhead whales (CV = 0.56; 95% CI = 0 to 1266).

The estimated number of gray whales within the nearshore survey area during the summer ranged from 0 (on nine surveys) to 602 (on 10 July 2006), with a mean of 151 gray whales (CV = 0.30; 95% CI = 46 to 224). In the mid-season, the estimated numbers of gray whales within the nearshore survey area ranged from zero (on five surveys) to 83 (on 6 Oct. 2006), with a mean of 14 gray whales (CV = 0.87; 95% CI = 0 to 43). During the late season, the estimated numbers of gray whales within the nearshore survey area was zero for all four of the surveys.

TABLE 5.5. Estimated numbers of whales in the eastern Chukchi Sea survey area, based on Jul.-Nov. surveys, including allowance for $f(0)$, and $g_a(0)$ correction factors.

			Beluga Whale					Bowhead Whale					Gray Whale				
Date in 2006	Survey No.	Effort (km)	Individuals[a]	Est. No. /100 km[b]	S.E.[b]	Est. No. Whales[b]	S.E.[b]	Individuals[a]	Est. No. /100 km[b]	S.E.[b]	Est. No. Whales[b]	S.E.[b]	Individuals[a]	Est. No. /100 km[b]	S.E.[b]	Est. No. Whales[b]	S.E.[b]
Early Season																	
10-Jul	1	552	7	5.95	4.54	1131	863	0			0		5	3.16	1.88	602	357
15-Jul	2	611	3	2.30	2.32	438	441	0			0		0			0	
18-Jul	3	236	0			0		0			0		0			0	
20-Jul	4	476	0			0		1	0.87	0.84	165	159	0			0	
23-24 Jul	5	786	0			0		0			0		3	1.56	1.69	296	322
25-Jul	6	760	0			0		0			0		2	1.01	0.77	192	146
23-Aug	7	447	0			0		0			0		3	1.82	1.69	345	322
28-30 Aug	8	505	1	0.57	0.54	109	102	0			0		0			0	
31 Aug-1 Sept	9	598	0			0		0			0		0			0	
3-Sep	10	302	0			0		0			0		0			0	
5-Sep	11	509	0			0		0			0		0			0	
11-12 Sept	12	404	0			0		0			0		0			0	
14-15 Sept	13	861	0			0		0			0		0			0	
21-23 Sept	14	666	1	0.29	0.26	56	49	2	1.13	0.96	216	184	2	0.94	1.11	178	210
24-Sep	15	894	4	0.91	0.42	173	79	0			0		2	0.61	0.40	116	76
Weighted Mean		(n=15)				**158**	**19**				**31**	**5**				**151**	**12**
Mid Season																	
30 Sept-2 Oct	16	840	0			0		0			0		0			0	
6-Oct	17	596	0			0		0			0		1	0.43	0.38	83	73
11-Oct	18	216	0			0		1	1.67	1.54	318	292	0			0	
14-15 Oct	19	598	0			0		0			0		0			0	
18-20 Oct	20	658	5	2.17	1.89	413	359	0			0		0			0	
21-23 Oct	21	751	0			0		1	0.48	0.45	92	85	0			0	
Weighted Mean		(n=6)				**79**	**28**				**40**	**11**				**14**	**5**
Late Season																	
25-26 Oct	22	529	5	1.91	0.86	364	165	0			0		0			0	
29-31 Oct	23	621	0			0		0			0		0			0	
7-9 Nov	24	267	0			0		2	2.83	2.43	538	462	0			0	
11-12 Nov	25	700	5	2.04	1.72	389	327	15	8.12	3.30	1544	629	0			0	
Weighted Mean		(n=4)				**251**	**49**				**662**	**186**				**0**	**0**

[a] Excludes sightings between trackline and inner truncation distance (100-450 m, depending on aircraft altitude and type); also excludes sightings beyond outer truncation distance (1000-2000 m, depending on aircraft altitude, sea conditions, ice cover and species).

[b] Calculated by the DISTANCE program including use of $f(0)$ and $ga(0)$ correction factors.

Coastline and Sawtooth Surveys

Distribution— Beluga whales were sighted throughout the survey area during the early, mid-, and late seasons, with most sightings occurring north of 69° N latitude (Figure 5.2). Beluga whales sighted during the study period were found between the 0 m and 50 m depth contours, although most of the survey area encompassed water depths between 5 m and 30 m (Figure 5.2).

Bowhead whales were found in the northern portion of the survey area during all three seasons, with all sightings occurring north of 70° N latitude (Figure 5.3). Bowheads sighted during the study period were found between the 10 m and 100 m depth contours (Figure 5.3).

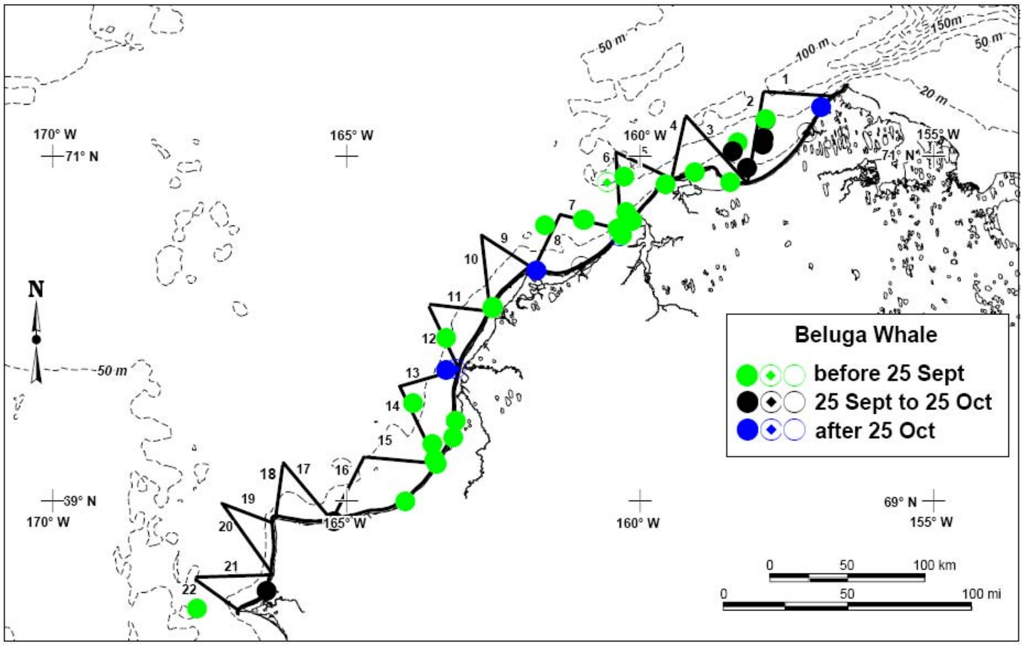

FIGURE 5.2. Locations of beluga whale sightings during aerial surveys in the eastern Chukchi Sea during July-Nov. of 2006. Solid symbols denote sightings during conditions when useable data were collected, open symbols containing a dot denote sightings during conditions when data were non-useable, and open symbols denote incidental sightings, including search and connect legs.

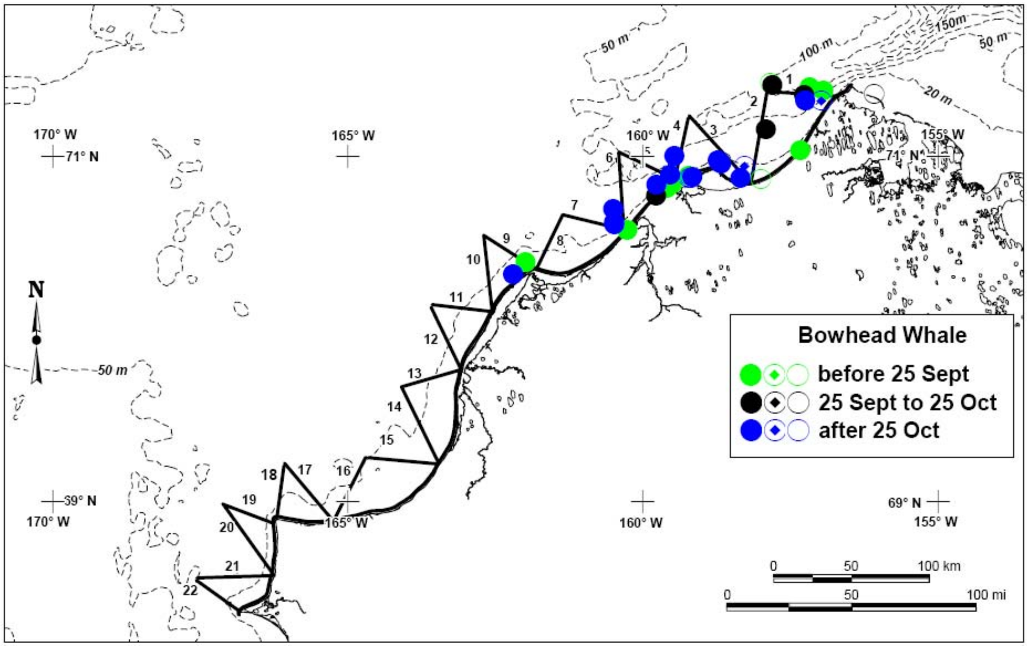

FIGURE 5.3. Locations of bowhead whale sightings during aerial surveys in the eastern Chukchi Sea during July-Nov. of 2006. See Fig. 5.2 for explanation of different symbols.

Gray whales were found in the central portion of the survey area during the early and mid- seasons, with most sightings occurring between Cape Lisburne (68°50' N latitude) and Icy Cape (70°20' N latitude; Figure 5.4). No gray whales were observed during the late season after 25 Oct. Nearly all gray whales were observed relatively near shore, between the 5 m and 20 m depth contours (Figure 5.4).

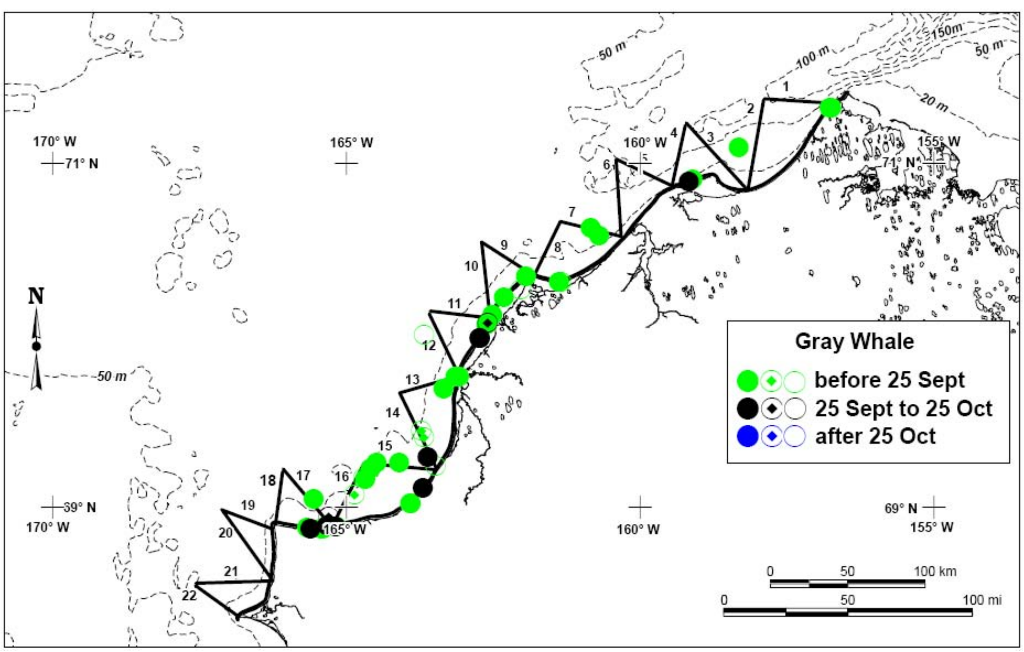

FIGURE 5.4. Locations of gray whale sightings during aerial surveys in the eastern Chukchi Sea during July-Oct. of 2006. See Fig. 5.2 for explanation of different symbols.

Most walruses were found in the central portion of the survey area during the early season (Figure 5.5), and were most often located in areas with ice floes. Of the 72 sightings of walruses for which behavior was recorded, 9 (12%) were observed hauled-out on ice floes.

Distances from Shore—Distance-from-shore data presented in this section are calculated only from useable data as defined earlier. Most of the coastline survey effort was within a single band (-5)–5 km from shore (Figure 5.6A). However, the sawtooth surveys had a relatively even distribution of survey effort between the 5 km and 35 km bands (Figure 5.6B). Sighting rates in each distance-from-shore category were calculated using effort values shown in Figure 5.6C.

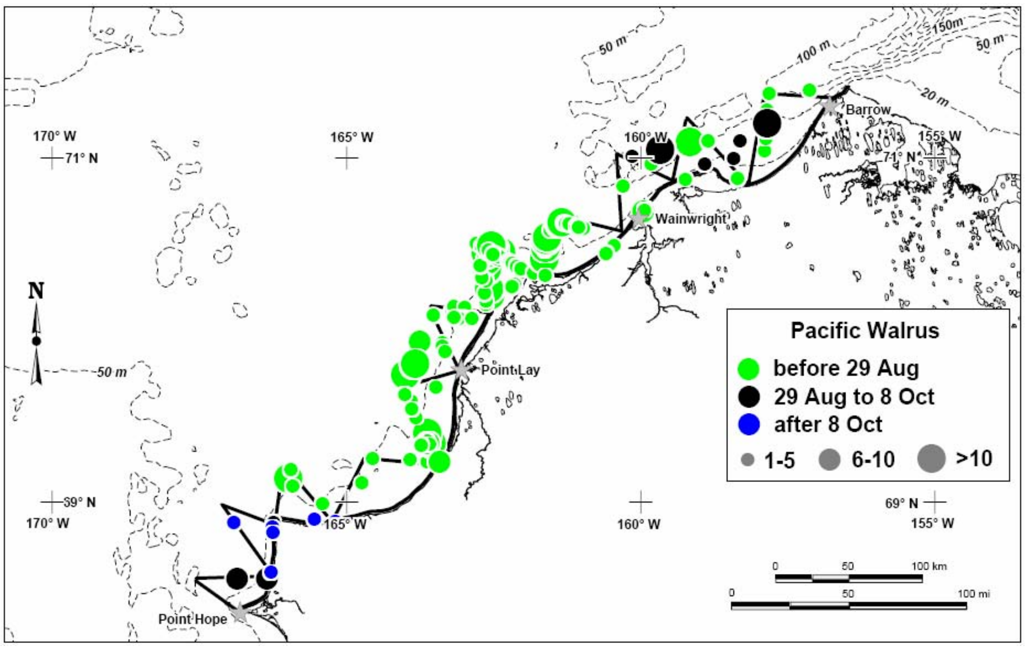

FIGURE 5.5. Locations of walrus sightings during aerial surveys in the eastern Chukchi Sea during July-Oct. of 2006, during all sighting conditions (useable, non-useable, and incidental).

Beluga whales had the greatest number of sightings (16) and individuals (342) in the band (-5)–5 km from shore (Figure 5.7A,B). The large number of individuals during the early season resulted primarily from observation of one group of 295 individuals. In Figure 5.7C,D, the same data have been converted to sightings or individuals per 100 km of aerial surveys based on survey effort data from Figure 5.6C. When adjusted for survey effort, the band 25–35 km from shore had the highest sighting rate (0.21 beluga whale sightings/100 km; Figure 5.7C), although the band (-5)–5 km from shore still had the highest counts of individuals with 3.27 belugas/100 km of survey because of large group sizes in the nearshore band (Figure 5.7D).

Bowhead whales had the greatest number of sightings (11) and individuals (17) in the band 5–15 km from shore (Figure 5.8A,B). Figure 5.8C,D, shows the numbers of sightings or individuals /100 km of aerial surveys based on survey effort data from Figure 5.6C. When adjusted for survey effort, bowhead sightings (0.25 sightings/100 km) and individuals (0.39 bowheads/100 km) were greatest in the 5–15 km from shore band (Figure 5.8C,D). However, the sample size was low and the increase in sighting rate and number of individuals in the 35-45 km band suggests that bowheads may have been more evenly distributed within the survey area than is suggested by data.

Gray whales had peak numbers of sightings (25) and individuals (33) in the band (-5)–5 km from shore (Figure 5.9A,B). When adjusted for survey effort, sightings (0.24 sightings/100 km) and individuals (0.32 gray whales/100 km) per 100 km of survey were still highest in the (-5)–5 km from shore band (Figure 5.9C,D).

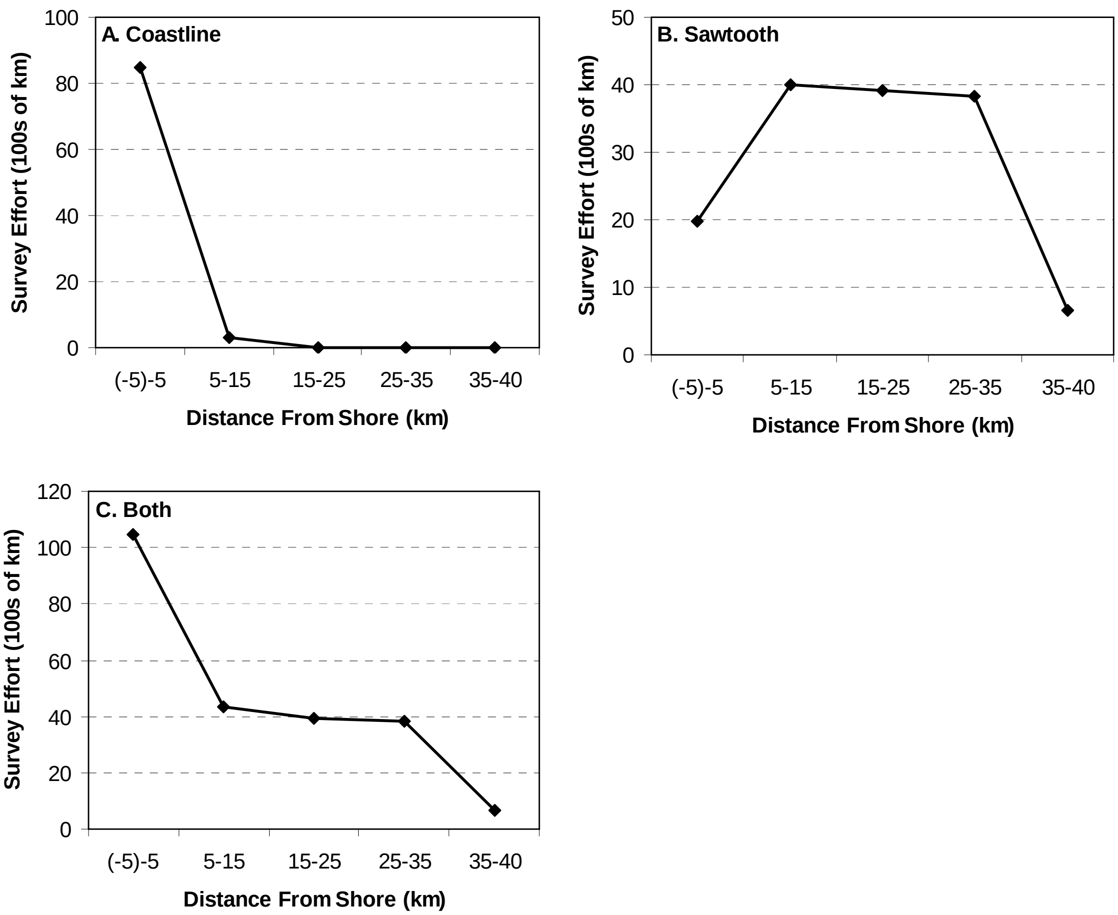

FIGURE 5.6. Aerial survey effort at various distances from shore of (**A**) coastline surveys, (**B**) sawtooth surveys, and (**C**) both coastline and sawtooth surveys, periods of non-useable data excluded. Based on aerial surveys in the Chukchi Sea, 9 Jul.-12 Nov. 2006.

Migration Timing—The seasonal timing of whale sightings during the study period was important in estimating the density of whales that were in the area at different times of the year. Survey coverage during the five-month period from July through November was highly variable, ranging from 1499 km in November to 7117 km in September (Fig. 5.10E).

Peak numbers of beluga whale sightings (18) and individuals (346) were recorded during July (Fig. 5.10A,B). When standardized for survey effort within the five-month period, the peak monthly rates (0.31 sightings/100 km and 5.96 individuals/100 km) were each recorded in July (Fig. 5.10C,D). However, standardized sighting rates show an increase in numbers from Aug. to Nov. (Fig. 5.10C).

Peak numbers of bowhead sightings (13) and individuals (19) were recorded during November (Fig. 5.11A,B). When standardized for survey effort within the five-month period, the peak rates (0.87 sightings/100 km and 1.27 individuals/100 km) were also recorded in November (Fig. 5.11C,D).

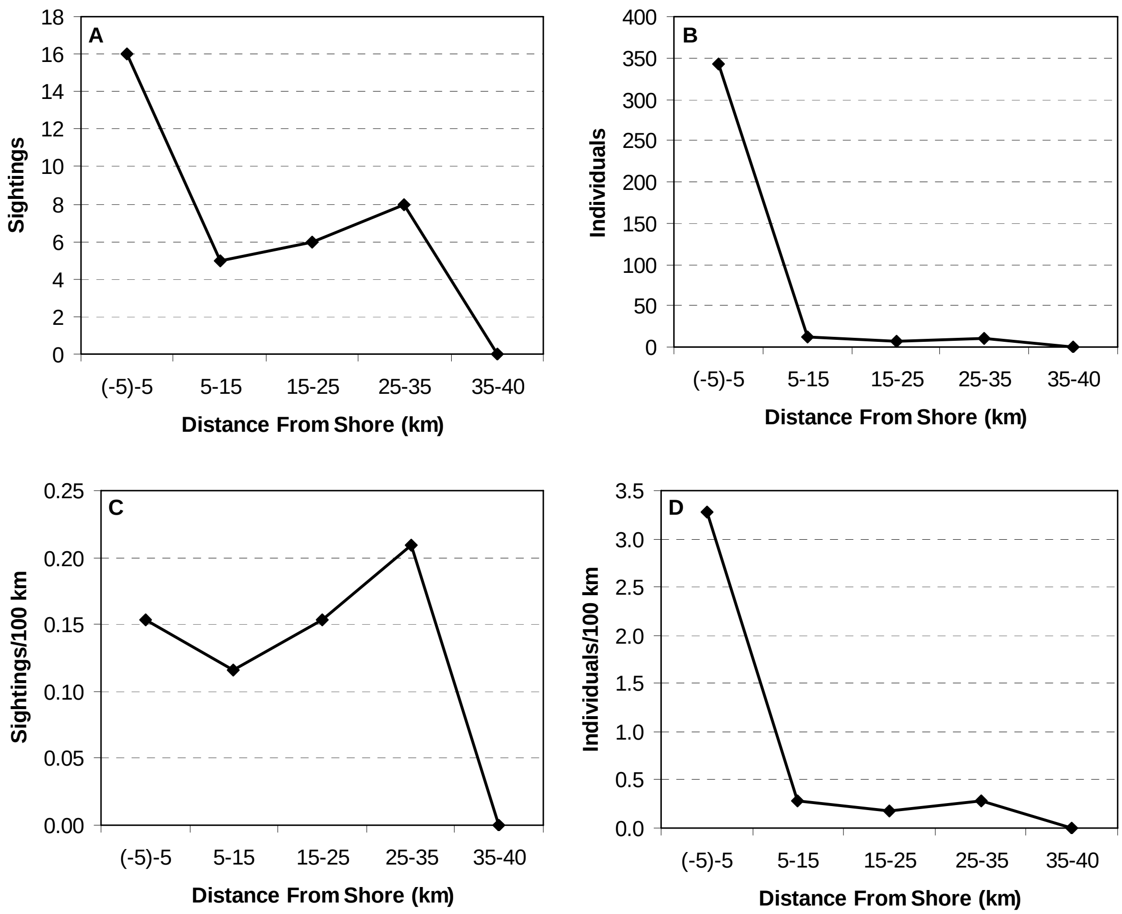

FIGURE 5.7. Distribution of beluga whales vs. distance from shore (10-km bands), excluding periods of non-useable data. Figures are based on aerial surveys of both the coastline and sawtooth transects in the Alaskan Chukchi Sea, 9 July to 12 Nov. 2006. (**A**) sightings and (**B**) individuals by distance from shore, and (**C**) sightings and (**D**) individuals per 100 km of survey effort. See Fig. 5.6C for survey effort vs. distance from shore.

Peak numbers of gray whale sightings (16) and individuals (22) were recorded during July (Fig. 5.12A,B). When standardized for survey effort within the five-month period that surveys were flown, the peak rates (0.28 sightings/100 km and 0.38 individuals/100 km) were also recorded in July (Fig. 5.12C,D).

***Behavior, Swimming Speeds, and Headings*—**The predominant behavior observed in beluga whales was traveling (21 of 30 (70%); Table 5.6). Of the six sightings of traveling whales with a swimming speed recorded, four (67%) were traveling at medium speed and two at slow speed.

The headings of 12 “traveling” individual beluga whales or beluga whale groups during the fall (Sept.-Nov.) consisted of a uniform distribution with no predominant direction observed (Figure 5.13). The vector mean heading was 342°T with an angular deviation of 82°T (p=0.22). Had our sample size been larger, we would have expected to see the mean vector heading in a southerly direction, coinciding with the fall migration of beluga whales. Sample size was too small to perform a valid test of directional trend for traveling beluga whales in the summer (July-Aug.).

The predominant behavior observed in bowhead whales was traveling. This behavior was recorded in 20 of 29 (69%) sightings (Table 5.6). Of the six sightings of traveling whales with a swimming speed recorded, three (50%) were traveling at medium speed and three at slow speed.

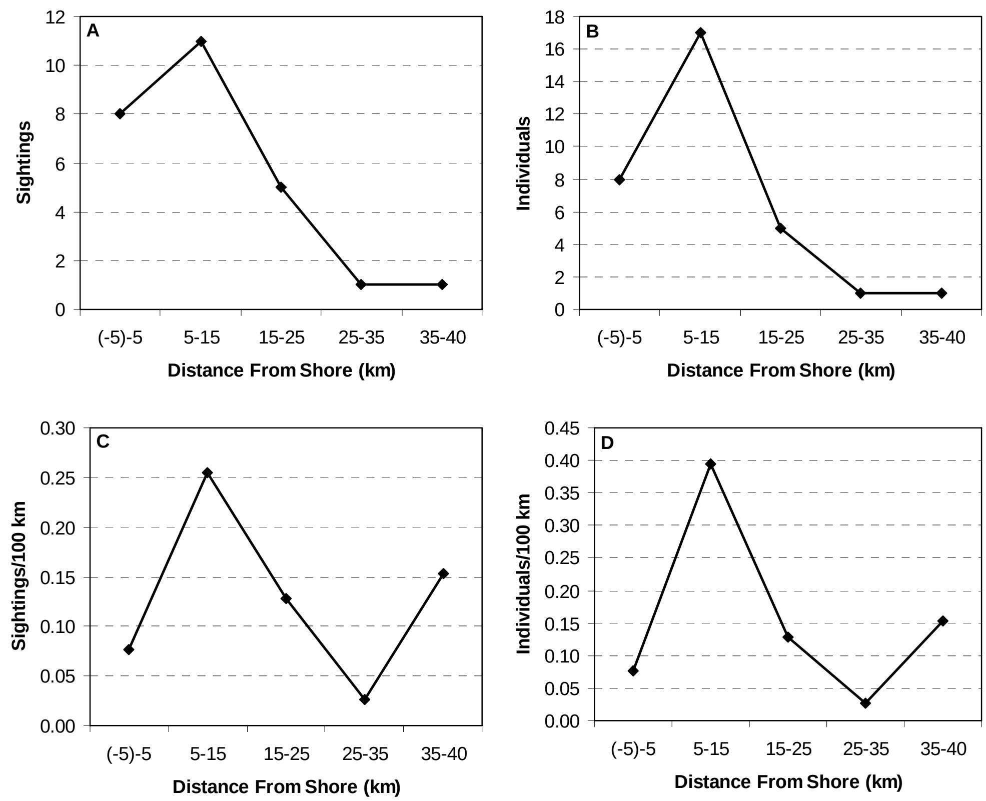

FIGURE 5.8. Distribution of bowhead whales vs. distance from shore (10-km bands), excluding periods of non-useable data. Figures are based on aerial surveys of both the coastline and sawtooth transects in the Alaskan Chukchi Sea, 9 July to 12 Nov. 2006. (**A**) sightings and (**B**) individuals by distance from shore, and (**C**) sightings and (**D**) individuals per 100 km of survey effort. See Fig. 5.6C for survey effort vs. distance from shore.

The headings of 17 “traveling” individual bowhead whales or bowhead whale groups during the fall (Sept.-Nov.) consisted of a uniform distribution with no predominant direction observed (Figure 5.13). The vector mean heading was 215°T with an angular deviation of 114°T (p=0.73). The paucity of bowhead sightings along nearshore transects suggests that the main migration corridor through the Chukchi Sea was farther offshore in an area not covered by our surveys. Had our surveys detected more bowheads, we would have expected to see the mean vector heading in a westerly or southwesterly direction. Because most of the bowhead whales observed in the summer were feeding, and only one was observed traveling, sample size was too small to perform a test of directional trend for traveling bowhead whales in the summer (July-Aug.).

The predominant behavior observed in gray whales was feeding. This behavior was recorded in 14 of 25 (56%) sightings (Table 5.6). Sample size was too small to perform a test of directional trend on traveling gray whales in the summer or fall.

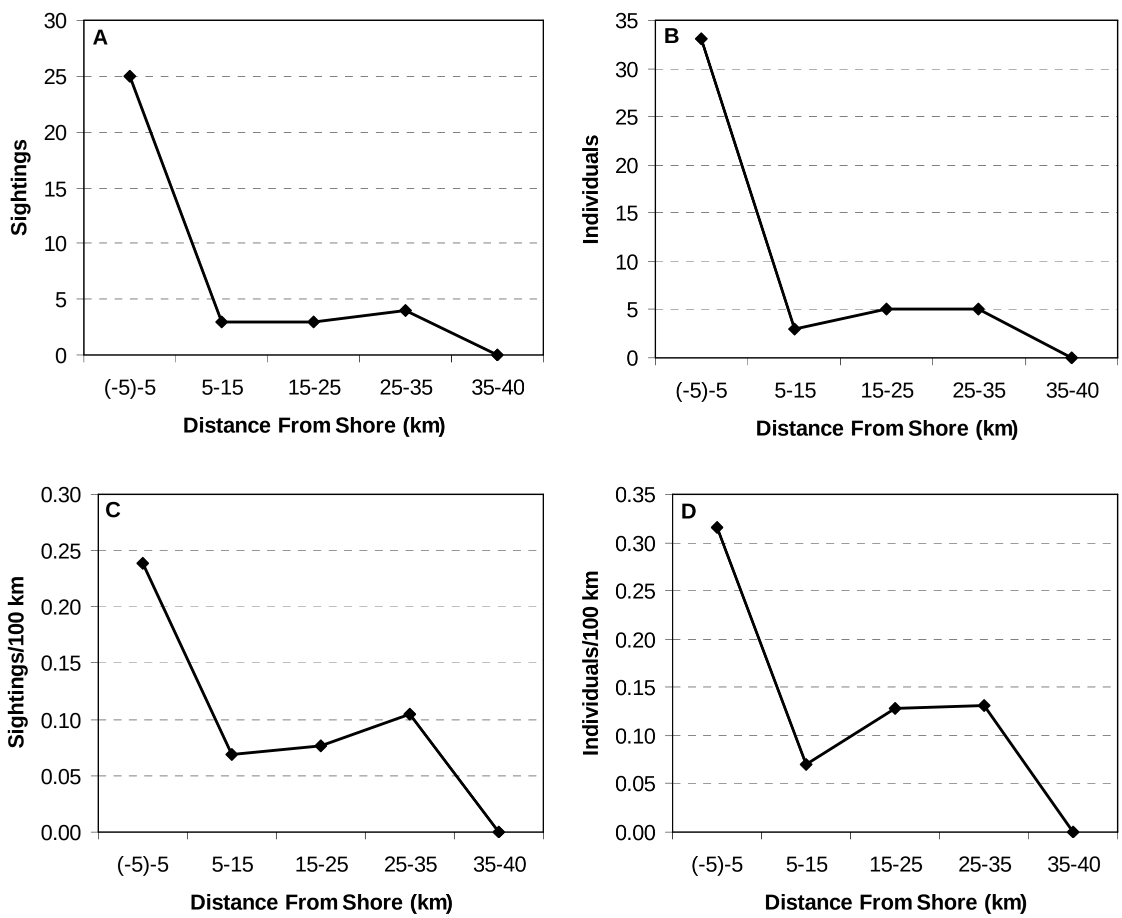

FIGURE 5.9. Distribution of gray whales vs. distance from shore (10-km bands), excluding periods of non-useable data. Figures are based on aerial surveys of both the coastline and sawtooth transects in the Alaskan Chukchi Sea, 9 July to 12 Nov. 2006. (**A**,) sightings and (**B**) individuals by distance from shore, and (**C**) sightings and (**D**) individuals per 100 km of survey effort. See Fig. 5.6C for survey effort vs. distance from shore.

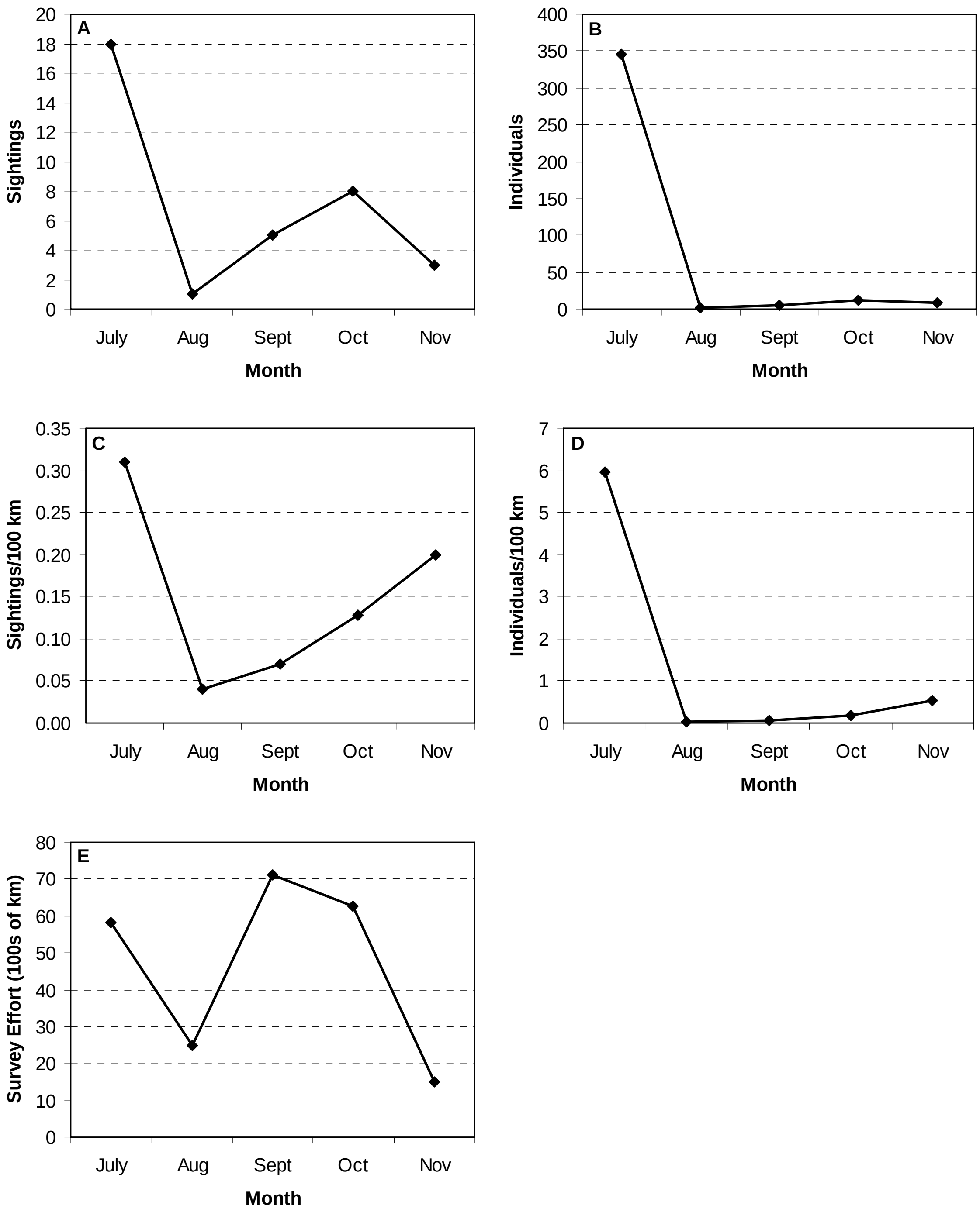

FIGURE 5.10. Seasonal pattern of beluga whales in 2006, excluding non-useable data based on aerial surveys in the Chukchi Sea during summer and autumn. Includes (**A**) sightings and (**B**) individuals by monthly periods, (**C**) sightings and (**D**) individuals per 100 km of survey effort, and (**E**) survey effort, in 100s of km.

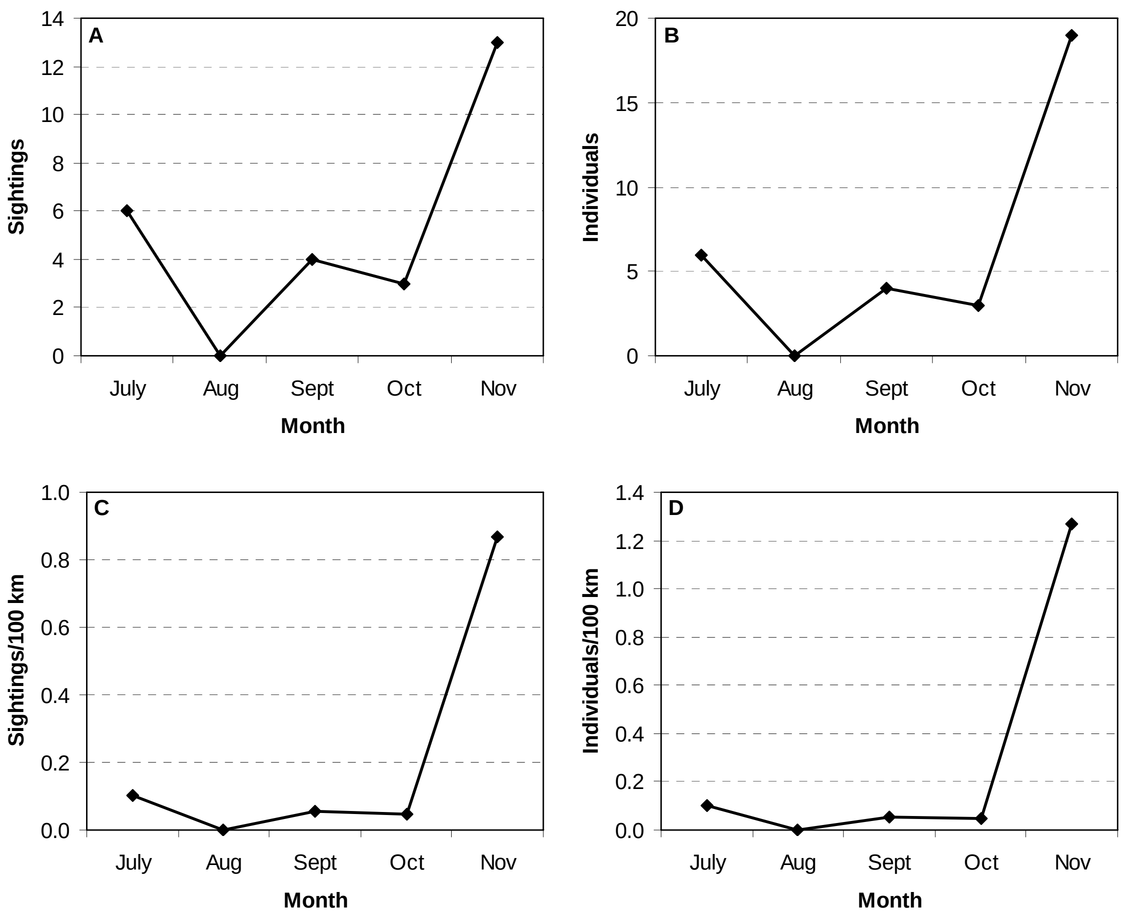

FIGURE 5.11. Seasonal pattern of bowhead whales in 2006, excluding non-useable data based on aerial surveys in the Chukchi Sea during summer and autumn. Includes (**A**) sightings and (**B**) individuals by monthly periods, (**C**) sightings and (**D**) individuals per 100 km of survey effort. See Fig. 5.10E for survey effort vs. distance from shore.

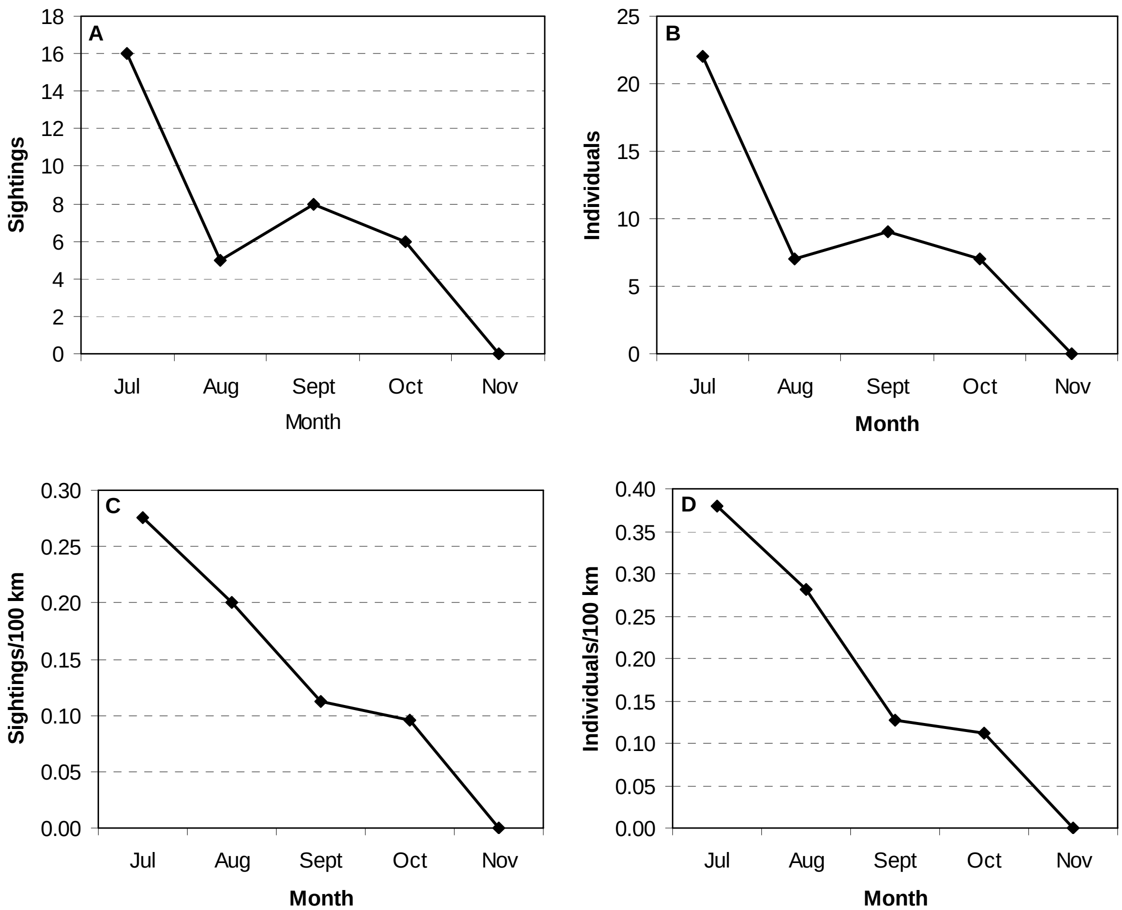

FIGURE 5.12. Seasonal pattern of gray whales in 2006, excluding non-useable data based on aerial surveys in the Chukchi Sea during summer and autumn. Includes (**A**) sightings and (**B**) individuals by monthly periods, (**C**) sightings and (**D**) individuals per 100 km of survey effort. See Fig. 5.10E for survey effort vs. distance from shore.

TABLE 5.6. Summary of whale sighting behaviors in the Alaskan Chukchi Sea during aerial surveys, including useable and non-useable data and off-transect sighting.

	Number of Sightings					
	Beluga Whale		Bowhead Whale		Gray Whale	
Behav.	n	%	n	%	n	%
Feed	4	13	5	17	14	56
Travel	21	70	20	69	8	32
Rest	4	13	3	10	2	8
Mill	1	3	1	3	1	4
Total	30	100	29	100	25	100

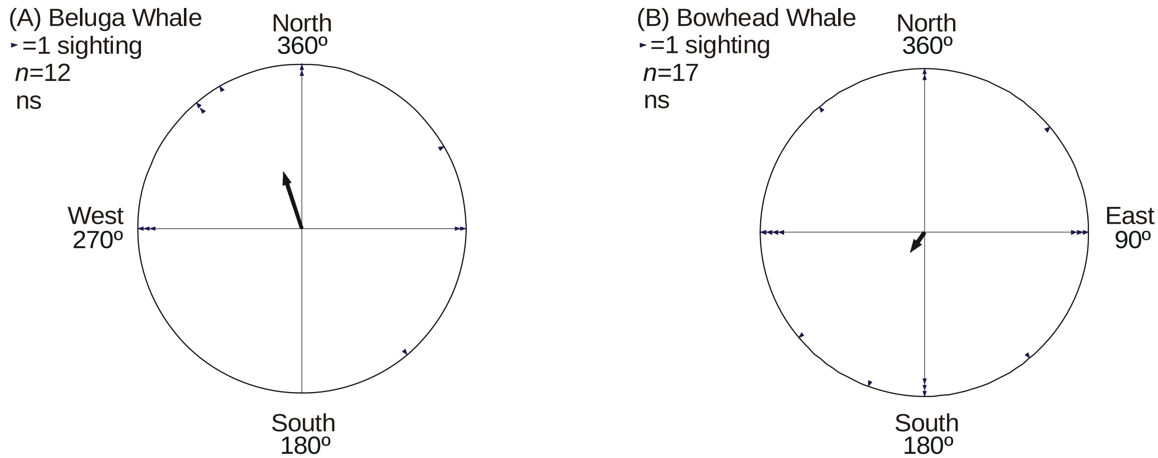

FIGURE 5.13. Headings of "traveling" whales in the Alaskan Chukchi survey area during the fall, Sept. to Nov. 2006, comparing (A) beluga whales, and (B) bowhead whales. Figures are based on sightings during aerial surveys, including useable, non-useable, and off-transect sightings; each sighting counted once regardless of the number of whales in the group.

Summary

Sighting rates and numbers of individual beluga whales recorded during the coastline surveys were greatest during the early season, followed by the late and mid-seasons, respectively. Most beluga whales winter in the Bering Sea and migrate north through the Chukchi Sea in the spring and on to summer feeding grounds in the Canadian Beaufort Sea before returning to the Chukchi Sea in the fall. Moore et al. (1993) reported migrating beluga whales along the Chukchi Sea coast in April and May. Some beluga whales also congregate in the Chukchi Sea in summer (June-July), although many of these whales may also migrate north into the ice pack and east into the Canadian Beaufort Sea (Suydam et al. 2001; 2005), suggesting possible overlap in the Chukchi and Beaufort sea stocks.

The higher sighting rates for beluga whales in the Chukchi Sea during the early and late seasons were consistent with beluga migratory patterns. The annual beluga whale hunt at Point Lay occurred on 13 July, just after the greatest numbers of belugas were recorded during the aerial surveys on 9-10 July in areas close to shore. Sighting rates and numbers of individual beluga whales were lowest in August and steadily increased in September, October, and November. However, the numbers of individuals during the Aug.-Nov. period remained relatively low compared to the July numbers, when the largest concentrations of beluga whales were observed near shore. When data from both the coastal and sawtooth surveys were considered, the overall sighting rate for beluga whales was greatest in the band located 25-35 km offshore, which may be an indicator of a more dispersed beluga whale migration pattern during the fall. Clark et al. (1993) reported both nearshore and offshore components of the beluga migration in the Chukchi Sea during fall.

During the sawtooth surveys, bowhead whale sighting rates and numbers of individuals were greatest during the late period. This was consistent with the bowhead whale fall migration pattern. The number of bowhead sightings was too low to determine a significant compass heading for migrating bowhead during the study period. The low number of bowhead sightings may be an indication that the main migration corridor was farther offshore than the area covered within the survey area. Moore and

Clarke (1993) suggested that bowheads may have a dispersed migration pattern in the northeastern Chukchi Sea during fall migration. Moore et al. (1995) reported on the occurrence of bowhead whales along the northern coast of Chukotka, Russia, and suggested that these whales may have migrated to that area from the eastern Beaufort Sea. Recent satellite data suggests that some bowhead whales continue their westward migration past Barrow through the Chukchi Sea to Chukotka (Quakenbush 2007). However, there is also evidence that records of bowhead whales along the Chukotka coast may be migrating whales that spent the summer feeding in the waters north of Chukotka (Moore et al. 1995). The fall migration route of bowhead whales back to the Bering Sea remains largely unknown.

For gray whales, sighting rates and number of individuals in the nearshore waters of the Chukchi Sea were greatest during the early season, followed by the mid-season. No gray whales were observed during the late season, which likely was due to the fall migration of gray whales out of the survey area. Nearly all gray whales were seen in relatively nearshore waters, between the 5 m and 20 m depth contours. This is consistent with the findings of Moore (2000), who reported that gray whales in the Chukchi Sea were seen most often in coastal/shoal habitats.

Pacific walruses were sighted most frequently and in the greatest numbers during the sawtooth surveys in the early season. Relatively few walruses were recorded during the coastal surveys. Most walruses occurred in large groups that were associated with ice floes.

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6. PASSIVE ACOUSTIC MONITORING OF MARINE MAMMALS IN THE CHUKCHI SEA[1]

Introduction

The Bioacoustics Research Program at the Cornell Laboratory of Ornithology (BRP) provided scientific environmental support for LGL Alaska Research to collect and analyze data from their Arctic Ocean Outer Continental Shelf Seismic Surveys. BRP staff deployed equipment for passive marine acoustic recording from 15 July through 15 October, 2006 and also provided technical field support. The original objectives of this effort were to:

a) detect the occurrence and approximate offshore distributions of beluga whales (*Delphinapterus leucas*), and possibly bowhead whales (*Balaena mysticetus*), during the mid-July to mid-August 2006 period and primarily bowhead whales during the mid-August to mid-October 2006 period,

b) measure and characterize ambient noise, and

c) measure received levels of seismic activities.

After completion of the field work, BRP staff extracted the acoustic data, organized it into a networked acoustic database, and began analysis. During the first stage of the analysis period and prior to the 21May 2007 Open-water meeting in Anchorage, Alaska, LGL provided a listing of 79 specific dates and time periods for which they requested detailed analysis. These analyses consisted of received level measurements of seismic airgun array events and of the time periods between those events. These analyses were completed and provided to LGL. BRP also established and provided LGL access to a server database containing all the original and processed data. By this mechanism LGL staff could query the data, download original data, or our analyses results, as needed.

This chapter provides:

1. A description of the deployment and recovery of the marine autonomous recording units (PUs).
2. Data on the occurrence of beluga whales and bowhead whales as detected by their species specific calls and as spatially sampled by the pop-ups.
3. Received levels and noise level statistics for examples of the extracted and analyzed acoustic data[2] to illustrate those data and the potential insights from their analyses.
4. The times of occurrence and examples of received levels of seismic events as recorded on seven representative pop-ups during 79 specific date and time periods as requested by LGL.
5. A discussion of the overall passive acoustic monitoring component of the project and a brief interpretation of the results based on the existing analyses of those data.

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[1] Christopher W. Clark, Bioacoustics Research Program, Cornell Laboratory of Ornithology.

[2] The size of the processed data is so great as to prohibit their total inclusion in this report. However, all data are archived on a server and available upon request.

A critical motivation for this passive acoustic effort was to collect acoustic recordings from representative areas of the Chukchi Sea region (within 90 kilometers of coastal Alaska, plus some additional detection distance further offshore) in order to detect the presence of bioacoustically active beluga whales and bowhead whales, measure their levels of bioacoustical activities during the mid-summer to early fall period, and measure the occurrences and received levels of seismic airgun array events. A further intention of the project as a whole was to compare and merge the spatio-temporal occurrences of the whales, as determined from detection of their sounds, with aerial survey sightings, and possibly to evaluate the combined acoustic detection and aerial sighting data relative to the occurrences and locations of seismic exploration activities. This latter task was not assigned to BRP as BRP was not privy to any information about the schedules or locations of industry activities. However, the bioacoustic data gathered by BRP instrumentation and processed by BRP analysts were viewed by BRP as a critical piece in the overarching task of objectively documenting, as best as possible given the conditions, the responses of whales to seismic activities and of evaluating the potential risks to beluga or bowhead whales from these activities. However, the interpretation of risk or behavioral impact analysis is included elsewhere in this Comprehensive Report and is not part of this chapter.

All times given in this report are local Alaska times (AKDT), not GMT (Zulu) times.

Methods

To collect acoustic recordings BRP provided a suite of twenty marine autonomous recording units (MARUs or "pop-ups"), and deployed these units in four areas extending from Cape Lisburne to Pt. Barrow, Alaska. Pop-ups (Figure 6.1) contain an external hydrophone and transducer, and internal signal conditioning, communication, CPU, and hard drive electronic sub-systems. Pop-ups are user-programmable and designed to operate in remote environments for many months at a time, and they have been used effectively to record the calls and songs of different baleen whale species in a variety of habitats (Clark et al. 2002, Clark and Clapham 2004.)

BRP provided technical personnel to deploy, refurbish, and recover pop-ups. The deployments were done in two phases, which are described in more detail in the following sections. Acoustic data collection in the first phase was designed to primarily record beluga whales that were expected to migrate along the coastal plane between Pt. Barrow and Cape Lisburne, while collection in the second phase was designed to record bowhead whales which were expected to mostly migrate westward from Pt. Barrow so as to occur well offshore, with a lesser number of animals expected to migrate southwesterly along the coastal plain (Moore and Reeves 1993.)

The plan for both phases was to deploy sets of five pop-ups off Cape Lisburne, Pt. Lay, Wainwright and Pt. Barrow, for a total deployment of twenty pop-ups in each phase. The plan for each site was to deploy five units in a southeast-to-northwest line such that four units were separated by approximately 9 kilometers (approximately five nautical miles) and the fifth pop-up was placed approximately 90 kilometers (approximately 50 nautical miles) offshore from the inshore set of four pop-ups. This deployment geometry is referred to as a 4-1 southeast-to-northwest configuration. Prior to deployment each set of five units was synchronized to GPS time.

Figure 6.1 Autonomous seafloor recorders, referred to as "pop-ups" during deployment off Cape Lisburne, Alaska.

Phase I

In the first phase, the pop-ups were programmed to record at a sampling rate of 10 kHz on a 10-minutes-on 20-minutes-off schedule so as to sub-sample throughout an eight-week period. Due to extensive ice cover, BRP was only able to deploy pop-ups off Cape Lisburne (Fig. 6.1) in the 4-1 southeast-to-northwest configuration (Fig. 6.2.) The four inshore pop-ups were separated by 9 kilometers (approximately five nautical miles) with an end-to-end length of approximately 28 kilometers (approximately 15 nautical miles.) The fifth pop-up was placed approximately 90 kilometers (approximately 50 nautical miles) offshore from the site. The precise locations of these five units and the dates of their deployment and recovery are listed in Table 6.1.

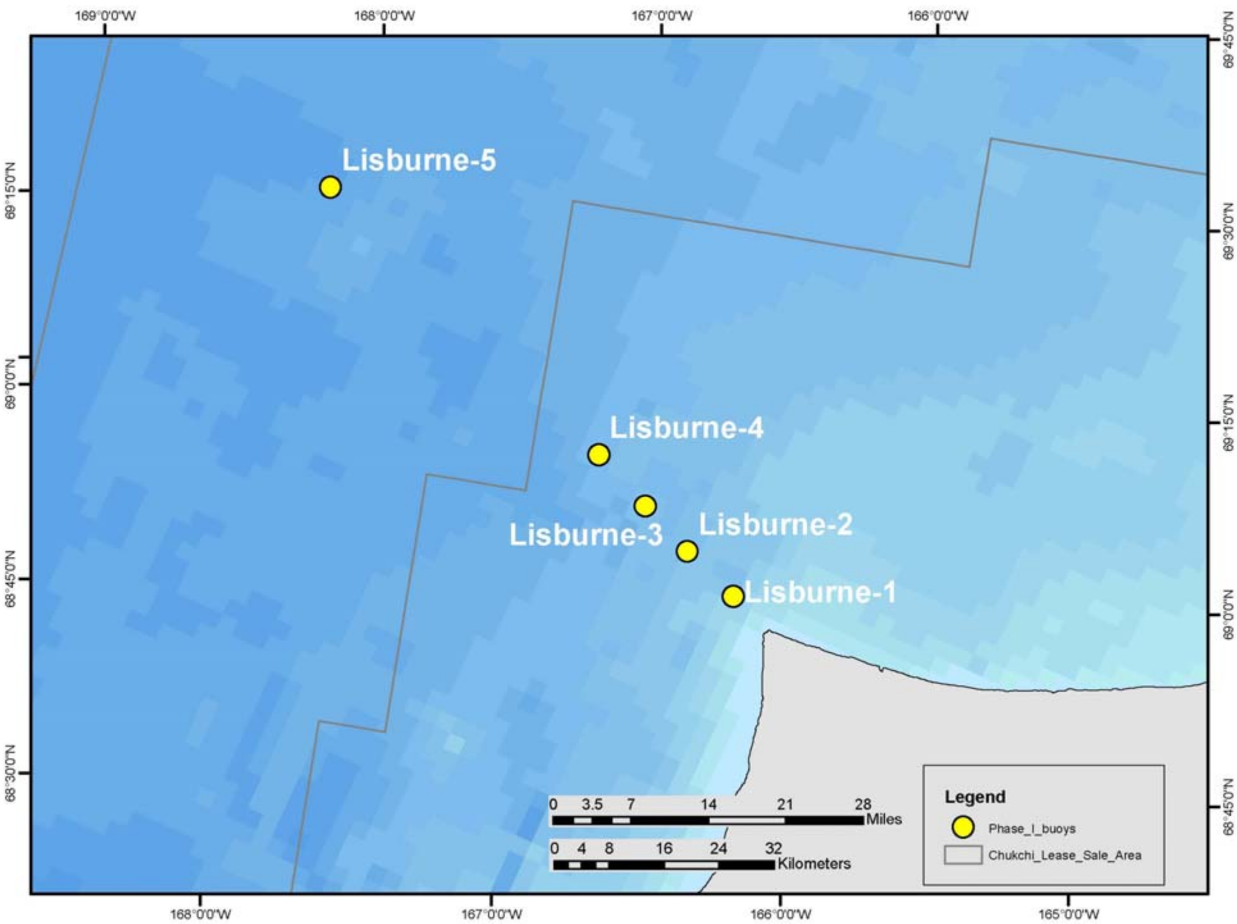

FIGURE 6.2. Phase I Deployment positions of five pop-ups off Cape Lisburne, 14-15 July through 10 September 2006.

TABLE 6.1. Phase I Deployment Locations and Dates of Operation for pop-ups (PU) off Cape Lisburne.

Location - Channel #	PU#	Latitude	Longitude	Deploy/Recover
Lisburne-1	21	N68° 55.0330'	W166° 21.2390'	14-Jul-06/10-Sep-06
Lisburne-2	32	N68° 57.8010'	W166° 32.8760'	15-Jul-06/10-Sep-06
Lisburne-3	59	N69° 00.6800'	W166° 43.5190'	15-Jul-06/10-Sep-06
Lisburne-4	56	N69° 04.0010'	W166° 55.6050'	15-Jul-06/10-Sep-06
Lisburne-5	84	N69° 20.5120'	W168° 04.3170'	15-Jul-06/10-Sep-06

Phase II

In the second phase, which commenced on September 12th, twenty pop-ups were deployed in four sets of five offshore of Cape Lisburne, Pt. Lay, Wainwright, and Pt. Barrow, Alaska. All units were programmed to record continuously at a sampling rate of 2 kHz. Figures 6.3 – 6.8 provide perspectives on the deployment locations and geometries relative to Alaska and local landmarks.

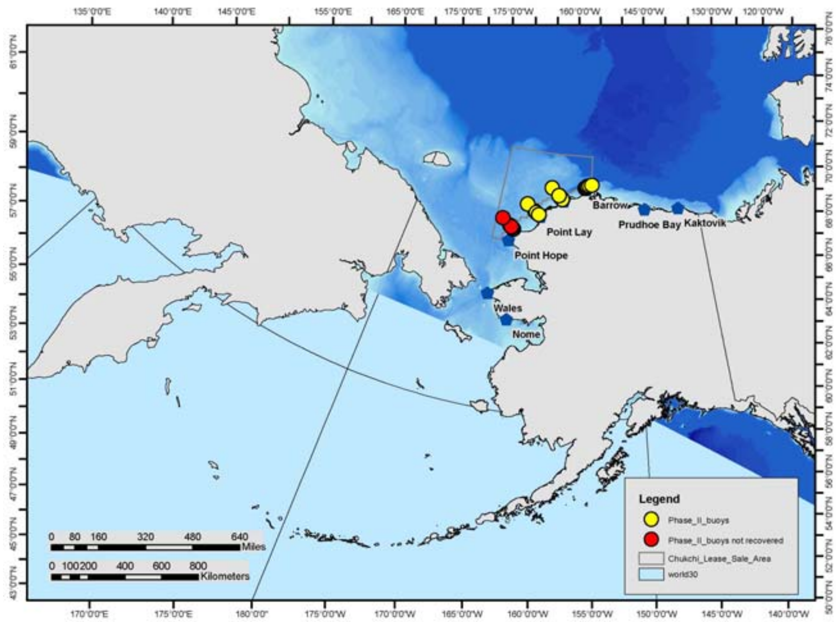

Figure 6.3. Map for Phase II showing generally the four areas where pop-ups were deployed offshore of Cape Lisburne, Pt. Lay, Wainwright, and Pt. Barrow, Alaska.

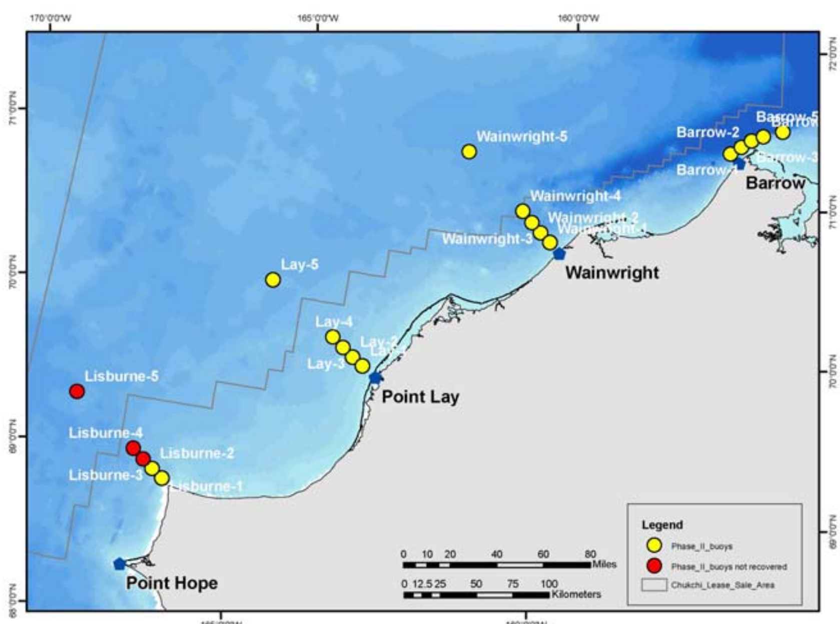

Figure 6.4. Map for Phase II showing the deployment geometries for the five pop-ups off Cape Lisburne, Pt. Lay, Wainwright, and Pt. Barrow, Alaska. The yellow dots indicate units that were successfully recovered, while the three red dots indicate the three units that were not recovered.

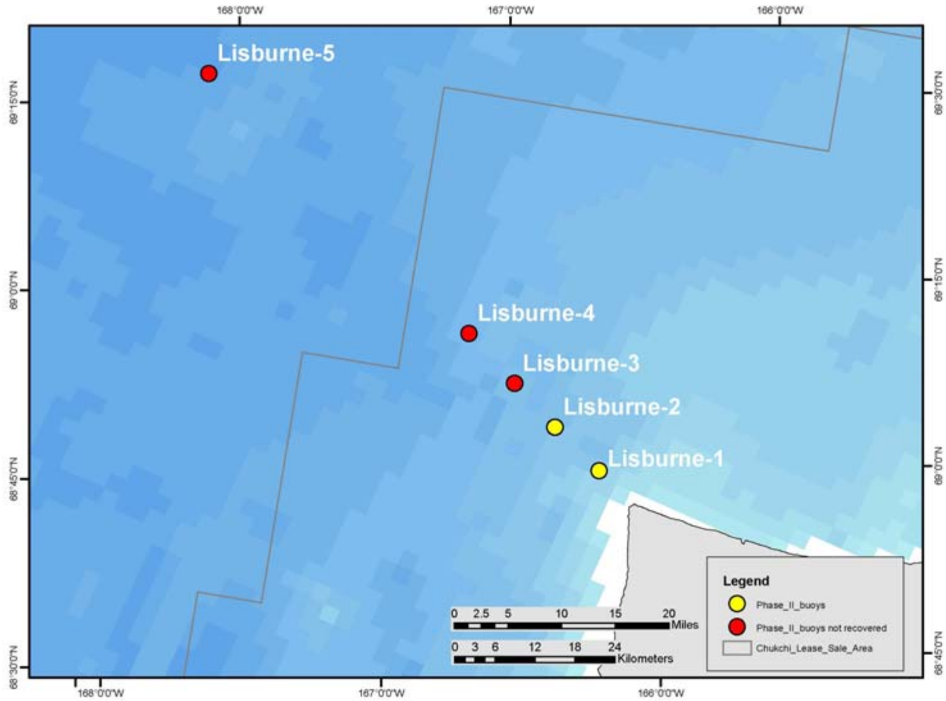

Figure 6.5. Phase II map showing the geometry for five pop-ups deployed off Cape Lisburne. The yellow dots indicate the two units that were successfully recovered, while the three red dots indicate the three units that were not recovered (see Table 6.2 for start and end dates.)

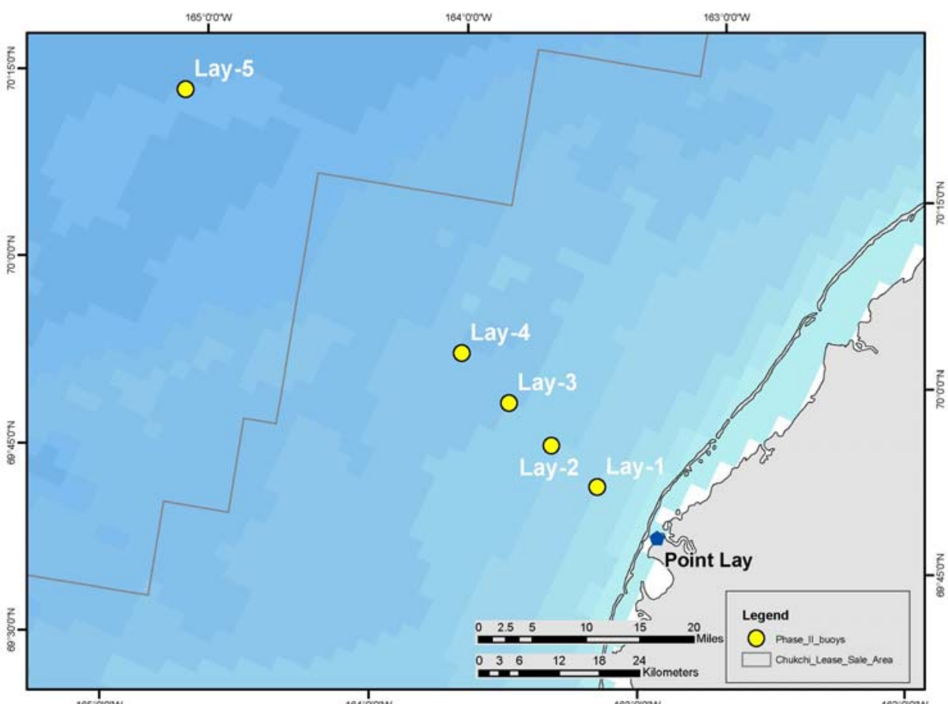

Figure 6.6. Phase II map showing the geometry for the five pop-ups deployed off Pt. Lay (see Table 6.2 for start and end dates.)

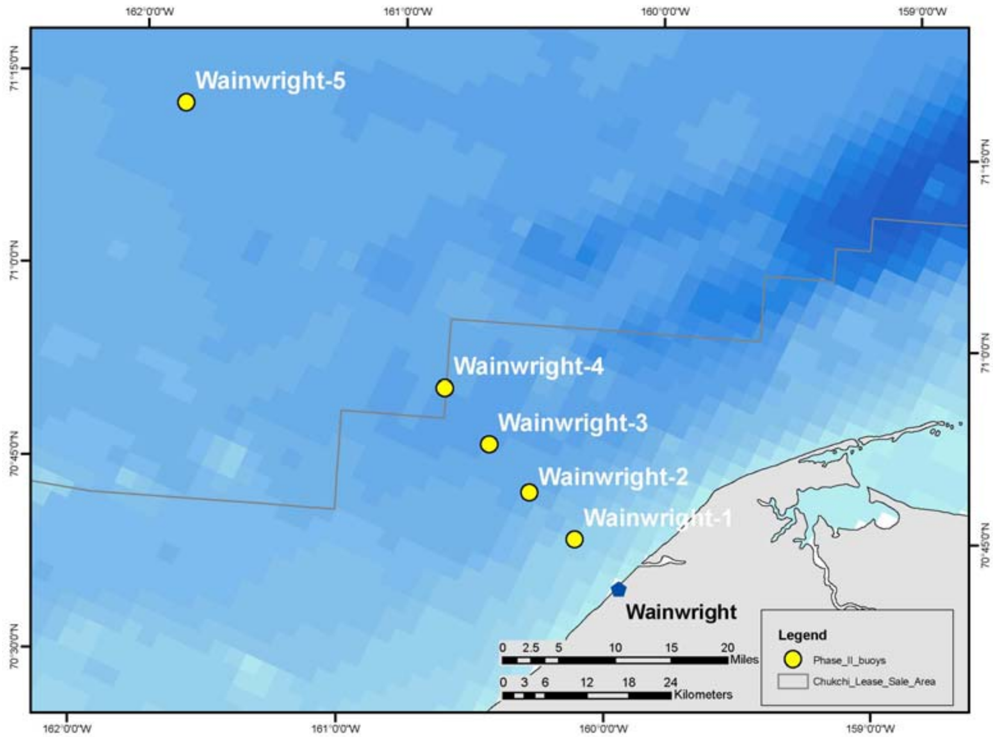

Figure 6.7. Phase II map showing the geometry for the five pop-ups deployed off Wainwright (see Table 6.2 for start and end dates.)

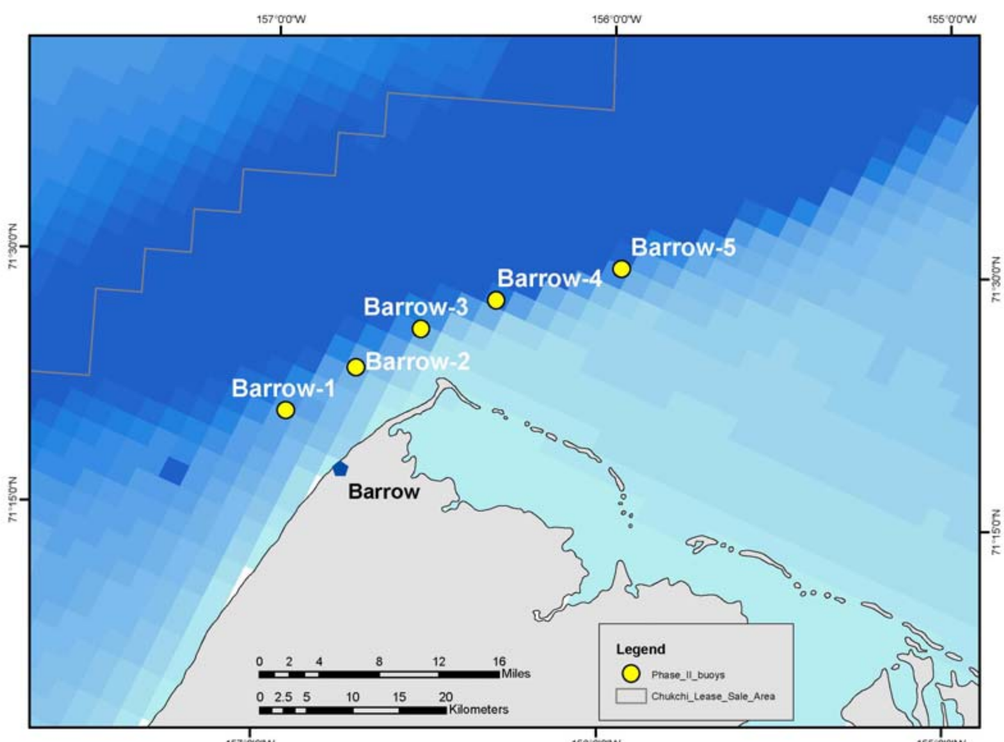

Figure 6.8. Phase II map showing the geometry for the five pop-ups deployed off Pt. Barrow (see Table 6.2 for start and end dates.)

The deployment geometries for Cape Lisburne, Pt. Lay, and Wainwright ran offshore in an approximate southeast-to-northwest configuration as originally proposed in the work plan. However, it was not possible to deploy pop-ups off Pt. Barrow in this configuration due to ice conditions at the time of the deployment. Instead, off Pt. Barrow, the four inshore units ran parallel to the coastline along the edge of the Barrow Canyon, and the fifth unit was deployed on the northern edge of the canyon. It is important to note that the geometry and technology of the Pt. Barrow pop-ups was not designed for acoustic location analysis, although we did eventually attempt to use it for this purpose (Clark et al. 1986; Clark and Ellison 2000.)

The precise locations of the original twenty units deployed in Phase II are given in Table 6.2[3]. Further details on the timing of the deployments are found in Annex A.

Table 6.2. Phase II Deployment Locations and Dates of Operation

Location - Channel #	PU#	Latitude	Longitude	Deploy/Recover
Lisburne-1	70	N68° 54.930'	W166° 21.490'	10-Sep06/13-Oct-06
Lisburne-2	89	N68° 57.780'	W166° 32.950'	10-Sep06/13-Oct-06
Lisburne-3	77	N69° 00.670'	W166° 43.640'	10-Sep06/Lost
Lisburne-4	61	N69° 03.960'	W166° 55.670'	10-Sep06/Lost
Lisburne-5	88	N69° 20.480'	W168° 04.450'	10-Sep06/Lost
Lay-1	97	N69° 48.678'	W163° 15.228'	12-Sep06/12-Oct-06
Lay-2	19	N69° 51.470'	W163° 26.856'	12-Sep06/12-Oct-06
Lay-3	66	N69° 54.420'	W163° 37.960'	12-Sep06/12-Oct-06
Lay-4	20	N69° 57.843'	W163° 50.402'	12-Sep06/12-Oct-06
Lay-5	63	N70° 15.510'	W165° 03.120'	09-Sep06/13-Oct-06
Wainwright-1	86	N70° 42.945'	W160° 09.880'	12-Sep06/12-Oct-06
Wainwright-2	50	N70° 46.283'	W160° 21.177	12-Sep06/12-Oct-06
Wainwright-3	74	N70° 49.765'	W160° 31.391	12-Sep06/12-Oct-06
Wainwright-4	95	N70° 53.734'	W160° 42.851'	12-Sep06/12-Oct-06
Wainwright-5	60	N71° 13.831'	W161° 49.305'	06-Sep06/12-Oct-06
Barrow-1	15	N71° 21.072'	W156° 56.180'	17-Sep06/16-Oct-06
Barrow-2	21	N71° 23.742'	W156° 44.133'	17-Sep06/16-Oct-06
Barrow-3	32	N71° 26.212'	W156° 32.878'	17-Sep06/16-Oct-06
Barrow-4	56	N71° 28.707'	W156° 21.722'	17-Sep06/16-Oct-06
Barrow-5	59	N71° 32.310'	W155° 57.228'	17-Sep06/16-Oct-06

[3] Note: The five units deployed off Cape Lisburne in July during Phase I were refurbished in Barrow and deployed off Barrow on 17 September.

Equipment Recovery

For Phase I, all five pop-ups from Cape Lisburne were recovered on 10 September 2006 and synchronized to GPS time on deck soon after recovery. In Phase II, poor weather prevented the BRP recovery team from reaching the *M/V Torsvik* in time to participate in the recovery of the Cape Lisburne, Pt. Lay, and Wainwright pop-ups using the acoustic transponder system. The pop-ups in these arrays were recovered by the *M/V Torsvik* crew, who waited for the back-up burn recovery system to release the units at the preprogrammed times (12 and 13 September 2006.) The three units most distant from shore at Cape Lisburne were not recovered (see Fig. 6.5.) The units recovered by the *M/V Torsvik* were shut down by BRP personnel when they boarded the vessel at Pt. Hope. The five units off Pt. Barrow were acoustically recovered by the BRP team from the *Peregrine* on 16 October 2006 and were shut down by BRP personnel. All sets of pop-ups were synchronized to GPS time after recovery.

Acoustic Data Extraction

After recovering pop-ups and returning to Ithaca NY, data were extracted from each unit's hard drive as binary files and converted into standard formatted sound files. In Phase I, a total of 232 GB of acoustic data were collected representing a total of 2,282 recording hours covering a total of 285 pop-up recording days. In Phase II, there was a total of 188 GB of acoustic data representing a total of 12,557 hours covering a total of 523 pop-up recording days. Acoustic data from individual Lisburne pop-ups in Phase I were stored and analyzed as individual data sets, while acoustic data from each of the four Phase II areas were merged into multi-channel files. For the five Pt. Barrow pop-ups, the multi-channel data were also synchronized in order to provide the opportunity for evaluating whether or not calling bowheads could be reliably located and tracked. All data were organized into a networked database on a server system that was accessible via the internet. Annex B-1 and Annex B-2 list the number of hours of acoustic data collected for each day from Phase I and Phase II, respectively.

Bioacoustic Analysis: Beluga and Bowhead Whales

All Phase I pop-up data were analyzed for the occurrences of beluga and bowhead whales at a 5-minute resolution. Detection of whale sounds was accomplished by experienced analysts scrolling through continuous spectrographic displays while visually searching for whale calls using XBAT (www.xbat.org), a MatLab-based extensible, bioacoustic analysis software tool developed at BRP (Figueroa 2005). Once a potential call was visually identified, the analyst listened to the sound and judged whether or not it was from a beluga or a bowhead. In the few cases where there was uncertainty as to the species identity of the calling animal, C.W. Clark listened to the sound and made the judgment. Once the sound was confirmed as a beluga or bowhead, the 5-minute time block and pop-up for which it occurred was positively scored as containing a beluga or bowhead. By this procedure all Phase I data were evaluated for the presence of beluga and bowhead whales on a daily basis and in terms of the portion of the day with detections. Figure 6.9 (top panel) shows a single channel spectrogram display which contains a few annotated beluga calls from Phase I as recorded off Cape Lisburne.

All Phase II pop-up data from each of the four sites (Cape Lisburne, Pt. Lay, Wainwright, and Pt. Barrow) were analyzed for the occurrence of bowhead whale calls using the a similar procedure to that used for Phase I analysis. However, for Phase II this was accomplished by experienced analysts who used XBAT to scroll through continuous 5-channel, not single channel, spectrographic displays while visually searching for bowhead whale calls[4]. Figure 6.9 includes an example spectrogram display containing a

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[4] Because data were collected late in the season and the sampling rate was 2 kHz, the chances of recording belugas in Phase II were considered very unlikely. Therefore, in Phase II we did not expect or attempt to detect belugas.

series of bowhead calls from Phase II as recorded off Pt. Barrow.

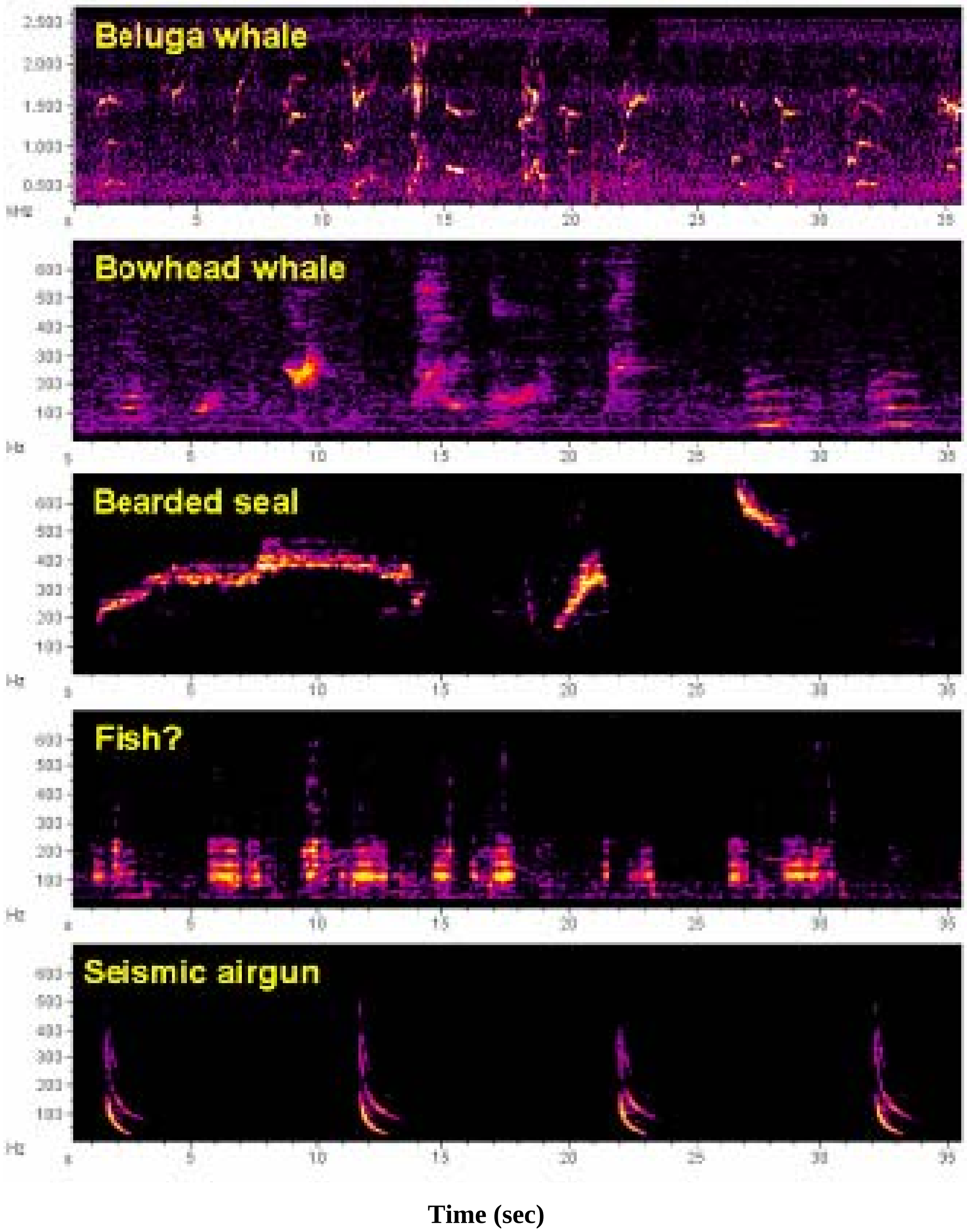


Figure 6.9. Spectrographic examples of various types of sounds collected on the pop-ups off Alaska during the summer and fall 2006. The panel labeled “Fish?” represents a sound type that is very similar to fish sounds recorded elsewhere.

Contrary to our original analysis plan, we did not apply automatic detection software because preliminary analysis with the automatic detection software revealed that results from this analysis were confounded by noise conditions that included seismic survey airgun array events and sounds from non-target species (e.g., bearded seals, *Erignathus barbatus,* and suspected fish sounds that might be Arctic Cod, *Arctogadus glacialis* (Figure 6.9.) All bowhead call detections were annotated and automatically entered into the XBAT database system. This provided a very efficient mechanism by which we could rapidly go to any annotated sound, export data tables, and in the case of the Barrow pop-ups run an automatic location tool.

The search strategy for bowhead calls was hierarchical. The first step was to determine the days on which bowhead calls occurred. Determination of daily presence / absence was conducted as follows. For every day and every pop-up, the data were "hand-browsed" until a bowhead vocalization was found, which indicated bowhead presence. After the first vocalization was found, the remainder of that day was skipped, and we went on to analyze the next day[5]. This procedure yielded a list of days and pop-ups on which at least one bowhead call was detected.

The second step was to determine the hours in which bowhead calls occurred. The hourly presence / absence procedure was similar to that for daily presence / absence; the acoustic data for the days on which bowhead calls were detected were "hand-browsed" starting at the hour when the first call was heard. Each subsequent hour was browsed until a bowhead vocalization was found, which indicated hourly presence. After the first vocalization was found, the remainder of that hour was skipped, and we went on to analyze the next hour[6]. From this analysis of the Pt. Barrow data we learned that bowhead calls were very common off Pt. Barrow throughout Phase II. Many of these calls were not the simple frequency-modulated sounds typical of bowheads during the spring migration (Clark and Johnson 1984; Clark et al. 1996), but were often mixtures of wild, complex sounds reminiscent of songs and sexually active groups (Würsig and Clark 1993). As a result, and knowing the importance of evaluating bowhead call activity as a function of industrial activity, we increased the analysis of the Pt. Barrow data so as to a) better document calling activity (e.g., types of calls and call rate), b) estimate the numbers of vocally active animals, and c) determine whether or not the data were amenable to acoustic location analysis.

Estimating the amount of bowhead call activity in an hour for every pop-up was accomplished by counting the number of calls in the first minute of every hour in which a call had been detected. To estimate of the number of vocally active whales, all calls in the first five minutes of every hour were scrutinized. Using patterns of arrival times for the same call on multiple channels, we determined whether 0, 1, 2, or more than 2 bowhead whales were present during the 5-minute period[7]. Figure 6.10 illustrates an example of three whales calling within the same two-minute period.

The two phases of the project covered approximately a three month time period and sampled a reasonably large area in the Chukchi Sea off the Alaskan coast from Cape Lisburne to Pt. Barrow. The product of the two parameters of time and space result in a spatio-temporal value representing a sizeable portion of the annual acoustic habitat for beluga and bowhead whales. To represent the overall characteristics and variability in this acoustic habitat we applied a set of analytical methods to the entire acoustic data set. For every day of data and for every pop-up, 24-hour spectrographic images, ambient noise order statistics (5%, 25%, 50%, 75%, 95%), and 1/3 octave received levels were computed and

[5] By this procedure, the entire day would be browsed if no vocalizations were found.
[6] For an hour where no vocalization was found, the entire hour would be browsed.
[7] Since only the first 5 minutes of each hour were analyzed, there may be additional animals present that would be evident within the remainder of each hour.

saved as MatLab files. In this perspective, all sounds contained in the record were considered part of the "ambient noise" habitat (i.e., the acoustic "scene"), and known sound sources were not parsed out. This use of the term "ambient noise" is therefore different from terminology in which sounds from discrete sources are distinguished from ambient noise. The resultant data set from this ambient noise analysis of the entire data set is

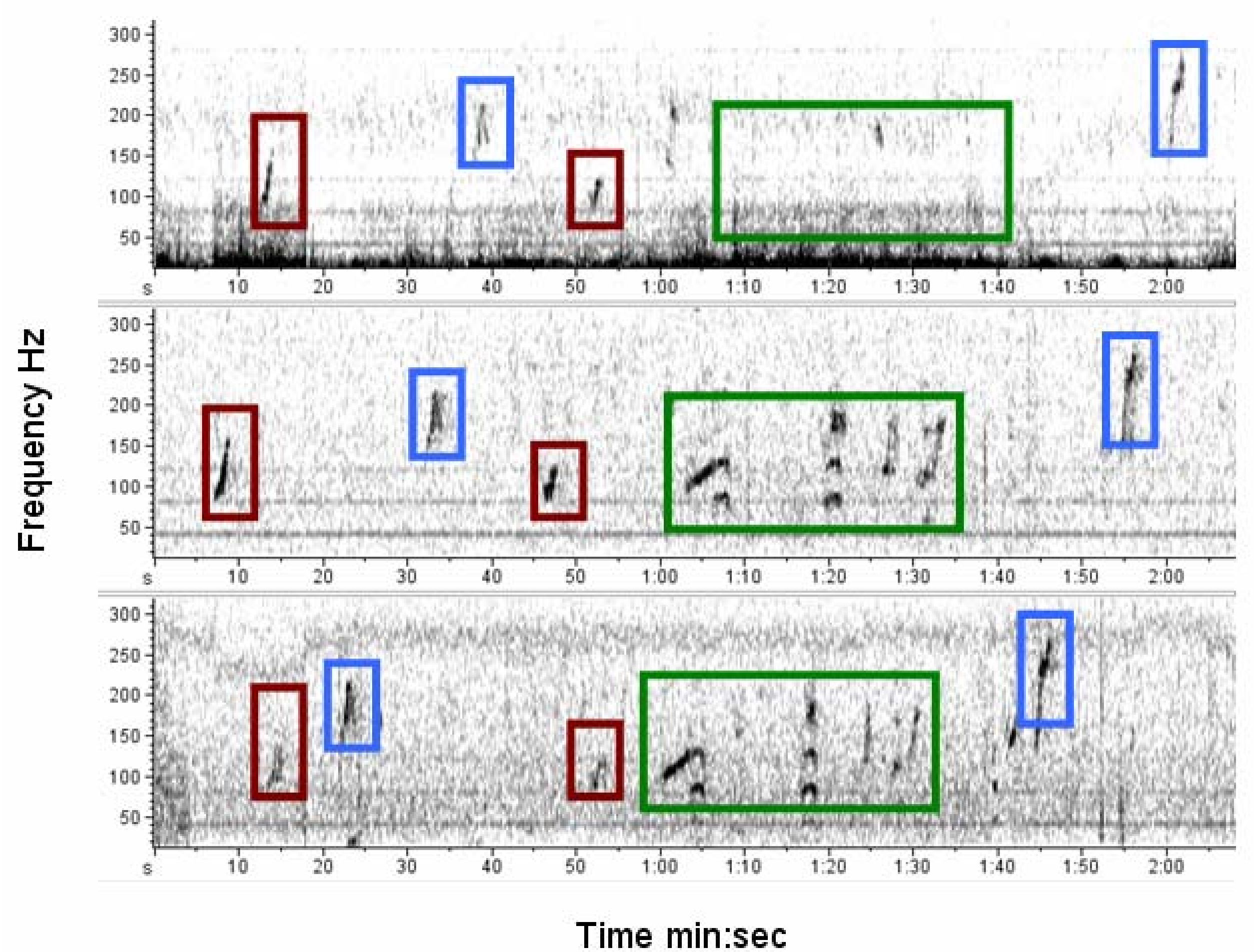


Figure 6.10. Three-channel spectrogram from Pt. Barrow pop-ups 15, 21, and 32 on 25 September at 05:05 when three different whales were calling, as indicated by the different patterns of call arrival times.

too large to be included in this chapter. Instead, we present examples of the analysis, with the caveat that all these data are available upon request.

These 24-h analysis files were extremely valuable as they provided an effective mechanism for quickly assessing data quality and for getting a feel for what was happening on any particular pop-up on any particular day. In some cases, the 24-h resolution was too coarse in its level of detail to reliably detect whales, and in these cases it was necessary to "zoom into" a day's acoustic scene. However, the resolution was usually good enough to reveal the occurrence of seismic activity.

Acoustic Occurrence of Seismic Activity

All Phase I pop-up data were analyzed for the daily presence-absence occurrence of seismic airgun array sounds. The identification of seismic sounds was significantly enhanced by the fact that such sounds almost always occur in long, regular sequences. Detection of seismic airgun array sounds was accomplished by analysts scrolling through continuous spectrographic displays while visually searching for and acoustically listening to seismic airgun array sounds using XBAT (www.xbat.org). Once the sound was confirmed, the day and pop-up for which it occurred was positively scored as containing seismic sounds. By this procedure all Phase I data were evaluated for the daily presence of seismic exploration activity on an hourly basis. Figure 6.9 (bottom panel) shows a single channel spectrogram display containing a sequence of seismic airgun array sounds from Phase I as recorded off Cape Lisburne.

All Phase II pop-up data from each of the four sites (Cape Lisburne, Pt. Lay, Wainwright, and Pt. Barrow) were analyzed for the occurrence of seismic airgun array sounds using the a three-step procedure similar to the Phase II process for detecting bowhead calls. The first step determined the days on which seismic airgun array sounds occurred. The second step determined the hours in which seismic airgun array sounds occurred, and the third step determined the 15-minute periods in which seismic airgun array sounds occurred. By this procedure, the presence / absence of seismic sounds was determined for each of the 96 15-minute daily time periods for all of Phase II.

Acoustic Analysis and Measurements of Selected Time Periods

Scientists from LGL provided a list of 79 date-time sample periods from Phase II for detailed analysis. During this phase, the amount of seismic airgun array activity varied from periods with only a single vessel shooting a mitigation airgun(s), to periods with one vessel operating a full airgun array, to periods with two vessels shooting their respective full airgun arrays. There were very few periods during which no airgun activity occurred. The 79 time periods selected for detailed received-level analysis were generally 1-3 hours in length. Time period length was determined by the length of time that the airgun status on the vessel(s) remained constant. During the first ~8 days (12 – 20 Sep.) of Phase II, two seismic vessels were operating in the Chukchi Sea. During these days 11 time periods were selected when both vessels had full airgun arrays active, 15 time periods were selected when one vessel was operating a full array and the other was firing a mitigation airgun (in one of these periods no mitigation airgun was firing), 4 time periods were selected during which both vessels were firing only their mitigation airgun(s), and 5 time periods were selected during which only one vessel was firing a migration airgun(s). During the rest of Phase II only one seismic vessel was operating, so an equal number (22) of full-array and mitigation airgun time periods were selected for analysis. BRP staff were not provided any information on the seismic airgun array activity occurring during these 79 samples (e.g., start and stop times of airgun array surveys, positions of seismic survey vessels, positions of support vessels), and thus were “blind” to the context of the samples. Although BRP was assigned the task of determining the times and absolute received levels for airgun array sounds, we were not assigned any responsibility relative to the potential impacts on bowhead whales from those seismic airgun array exposures (e.g., estimating the extent of zones of exposure to specific received levels.) Analyses of the 79 Phase II date-time sample periods were restricted to Pt. Barrow channels 2 and 5 (PU21 = ch-2, and PU59 = ch-5), Wainwright channels 2 and 5 (PU50 = ch-2, and PU60 = ch-5), Pt. Lay channels 2 and 5 (PU19 = ch-2, and PU63 = ch-5), and Cape Lisburne channel 2 (PU89 = ch-2) for a total of seven pop-ups being included in the analyses (see Figs. 6.4 – 6.8 and Table 6.2, above.)

An energy detector in XBAT was used to search for seismic airgun array events (also referred to as “pings”) in each of the 79 day-time sample periods. A specific set of detector parameters was used in the detection of high signal-to-noise (SNR) seismic sound events, and a second parameter set was used for the detection of low SNR seismic sound events.

This detection process performed well for high SNR events. Given time constraints, we were not able to determine precisely the percentage of high and low SNR events that were detected. However, it was clear that a much lower percentage of low SNR events were detected compared to high SNR events

This low detection rate was due to overall ambient noise conditions, which included sounds possibly made by Arctic Cod.

False detections were removed from each time period as efficiently as possible. In the case of high SNR events, we were able to straightforwardly identify false detections that occurred outside of the regular time-interval pattern of seismic airgun array events. However, in the case of low SNR events, this regular time-interval pattern was not always clearly evident. When it was evident, it was often sporadic. Our approach was to keep all sequences of detections in which we could observe a clear, regular time-interval pattern of seismic airgun array events. Irregularly spaced sequences of low SNR detections were removed, although they often contained seismic events interspersed with non-seismic events.

Using XBAT, a time-frequency event "box" was created around each ping. The time dimensions of the box included a pad of 0.02 seconds inserted before the start and after the end of the ping. For each set of time-frequency box detections that remained after false detections were removed, we created a duplicate set of time-frequency boxes, shifted in most cases ahead by 5 seconds. In cases where seismic events with high SNR were detected, this enabled the creation of pair-wise segments of sound with the same time-frequency bounds, but representing a seismic airgun array event and an ambient sound sample without a seismic event, respectively. In cases where seismic events with low SNR were detected, due to both our protocol for removing false detections and due to time constraints, we were almost always able to create pairs of adjacent ping and ambient noise samples. In tables and plots, these time-shifted, non-seismic events are labeled "inter-ping" events.

One confounding factor when making these pair-wise, ping and inter-ping event boxes was the presence of multiple, simultaneously active sources of seismic activity. In these cases the second source of seismic activity made it nearly impossible to find uncontaminated ambient noise samples to match with the first (i.e., dominant) source. In these situations we either altered the amount of time by which the detection event boxes were shifted, and/or removed those "inter-ping" events that contained an event from a second seismic airgun array.

Received level measurements (RMS re 1 μPa) were made for each ping event, and for each event containing ambient sound. These measurements were made over a frequency band of 70 to 450 Hz. The lower limit of this band represents the minimum frequency at which the pop-up records with a flat frequency-response. The upper limit corresponds with the upper frequency limit of the majority of bowhead whale calls and is also within the flat frequency response range of the pop-ups.

Results

Beluga and Bowhead Whales

Phase I. Detection of beluga whale sounds was only conducted for the Phase I data. Belugas were detected on seven of the 57 days from 15 July through 9 September (Figure 6.11). They were never detected on the pop-up closest to shore (PU21). From the times of day and the pop-up locations of beluga call occurrence it appears that for four of the seven days (28 July, 15 August, 24 August, and 27 August) multiple pop-ups detected the same beluga group. Furthermore, it appears that on two pairs of days (28-29 July, and 26-27 August) detections are of the same beluga group. Thus, for example on 28 July beluga calls were detected on pop-ups (32, 59, and 56) at the same times late in the day and detections continued on PU59 into the early morning.

On days when beluga sounds were detected, they were only detected for portions of the day (Figure 6.12). Thus, for example, on 16 July, belugas were detected on PU84 between 19:05 and 20:35, while on 15 August on PU59 belugas were detected from 02:35 – 06:10, and then intermittently until 09:30.

Based on this synthesis of the beluga acoustic detection data, only five groups of belugas were detected on the total of 285 days of pop-up recording data. No bowheads were detected in Phase I. Annex C shows the tabulated results from these whale detection analyses.

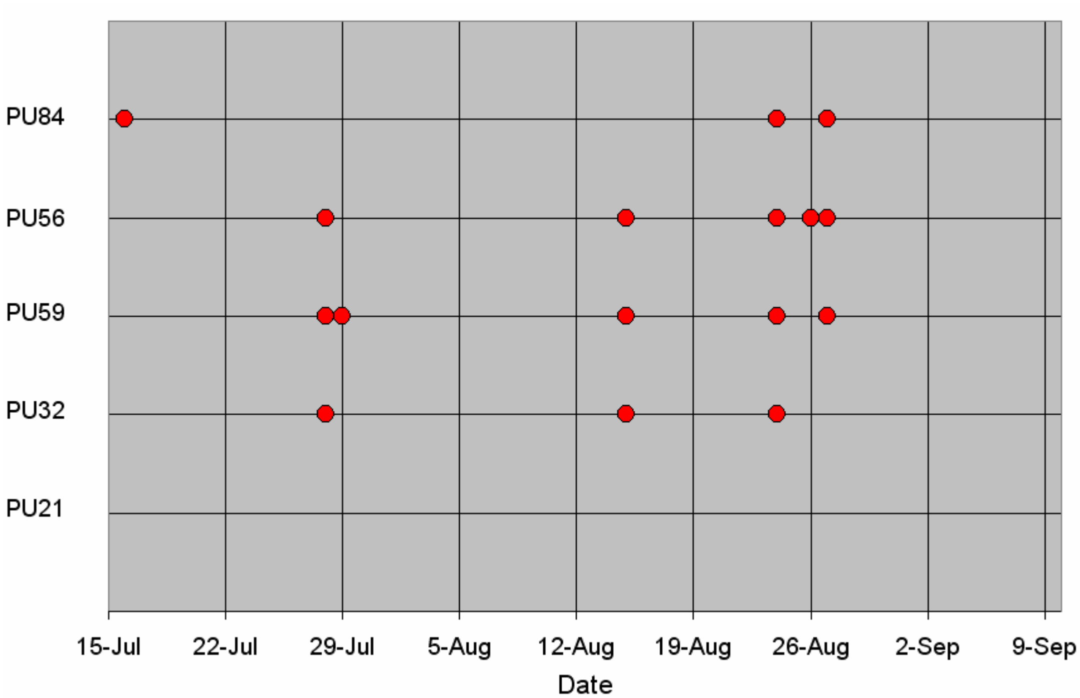


Figure 6.11. Schematic showing the days on which beluga sounds were detected for each of the five pop-ups in Phase I.

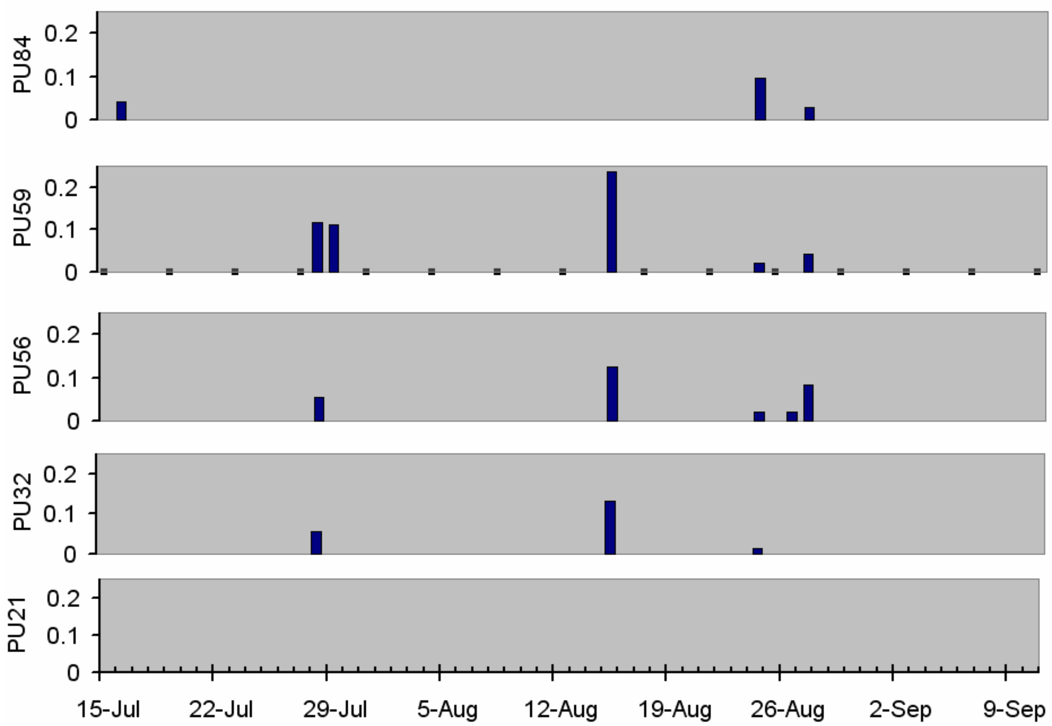


Figure 6.12. Histogram showing the daily proportion of time when beluga sounds were detected (see text for details.)

Phase II. In Phase II, no beluga sounds were detected on any of the 17 pop-ups, and no bowhead calls were detected on the two Cape Lisburne pop-ups. Given that these two Cape Lisburne pop-ups were close to shore and there was no acoustic sampling further offshore, we cannot evaluate whether or not bowhead calls were available for detection as far off as 90 kilometers from Cape Lisburne.

Bowhead calls were detected off Pt. Barrow, Wainwright and Pt. Lay. Figures 6.13, 6.14, and 6.15 show the daily presence / absence detection data at each of these three sites, respectively. These daily detections show two interesting patterns: decreasing detections as one moves from Pt. Barrow to Wainwright to Pt. Lay, and a shift in detections relative to the coast as one moves from Wainwright, where there are both offshore (PU60; Wainwright-5) and inshore (PU86, PU50, PU74, and PU95; Wainwright-1-4) detections, to Pt. Lay, where there are only inshore detections (PU97, PU19, PU66, and PU20; Pt. Lay 1-4). Annexes D-1, D-2, and D-3 tabulate the daily detection results for bowheads for Pt. Barrow, Wainwright and Pt. Lay, respectively.

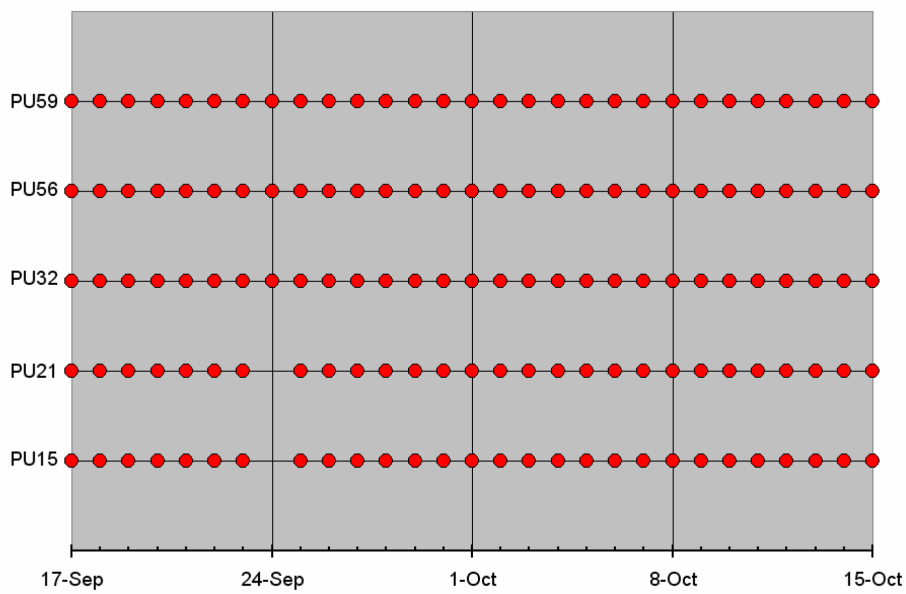


Figure 6.13. Pop-up days on which bowhead sounds were detected off Pt. Barrow, Phase II.

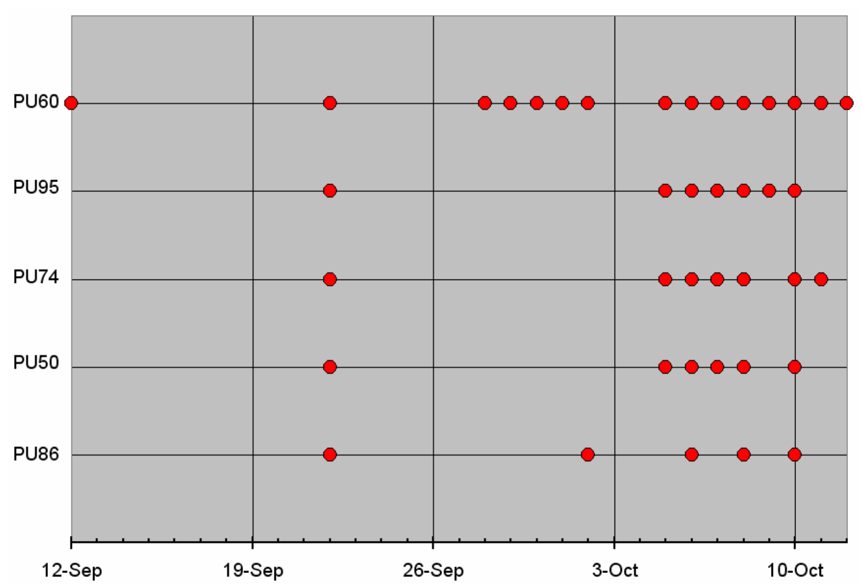


Figure 6.14. Pop-up days on which bowhead sounds were detected off Wainwright, Phase II.

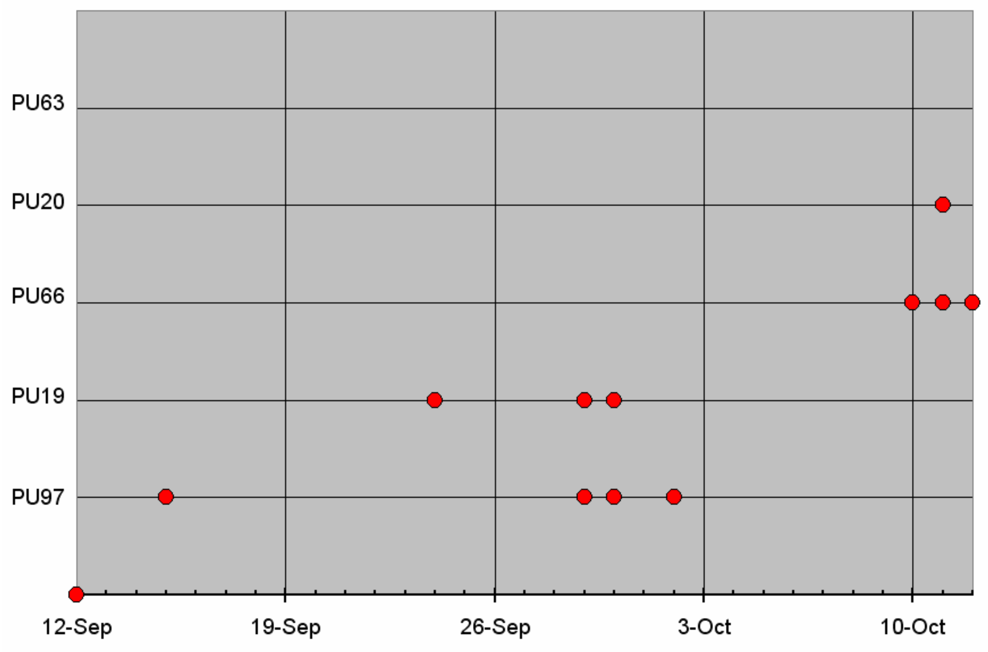


Figure 6.15. Pop-up days on which bowhead sounds were detected off Pt. Lay, Phase II.

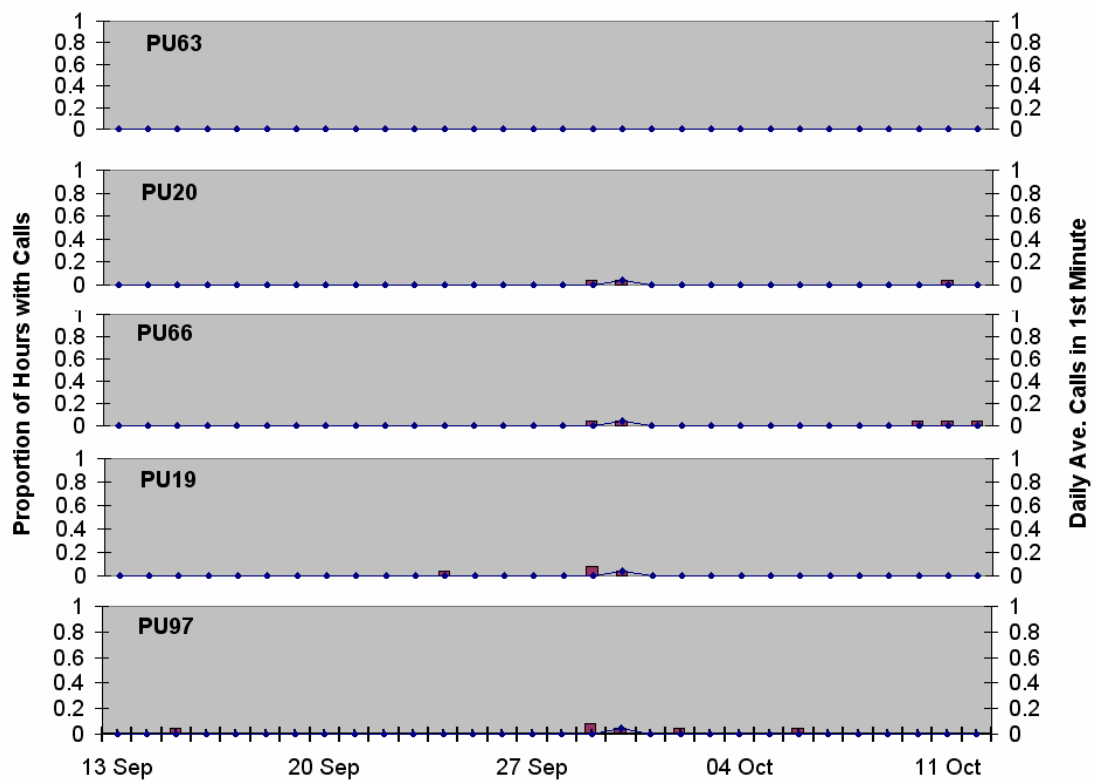


Figure 6.16. Daily bowhead call detections for Pt. Lay measured as the proportion of hours in which calls were detected (histogram, dark bars) and the daily average number of calls in the first minute of each hour (dotted line.) PU97 was the pop-up closest to shore, and PU63 was the pop-up furthest from shore.

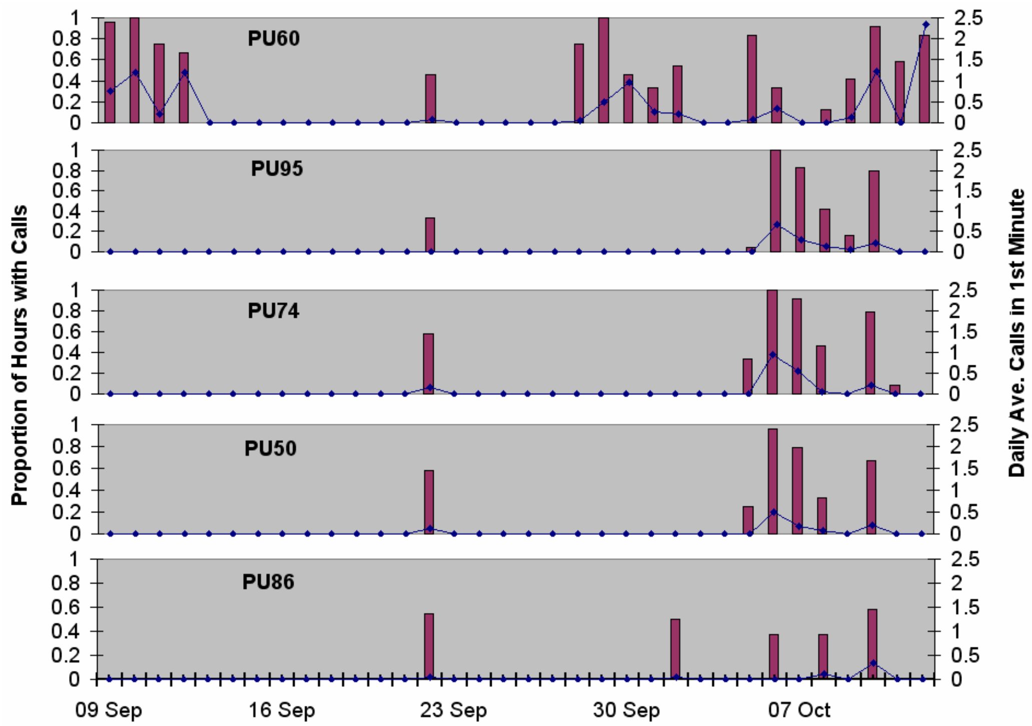


Figure 6.17. Daily bowhead call detections for Wainwright measured as the proportion of hours in which calls were detected (histogram, dark bars) and the daily average number of calls in the first minute of each hour (dotted line.) PU86 was the pop-up closest to shore, and PU60 was furthest from shore.

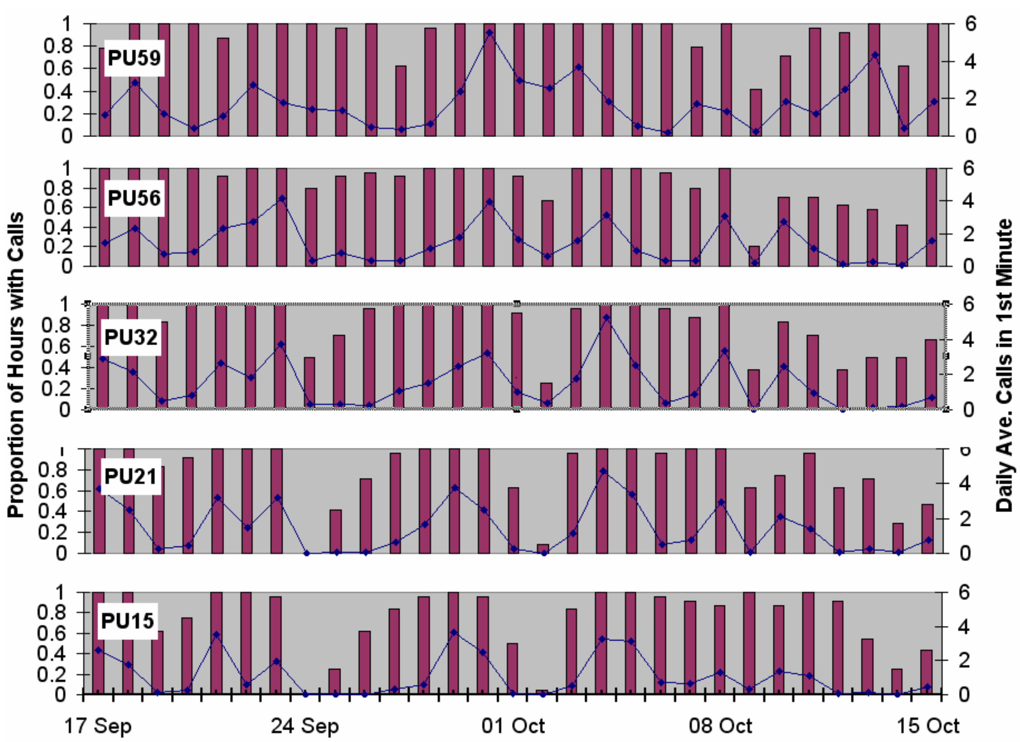


Figure 6.18. Daily bowhead call detections for Pt. Barrow measured as the proportion of hours in which calls were detected (histogram, dark bars) and the daily average number of calls in the first minute of each hour (dotted line.) PU59 was the pop-up furthest to the east, and PU15 was furthest to the west.

The results of hourly 1-minute bowhead call counts and the daily proportion of hours in the day with bowhead calls for Pt. Lay, Wainwright and Pt. Barrow are shown in Figures 6.16, 6.17, and 6.18, respectively.

Bowhead detections for Pt Lay were very sparse and support the conclusion that very few animals passed through this area, and all were within about 25 miles of the coast. The call counts and daily proportion data for Wainwright indicate increasing detections across a broad front after 5 October, while the data for Pt. Barrow indicate decreasing bowhead call detections after about 8 October.

For the estimates of the number of vocally active whales off Pt. Barrow in the first five minutes of every hour there was a significant auto-correlation in the estimates over the first three hours. Therefore, only estimates for every fourth hour are presented here along with the reminder that our highest estimate of three calling whales in a five-minute interval is considered conservative. This value of three should be interpreted as the minimum number of calling whales because in many cases analysts were only certain that there were more than two calling whales but could not be certain of whether there were three or more than three calling whales. This analysis revealed that in the total 168 4-hour samples, there were three samples when no whales were detected, 18 with one whale detected, 50 with two whales detected, and 97 with three or more whales detected. Figure 6.19 shows these data for the entire period from 17 September (Julian day 260) to 15 October (Julian day 288.) As can be seen in this figure, for the majority of time off Pt. Barrow (58%) there were at least three or more whales calling.

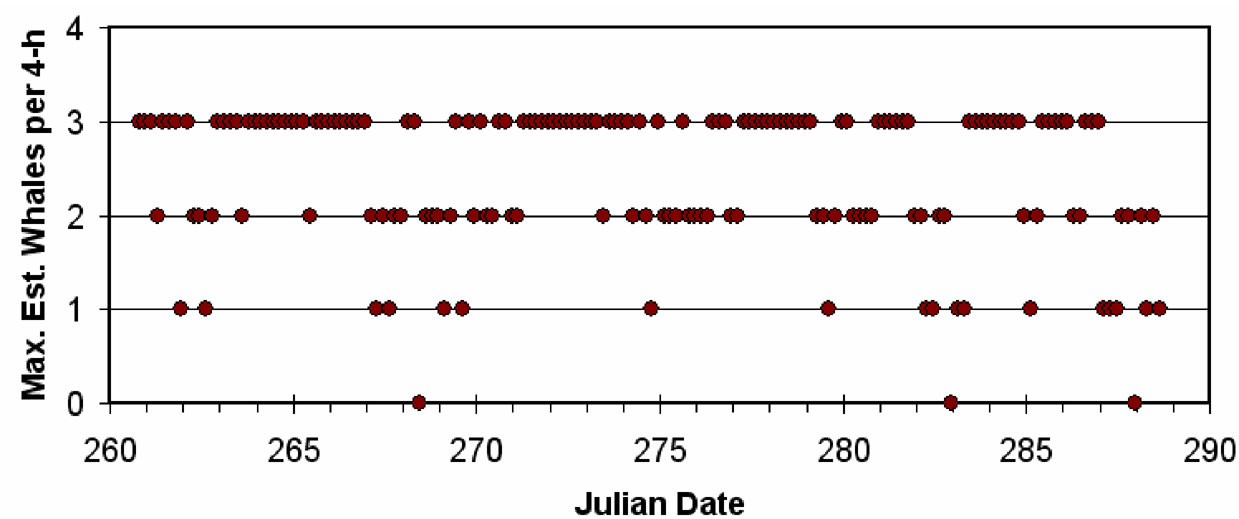


Figure 6.19. Estimates of the maximum number of calling bowheads in the first five minutes of every fourth hour off Pt. Barrow from 17 September (Julian day 260) to 15 October (Julian day 288.)

Ambient Noise Measurements

Ambient noise analysis was conducted for every day for all acoustic data from Phase I and Phase II. Representative spectrographic examples of these analyses for selected days are provided as figures to illustrate the richness of the acoustic data set as well as the types of analyses completed and available. These representative examples include 24-hour, 1-hour, and 5-min spectrograms for three different conditions: a Phase II day with bowhead call detections from PU56 off Pt. Barrow on 29 September 2006 (Figure 6.20,) a Phase II day without seismic airgun array activity from PU50 approximately 18 kilometers off Wainwright, on 20 September 2006 (Figure 6.21,) and a Phase II day with seismic airgun array activity from PU60 approximately 90 kilometers off Wainwright, on 16 September 2006 (Figure 6.22.) These 24-h spectrograms are calculated using relatively long integration times (i.e., 86 s integration time; one spectral frame every 43 s), and are not intended to reveal rare transient events such as bowhead calls. Rather, they are intended to provide a mechanism to rapidly review a day of acoustic data in order to evaluate data quality and to identify data gaps, times when a ship was passing by or times when a seismic airgun array was operating. The 1-h spectrogram has a shorter integration time (4 s, one spectral frame every 2 s) than the 24-h spectrogram and can reveal some transient events such as seismic airgun array sounds or bowhead calls, but not always in enough detail to easily identify the sound source type. The 5-min spectrogram has a very short integration time (0.26 s, one spectral frame every 0.13 s) and can reveal details of individual transients so that they can be identified. The trade off between these different levels of analysis is one of computation time and amount of data versus resolution: the higher the resolution, the longer the computation time and the larger the resultant data file.

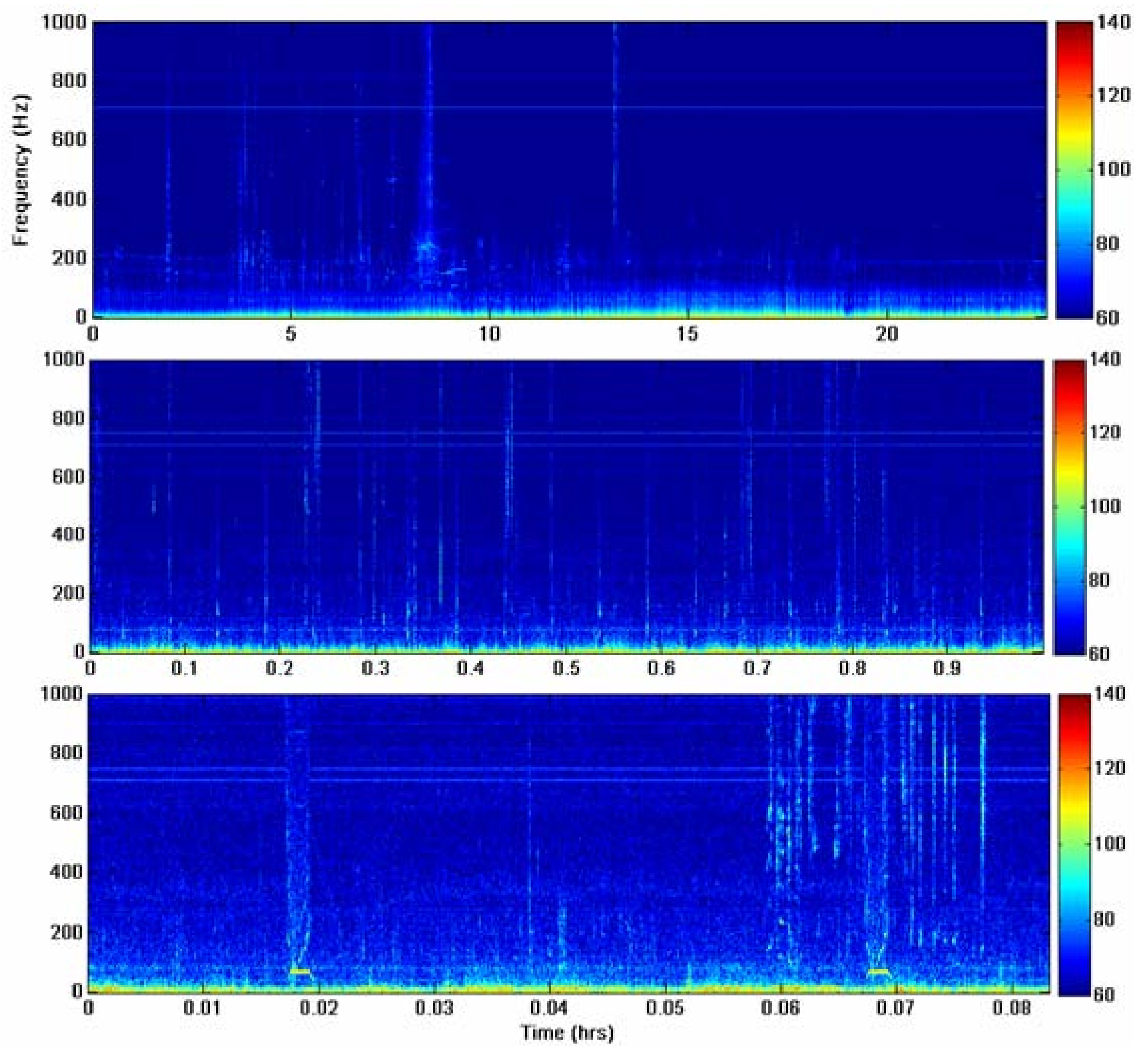


Figure 6.20. Example spectrograms for a day with bowhead whale acoustic detections: 24-h (00:00-24:00, top panel), 1-h (05:00-06:00, middle panel), and 5-min (05:10-05:15, bottom panel.) Data are from PU56, Pt. Barrow-4, on 29 September 2006. In the bottom panel a cluster of bowhead calls is evident between 0.06 – 0.08 hrs. The regular, thin vertical lines in the middle panel and two bright yellow bars in the bottom panel are noise from the pop-up's hard drive spin up. Color bar is RMS pressure level in dB re 1µPa.

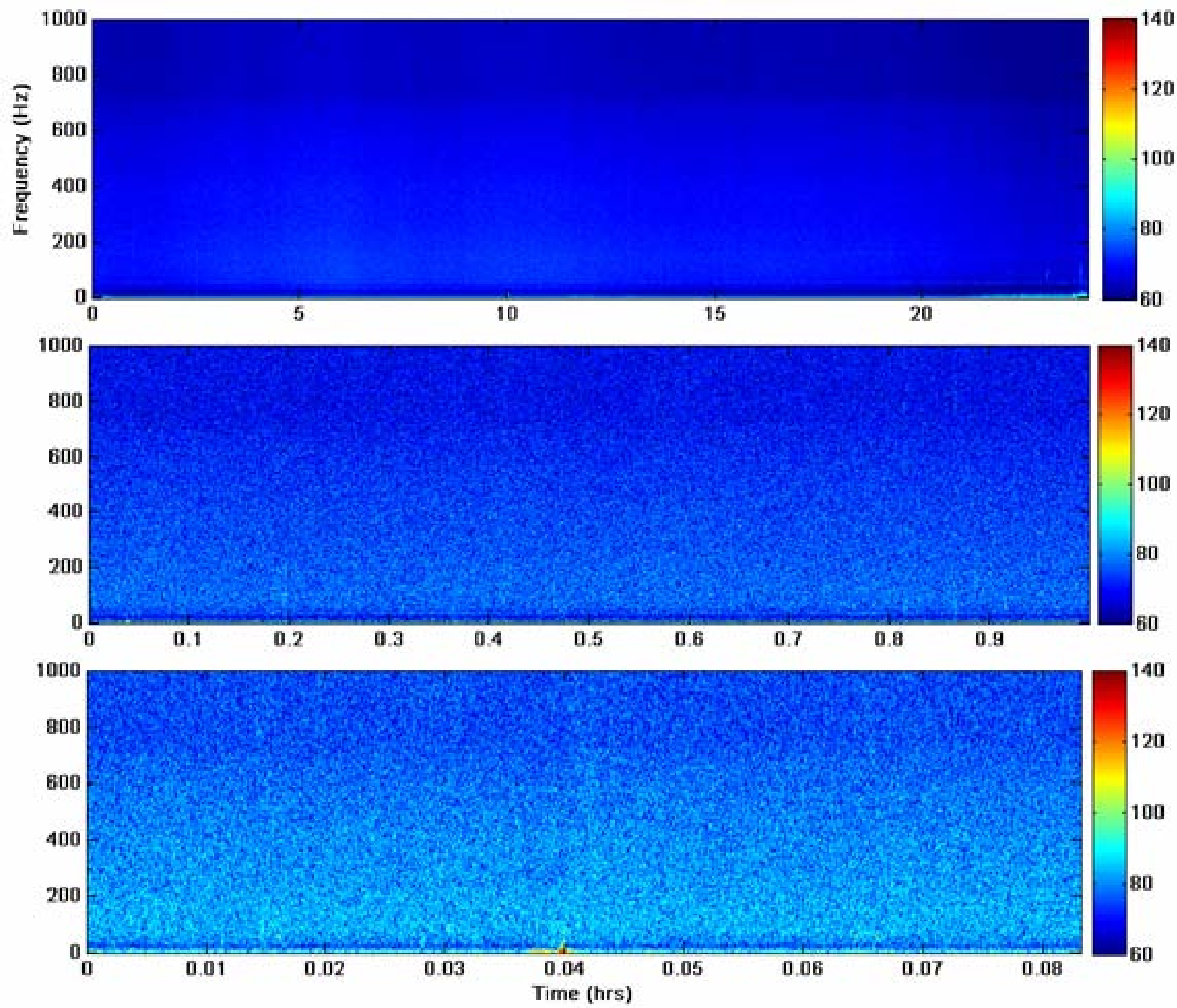


Figure 6.21. Example spectrograms for a day without seismic airgun array or bowhead whale vocal activity: 24-h (00:00-24:00, top panel), 1-h (10:00-11:00, middle panel), and 5-min (10:00-10:05, bottom panel.) Data are from PU50, Wainwright-2, on 20 September 2006 and the same as used in Figure 6.23 showing RMS noise levels. Color bar is RMS pressure level in dB re 1µPa.

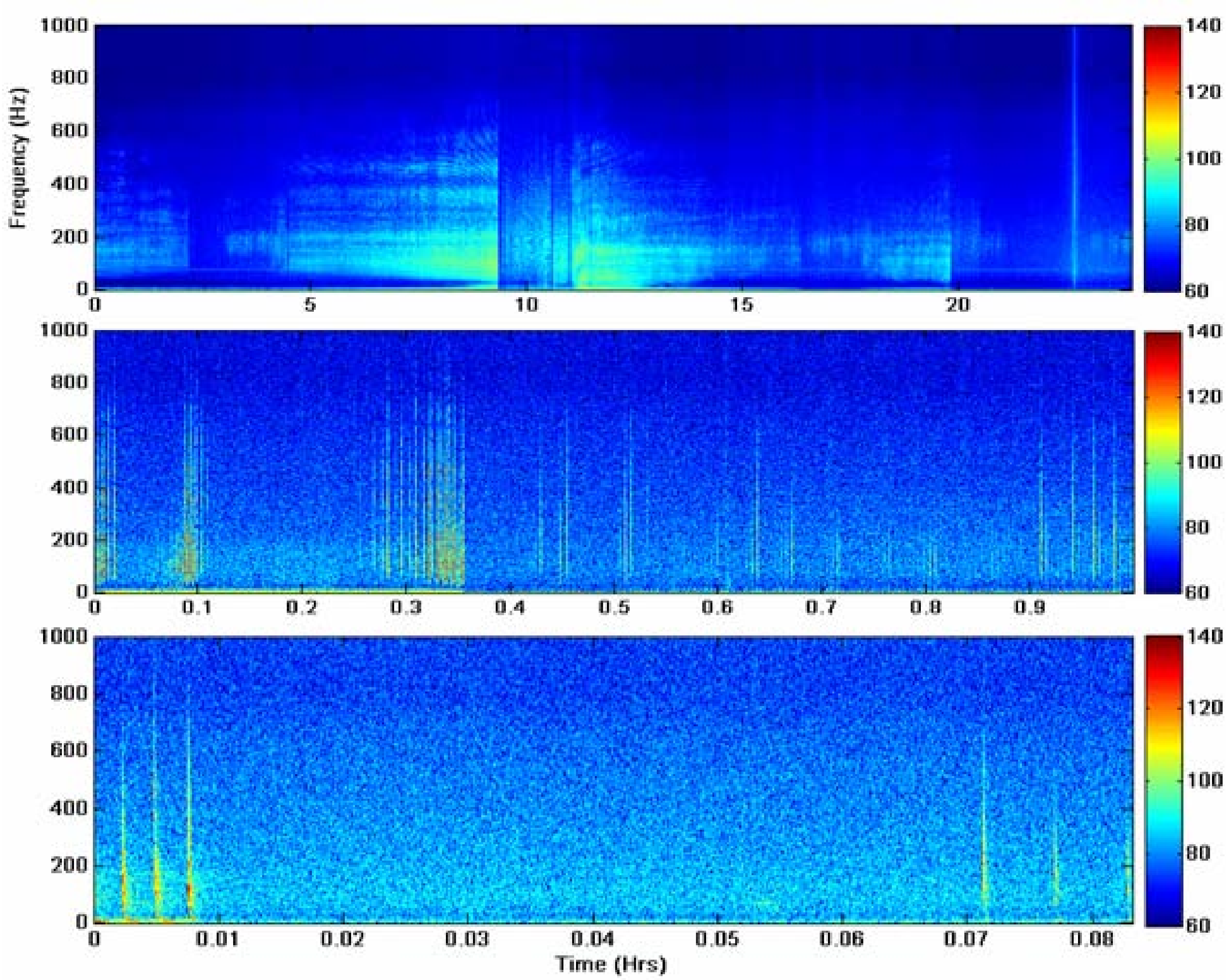


Figure 6.22. Example spectrograms for a day with seismic airgun array activity: 24-h (00:00-24:00, top panel), 1-h (09:00-1000, middle panel), and 5-min (09:00-09:05, bottom panel.) Data are from PU60, Wainwright-5, on 16 September 2006 and the same as presented in Figure 6.24 showing RMS noise levels. Color bar is RMS pressure level in dB re 1µPa.

Further representative examples of analysis include 24-hour, 1-hour and 5-min RMS measurements for a day without seismic airgun array activity (Figure 6.23) and a day with seismic activity (Figure 6.24,) where the RMS measurement includes the eight 1/3 octave bands covering the dominant frequency band of bowhead whale calls (70 – 450 Hz.) Calibration results for 10 pop-ups in the summer of 2006 (not the actual units used in this project) shown that the units had very consistent frequency responses (±1 dB) in the 55 – 500 Hz frequency range. Therefore, the dB values in these figures for the 70 - 450 Hz frequency band are assumed to be reliable measures of absolute received levels.

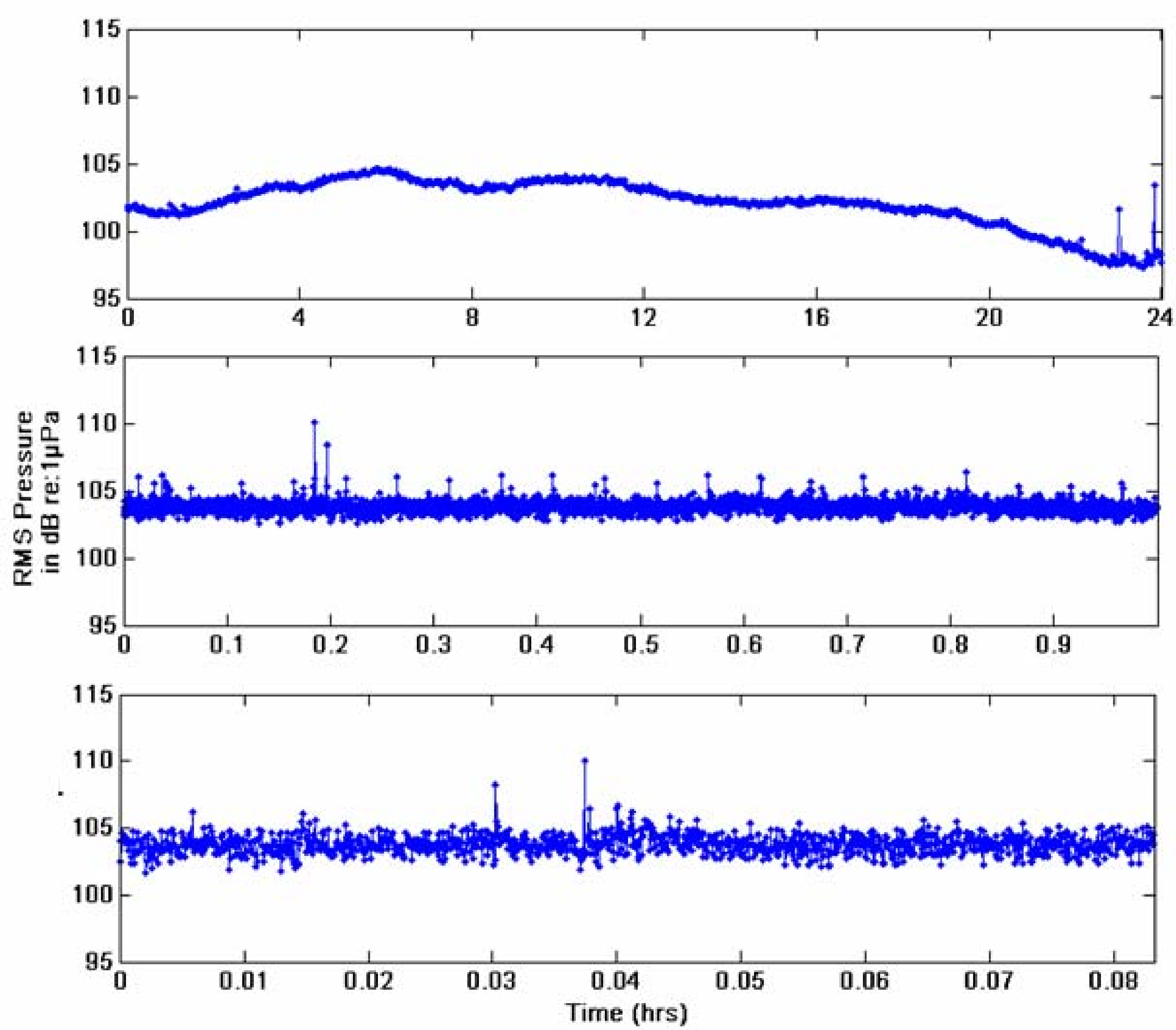


Figure 6.23. RMS noise levels (dB re 1 µPa, 70-450 Hz) for a day without seismic airgun array activity: 24-4 (top panel, 00:00-24:00, 86 sec integration time), 1-h (middle panel, 10:00-11:00, 1 sec integration time), and 5-min (bottom panel, 10:00 – 10:05, 0.26 sec integration time.) Data are from PU50, Wainwright-2, on 20 September 2006 and the same as used in the Figure 6.21 spectrogram.

These RMS noise level plots provide a quantitative measure of the how sound level varies over time but with different time resolutions. In the 24-h plot analyses a new noise level is calculated every 43 sec, whereas the noise levels for the 1-h and 5-min analyses are 2 s and 0.115 s, respectively. Therefore, the 24-h plot will not reveal the occurrence of individual seismic airgun array events, as would the 1-h and 5-min plots, but instead will show the occurrence of an operating seismic airgun array as a smoothly varying curve. For this reason one cannot distinguish between the occurrence of an operating seismic airgun array and ambient noise from the 24-h plot. In contrast, one can use the 1-h and 5-min analyses to observe the occurrence of an operating seismic airgun array provided that the individual events are not masked by ambient noise. Furthermore, the 1-h and 5-min analyses will show the occurrence of individual seismic airgun array events, but the peak value of the events will be different because of the different resolutions (i.e., integration times) of the two analyses. Such differences are apparent in Figure 6.24 if one compares the RMS levels of the seismic airgun array events as plotted in the middle panel (4 s integration time) with those in the bottom panel (0.26 s integration time), where the first break in the occurrence of events at approximately 0.35 h in the middle (1-h) plot coincides with the end of three discrete seismic events at approximately 0.01 h in the bottom (5-min) plot. This difference illustrates the point that to measure the received levels of transient events such as those from bowhead whales or seismic airgun arrays, one should avoid using an integration time that is greater than the duration of the event being measured.

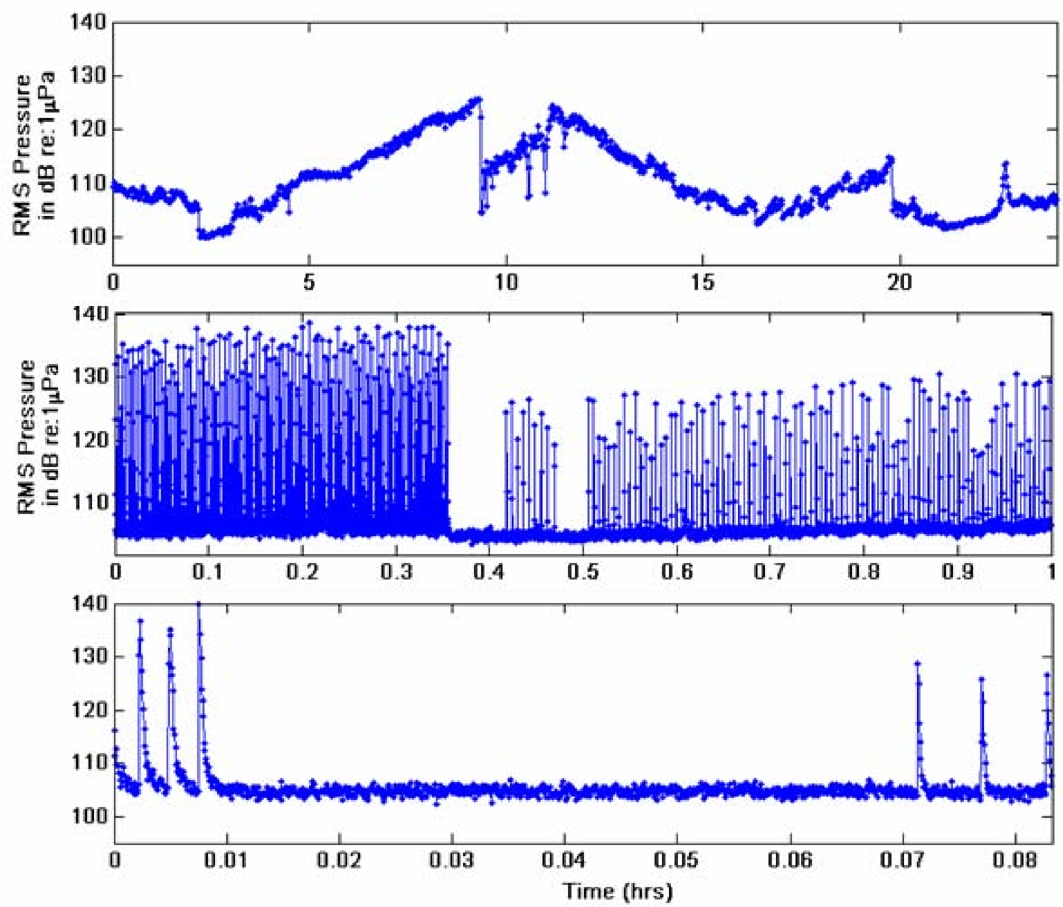


Figure 6.24. RMS noise levels (dB re 1 µPa, 70-450 Hz) for a day with seismic airgun array activity: 24-h (top panel, 00:00-24:00, 86 sec integration time), 1-h (middle panel, 9:00-10:00, 1 sec integration time), and 5-min (bottom panel, 09:20:50 – 0925:50, 0.26 sec integration time.) Data are from PU60, Wainwright-5, on 16 September 2006 and the same as used in the Figure 6.22 spectrogram.

Finally, representative examples of ambient noise, order statistics for 24-hour, 1-hour, and 5-min periods with and without seismic airgun array activity are provided to illustrate the types of statistical analysis completed for all pop-up acoustic data (Figure 6.25.) The five different colored lines in these plots represent the 5%, 25%, 50%, 75% and 95% order statistics based on spectrographic analysis, and thereby represent a way of measuring frequency dependent variability in the acoustic environment for different periods of time.

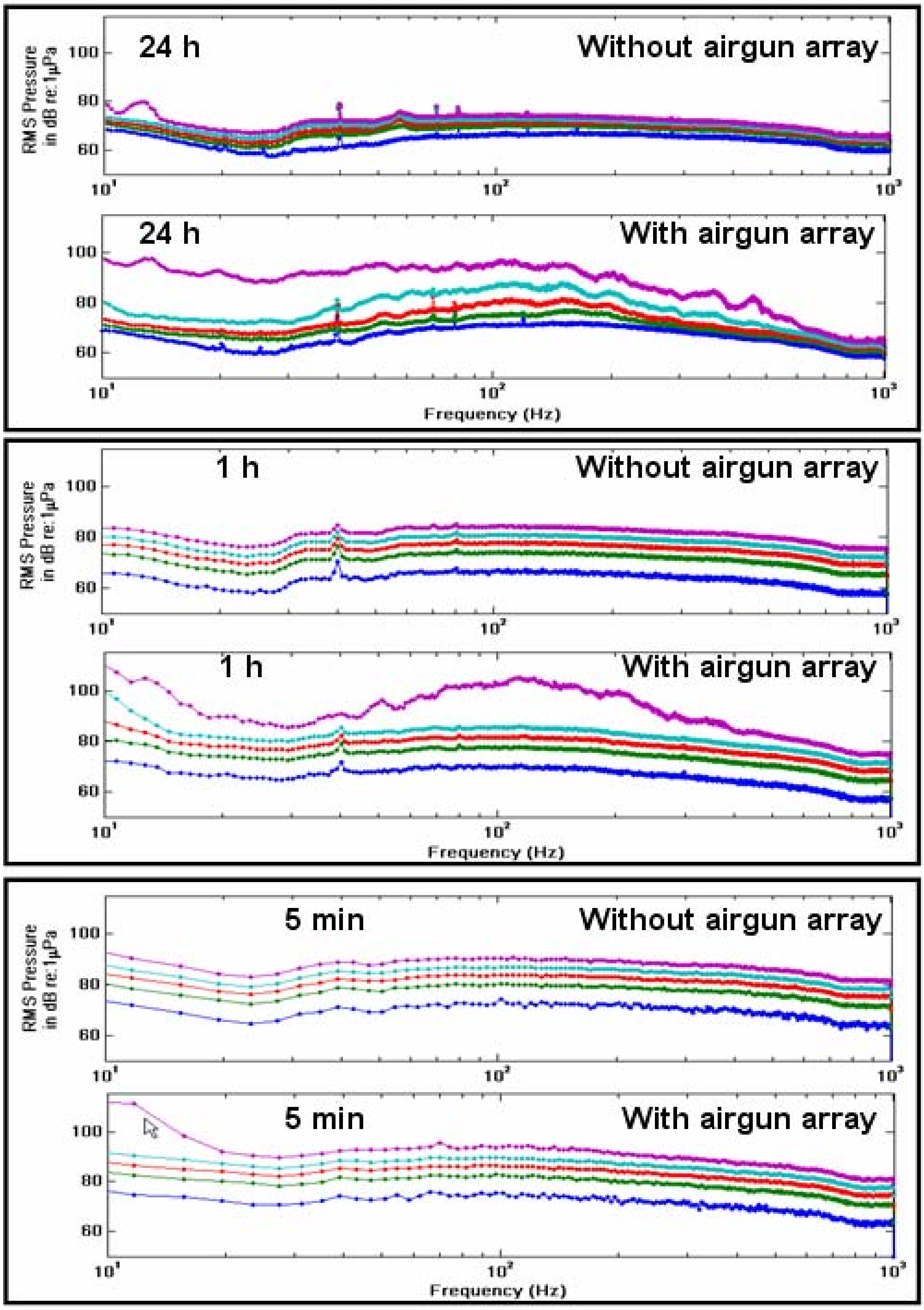


Figure 6.25. Spectrum level noise, order statistics for a day without seismic activity (Wainright-5, 20 Sept 06, PU50; see Figs 6.21 and 6.23) and a day with seismic airgun array activity (Wainwright-5, 16 Sept 06, PU60; see Figs. 6.22 and 6.24) for each of three different sampling durations (24-h, 1-h and 5-min.) The five different order statistics are for 5% (dark blue), 25% (green), 50% (red), 75% (aqua), and 95% (purple.) The received level value (RMS pressure in dB re μPa) range is 50 – 115 dB, while the frequency range is 10-1000 Hz, log scale.

Acoustic Occurrence of Seismic Activity

Documentation of seismic airgun array activity was completed for the entire data set at a 24-h (daily) resolution for Phase I and a 15-minute resolution for Phase II. Example spectrograms and order statistics are presented here as comparative illustrations for the condition when a single seismic airgun array was operating (Figures 6.26 and 6.27) and for a case when multiple airgun arrays were operating (Figure 6.28 and 6.29.)

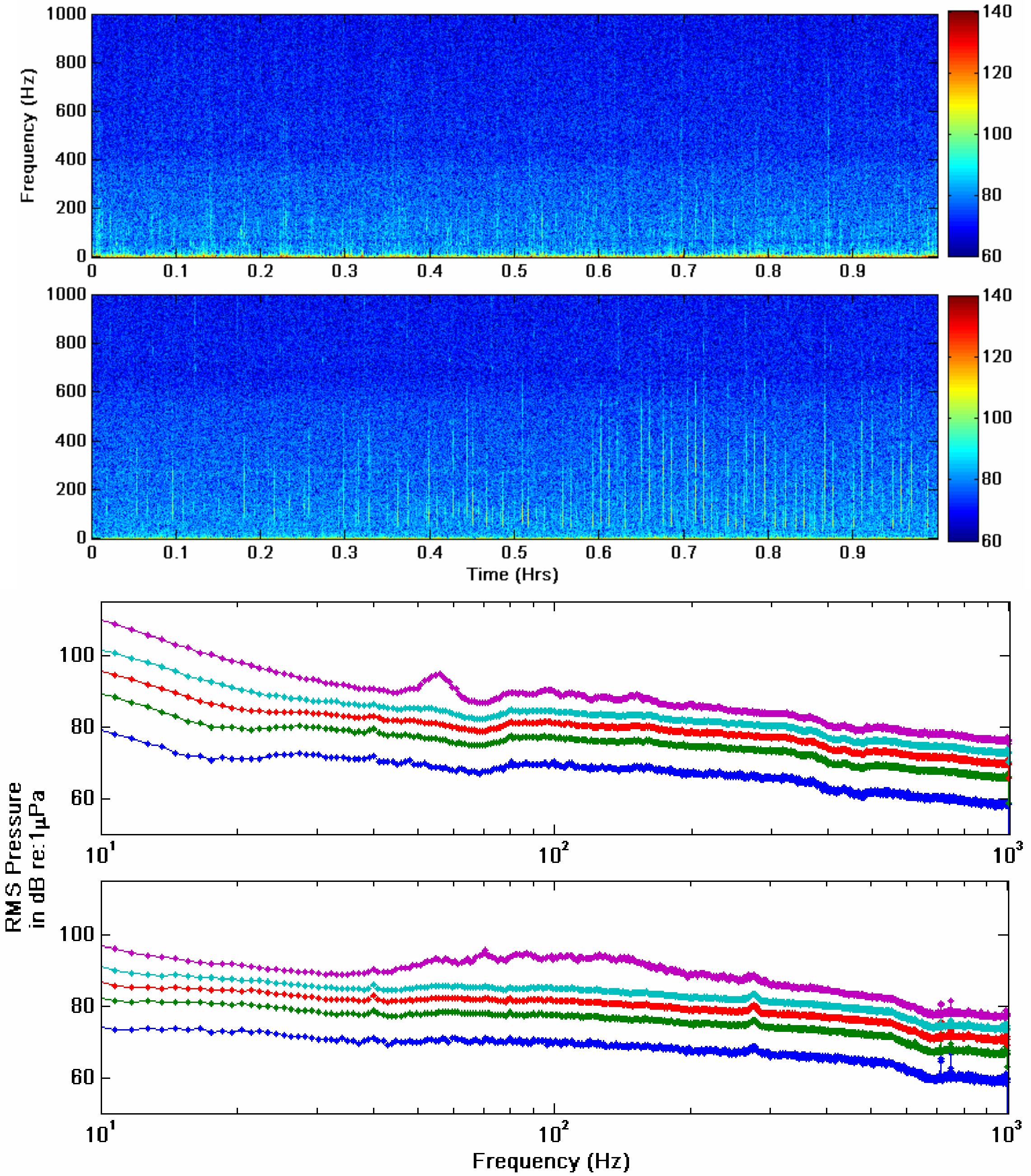


Figure 6.26. Spectrograms and order statistics from two Pt. Lay pop-ups (ch-2, PU19, top; and ch-5, PU63, bottom: see Table 6.2, Fig. 6.6) on 16 September, 10:00 – 11:00h when a single seismic airgun array was operating. Color bar is RMS pressure level in dB re 1µPa. The five different order statistics are for 5% (dark blue), 25% (green), 50% (red), 75% (aqua), and 95% (purple.) The received level value (RMS pressure in dB re µPa) range is 50 – 115 dB, while the frequency range is 10-1000 Hz, log scale.

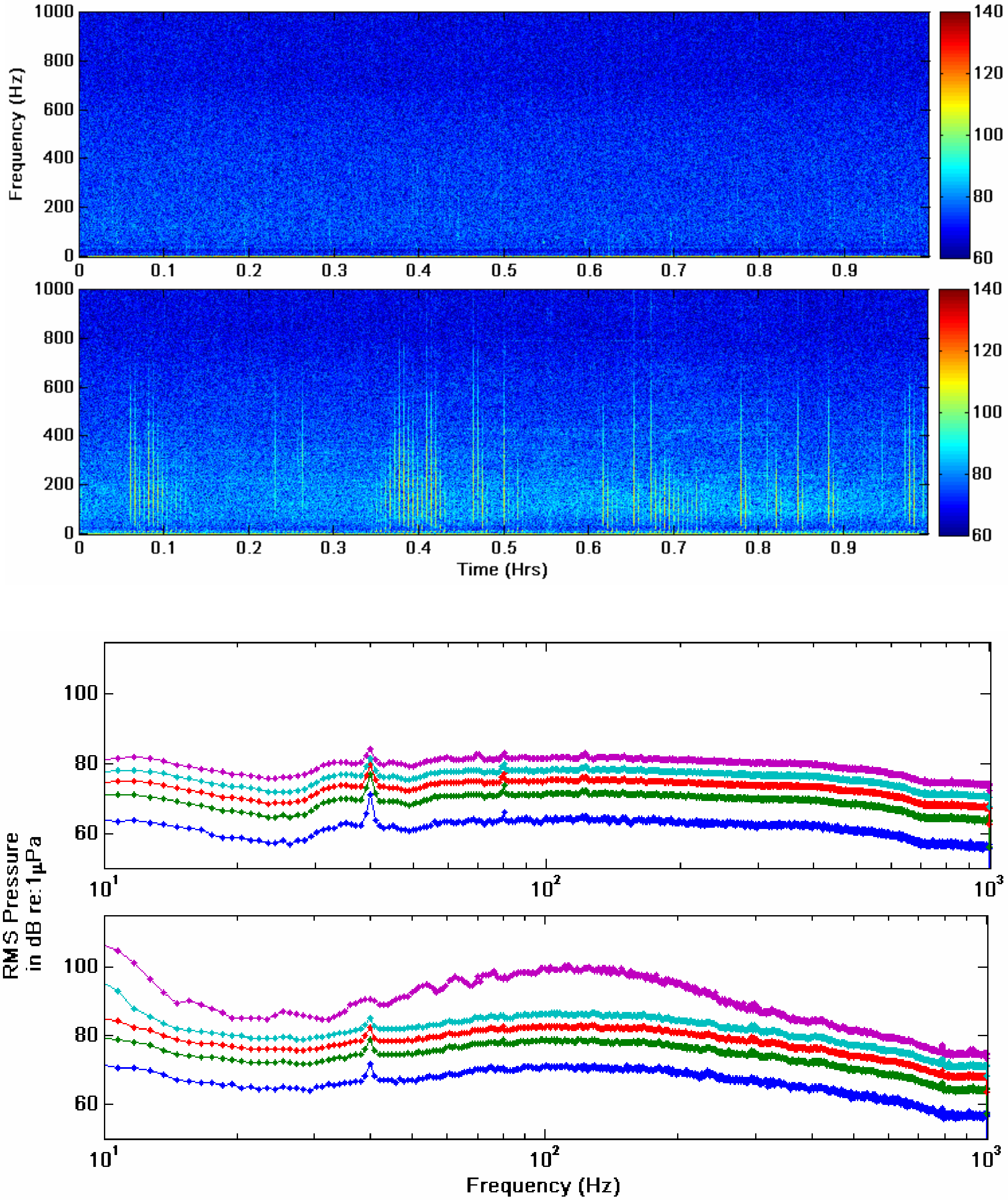


Figure 6.27. Spectrograms and order statistics for two Wainwright pop-ups (ch-2, PU50, top; and ch-5, PU60, bottom: see Table 6.2, Fig. 6.7) on 16 September, 10:00 – 11:00h when a single seismic airgun array was operating. Color bar is RMS pressure level in dB re 1μPa. The five different order statistics are for 5% (dark blue), 25% (green), 50% (red), 75% (aqua), and 95% (purple.) The received level value (RMS pressure in dB re μPa) range is 50 – 115 dB, while the frequency range is 10-1000 Hz, log scale.

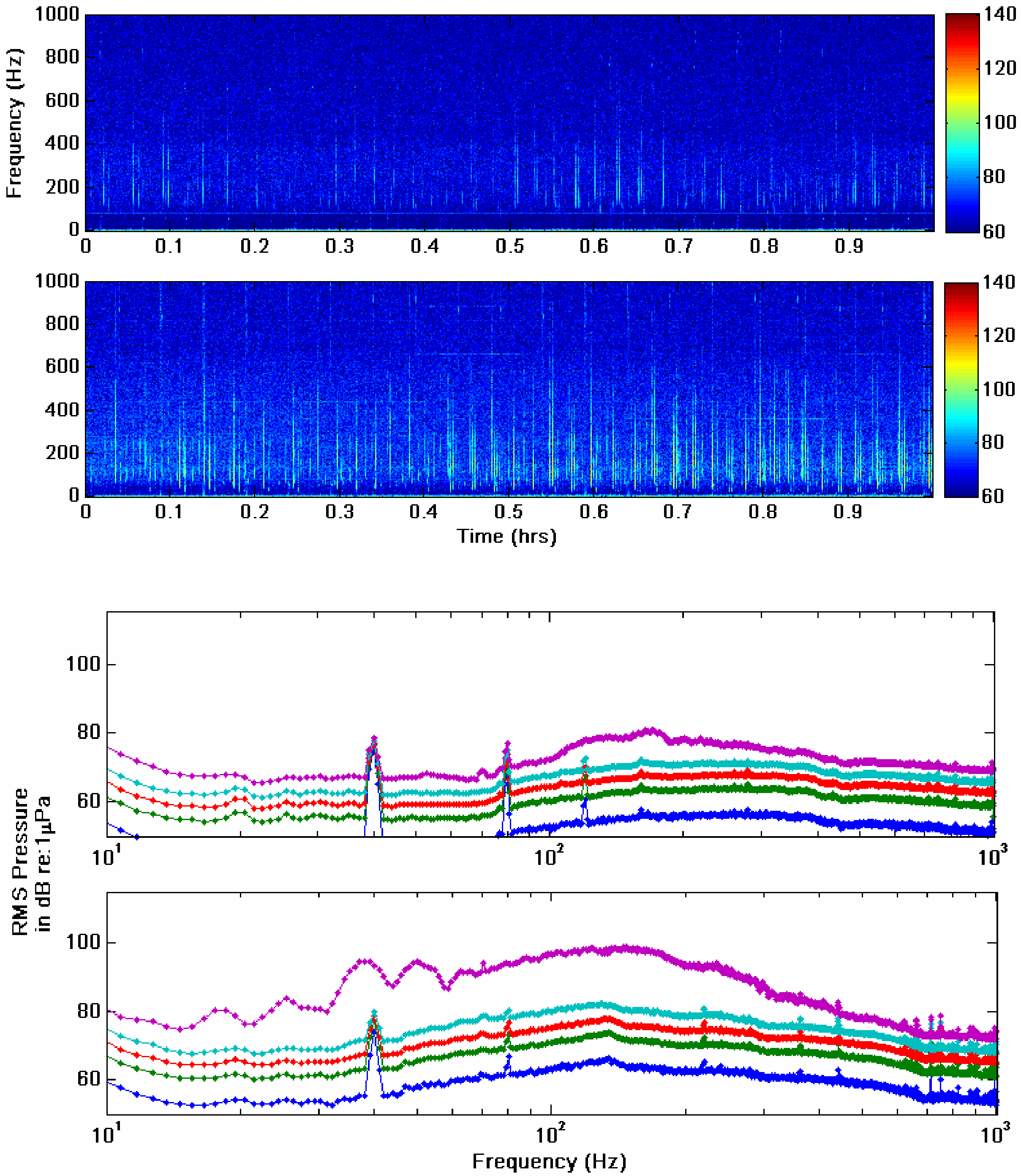
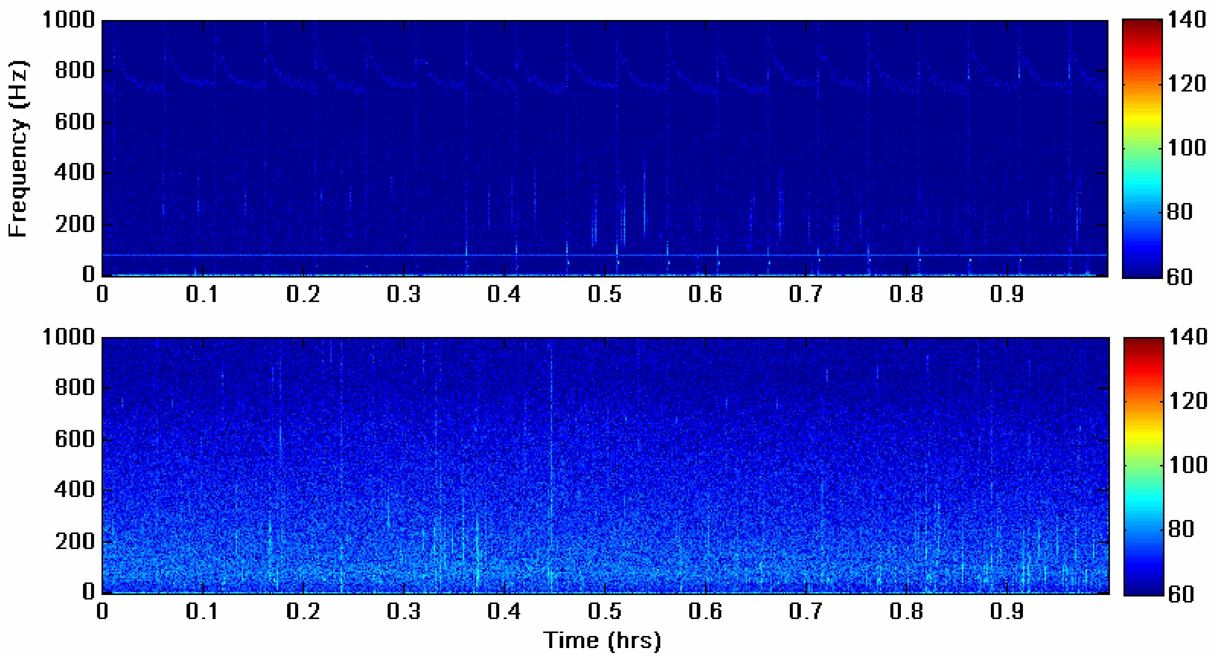


Figure 6.28. Spectrograms and order statistics for two Pt. Lay pop-ups (ch-2, PU19 top; and ch-5, PU63 bottom: see Table 6.2, Fig. 6.6) on 18 September, 16:00-17:00h when multiple airgun arrays were operating. Color bar is RMS pressure level in dB re 1µPa. The five different order statistics are for 5% (dark blue), 25% (green), 50% (red), 75% (aqua), and 95% (purple.) The received level value (RMS pressure in dB re µPa) range is 50 – 115 dB, while the frequency range is 10-1000 Hz, log scale.



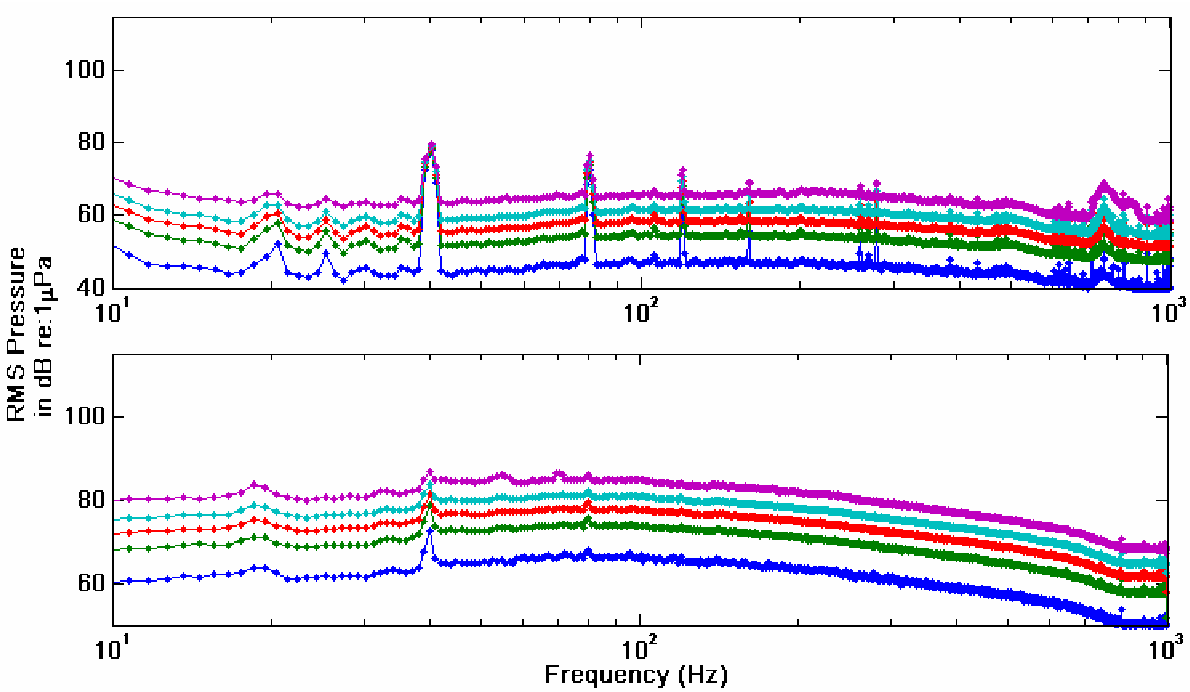


Figure 6.29. Spectrograms and order statistics for two Wainwright pop-ups (ch-2, PU50, top; and ch-5, PU60, bottom: see Table 6.2, Fig. 6.7) on 18 September, 16:00-17:00h when multiple airgun arrays were operating. Color bar is RMS pressure level in dB re 1µPa. The five different order statistics are for 5% (dark blue), 25% (green), 50% (red), 75% (aqua), and 95% (purple.) The received level value (RMS pressure in dB re µPa) range is 50 – 115 dB, while the frequency range is 10-1000 Hz, log scale.

As discussed above in the methods sections "***Acoustic Occurrence of Seismic Activity***" and "***Acoustic Analysis and Measurements of Selected Time Periods***," detection analyses might have missed some occurrences of seismic airgun array activity when SNR was poor. However, it was obvious from the initial detection results that seismic airgun array activity occurred throughout a significant portion of the times when these offshore pop-ups were operating. For Phase I, detection results were hampered by having pop-ups only off Cape Lisburne, and therefore these detection results most likely under-represent the actual occurrences of seismic airgun array activity during the 15 July through 10 September 2007 period. For Phase II, it was immediately obvious that seismic airgun array activity was occurring closest to the 90 kilometer offshore pop-ups either off the Pt. Lay (PU63 = ch-5, see Fig 6.6) or Wainwright (PU60 = ch-5, see Fig. 6.7.) Because of the number and distribution of pop-ups during Phase II, the detection results for this phase most likely are a very good representation of the actual occurrences of seismic airgun array activity during the 12 September through 13 October 2007 period.

To provide an overall perspective on the temporal scale over which seismic airgun arrays were acoustically detected, listings of the dates and times when seismic airgun array events were detected or not detected during Phase I and Phase II are presented.

For the Phase I analysis data from all five pop-ups in the Lisburne array (see Fig 6.2) were used to determine the daily occurrence of seismic airgun array activity, and Figure 6.30 shows the daily number of pop-ups on which seismic airgun array events were detected on the Lisburne pop-ups during Phase I.

For the Phase II analysis only the 90 kilometer offshore pop-ups from Pt. Lay (PU63 = ch-5, see Fig 6.6) and Wainwright (PU60 = ch-5, see Fig. 6.7) were used as the detection sensors. Figure 6.31 shows the date-times (15-minute resolution) of seismic airgun array events as detected on these two pop-ups approximately 90 km offshore of Pt. Lay or Wainwright.

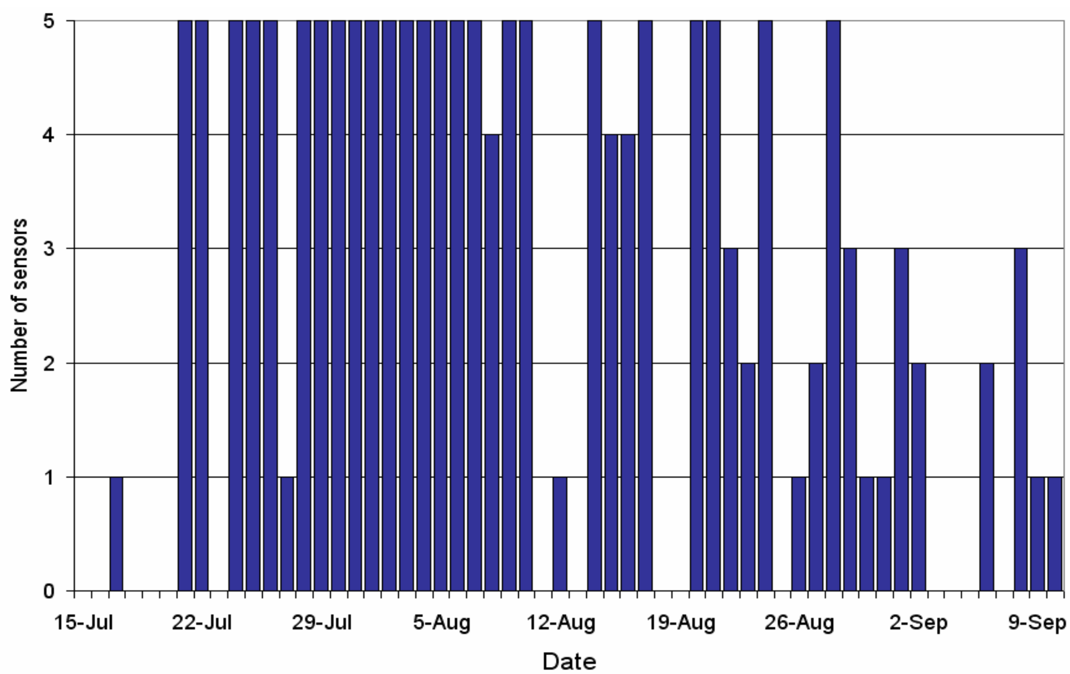


Figure 6.30. Daily number of pop-up sensors on which seismic airgun array sounds were detected during Phase I (off Cape Lisburne only.)

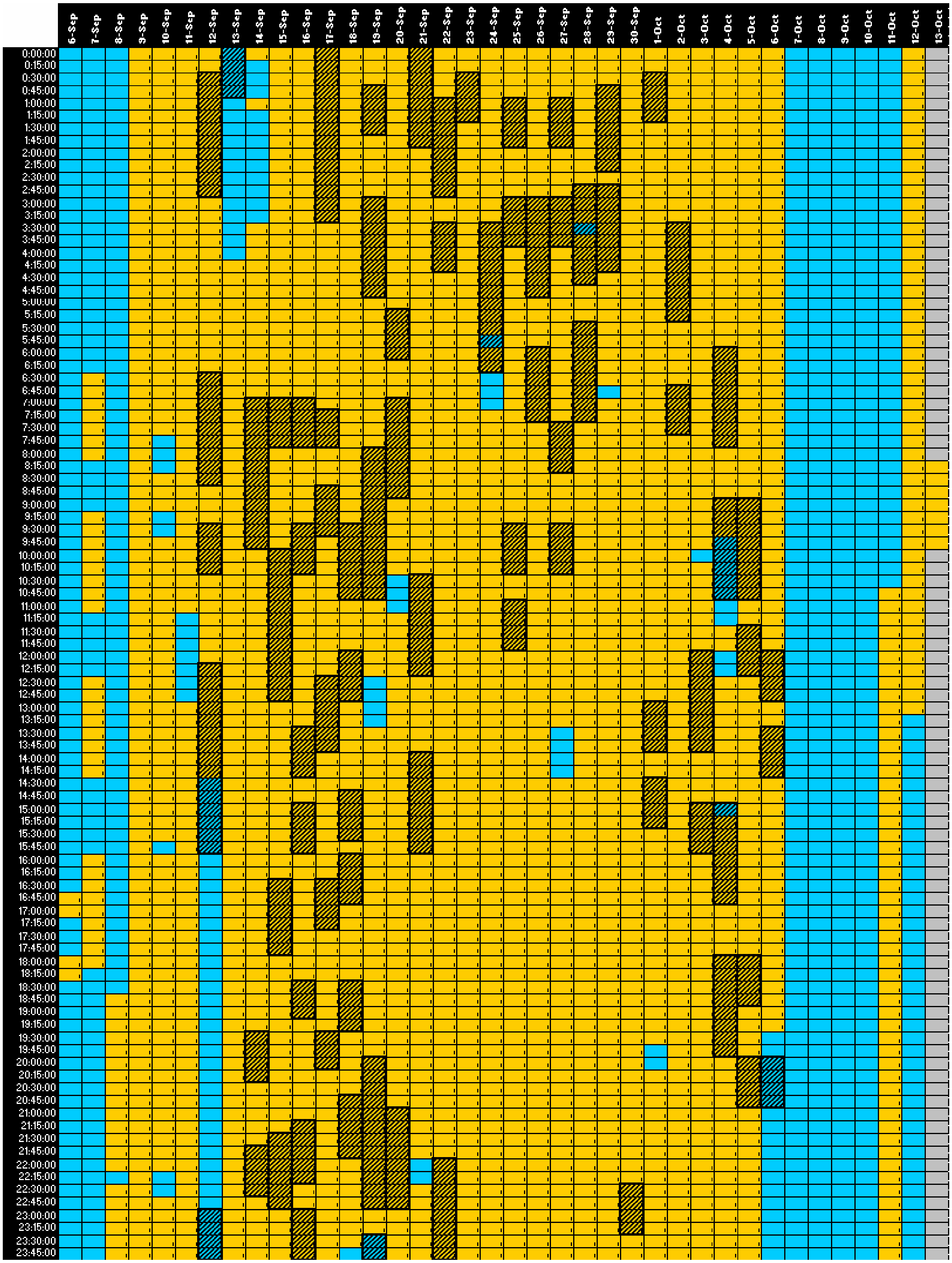


Figure 6.31. Daily, 15-minute periods on which seismic airgun array sounds were detected (yellow) or not detected (blue) on either of the two most offshore (90 km) pop-ups off Pt. Lay (PU63) and Wainwright (PU60) during Phase II (see Figs. 6.4, 6.6, and 6.7, and Table 6.2.) Hatched indicates a date-time sample period selected for detailed analysis. Grey indicates no data.

Measurements of Selected Date-Time Sample Periods

LGL staff provided BRP with 79 date-time sample periods from Phase II (see Fig. 6.31, above and Annex E and Annex F) that included a variety of conditions (e.g., no seismic airgun array activity, one airgun array operating, and two airgun arrays operating.)

In order to adequately quantify seismic airgun array received levels for the 79 date-time sample periods, sound analysis integration time was adjusted to 1 second, and spectrographic images, ambient noise order statistics (5%, 25%, 50%, 75%, 95%), and 1/3 octave received levels were recomputed and saved as MatLab files. Results from this process were then carefully screened to yield RLs of individual ping and inter-ping events at each pop-up. Several examples are provided here to illustrate these RL differences as measured at different pop-ups. These examples include RLs (Figures 6.32 and 6.34) and a 3dB RL histogram (Figures 6.33 and 6.35.)

The first example is for the LGL date-time sample period #14 on 16 September, 09:30 – 10:30h when a single airgun array was operating.

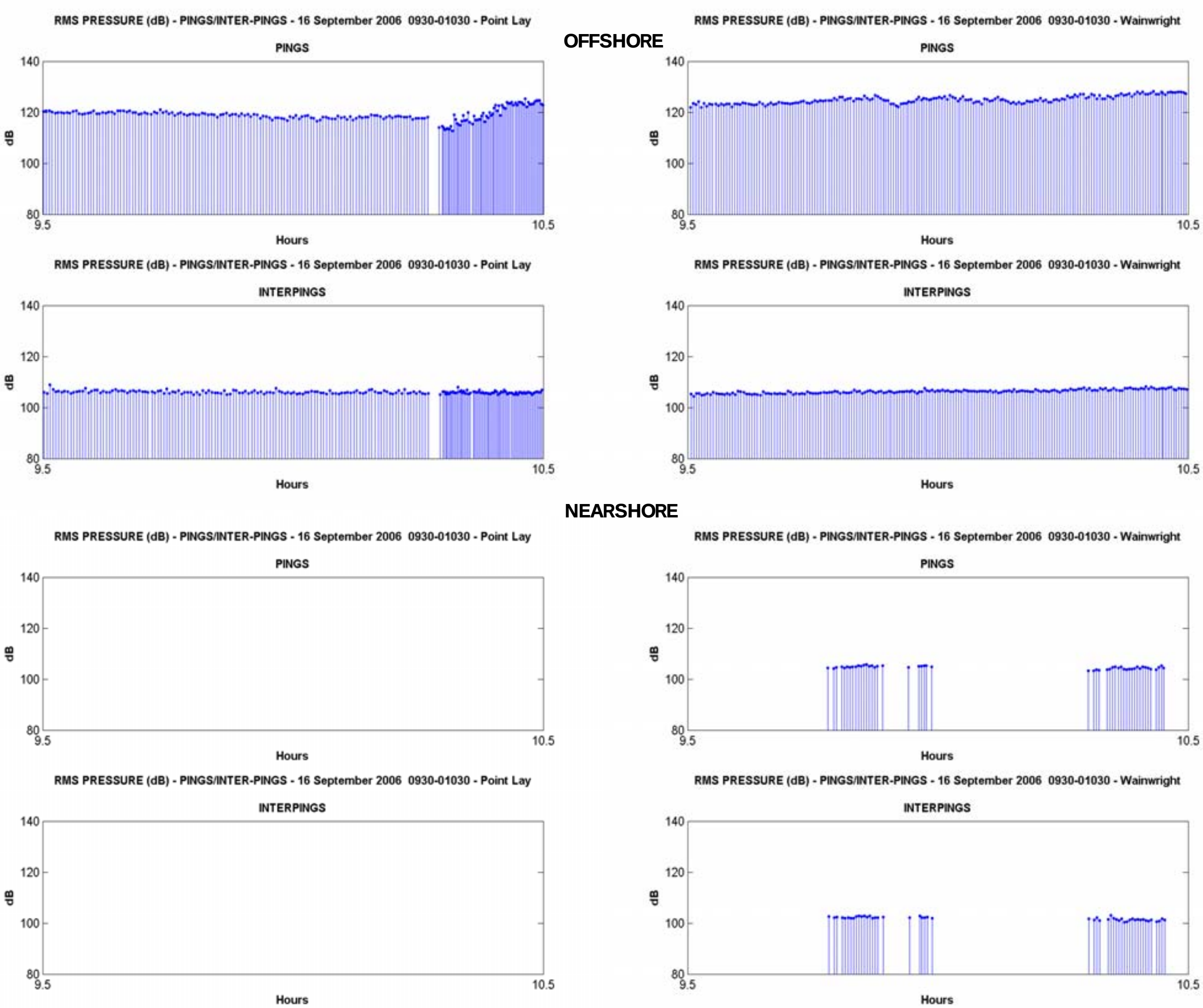


Figure 6.32. Pairs of received levels for seismic airgun array events (pings) and silent gaps between events (inter-pings) for Pt. Lay ch-5 (PU63, ca. 90 km offshore), Pt. Lay ch-2 (PU19, ca. 18 km offshore), Wainwright ch-5 (PU60, ca. 90 km offshore), and Wainwright ch-2 (PU50, ca. 18 km offshore) on 16 September, 09:30 – 10:30h (Date-time sample period #14.) There were no detections for Cape Lisburne.

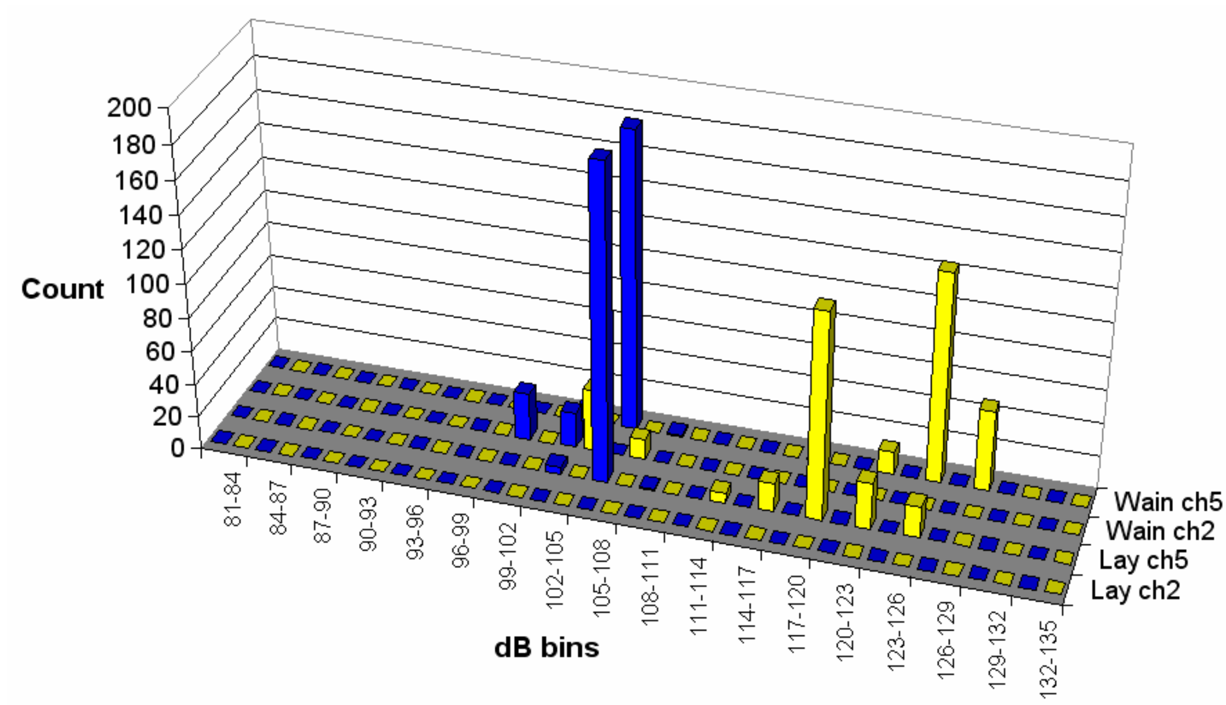


Figure 6.33. Histogram showing the distribution of RLs at four pop-ups: Pt. Lay, ch-2 (PU19) and ch-5 (PU63): and Wainwright ch-2 (PU50) and ch-5 (PU60) for seismic airgun array events (yellow, pings) and for the short periods between those events (blue, inter-pings) on 16 September, 09:30 – 10:30h (date-time sample period #14.)

In some cases it was evident that more than one seismic airgun array was operating. In this situation quiet periods between pings (i.e., inter-pings) were difficult to find and measure. The following set of figures provides an example when two airgun arrays were operating and is for the LGL date-time sample period #28 on 18 September, 16:00 – 17:00h.

The number of seismic event detections varied considerably from pop-up to pop-up (Annex E and Annex F.) The greatest total number of seismic events, 32332, was detected on the pop-up 90 km off of Pt. Lay (PU63, ch-5), while the fewest number, 5, was detected on Pt Barrow's ch-5 (PU59.) When detections per pop-up are converted to rates (events per hour), these counts translate into 268 events/h for Pt. Lay ch-5 and 0.05 events/h for Pt. Barrow ch-5. Figure 6.36 shows hourly rates for each of the 79 date-time sample periods for six pop-ups (Lisburne ch-2, Pt. Lay ch-2 and ch-5, Wainwright ch-2 and ch-5), while Annex E is a listing of these same data. As evident from the extremely few seismic airgun array detections off Pt. Barrow, in cases of poor SNR, accurate assessments of detections were difficult.

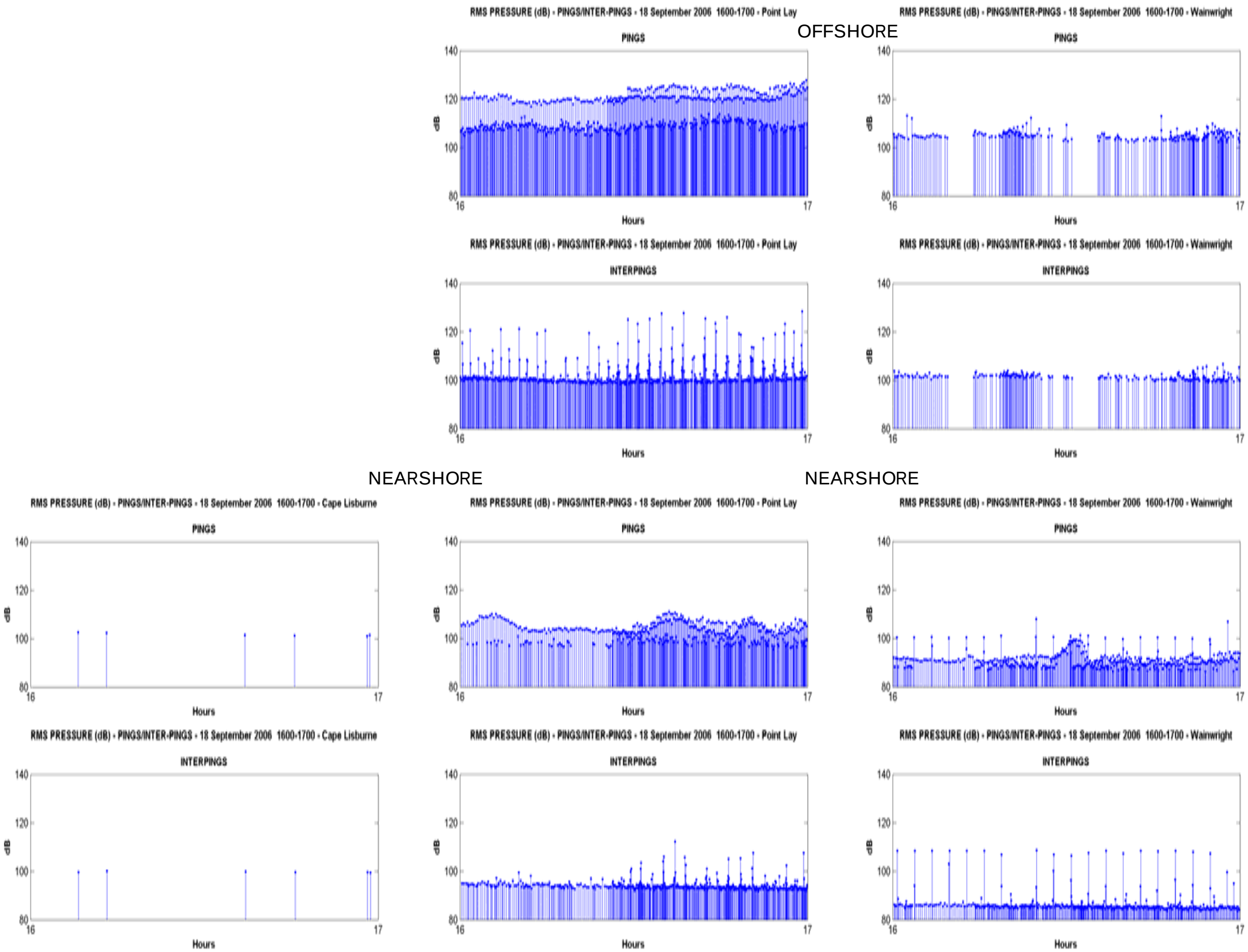


Figure 6.34. Pairs of received levels for seismic airgun array events (pings) and silent gaps between events (inter-pings) for Cape Lisburne pop-up ch-2 (PU89, ca. 18 km offshore), Pt. Lay pop-up ch-5 (PU63, ca. 90 km offshore), Pt. Lay pop-up ch-2 (PU50, ca. 18 km offshore), and Wainwright pop-up ch-5 (PU60, ca. 90 km offshore),Wainwright pop-up ch2 (PU50, ca. 18 km offshore) on 18 September, 16:00-17:00h (date-time sample period #28.)

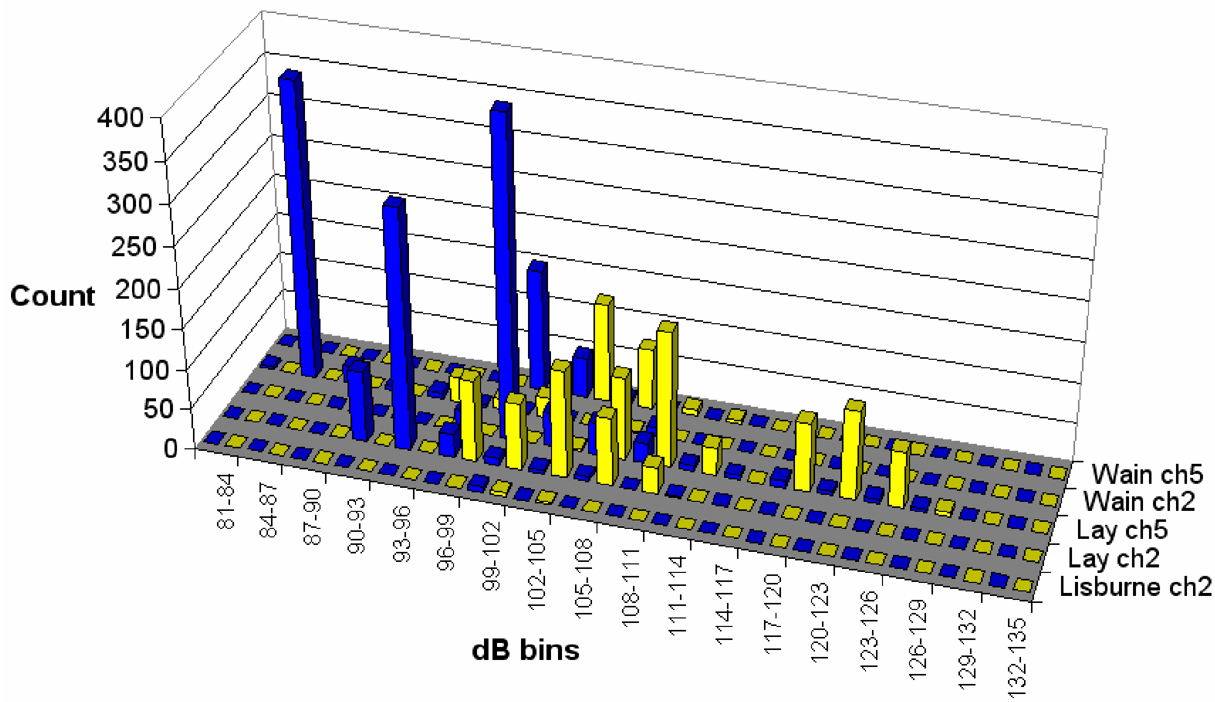


Figure 6.35. Histogram showing the distribution of RLs at five pop-ups: Cape Lisburne ch-2 (PU89), Pt. Lay, ch-2 (PU19) and ch-5 (PU63): and Wainwright ch-2 (PU50) and ch-5 (PU60) for seismic airgun array events (yellow, pings) and for the short periods between those events (blue, inter-pings) on 18 September, 16:00-17:00h (date-time sample period #28.)

The received levels of seismic airgun array events during 79 date-time sample periods varied considerably from recorder to recorder. Received levels were highest at the recorders 90 km off Pt. Lay and Wainright. Maximum received levels (RMS dB re 1 µPa) for the pop-up 90 km off of Pt. Lay (PU63) ranged from 104 – 136 dB and from 101 – 132 dB for the pop-up 90 km off of Wainwright (PU60.) For comparison, maximum received levels (RMS dB re 1 µPa) for the pop-up 18 km off of Pt. Lay (PU19) ranged from 100 – 118 dB and from 90 – 116 dB for the pop-up 18 km off of Wainwright (PU50.). Maximum received levels (RMS dB re 1 µPa) for the recorder 18 km off Cape Lisburne (PU89) ranged from 97 – 111 dB. Received level estimates were not possible for any of the five seismic events detected off Pt. Barrow as the signal was in the noise.

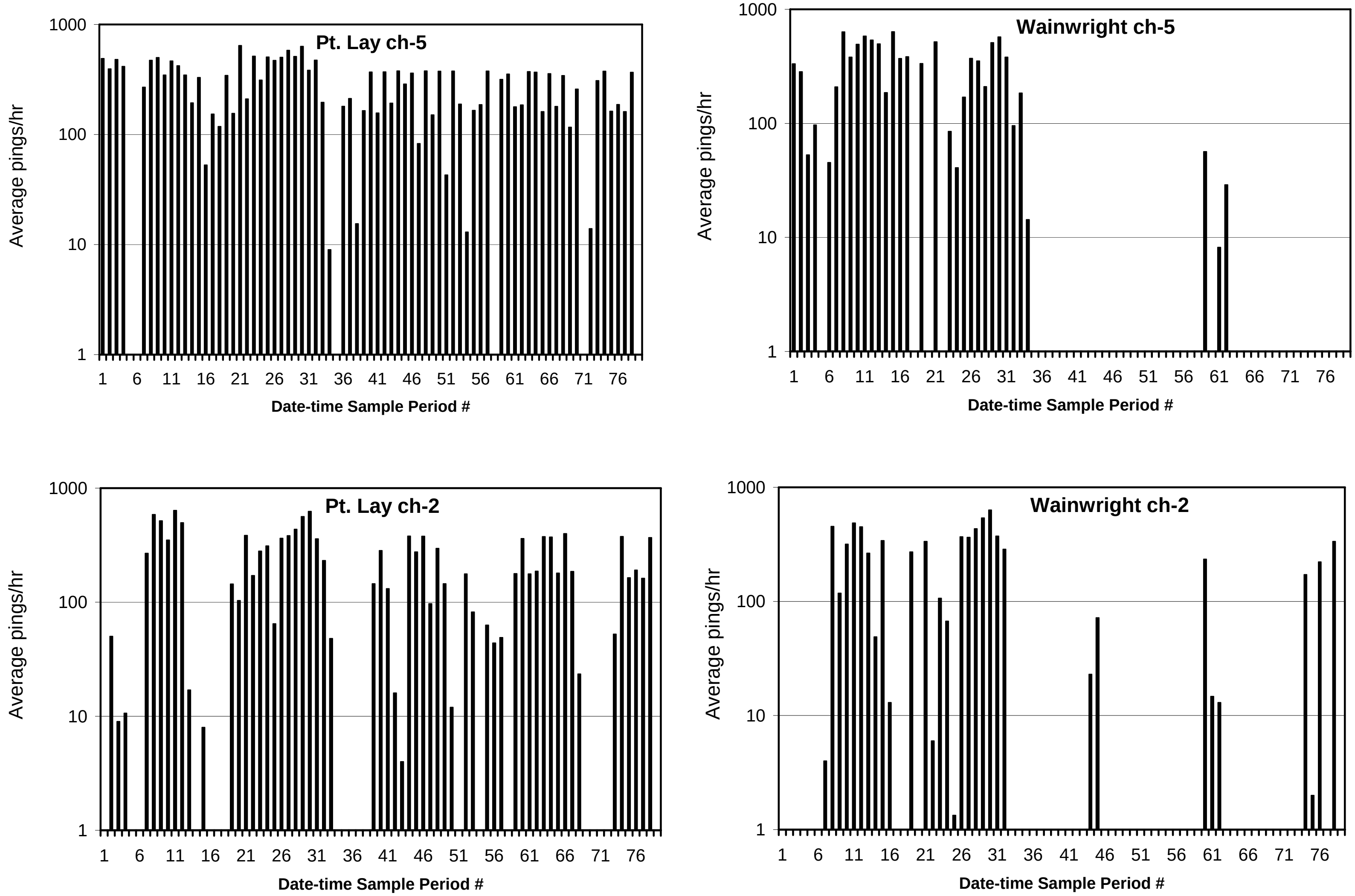
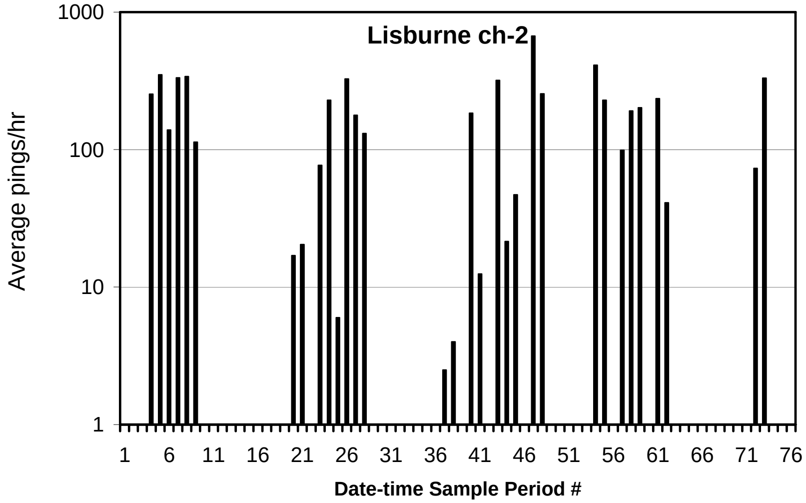


Figure 6.36-A. Number of seismic airgun array events detected per hour at Pt. Lay ch-5 (PU63) and ch-2 (PU19) and Wainwright ch-5 (PU60) and ch-2 (PU50) for each of the 79 date-time sample periods.



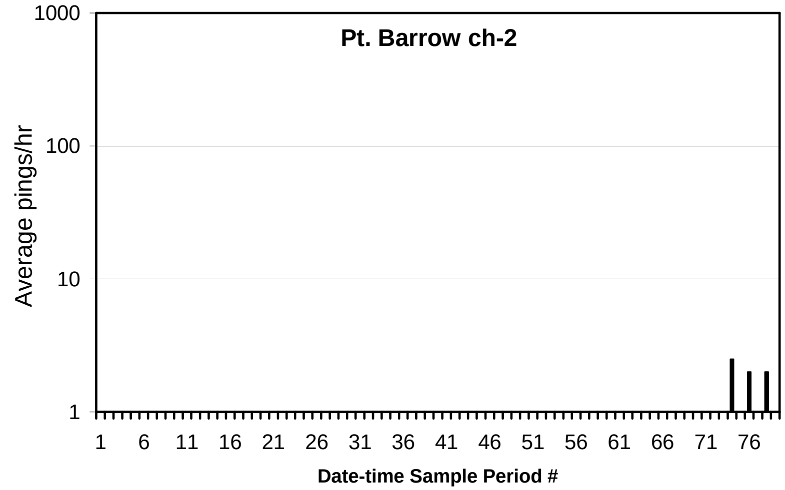


Figure 6.36-B. Number of seismic airgun array events per hour for each of the 79 date-time sample periods at Cape Lisburne ch-2 (PU89) and Pt. Barrow ch-2 PU21.)

Discussion

We present here a limited interpretation of seismic airgun array activities as viewed through the data received on these seven pop-ups, but without any specific information on industrial activities (e.g., periods with seismic airgun array activity, number of seismic airgun array survey vessels or support vessels.)

This chapter primarily describes the tasks completed by Cornell's Bioacoustic Research Program in support of the acoustic monitoring effort required by LGL Alaska Research to collect and analyze data from their Arctic Ocean Outer Continental Shelf Seismic Surveys. In support of this effort BRP provided a suite of 22 pop-ups and made every effort to deploy and retrieve the pop-ups to meet the acoustic monitoring requirements. All recovered pop-ups successfully recorded data as expected. Three units deployed off Cape Lisburne in September 2006 and scheduled for recovery in October 2006 were never recovered.

The Phase I passive acoustic monitoring effort was designed to detect beluga whale sounds. Due to ice conditions, data from Phase I were limited to Cape Lisburne, and there were only seven days on which beluga whale sounds were detected, and no bowhead whale calls were detected. No belugas were detected on the pop-up closest to Cape Lisburne (ca. 9 km offshore). When belugas were detected, they were detected on the four pop-ups deployed between 18 and 90 km offshore. Overall, these results suggest that relatively few belugas were moving through the Cape Lisburne area from mid-July through early September 2006, and when they were detected, they were more than 10 kilometers from shore.

The Phase II passive acoustic monitoring effort was designed to detect bowhead whale calls. Data from Phase II (10 September – 12-15 October) provided good coverage of the Pt. Lay, Wainwright and Pt. Barrow areas, but Cape Lisburne data were impacted by the loss of the three most offshore units. After completion of the initial review and analyses of the Phase II acoustic data, analyses plans were modified to better provide support for describing received levels of individual seismic airgun array events and the gaps of time between those events. For this effort, LGL generated a list of 79 date-time sample period that BRP analyzed in detail.

One important task in the analysis of the Phase II data was the detection of bowhead whales. Originally, we had hoped to possibly use these data to compute locations and tracks of vocalizing bowheads and then use all these bioacoustic results to: a) analyze the relationship between seismic airgun array events and bowhead whale call rates as a means of evaluating potential impacts of seismic airgun array sounds on calling behavior, b) determine the distances of calling whales from active seismic airgun array sources, and c) use spatial and temporal locations to better define the fall migration corridor. Although the nearshore Phase II sets of pop-ups for Pt. Lay and Wainwright were configured to possibly locate calling bowheads, very few calls were detected at three or more pop-ups at these two sites. As a result, we did not attempt acoustic location or tracking analyses on these data. For Pt. Barrow in September, pop-ups could not be deployed as originally planned because of heavy ice conditions, so instead were deployed in a line running approximately southwest to northeast, with units spaced approximately 5 miles apart (Fig. 6.8.) Upon first review of the Pt. Barrow data, we found a high number of bowhead calls. Many of these sounds were detected on three of the units, raising the expectation that we might be able to reliably locate calling animals. This expectation was not born out as most of the sounds were distorted by reverberation and were very difficult to locate. Furthermore, analysis of the Pt. Barrow data for seismic airgun array sounds yielded only five seismic airgun array detections, and the signal to noise ratio for those five events were so low that reliable RLs could not be calculated. Therefore, at the 21 May 2007 meeting in Anchorage it was agreed that BRP would not attempt any further location analysis. This recommendation was based on several factors including: the deployment geometry of the pop-ups off Pt. Barrow was not designed to locate whales, the resultant data were contaminated with reverberation, and the very few seismic airgun array vents that were detected had very low received levels. As a result of this situation there was no effort by BRP to analyze the relationship between seismic airgun array events and bowhead whale call rates as a means of evaluating potential impacts of seismic sounds on calling behavior, determine the distances of calling whales from active seismic sources, or use spatial and temporal locations to better define the fall migration corridor.

The almost total lack of seismic airgun array detections on any of the five Pt. Barrow pop-ups combined with the relatively high levels of vocal activity on these units suggests that changes in the bowhead whale call rates off Pt. Barrow were not influenced by seismic survey activities occurring in the Chukchi Sea region somewhere offshore of the pop-ups deployed 90 km offshore of Pt. Lay and Wainwright. The bowhead call detection data do indicate a shift from a broad but mostly offshore distribution at Wainwright (Fig. 6.14) to an inshore distribution off Pt. Lay (Figs. 6.15.) This pattern seems to indicate that only a few animals were moving southwesterly along the coastline, and is not inconsistent with earlier evidence indicating two fall migration routes; a primary route far offshore heading westward toward Wrangel Island and a secondary inshore route along the coast (Moore and Reeves 1993.) Unfortunately, pop-ups were not deployed more than 90 km offshore of Pt. Lay and Wainwright, and their inshore units were removed by 12-13 October, so further acoustic monitoring effort is required to gain insights into the fall migration of bowheads in the Chukchi Sea. In any case, the observed pattern of bowhead call rates off Pt. Lay in 2006 were extremely low (< 0.05 calls/h), so it is unreasonable to interpret the change in distribution from Wainwright to Pt. Lay as an avoidance reaction to the offshore seismic airgun array activity.

Overall, seismic activity in the Chukchi Sea, as evidenced by the high rates of detected seismic airgun array events, was nearly continuous throughout the 9 September through 6 October 2006 period. There was insufficient evidence to evaluate either beluga or bowhead distributions or relative levels of vocal activity in relation to seismic airgun array activities. The high level of bowhead calling activity off Pt. Barrow was expected. Unfortunately, there is no baseline bioacoustic data for the area to the west of Barrow against which these 2006 Chukchi Sea data might be compared. Thus, although there is historical aerial survey evidence from past decades indicating that as bowheads migrated west past Pt. Barrow in the fall, some moved westward across the Chukchi Sea and some moved southwestward along a more coastal route. Our acoustic monitoring effort ended between 12-15 October about the time when bowhead call rates off Pt. Barrow were showing signs of decreasing and those for Wainwright had just gone through a 5-6 day crescendo, with the highest rates occurring around the Wainright pop-up that was 90 km offshore (Fig. 6.17.) It is interesting to note that this 5-6 day surge between 6-11 October (Fig. 6.16) on the four inshore pop-ups off Wainwright occurred at the very same time when there was a lull in seismic activity (Fig. 6.31). At this point this is a coincidence that cannot be given any more weight than an anecdote. Similarly, there are two obvious dips in bowhead calling activity levels during 24-25 September and during 30 Sept – 1 October (Fig. 6.18), raising the question of whether these were coincident with fall whaling activities off Pt. Barrow. In any case, until and unless much more is known about variations in the acoustic behavior of bowhead whales during the fall migration from Pt. Barrow and west into the Chukchi Sea, these types of coincidences, although not inconsistent with the general hypothesis that bowhead whales respond to increases in anthropogenic sounds, remain anecdotal.

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ANNEX A. Summary of pop-up (PU) deployment information for Phase I and Phase II (PU77, PU61, and PUS88 were not recovered).

	Chukchi-2006July Phase I Deployment										
PU #	**Location**	**Latitude**	**Longitude**	**Depth(m)**	**Sample Rate**	**Start Date**	**Start Time**	**Drop Date**	**Drop Time**	**Retrieval Date**	**Retrieval Time**
21	Lisburne	N68º 55.033'	W166º 21.239'	29.2	10000 hz	7/14/2006	22:34:04	7/14/2006	23:29:00	9/10/2006	3:41
32	Lisburne	N68º 57.801'	W166º 32.876'	34.9	10000 hz	7/14/2006	22:38:08	7/15/2006	0:14:00	9/10/2006	4:45:00
59	Lisburne	W69º 00.680'	W166º 43.519'	41.2	10000 hz	7/14/2006	22:31:58	7/15/2006	0:55:00	9/10/2006	5:53:00
56	Lisburne	W69º 04.001'	W166º 55.605'	44.1	10000 hz	7/14/2006	22:33:15	7/15/2006	1:43:00	9/10/2006	6:52:00
84	Lisburne	N69º 20.512'	W168º 04.317'	50.7	10000 hz	7/14/2006	23:34:40	7/15/2006	4:57:00	9/10/2006	11:20:00

	Chukchi-2006Sept Phase II Deployment										
PU #	**Location**	**Latitude**	**Longitude**	**Depth(m)**	**Sample Rate**	**Start Date**	**Start Time**	**Drop Date**	**Drop Time**	**Retrieval Date**	**Retrieval Time**
15	Barrow-1	N71° 21.072'	W156°56.180'	53.1m	2000Hz	9/17/2006	11:31:10	9/17/2006	12:32:00	10/15/2006	15:40:00
21	Barrow-2	N71° 23.742'	W156°44.133'	53.8m	2000Hz	9/17/2006	11:19:17	9/17/2006	13:24:00	10/15/2006	16:33:45
32	Barrow-3	N71° 26.212'	W156°32.878'	64.7m	2000Hz	9/17/2006	11:07:22	9/17/2006	14:17:00	10/15/2006	17:18:15
56	Barrow-4	N71° 28.707'	W156°21.722'	103.5m	2000Hz	9/17/2006	10:55:17	9/17/2006	15:02:00	10/15/2006	18:08:00
59	Barrow-5	N71° 32.310'	W156°57.228'	149.3m	2000Hz	9/17/2006	10:37:16	9/17/2006	16:22:00	10/15/2006	19:16:00
97	Lay-1	N69° 48.678'	W163° 15.228'	15.9m	2000Hz	9/11/2006	15:06:06	9/12/2006	5:01:00	10/13/2006	8:00:00
19	Lay-2	N69° 51.470'	W163° 26.856'	20.6m	2000Hz	9/11/2006	15:27:27	9/12/2006	5:42:00	10/13/2006	10:00:00
66	Lay-3	N69° 54.420'	W163°37.960'	24.1m	2000Hz	9/11/2006	15:45:08	9/12/2006	6:30:00	10/13/2006	12:00:00
20	Lay-4	N69° 54.420'	W163°50.402'	27.9m	2000Hz	9/11/2006	16:02:32	9/12/2006	7:15:00	10/13/2006	14:00:00
63	Lay-5	N70° 15.510'	W165° 3.120'	41.4m	2000Hz	9/5/2006	17:03:09	9/9/2006	1:41:00	10/13/2006	18:00:00
70	Lisburne-1	N68° 54.930'	W166° 21.490'	28.9m	2000Hz	9/9/2006	16:31:36	9/10/2006	3:48:00	10/14/2006	8:00:00
89	Lisburne-2	N68° 57.780'	W166° 32.950'	34.5m	2000Hz	9/9/2006	17:08:07	9/10/2006	5:00:00	10/14/2006	10:00:00
~~77~~	~~Lisburne-3~~	~~N69° 0.670'~~	~~W166° 43.640'~~	~~41.5m~~	~~2000Hz~~	~~9/9/2006~~	~~17:45:23~~	~~9/10/2006~~	~~6:00:00~~	~~10/14/2006~~	~~12:00:00~~
~~61~~	~~Lisburne-4~~	~~N69° 3.960'~~	~~W166° 55.670'~~	~~43.9m~~	~~2000Hz~~	~~9/9/2006~~	~~17:39:22~~	~~9/10/2006~~	~~7:06:00~~	~~10/14/2006~~	~~14:00:00~~
~~88~~	~~Lisburne-5~~	~~N69° 20.480'~~	~~W168° 4.450'~~	~~50.0m~~	~~2000Hz~~	~~9/10/2006~~	~~11:35:06~~	~~9/10/2006~~	~~11:45:00~~	~~10/14/2006~~	~~18:00:00~~
86	Wainwright-1	N70° 42.945'	W160°09.880	23.2m	2000Hz	9/11/2006	17:19:11	9/12/2006	20:26:00	10/12/2006	8:00:00
50	Wainwright-2	N70° 46.283'	W160°21.177	47.2m	2000Hz	9/11/2006	17:03:17	9/12/2006	19:45:00	10/12/2006	10:00:00
74	Wainwright-3	N70° 49.765'	W160°31.391	51.2m	2000Hz	9/11/2006	16:45:27	9/12/2006	18:58:00	10/12/2006	12:00:00
95	Wainwright-4	N70° 53.734'	W160°42.851'	51.6m	2000Hz	9/11/2006	16:28:40	9/12/2006	18:10:00	10/12/2006	14:00:00
60	Wainwright-5	N71° 13.831'	W161° 49.305'	50.0m	2000Hz	9/5/2006	16:04:23	9/6/2006	15:55:00	10/12/2006	18:00:00

red=lost PU

ANNEX B-1. Summary of pop-up (PU) dates and hours of acoustic recording for Phase I (10 minutes on, 20 minutes off) and Phase II.

		Phase I, Cape Lisburne												
		Ch1	Ch2	Ch3	Ch4	Ch5			Ch1	Ch2	Ch3	Ch4	Ch5	
		PU21	PU32	PU59	PU56	PU84			PU21	PU32	PU59	PU56	PU84	
July	14	1					August	13	24	24	24	24	24	
July	15	24	24	23	22		August	14	24	24	24	24	24	
July	16	24	24	24	24	24	August	15	24	24	24	24	24	
July	17	24	24	24	24	24	August	15	24	24	24	24	24	
July	18	24	24	24	24	24	August	16	24	24	24	24	24	
July	19	24	24	24	24	24	August	17	24	24	24	24	24	
July	20	24	24	24	24	24	August	18	24	24	24	24	24	
July	21	24	24	24	24	24	August	19	24	24	24	24	24	
July	22	24	24	24	24	24	August	20	24	24	24	24	24	
July	23	24	24	24	24	24	August	21	24	24	24	24	24	
July	24	24	24	24	24	24	August	22	24	24	24	24	24	
July	25	24	24	24	24	24	August	23	24	24	24	24	24	
July	26	24	24	24	24	24	August	24	24	24	24	24	24	
July	27	24	24	24	24	24	August	25	24	24	24	24	24	
July	28	24	24	24	24	24	August	26	24	24	24	24	24	
July	29	24	24	24	24	24	August	27	24	24	24	24	24	
July	30	24	24	24	24	24	August	28	24	24	24	24	24	
July	31	24	24	24	24	24	August	29	24	24	24	24	24	
August	1	24	24	24	24	24	August	30	24	24	24	24	24	
August	2	24	24	24	24	24	August	31	24	24	24	24	24	
August	3	24	24	24	24	24	Sept	1	24	24	24	24	24	
August	4	24	24	24	24	24	Sept	2	24	24	24	24	24	
August	5	24	24	24	24	24	Sept	3	24	24	24	24	24	
August	6	24	24	24	24	24	Sept	4	24	24	24	24	24	
August	7	24	24	24	24	24	Sept	5	24	24	24	24	24	
August	8	24	24	24	24	24	Sept	6	24	24	24	24	24	
August	9	24	24	24	24	24	Sept	7	24	24	24	24	24	
August	10	24	24	24	24	24	Sept	8	24	24	24	24	24	
August	11	24	24	24	24	24	Sept	9	24	24	24	24	24	Grand
August	12	24	24	24	24	24	Sept	10	4	5	6	7	11	Totals
							Total hours covered		1373	1373	1373	1373	1355	6847
							Total hours recorded		458	458	458	458	452	2282

ANNEX B-2. Summary of pop-up (PU) dates and hours of acoustic recording for Phase II. The blue highlighted cells indicate the days and pop-ups on which the 79 selected time periods provided by LGL were analyzed in greater detail (see Annex E for a listing of these 79 date-time periods.)

		Barrow					Wainwright					Lay					Lisburne		
		ch1	ch2	ch3	ch4	ch5	ch1	ch2	ch3	ch4	ch5	ch1	ch2	ch3	ch4	ch5	ch1	ch2	
Sept	6										8								
Sept	7										24								
Sept	8										24								
Sept	9										24					22			
Sept	10										24					24	20	19	
Sept	11										24					24	24	24	
Sept	12						4	4	5	6	24	19	18	18	17	24	24	24	
Sept	13						24	24	24	24	24	24	24	24	24	24	24	24	
Sept	14						24	24	24	24	24	24	24	24	24	24	24	24	
Sept	15						24	24	24	24	24	24	24	24	24	24	24	24	
Sept	16						24	24	24	24	24	24	24	24	24	24	24	24	
Sept	17	11	11	10	9	8	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	18	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	19	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	20	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	21	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	22	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	23	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	25	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	26	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	27	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	28	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	29	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Sept	30	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	1	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	2	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	3	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	4	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	5	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	6	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	7	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	8	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	9	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	10	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	11	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Oct	12	24	24	24	24	24	8	10	12	14	18	24	24	24	24	24	24	24	
Oct	13	24	24	24	24	24						8	10	12	14	18	24	24	
Oct	14	24	24	24	24	24											8	10	Grand
Oct	15	15	17	17	18	19													Total
Totals		674	676	675	675	675	708	710	713	716	866	747	748	750	751	832	820	821	12557

ANNEX C. Table listing the dates and pop-ups during Phase I on which beluga or bowhead whale sounds were ("1") or were not ("0") detected off Cape Lisburne. Dates on which a detection occurred are highlighted. PU21 was the pop-up closest to shore, and PU84 was the pop-up furthest from shore.

PU#	PU21		PU32		PU56		PU59		PU84	
Date 2006	Beluga	Bowhead	Beluga	Bowhead	Beluga	Bowhead	Beluga	Bowhead	Beluga	Bowhead
15-Jul	0	0	0	0	0	0	0	0	0	0
16-Jul	0	0	0	0	0	0	0	0	1	0
17-Jul	0	0	0	0	0	0	0	0	0	0
18-Jul	0	0	0	0	0	0	0	0	0	0
19-Jul	0	0	0	0	0	0	0	0	0	0
20-Jul	0	0	0	0	0	0	0	0	0	0
21-Jul	0	0	0	0	0	0	0	0	0	0
22-Jul	0	0	0	0	0	0	0	0	0	0
23-Jul	0	0	0	0	0	0	0	0	0	0
24-Jul	0	0	0	0	0	0	0	0	0	0
25-Jul	0	0	0	0	0	0	0	0	0	0
26-Jul	0	0	0	0	0	0	0	0	0	0
27-Jul	0	0	0	0	0	0	0	0	0	0
28-Jul	0	0	1	0	1	0	1	0	0	0
29-Jul	0	0	0	0	0	0	1	0	0	0
30-Jul	0	0	0	0	0	0	0	0	0	0
31-Jul	0	0	0	0	0	0	0	0	0	0
1-Aug	0	0	0	0	0	0	0	0	0	0
2-Aug	0	0	0	0	0	0	0	0	0	0
3-Aug	0	0	0	0	0	0	0	0	0	0
4-Aug	0	0	0	0	0	0	0	0	0	0
5-Aug	0	0	0	0	0	0	0	0	0	0
6-Aug	0	0	0	0	0	0	0	0	0	0
7-Aug	0	0	0	0	0	0	0	0	0	0
8-Aug	0	0	0	0	0	0	0	0	0	0
9-Aug	0	0	0	0	0	0	0	0	0	0
10-Aug	0	0	0	0	0	0	0	0	0	0
11-Aug	0	0	0	0	0	0	0	0	0	0
12-Aug	0	0	0	0	0	0	0	0	0	0
13-Aug	0	0	0	0	0	0	0	0	0	0
14-Aug	0	0	0	0	0	0	0	0	0	0
15-Aug	0	0	1	0	1	0	1	0	0	0
16-Aug	0	0	0	0	0	0	0	0	0	0
17-Aug	0	0	0	0	0	0	0	0	0	0
18-Aug	0	0	0	0	0	0	0	0	0	0
19-Aug	0	0	0	0	0	0	0	0	0	0
20-Aug	0	0	0	0	0	0	0	0	0	0
21-Aug	0	0	0	0	0	0	0	0	0	0
22-Aug	0	0	0	0	0	0	0	0	0	0
23-Aug	0	0	0	0	0	0	0	0	0	0
24-Aug	0	0	1	0	1	0	1	0	1	0
25-Aug	0	0	0	0	0	0	0	0	0	0
26-Aug	0	0	0	0	1	0	0	0	0	0
27-Aug	0	0	0	0	1	0	1	0	1	0
28-Aug	0	0	0	0	0	0	0	0	0	0
29-Aug	0	0	0	0	0	0	0	0	0	0
30-Aug	0	0	0	0	0	0	0	0	0	0
31-Aug	0	0	0	0	0	0	0	0	0	0
1-Sep	0	0	0	0	0	0	0	0	0	0
2-Sep	0	0	0	0	0	0	0	0	0	0
3-Sep	0	0	0	0	0	0	0	0	0	0
4-Sep	0	0	0	0	0	0	0	0	0	0
5-Sep	0	0	0	0	0	0	0	0	0	0
6-Sep	0	0	0	0	0	0	0	0	0	0
7-Sep	0	0	0	0	0	0	0	0	0	0
8-Sep	0	0	0	0	0	0	NA	NA	0	0
9-Sep	0	0	0	0	0	0	NA	NA	0	0

ANNEX D-1. Table listing the dates and pop-ups during Phase II on which bowhead whale sounds were ("1") or were not ("0") detected off Pt. Barrow. Dates on which at least one detection occurred are highlighted. PU15 was the pop-up closest to shore, and PU59 was the pop-up furthest from shore.

PU#	PU15	PU21	PU32	PU56	PU59
Date 2006	Bowhead	Bowhead	Bowhead	Bowhead	Bowhead
17-Sep	1	1	1	1	1
18-Sep	1	1	1	1	1
19-Sep	1	1	1	1	1
20-Sep	1	1	1	1	1
21-Sep	1	1	1	1	1
22-Sep	1	1	1	1	1
23-Sep	1	1	1	1	1
24-Sep	0	0	1	1	1
25-Sep	1	1	1	1	1
26-Sep	1	1	1	1	1
27-Sep	1	1	1	1	1
28-Sep	1	1	1	1	1
29-Sep	1	1	1	1	1
30-Sep	1	1	1	1	1
1-Oct	1	1	1	1	1
2-Oct	0	1	1	1	1
3-Oct	1	1	1	1	1
4-Oct	1	1	1	1	1
5-Oct	1	1	1	1	1
6-Oct	1	1	1	1	1
7-Oct	1	1	1	1	1
8-Oct	1	1	1	1	1
9-Oct	1	1	1	1	1
10-Oct	1	1	1	1	1
11-Oct	1	1	1	1	1
12-Oct	1	1	1	1	1
13-Oct	1	1	1	1	1
14-Oct	1	1	1	1	1
15-Oct	1	1	1	1	1

ANNEX D-2. Table listing the dates and pop-ups during Phase II on which bowhead whale sounds were ("1") or were not ("0") detected off Wainwright. Dates on which at least one detection occurred are highlighted. PU86 was the pop-up closest to shore, and PU60 was the pop-up furthest from shore. NA indicates a day for which no data are available, while "on ship" indicates a day when the pop-up, although operating, was still on the ship and not yet deployed.

PU#	PU86	PU50	PU74	PU95	PU60
Date 2006	Bowhead	Bowhead	Bowhead	Bowhead	Bowhead
5-Sep	NA	NA	NA	NA	0
6-Sep	NA	NA	NA	NA	0
7-Sep	NA	NA	NA	NA	0
8-Sep	NA	NA	NA	NA	0
9-Sep	NA	NA	NA	NA	1
10-Sep	NA	NA	NA	NA	1
11-Sep	on ship	on ship	on ship	on ship	1
12-Sep	0	0	0	0	1
13-Sep	0	0	0	0	0
14-Sep	0	0	0	0	0
15-Sep	0	0	0	0	0
16-Sep	0	0	0	0	0
17-Sep	0	0	0	0	0
18-Sep	0	0	0	0	0
19-Sep	0	0	0	0	0
20-Sep	0	0	0	0	0
21-Sep	0	0	0	0	0
22-Sep	1	1	1	1	1
23-Sep	0	0	0	0	0
24-Sep	0	0	0	0	0
25-Sep	0	0	0	0	0
26-Sep	0	0	0	0	0
27-Sep	0	0	0	0	0
28-Sep	0	0	0	0	1
29-Sep	0	0	0	0	1
30-Sep	0	0	0	0	1
1-Oct	0	0	0	0	1
2-Oct	0	0	0	0	1
3-Oct	0	0	0	0	0
4-Oct	0	0	0	0	0
5-Oct	0	1	1	1	1
6-Oct	1	1	1	1	1
7-Oct	0	1	1	1	0
8-Oct	1	1	1	1	1
9-Oct	0	0	0	1	1
10-Oct	1	1	1	1	1
11-Oct	0	0	1	0	1
12-Oct	0	0	0	0	1

ANNEX D-3. Table listing the dates and pop-ups during Phase II on which bowhead whale sounds were ("1") or were not ("0") detected off Pt. Lay. Dates on which at least one detection occurred are highlighted. PU97 was the pop-up closest to shore, and PU63 was the pop-up furthest from shore. NA indicates a day for which no data are available, while "on ship" indicates a day when the pop-up, although operating, was still on the ship and not yet deployed.

PU#	PU97	PU19	PU66	PU20	PU63
Date 2006	Bowhead	Bowhead	Bowhead	Bowhead	Bowhead
9/5/2006	NA	NA	NA	NA	on ship
9/6/2006	NA	NA	NA	NA	on ship
9/7/2006	NA	NA	NA	NA	on ship
9/8/2006	NA	NA	NA	NA	on ship
9/9/2006	NA	NA	NA	NA	on ship
9/10/2006	NA	NA	NA	NA	0
9/11/2006	on ship	on ship	on ship	on ship	0
9/12/2006	on ship/0	on ship/0	on ship/0	on ship/0	0
9/13/2006	0	0	0	0	0
9/14/2006	0	0	0	0	0
9/15/2006	1	0	0	0	0
9/16/2006	0	0	0	0	0
9/17/2006	1	0	0	0	0
9/18/2006	0	0	0	0	0
9/19/2006	0	0	0	0	0
9/20/2006	0	0	0	0	0
9/21/2006	0	0	0	0	0
9/22/2006	0	0	0	0	0
9/23/2006	0	0	0	0	0
9/24/2006	0	1	0	0	0
9/25/2006	0	0	0	0	0
9/26/2006	0	0	0	0	0
9/27/2006	0	0	0	0	0
9/28/2006	0	0	0	0	0
9/29/2006	1	1	0	0	0
9/30/2006	1	1	0	0	0
10/1/2006	0	0	0	0	0
10/2/2006	1	0	0	0	0
10/3/2006	0	0	0	0	0
10/4/2006	0	0	0	0	0
10/5/2006	0	0	0	0	0
10/6/2006	0	0	0	0	0
10/7/2006	0	0	0	0	0
10/8/2006	0	0	0	0	0
10/9/2006	0	0	0	0	0
10/10/2006	0	0	1	0	0
10/11/2006	0	0	1	1	0
10/12/2006	0	0	1	0	0
10/13/2006	0/on ship	0/on ship	0/on ship	0/on ship	0/on ship
10/14/2006	on ship	on ship	on ship	on ship	on ship

ANNEX E. Listing of the 79 date-time sample periods and the number of seismic airgun array events normalized to an hourly rate ("Detected ping events per hour") for each sample period.

Sample Period #	Start Date	Start AKDT	Stop AKDT	Lisb Ch2	Lay #2	Lay #5	Wain #2	Wain #5	Barr #2	Barr #5
				Detected ping events per hour						
1	12-Sep-06	0:36:00	3:00:00	0	NA	492	NA	334	0	0
2	12-Sep-06	6:30:00	8:45:00	0	50	396	NA	284	0	0
3	12-Sep-06	9:30:00	10:30:00	0	9	482	NA	53	0	0
4	12-Sep-06	12:20:00	16:00:00	0	11	416	NA	97	0	0
5	12-Sep-06	23:05:00	1:05:00	0	0	0	0	0	0	0
6	14-Sep-06	7:00:00	10:00:00	0	0	0	0	45	0	0
7	14-Sep-06	19:30:00	20:30:00	254	268	270	4	209	0	0
8	14-Sep-06	21:50:00	22:40:00	350	586	474	455	635	0	0
9	15-Sep-06	7:00:00	8:00:00	139	516	501	118	381	0	0
10	15-Sep-06	10:00:00	13:00:00	333	351	348	318	494	0	0
11	15-Sep-06	16:30:00	18:00:00	340	639	466	488	583	0	0
12	15-Sep-06	21:30:00	23:00:00	113	497	423	452	539	0	0
13	16-Sep-06	7:00:00	8:00:00	0	17	348	265	498	0	0
14	16-Sep-06	9:30:00	10:30:00	0	0	194	49	186	0	0
15	16-Sep-06	13:35:00	14:35:00	0	8	330	342	636	0	0
16	16-Sep-06	15:00:00	16:00:00	0	0	53	13	371	0	0
17	16-Sep-06	18:30:00	19:20:00	0	0	154	0	384	0	0
18	16-Sep-06	21:10:00	22:30:00	0	0	119	0	0	0	0
19	16-Sep-06	23:00:00	3:30:00	0	144	345	271	335	0	0
20	17-Sep-06	7:20:00	8:00:00	0	104	156	0	0	0	0
21	17-Sep-06	8:50:00	9:50:00	0	385	644	336	519	0	0
22	17-Sep-06	12:30:00	14:00:00	0	171	211	6	0	0	0
23	17-Sep-06	16:30:00	17:30:00	17	280	517	107	85	0	0
24	17-Sep-06	19:30:00	20:20:00	20	311	313	67	41	0	0
25	18-Sep-06	9:30:00	11:00:00	0	65	508	1	170	0	0
26	18-Sep-06	12:00:00	13:00:00	77	364	472	369	372	0	0
27	18-Sep-06	14:40:00	15:40:00	229	383	504	365	353	0	0
28	18-Sep-06	16:00:00	17:00:00	6	436	584	434	210	0	0
29	18-Sep-06	18:30:00	19:30:00	327	564	513	540	510	0	0
30	18-Sep-06	20:40:00	22:00:00	178	625	635	634	574	0	0
31	19-Sep-06	0:50:00	1:50:00	131	359	384	374	381	0	0
32	19-Sep-06	3:00:00	5:00:00	0	232	475	288	96	0	0
33	19-Sep-06	8:00:00	11:00:00	0	48	196	0	185	0	0
34	19-Sep-06	20:00:00	23:00:00	0	0	9	0	14	0	0
35	19-Sep-06	23:30:00	0:00:00	0	0	0	0	0	0	0
36	20-Sep-06	5:20:00	6:20:00	0	0	181	0	0	0	0
37	20-Sep-06	7:00:00	9:00:00	0	0	213	0	0	0	0
38	20-Sep-06	21:00:00	23:00:00	0	0	16	0	0	0	0
39	21-Sep-06	0:00:00	2:00:00	0	145	165	0	0	0	0

ANNEX E continued.

Sample Period #	Start		Stop	Detected ping events per hour						
	Date	AKDT	AKDT	Lisb Ch2	Lay #2	Lay #5	Wain #2	Wain #5	Barr #2	Barr #5
40	21-Sep-06	10:30:00	12:30:00	3	284	370	0	0	0	0
41	21-Sep-06	14:00:00	16:00:00	4	132	157	0	0	0	0
42	22-Sep-06	1:00:00	3:00:00	0	16	372	0	0	0	0
43	22-Sep-06	3:30:00	4:30:00	184	4	193	0	0	0	0
44	22-Sep-06	22:00:00	0:00:00	13	380	380	23	0	0	0
45	23-Sep-06	0:30:00	1:30:00	0	276	288	72	0	0	0
46	24-Sep-06	3:30:00	4:30:00	319	379	362	0	0	0	0
47	24-Sep-06	4:30:00	6:30:00	22	97	83	0	0	0	0
48	25-Sep-06	1:00:00	2:00:00	47	296	379	0	0	0	0
49	25-Sep-06	3:00:00	4:00:00	0	145	151	0	0	0	0
50	25-Sep-06	9:30:00	10:30:00	671	12	377	0	0	0	0
51	25-Sep-06	11:00:00	12:00:00	255	0	43	0	0	0	0
52	26-Sep-06	3:00:00	5:00:00	0	177	378	0	0	0	0
53	26-Sep-06	6:00:00	7:30:00	0	82	189	0	0	0	0
54	27-Sep-06	1:00:00	2:00:00	0	0	13	0	0	0	0
55	27-Sep-06	3:00:00	4:00:00	0	63	166	0	0	0	0
56	27-Sep-06	7:30:00	8:30:00	0	44	187	0	0	0	0
57	27-Sep-06	9:30:00	10:30:00	412	49	378	0	0	0	0
58	28-Sep-06	2:50:00	4:50:00	229	0	0	0	0	0	0
59	28-Sep-06	5:30:00	7:30:00	0	178	318	0	57	0	0
60	29-Sep-06	0:40:00	2:30:00	99	361	355	235	0	0	0
61	29-Sep-06	2:40:00	4:30:00	191	177	179	15	8	0	0
62	30-Sep-06	22:30:00	23:30:00	202	187	186	13	29	0	0
63	1-Oct-06	0:30:00	1:30:00	0	376	374	0	0	0	0
64	1-Oct-06	13:00:00	14:00:00	235	372	369	0	0	0	0
65	1-Oct-06	14:30:00	15:30:00	41	180	162	0	0	0	0
66	2-Oct-06	3:30:00	5:30:00	0	399	358	0	0	0	0
67	2-Oct-06	6:45:00	7:45:00	0	186	180	0	0	0	0
68	3-Oct-06	12:00:00	14:00:00	0	24	344	0	0	0	0
69	3-Oct-06	15:00:00	16:00:00	0	0	117	0	0	0	0
70	4-Oct-06	6:00:00	8:00:00	0	0	259	0	0	0	0
71	4-Oct-06	9:00:00	11:00:00	0	0	0	0	0	0	0
72	4-Oct-06	15:00:00	17:00:00	0	0	14	0	0	0	2
73	4-Oct-06	18:00:00	20:00:00	0	52	310	0	0	0	0
74	5-Oct-06	9:00:00	11:00:00	0	377	377	172	0	3	0
75	5-Oct-06	11:30:00	12:30:00	73	164	163	2	0	0	0
76	5-Oct-06	18:00:00	19:00:00	332	191	188	222	0	2	2
77	6-Oct-06	12:00:00	13:00:00	0	162	162	1	0	0	0
78	6-Oct-06	13:30:00	14:30:00	0	368	368	336	0	2	0
79	6-Oct-06	20:00:00	21:00:00	0	0	0	0	0	0	0
	Average Pings/hour			77	180	268	98	118	0	0
	Average Pings/min			1	3	4	2	2	0	0

ANNEX F. Listing of the 79 date-time sample periods and the total number of seismic airgun array events ("Number of detected ping events") for each sample period. Note that the column headed "Total" is the sum of all events detected on all pop-ups and thus includes many cases in which the same event is detected multiple times.

Sample Period #	Start		Stop		Number of detected ping events							
	Date	AKDT	AKDT	Total Hrs	Lisb Ch2	Lay #2	Lay #5	Wain #2	Wain #5	Barr #2	Barr #5	TOTAL
1	12-Sep-06	0:36:00	3:00:00	2:24:00	0	NA	1180	NA	801	0	0	1981
2	12-Sep-06	6:30:00	8:45:00	2:15:00	0	113	891	NA	639	0	0	1643
3	12-Sep-06	9:30:00	10:30:00	1:00:00	0	9	482	NA	53	0	0	544
4	12-Sep-06	12:20:00	16:00:00	3:40:00	0	39	1527	NA	355	0	0	1921
5	12-Sep-06	23:05:00	1:05:00	2:00:00	0	0	0	0	0	0	0	0
6	14-Sep-06	7:00:00	10:00:00	3:00:00	0	0	0	0	136	0	0	136
7	14-Sep-06	19:30:00	20:30:00	1:00:00	254	268	270	4	209	0	0	1005
8	14-Sep-06	21:50:00	22:40:00	0:50:00	292	488	395	379	529	0	0	2083
9	15-Sep-06	7:00:00	8:00:00	1:00:00	139	516	501	118	381	0	0	1655
10	15-Sep-06	10:00:00	13:00:00	3:00:00	1000	1052	1043	954	1483	0	0	5532
11	15-Sep-06	16:30:00	18:00:00	1:30:00	510	958	699	732	874	0	0	3773
12	15-Sep-06	21:30:00	23:00:00	1:30:00	170	746	634	678	808	0	0	3036
13	16-Sep-06	7:00:00	8:00:00	1:00:00	0	17	348	265	498	0	0	1128
14	16-Sep-06	9:30:00	10:30:00	1:00:00	0	0	194	49	186	0	0	429
15	16-Sep-06	13:35:00	14:35:00	1:00:00	0	8	330	342	636	0	0	1316
16	16-Sep-06	15:00:00	16:00:00	1:00:00	0	0	53	13	371	0	0	437
17	16-Sep-06	18:30:00	19:20:00	0:50:00	0	0	128	0	320	0	0	448
18	16-Sep-06	21:10:00	22:30:00	1:20:00	0	0	158	0	0	0	0	158
19	16-Sep-06	23:00:00	3:30:00	4:30:00	0	650	1551	1220	1507	0	0	4928
20	17-Sep-06	7:20:00	8:00:00	0:40:00	0	69	104	0	0	0	0	173
21	17-Sep-06	8:50:00	9:50:00	1:00:00	0	385	644	336	519	0	0	1884
22	17-Sep-06	12:30:00	14:00:00	1:30:00	0	257	317	9	0	0	0	583
23	17-Sep-06	16:30:00	17:30:00	1:00:00	17	280	517	107	85	0	0	1006
24	17-Sep-06	19:30:00	20:20:00	0:50:00	17	259	261	56	34	0	0	627
25	18-Sep-06	9:30:00	11:00:00	1:30:00	0	97	762	2	255	0	0	1116
26	18-Sep-06	12:00:00	13:00:00	1:00:00	77	364	472	369	372	0	0	1654
27	18-Sep-06	14:40:00	15:40:00	1:00:00	229	383	504	365	353	0	0	1834
28	18-Sep-06	16:00:00	17:00:00	1:00:00	6	436	584	434	210	0	0	1670
29	18-Sep-06	18:30:00	19:30:00	1:00:00	327	564	513	540	510	0	0	2454
30	18-Sep-06	20:40:00	22:00:00	1:20:00	237	833	847	845	765	0	0	3527
31	19-Sep-06	0:50:00	1:50:00	1:00:00	131	359	384	374	381	0	0	1629
32	19-Sep-06	3:00:00	5:00:00	2:00:00	0	464	949	575	191	0	0	2179
33	19-Sep-06	8:00:00	11:00:00	3:00:00	0	144	589	0	554	0	0	1287
34	19-Sep-06	20:00:00	23:00:00	3:00:00	0	0	27	0	43	0	0	70
35	19-Sep-06	23:30:00	23:59:59	0:30:00	0	0	0	0	0	0	0	0
36	20-Sep-06	5:20:00	6:20:00	1:00:00	0	0	181	0	0	0	0	181
37	20-Sep-06	7:00:00	9:00:00	2:00:00	0	0	426	0	0	0	0	31
38	20-Sep-06	21:00:00	23:00:00	2:00:00	0	0	31	0	0	0	0	31
39	21-Sep-06	0:00:00	2:00:00	2:00:00	0	290	330	0	0	0	0	620

ANNEX F continued.

Sample Period #	Start Date	Start AKDT	Stop AKDT	Total Hrs	Lisb Ch2	Lay #2	Lay #5	Wain #2	Wain #5	Barr #2	Barr #5	TOTAL
					Number of detected ping events							
40	21-Sep-06	10:30:00	12:30:00	2:00:00	5	567	740	0	0	0	0	1312
41	21-Sep-06	14:00:00	16:00:00	2:00:00	8	263	314	0	0	0	0	585
42	22-Sep-06	1:00:00	3:00:00	2:00:00	0	32	744	0	0	0	0	776
43	22-Sep-06	3:30:00	4:30:00	1:00:00	184	4	193	0	0	0	0	381
44	22-Sep-06	22:00:00	0:00:00	2:00:00	25	760	760	46	0	0	0	1591
45	23-Sep-06	0:30:00	1:30:00	1:00:00	0	276	288	72	0	0	0	636
46	24-Sep-06	3:30:00	4:30:00	1:00:00	319	379	362	0	0	0	0	1060
47	24-Sep-06	4:30:00	6:30:00	2:00:00	43	194	166	0	0	0	0	403
48	25-Sep-06	1:00:00	2:00:00	1:00:00	47	296	379	0	0	0	0	722
49	25-Sep-06	3:00:00	4:00:00	1:00:00	0	145	151	0	0	0	0	296
50	25-Sep-06	9:30:00	10:30:00	1:00:00	671	12	377	0	0	0	0	1060
51	25-Sep-06	11:00:00	12:00:00	1:00:00	255	0	43	0	0	0	0	298
52	26-Sep-06	3:00:00	5:00:00	2:00:00	0	354	756	0	0	0	0	1110
53	26-Sep-06	6:00:00	7:30:00	1:30:00	0	123	284	0	0	0	0	407
54	27-Sep-06	1:00:00	2:00:00	1:00:00	0	0	13	0	0	0	0	13
55	27-Sep-06	3:00:00	4:00:00	1:00:00	0	63	166	0	0	0	0	229
56	27-Sep-06	7:30:00	8:30:00	1:00:00	0	44	187	0	0	0	0	231
57	27-Sep-06	9:30:00	10:30:00	1:00:00	412	49	378	0	0	0	0	839
58	28-Sep-06	2:50:00	4:50:00	2:00:00	458	0	0	0	0	0	0	458
59	28-Sep-06	5:30:00	7:30:00	2:00:00	0	356	635	0	113	0	0	1104
60	29-Sep-06	0:40:00	2:30:00	1:50:00	182	662	650	431	0	0	0	1925
61	29-Sep-06	2:40:00	4:30:00	1:50:00	350	325	328	27	15	0	0	1045
62	30-Sep-06	22:30:00	23:30:00	1:00:00	202	187	186	13	29	0	0	617
63	1-Oct-06	0:30:00	1:30:00	1:00:00	0	376	374	0	0	0	0	750
64	1-Oct-06	13:00:00	14:00:00	1:00:00	235	372	369	0	0	0	0	976
65	1-Oct-06	14:30:00	15:30:00	1:00:00	41	180	162	0	0	0	0	383
66	2-Oct-06	3:30:00	5:30:00	2:00:00	0	797	715	0	0	0	0	1512
67	2-Oct-06	6:45:00	7:45:00	1:00:00	0	186	180	0	0	0	0	366
68	3-Oct-06	12:00:00	14:00:00	2:00:00	0	47	688	0	0	0	0	735
69	3-Oct-06	15:00:00	16:00:00	1:00:00	0	0	117	0	0	0	0	117
70	4-Oct-06	6:00:00	8:00:00	2:00:00	0	0	518	0	0	0	0	518
71	4-Oct-06	9:00:00	11:00:00	2:00:00	0	0	0	0	0	0	0	0
72	4-Oct-06	15:00:00	17:00:00	2:00:00	0	0	28	0	0	0	3	31
73	4-Oct-06	18:00:00	20:00:00	2:00:00	0	105	620	0	0	0	0	725
74	5-Oct-06	9:00:00	11:00:00	2:00:00	0	754	754	344	0	5	0	1857
75	5-Oct-06	11:30:00	12:30:00	1:00:00	73	164	163	2	0	0	0	402
76	5-Oct-06	18:00:00	19:00:00	1:00:00	332	191	188	222	0	2	2	937
77	6-Oct-06	12:00:00	13:00:00	1:00:00	0	162	162	1	0	0	0	325
78	6-Oct-06	13:30:00	14:30:00	1:00:00	0	368	368	336	0	2	0	1074
79	6-Oct-06	20:00:00	21:00:00	1:00:00	0	0	0	0	0	0	0	0
	Totals			119:19:00	**7248**	**18841**	**32332**	**10260**	**14215**	**9**	**5**	**82515**

7. VESSEL-BASED SHALLOW HAZARDS SURVEYS–*HENRY CHRISTOFFERSEN*[1]

Introduction

SOI conducted site clearance and shallow hazards surveys in the Beaufort Sea from the vessel M/V *Henry Christoffersen* (*Henry C.*) to identify potentially hazardous or sensitive conditions and sites at or below sea level that could affect potential drilling operations. One aspect of the shallow hazards surveys involved using a small airgun array similar to the larger arrays used on the seismic vessels in the Chukchi Sea. A general description of the shallow hazards surveys, including dates and locations of activities and type of survey equipment used, is provided in Chapter 2. This section summarizes the visual monitoring effort and marine mammal sightings from the *Henry C.* during the Beaufort Sea shallow hazards survey work. It is followed by a chapter describing the aerial component of the Beaufort Sea monitoring and mitigation program.

Objectives and Monitoring Tasks

The objectives of the marine mammal monitoring and mitigation program for the shallow hazards surveys in the Beaufort Sea were the same as those discussed for seismic surveys in the Chukchi Sea. The main purpose of the mitigation program was to avoid or minimize potential effects of the airgun array used during the shallow hazards surveys on marine mammals. This was accomplished with vessel-based monitoring by MMOs as described in Chapter 3 for the Chukchi Sea monitoring program.

Methods

Safety and Potential Disturbance Radii

Sound levels for a four-airgun, 240 in^3 source on the *Henry C.* were modeled by JASCO prior to the field season. Field measurements of the produced sound from the array were conducted by Greeneridge Sciences on 8 Aug. 2006 in the Beaufort Sea, east of Kaktovik. Safety and disturbance radii were determined after initial analysis of the measurements and were used by MMOs onboard the *Henry C.* for mitigation purposes (Table 7.1). After the field season, preliminary field measurements were refined and final safety and disturbance radii, which were slightly reduced compared to the preliminary radii, were determined. Both preliminary and final measured radii for the 190, 180, 170, and 160 dB (rms) zones were greater than modeled radii for the four-airgun array (Table 7.1), but the measured radius for the 120 dB zone was less than the modeled radius. However, the sound source actually used during the one day of airgun activity (25 Sept.) was a two-airgun, 140 in^3 array. Therefore, safety and disturbance radii associated with the four-airgun array used for mitigation and exposure estimates provided in this report are conservative. The actual safety and disturbance radii were likely significantly reduced compared to the measured radii.

Mitigation Measures as Implemented

The mitigation measures implemented for the shallow hazards surveys (power downs, shut downs, and ramp ups) were the same as those used for the deep-penetration seismic surveys conducted in the Chukchi Sea and described in Chapter 3. The standard safety radii of 190 and 180 dB (rms) for pinnipeds and cetaceans, respectively, and the 160 and 120 dB (rms) disturbance radii required by NMFS in the IHA issued to SOI for the seismic activities in the Chukchi Sea, also applied to the shallow hazards work

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in the Beaufort Sea. The 190 and 180 dB (rms) safety radii and the 160 dB (rms) disturbance radius were monitored by MMOs onboard the *Henry C*. Aerial surveys were used to monitor the 120 dB (rms) disturbance radius, which was too large to be monitored by vessel-based MMOs. The aerial survey component of the Beaufort Sea monitoring program is described in Chapter 8.

Table 7.1. Comparison of sizes of modeled radii with measured radii obtained during sound source measurements for the four-airgun cluster deployed from the *Henry Christoffersen* in the Beaufort Sea, Alaska, 2006. Preliminary measured radii were used by MMOs on the vessel.

Received Level dB re 1 µPa	Radii based on JASCO modeling (km)	Preliminary Measured Radii (km)	Final Measured Radii (km)
190	0.02	0.12	0.089
180	0.15	0.33	0.25
170	0.3	0.88	0.68
160	0.99	2.22	1.75
120	35.98	24.5	22.22

Visual Monitoring Methods

The visual monitoring methods used by MMOs onboard the *Henry C.* were the same as those used by MMOs onboard the seismic and chase vessels in the Chukchi Sea and are discussed in detail in Chapter 3 and in SOI's 90-day report (Patterson et al. 2007). The analysis methods for the *Henry C.* data were similar to those used for vessel-based monitoring in the Chukchi Sea (see Chapter 3) and are discussed below.

Categorization of Data

Observer effort and marine mammal sightings were divided into several analysis categories related to useability and environmental variables (seismic activity, proximity to shore, and seasonality). The *Henry C.* was the only JMP vessel to operate in the Beaufort Sea for a significant period, so there was no pooling of *Henry C.* data with data from other vessels.

Seismic Activity

In general, data were categorized as seismic or non-seismic. The seismic category included all data collected from the shallow hazards survey vessel (*Henry C.*) while the airguns were operating. The non-seismic category included all data obtained before the airguns were activated (pre-seismic) or >1 or >2 h (for pinnipeds and cetaceans/ursids, respectively) after the airguns were deactivated. Data collected during post-seismic periods from 3 min to 1 h (for pinnipeds) or 2 h (for cetaceans and ursids) after cessation of seismic activity were considered either "recently exposed" (3–30 min) or "potentially exposed" (30 min to 1h for pinnipeds or 2 h for cetaceans and ursids) to seismic sound levels, and were excluded from analyses. Thus, the post-seismic data (3 min to 1 or 2 h after cessation of seismic) were not included in either the seismic or non-seismic categories. The reasoning behind these cut-points is discussed in Chapter 3, and also in the 90-day report (Patterson et al. 2007).

Proximity to Shore

Data were classified as nearshore if they were collected within 25 km of shore, or offshore if they were obtained farther than 25 km from shore.

<u>*Seasonality*</u>

Cetaceans—Seasonal demarcations for whales in the Beaufort Sea were based on the migration patterns of bowhead whales. The start of the autumn bowhead migration through the Beaufort Sea as defined in the IHA from NMFS (Appendix A in Patterson et al. 2007) was after 1 Sept. There are data, however, from 1979–2000 in the eastern Alaskan Beaufort Sea, that suggest an average start date of the autumn bowhead migration may be around 28 Aug. (Fig. 9.12 *in* Miller et al. 2002). Using the same data, the average end date appears to be around 15 Oct. Therefore, the "Early Season" (pre-migration) was considered to be prior to 28 Aug., the "Mid-season" (during migration) from 28 Aug. to 15 Oct., and the "Late Season" (post-migration), from 16 Oct. onward. These dates were applied to all cetacean sightings in the Beaufort Sea.

Pinnipeds—Significant changes in the distribution and abundance of pinnipeds resulting from predictable migratory movements were not expected. Therefore, pinniped data were not categorized by season.

Movement and Behavior

Only limited behavioral data were collected during this project because marine mammals were often seen at a distance from the vessel and were typically not tracked for long distances or durations while the vessel was underway. The two variables examined quantitatively to assess potential effects of seismic activities on behavior were the records of movement and behavior when the animal(s) were first sighted (see Ireland et al. 2007a,b; Patterson et al. 2007 for a full list of variables and definitions). Additionally, the closest point of approach (CPA) distance recorded for each sighting was also used as an indicator of behavior (see Appendix Table G.3 in the Shell, CPAI and GXT 2006 90-day reports for details on sightings).

Estimation of Densities

It is difficult to obtain meaningful estimates of the number of marine mammals exposed to various levels of seismic sounds for multiple 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 vary 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 and dependent on water depth, source depth, water-mass, 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 strength of sounds received by marine mammals also varies depending on their depth 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.

Raw sighting data obtained from marine mammal surveys provide, at best, an index of the number of animals that might have been present during the survey (Eberhardt et al. 1979; Best 1982; Hiby and Hammond 1989).

Line transect methodology (Buckland et al. 2001) using the DISTANCE program (Thomas et al. 2006, version 5.0, release 2) is the most commonly used method for estimating densities of animals from survey data. In theory, two correction factors, $f(0)$ and $g(0)$, can be computed from the raw survey data or from other observations to minimize most biases in estimates of actual numbers of marine mammals present. For a more detailed description, see the section *Estimation of Densities* in Chapter 3 and Appendix B. Densities of pinnipeds were calculated using line transect methodology for non-seismic periods only, as this was the only category with sufficient effort and sightings to produce reliable density estimates.

Disturbance and Safety Criteria

Table 7.1 shows estimated received sound levels at various distances from the four-airgun 280-in^3 source that was used on 8 Aug. during sound source measurements. These measurements are likely overly precautionary since the shallow hazards survey that took place on 25 Sept. utilized a two-airgun array with a total volume of 140 in^3. Sound source measurements were used to determine the 190 through 120-dB radii, and mitigation distances were established from these measurements. 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 of ≥180 dB and ≥190 dB re 1 μPa (rms), respectively. NMFS commonly assumes that cetaceans and seals exposed to pulsed sounds with received levels ≥160 dB (rms) might be disturbed, although there is little evidence that most pinnipeds or delphinids exposed to airgun sounds with levels just above 160 dB rms are disturbed. For instance, the reaction threshold for most toothed whales is unknown but is presumably >160 dB (rms) because of their poorer hearing sensitivity at low frequencies (NMFS 2005; NMFS 2006; Richardson et al. 1995; Richardson and Würsig 1997).

Estimated Number of Marine Mammals Potentially Ensonified

In the past, three methods have been applied to estimate the number of pinnipeds and cetaceans exposed to seismic sound levels strong enough to have possibly caused disturbance or other effects:

(A) minimum estimates based on direct observations

(B) estimates based on pinniped and cetacean densities derived from observations made during seismic periods

(C) estimates based on pinniped and cetacean densities derived from observations made during non-seismic periods

The actual number of individuals exposed to, and potentially affected by, strong seismic survey sounds was likely between the minimum and maximum estimates resulting from methods ***(A)*** and ***(C)***, provided below. Because no animals were observed during the limited seismic periods, it was not possible to calculate an estimate based on method ***(B)***. Calculation of densities and the correction factors used to compute densities are described above and in Appendix B.

Method ***(C)*** above provides an estimate of the number of animals that would have been exposed to seismic sounds at various levels if the seismic activities did not influence the distribution of animals near the activities. However, it is known that some animals are likely to have avoided the area near the seismic vessel while airguns were firing (see Richardson et al. 1995, 1999; Stone 2003; Gordon et al. 2004; Smultea et al. 2004). Within the assumed 160–170 dB radii around the source (i.e., ~1.8–0.7 km), and perhaps farther away in the case of the more sensitive species and individuals, the distribution and behavior of cetaceans and pinnipeds may have been altered as a result of the seismic survey. This could occur as a result of reactions to the active airgun array, the source vessel, or other vessels working in the area. The extent to which the distribution and behavior of pinnipeds might be affected by the airguns is uncertain, given the variability in previous results (Thompson et al. 1998; Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). Likewise, it is safe to assume that some cetaceans, when approached by the seismic survey, would have moved away before they were in view.

Determining the number of animals potentially affected by seismic operations required both an estimated animal density (obtained as described above and in Appendix B) and an estimate of the extent to which marine mammals could have been exposed to a given sound level (≥160, ≥170, ≥180, and ≥190 dB (rms)). More detailed descriptions of this process can be found in the section *Estimated Number of Marine Mammals Potentially Ensonified* in Chapter 3. Calculations were made for the following groups:

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

Results

SOI's shallow hazards and site clearance surveys in the Beaufort Sea were conducted from 1 Aug. to 3 Oct. 2006. During the 8213 km of *Henry C.* cruise operations within the study area in the Alaskan Beaufort Sea, there were 5145 km of visual observation effort over 526 h, of which, 3152 km (61%) of effort over 284 h were classified as useable (defined above and in Chapter 3). Airguns were operated for only 98 km (10 h), with 57 km (~4 h) of airgun operations classified as useable for analysis purposes (Table 7.2). Limited observations were carried out from the *Henry C.* during periods of darkness, totaling just 36.9 km (4.7 h) of effort. All nighttime effort was during non-seismic periods and there were no marine mammals observed. Effort carried out during periods of darkness was not considered useable in later analyses. Average Beaufort wind force (Bf) during nighttime observations was 2.3 (range 0 to 5, n = 13), compared to 1.7 (range 0 to 5, n = 1999) during daytime observations. Daytime visibility averaged 6.9 km (median = 10 km, range = 0 to 10 km, n = 1990).

Numbers of Marine Mammals Seen

A total of 451 individual marine mammals were seen in 412 groups within the study area. Sightings during useable periods included 320 seals and four polar bears (Table 7.3). No walruses were identified from the *Henry C.* Most sightings occurred in the nearshore region, where most of the visual observation effort was carried out (Table 7.2). There were no sightings of cetaceans or walruses. Additionally, there were no useable sightings of pinnipeds hauled out on ice.

The majority of sightings in the nearshore were of unidentified seals (63% or 180 sightings; Table 7.3). Ringed and spotted seals together accounted for 33% (96 sightings), and bearded seals 4% (12 sightings).

In the nearshore, there were two sightings of polar bears (Table 7.3). One sighting was of a single adult bear on the ice feeding on a dead seal, and one sighting was of a female and cub that entered the water as the vessel approached. In the offshore region, there was one sighting of a single polar bear swimming.

TABLE 7.2. Useable visual observation effort in (**A**) kilometers, and (**B**) hours, from the *Henry C.* within the Beaufort Sea, nearshore and offshore regions, subdivided by Beaufort wind force[a] and seismic activity. Effort varies for pinnipeds due to the differences in their post-seismic period.

	Nearshore							Offshore						
Beaufort Wind Force	**0**	**1**	**2**	**3**	**4**	**5**	***Total***	**0**	**1**	**2**	**3**	**4**	**5**	***Total***
A. Effort in km														
Non-seismic														
Cetaceans	202	1432	693	465	267	84	***3143***	0	48	13	47	2	0	***109***
Pinnipeds	202	1438	693	468	267	84	***3152***	0	48	13	50	2	0	***112***
Ursids	202	1432	693	465	267	84	***3143***	0	48	13	47	2	0	***109***
Seismic														
Cetaceans	37	7	7	7	0	0	***57***	0	0	0	2	0	0	***2***
Pinnipeds	37	7	7	7	0	0	***57***	0	0	0	2	0	0	***2***
Ursids	37	7	7	7	0	0	***57***	0	0	0	2	0	0	***2***
B. Effort in h														
Non-seismic														
Cetaceans	16	129	65	43	26	5	***284***	0	5	2	5	0	0	***12***
Pinnipeds	16	130	65	43	26	5	***284***	0	5	2	5	0	0	***13***
Ursids	16	129	65	43	26	5	***284***	0	5	2	5	0	0	***12***
Seismic														
Cetaceans	0.4	1	1	1	0	0	***4***	0	0	0	0.3	0	0	***0.3***
Pinnipeds	0.4	1	1	1	0	0	***4***	0	0	0	0.3	0	0	***0.3***
Ursids	0.4	1	1	1	0	0	***4***	0	0	0	0.3	0	0	***0.3***

Note: Totals are of unrounded values.
[a] See *Useability Criteria* in *Methods* in this Chapter, and in Chapter 3.
[b] Beaufort Wind Force scale: 0 is < 1 knot (<1 mph); 1 is 1-3 knots (1-3 mph); 2 is 4-6 knots (4-7 mph); 3 is 7-10 knots (8-12 mph); 4 is 11-16 knots (13-18 mph); 5 is 17-21 knots (19-24 mph).

TABLE 7.3. Numbers of useable sightings (individuals observed) in the Beaufort Sea, from the *Henry C.* between 1 Aug. and 3 Oct. 2006. Non-seismic sightings are sub-divided by proximity to shore. There were no useable sightings during seismic periods from the *Henry C.* See *Methods* in Chapter 3 for the definition of these data categories.

	Non-seismic		
Species	**Nearshore**	**Offshore**	**Total**
Cetaceans	0	0	0
Pinnipeds in Water			
Odobenids			
Pacific Walrus	0	0	0
Phocids			
Bearded Seal	12(13)	0	12(13)
Phoca sp.	96(109)	4(4)	100(113)
Unidentified Seal	180(190)	4(4)	184(194)
Total Pinnipeds in Water	***288(312)***	***8(8)***	***296(320)***
Pinnipeds on Ice	0	0	0
Ursids			
Polar bear	2(3)	1(1)	3(4)

Detection Rates of Marine Mammals

Detection rates (number of useable sightings/1000 km of useable effort) for pinnipeds and polar bears categorized by proximity to shore and seismic activity are presented in Table 7.4. Only the nearshore region during non-seismic periods contained sufficient useable effort for analysis of detection rates. Effort in the nearshore seismic (57.4 km), offshore non-seismic (112.1 km), and offshore seismic (0.0 km) categories was insufficient to calculate detection rates.

The number of detections and detection rate for pinnipeds was greatest in the nearshore area during non-seismic periods (Table 7.4). Despite a large amount of ice in the operating area, there were no useable sightings of pinnipeds hauled out on ice. Fog and low ship speed (which was often related to the presence of ice) rendered the few sightings of hauled out pinnipeds unusable.

TABLE 7.4. Useable pinniped detections (sightings), effort in km, and detection rates (number of detections per 1000 km) from the *Henry C.* in the Alaskan Beaufort Sea, in nearshore areas during non-seismic activities.

Nearshore Non-Seismic	No. of Detections	Effort (km)	Detections/ 1000km
Pinnipeds in Water	288	3151.7	91.4
Ursids	2	3142.6	0.6

There were no cetacean detections despite significant observation effort during non-seismic periods in the nearshore region in the cetacean early and mid-seasons. There was no effort in the late season for cetaceans.

Marine Mammal Behavior

Closest Observed Point of Approach (CPA)—No animals were observed during seismic periods; therefore, no comparison of CPA or other behavior categories can be made for seismic vs. non-seismic periods. The mean CPA of pinnipeds in water was 248 m (n = 296, s.d. = 196). For polar bears the mean CPA was 1486 m (n = 3, s.d. = 1555).

Movement—Movement was recorded for 296 sightings of pinnipeds and three sightings of polar bears during non-seismic periods (Table 7.5). Swimming away was the most frequently observed movement of pinnipeds and polar bears (34% and 67%, respectively). The other most frequently observed movements by pinnipeds were swimming toward and swimming parallel to the vessel.

First Observed Behavior—The most common first observed behavior of pinnipeds was "dive" and accounted for 36% of the behaviors recorded (Table 7.6). Behavior was recorded for only two of the polar bear sightings, and both were categorized as "swim/travel."

TABLE 7.5. Numbers of useable sightings of marine mammals by movement category during non-seismic periods from the *Henry C*. There were no sightings of cetaceans and no sightings of any marine mammals during seismic periods.

	Movement Relative to Vessel									
Taxonomic Group	**Mill**	**Swim Perpen-dicular**	**Swim Away**	**Swim Parallel**	**Swim Toward**	**Hauled Out**	**Flee**	**No movement**	**Unknown**	***Total***
Pinnipeds	6	17	102	33	61	0	5	21	51	***296***
Polar Bears	0	0	2	0	0	0	0	1	0	***3***

[a] See *Useability Criteria* in *Methods* in this Chapter and Chapter 3.

TABLE 7.6. Numbers of useable sightings of marine mammals by behavior category (see *Methods* in Chapter 3 for details on these categories) during non-seismic and seismic periods from the *Henry C.* within the Beaufort Sea. Note that there were no useable sightings of cetaceans or pinnipeds hauled out.

Taxonomic Group	**Dive**	**Look**	**Rest**	**Swim / Travel**	**Surface Active**	***Total***
Pinnipeds	106	94	8	79	9	***296***
Polar Bears	0	0	0	2	0	***2***

[a] See *Useability Criteria* in *Methods* in this Chapter and Chapter 3.

Estimated Numbers of Pinnipeds Present and Potentially Affected

It was difficult to obtain meaningful estimates of "take by harassment," since no useable marine mammal sightings were made during the limited seismic operations.

Estimates from Direct Observations

The number of marine mammals observed from the *Henry C.* during Beaufort Sea monitoring provided a minimum estimate of the number of marine mammals potentially affected by seismic sounds. This was likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range of the MMOs, 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, no marine mammals were sighted within the small safety radius around the airguns while seismic operations were conducted. As no marine mammals were seen during airgun operations, the direct estimate of the number exposed to ≥190 dB rms was zero.

Marine Mammals Potentially Exposed to Sounds ≥160 dB re 1 µPa (rms)—Similarly, no marine mammals were sighted in the water under useable (or non-useable) conditions when the airguns were operating, and the direct estimate of the number of marine mammals exposed to ≥160 dB was zero.

Estimates Extrapolated from Density

The number of marine mammals directly sighted by MMOs underestimates the actual number present, as described in Chapter 3. Indirect estimates based on the area ensonified to various received levels (Table 7.7) and estimated marine mammal density provide alternative estimates that can correct for this underestimation. The methodology used for the indirect estimates was described in SOI's 90-day report to NMFS (Patterson et al. 2007).

Using line transect methodologies described in Chapter 3 and Appendix B, pinniped density was estimated to be 358 individuals/1000 km^2. This density calculation was used to estimate both the number of different *individual* pinnipeds exposed to seismic sounds ≥160, ≥170, ≥180, and ≥190 dB (rms), and the average number of *exposures* of each pinniped to the various levels. As discussed in the Chukchi Sea section (Chapter 3), estimated number of exposures will exceed the estimated number of different individuals exposed if the airguns are towed back and forth through the same region a number of times, exposing some animals to airgun sound on more than one pass. No cetaceans were observed from the vessel at any time during operations, so density and take estimates at distances equal to received levels of 160, 170, 180, and 190 dB rms were not calculated. Estimates of marine mammals exposed to lower received levels are presented in Chapter 8.

Estimates of marine mammals potentially ensonified to the various sound pressure levels are based on the actual airgun operations. These estimates are lower than those provided in the IHA application, in part, because the estimates in the application assumed that SOI would conduct far more seismic surveying in the Beaufort Sea than actually occurred, and because the actual airgun array used was reduced in size compared to the array proposed in the application. In addition, the following estimates assume that all marine mammals present were well below the surface, and that marine mammals did not move away from the path of the approaching *Henry C.* Those assumptions probably did not apply to all animals; therefore indirect estimates of the numbers of marine mammals exposed to various sound levels based on densities during non-seismic periods are probably overestimates.

Table 7.8 summarizes the estimated number of seals that might have been exposed to sounds with various received levels. 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 are unlikely to be disturbed appreciably by airgun sounds until exposed to received levels of 170 dB (Harris et al. 2001; Moulton and Lawson 2002). 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.

(A) ≥160 dB (rms)—We estimate that there would have been ~1.21 exposures to each of ~148 individual seals (ringed, bearded, and spotted) to airgun pulses with received levels ≥160 dB re 1 μPa (rms) during the shallow-hazards survey, if all seals were below the surface of the water and showed no avoidance of the approaching vessel, and if the four-airgun 280-in^3 source had been used for all airgun operations (Table 7.8). Given the predominance of ringed seals in the Beaufort Sea, most of the exposures would have been of ringed seals, with lesser numbers of exposures of bearded and spotted seals.

(B) ≥170 dB (rms)—Seals were unlikely to be disturbed unless exposed to received levels of airgun sounds ≥170 dB re 1 μPa (rms). If so, then the estimated number of exposures would be ~37% of the corresponding estimates for ≥160 dB, based on the proportionally smaller area exposed to ≥170 dB. Overall, there would have been ~63 exposed seals, averaging ~1.1 exposures each, to seismic sounds with received levels ≥170 dB (Table 7.8).

TABLE 7.7. The areas (km^2) potentially ensonified to various levels by the airguns on the *Henry C*. during its operations within the Beaufort Sea study area, 1 Aug. – 3 Oct. 2006. (**A**) Maximum area ensonified, with overlapping areas counted multiple times. (**B**) Total area ensonified, with overlapping areas counted only once.

	Sound Pressure Level (dB re1µPa (rms))				
	≥ 120	**≥ 160**	**≥ 170**	**≥ 180**	**≥ 190**
Nearshore					
A. Including Overlap Area	5008	433	160	58	21
B. Excluding Overlap Area	4235	347	150	56	20
Offshore					
A. Including Overlap Area	3759	67	25	9	3
B. Excluding Overlap Area	2920	67	25	9	3
Total					
A. Including Overlap Area	8767	500	185	67	24
B. Excluding Overlap Area	7155	414	175	65	23

TABLE 7.8. Estimated numbers of individual pinnipeds exposed (ringed, spotted, and bearded seals), and average number of exposures per individual, to sounds with various received levels during airgun operations from the *Henry C.*

		Nearshore		Offshore		*Total*	
	Exposure level in dB re 1µPa (rms)	**Individuals**	**Exposures / Individual**	**Individuals**	**Exposures / Individual**	**Individuals**	**Exposures / Individual**
Based on non-seismic density [a]							
Pinnipeds	**≥ 160**	124	1.2	24	1.0	148	1.2
	≥ 170	54	1.1	9	1.0	63	1.1
	≥ 180	20	1.0	3	1.0	23	1.0
	≥ 190	7	1.1	1	1.0	8	1.0

[a] Nearshore non-seismic densities were applied to both nearshore and offshore ensonified areas.

(C) ≥180 dB (rms)—Some seals may have been within the 180 dB radius around the operating airguns but were not seen by the observers, even though all airgun operations were in daylight. The 180 dB radius for the four-airgun 280-in^3 source was empirically measured by Greeneridge Sciences as 250 m (Table 7.1). Based on the densities of seals estimated from the sighting data during non-seismic conditions, there would have been ~1 exposure to ≥ 180 dB to each of 23 seals (Table 7.8). The latter estimate exceeds the zero seals observed directly in areas exposed to ≥180 dB. The difference can be attributed, in part, to the fact that the estimates in Table 7.8 include any seals that met either of the following criteria:

- avoided exposure to ≥180 dB by swimming away from the approaching shallow-hazards survey vessel before entering the 180 dB radius
- were present but missed by visual observers because of the inevitable difficulties in sighting small seals in the water. 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).

(D) ≥190 dB (rms)—Likewise, based on the densities of seals calculated from our sighting data, we estimate that there would have been eight seals with ~1 exposure each to airgun sounds with received levels ≥190 dB (rms) (Table 7.8). However, some of these seals likely would have moved away before the received level reached 190 dB. Others might not have been far enough below the surface to be exposed to ≥190 dB. Also, given the use of a smaller airgun source than originally planned, the 190 dB radius would have been less than the 89 m measured during verification of the sound source. Thus, the above number likely overestimates the number of seals exposed to ≥190 dB.

Summary

Vessel-based marine mammal monitoring was conducted from the *Henry Christoffersen* during shallow hazard and site clearance activities in the Beaufort Sea in 2006. Most of the geotechnical equipment used during the shallow hazard and site clearance activities produced low level sound pressures that were not likely to impact marine mammals. A small array comprised of four 70-in^3 airguns (280 in^3 total volume) was onboard the *Henry C*. and sound pressure level from the four-airgun array was measured on 8 Aug. Final measured distances for the 180 and 190 dB (rms) safety radii were 0.25 and 0.089 km, respectively. The airgun array was used for site clearance on one day (25 Aug.) and only two airguns (140 in^3 total volume) were used rather than the full four gun array. However, disturbance and safety radii for mitigation purposed and for exposure estimates were based on the measured radii for the four-airgun array. Thus, the estimated numbers of exposures of marine mammals to the airgun sound on 25 Aug. were conservative.

Based on direct observations, no cetaceans or pinnipeds were exposed to SPLs ≥160, 180 or 190 dB. Exposure estimates based on marine mammal density (Table 7.8) were lower than those proposed in the IHA application primarily because the estimates in the application assumed that SOI would conduct far more seismic surveying in the Beaufort Sea than actually occurred, and because the actual airgun array used was reduced in size compared to the array proposed in the application.

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8. BEAUFORT SEA AERIAL SURVEYS IN SUPPORT OF SHALLOW HAZARDS SURVEYS[1]

Introduction

SOI planned to conduct seismic exploration activities in the Beaufort Sea in 2006 and designed an aerial survey program in support of those seismic activities. Aerial surveys were originally intended to be flown during summer (July to late August) to collect information on species and densities of cetaceans present at that time of year, because no summer surveys had been conducted in the offshore Beaufort Sea since the mid 1980's (Moore and DeMaster 1998; Moore et al. 2000). Those earlier surveys found relatively few cetaceans in the project area during July and August (Moore and Reeves 1993; Moore et al. 1993a), but abundance, and therefore possibly distribution, of both gray whales (Rugh et al. 2005) and bowheads (George et al. 2004; Zeh and Punt 2005) have increased since those surveys were completed. In addition, fall surveys (late August to October) were planned to obtain detailed data on the abundance, distribution, and movements of marine mammals, particularly bowhead whales, within ~50 km to the east and ~70 km to the west of the primary seismic vessel, and to monitor the 120 dB radius for bowhead whales prior to and during seismic activities. Logistical problems early in the summer season precluded SOI's ability to conduct summer aerial surveys, and the aerial survey program did not begin until 26 Aug.

Objectives

The original objectives of the aerial surveys were

- to advise operating vessels as to the presence of marine mammals in the general area of operation, and in so doing meet requirements of the IHA issued by NMFS;
- to collect and report data on the distribution, abundance, orientation and behavior of marine mammals near the seismic operations with special emphasis on migrating bowhead whales;
- to support regulatory reporting and Inupiat communications related to the estimation of impacts of seismic operations on marine mammals;
- to monitor the accessibility of bowhead whales to Inupiat hunters;
- if whales deflect around seismic activities, to document how far west of seismic activities bowhead whales travel before they return to their normal migration paths, and, if possible, to document how far east of seismic operations the deflection may occur.

SOI's seismic source vessel, the *Gilavar*, conducted seismic operations in the Chukchi Sea until mid-September, when it was to transit to the Beaufort Sea to continue seismic acquisition within specific lease holdings. However, due to weather and ice conditions, the *Gilavar* terminated its seismic activities in mid-September and did not conduct deep seismic acquisition in the Beaufort Sea in 2006. SOI's vessel-based activities in the Beaufort Sea were limited to site clearance and shallow hazard surveys in the mid- and eastern Alaskan Beaufort Sea using the *Henry Christoffersen*. Consequently, some of the original objectives of the aerial survey program could not be achieved. For example, since the *Gilavar* did not conduct any seismic activities in the Beaufort Sea, it was not possible to document whether or not there was bowhead deflection away from the seismic vessel and where the subsequent return to their migratory path occurred.

[1] Tannis Thomas, William R. Koski, and Ted Elliot LGL Limited, King City, Ontario.

Methods

Aerial surveys supported the shallow hazards and site clearance activities conducted from the *Henry Christoffersen*. In 2006, the shallow hazards vessel (*Henry Christoffersen*) conducted seismic activities on 25 Sept. in Camden Bay west of Kaktovik. No aerial surveys were flown on 25 Sept. due to poor weather conditions, but surveys were flown on 23–24 Sept. to monitor and clear the 120 dB zone prior to the seismic activities, as required in the IHA. The 120 dB zone is an area within which there has been concern that sound levels may cause some disturbance to migrating bowhead cow/calf pairs. Monitoring of the 120 dB zone has not previously been required in IHAs. Given the very limited airgun operations in the Beaufort Sea in autumn 2006, there were insufficient 2006 data with which to analyze differences in cetacean distribution with and without seismic activity.

Survey Area

A series of eight north-south transect lines was established to monitor the project area in Camden Bay, where SOI planned to conduct shallow hazard and site clearance surveys (Figure 8.1). The length of the transect lines varied from ~51 to 74 km and the survey area covered ~5658 km^2. Nine aerial surveys of the project area were conducted using a Twin Otter aircraft flown at 1,000 ft above ground level at an airspeed of approximately 120 knots. The first seven surveys, conducted between 26 Aug. and 14 Sept., were pre-seismic surveys intended to collect baseline data on the distribution and abundance of marine mammals in the project area. The surveys conducted on 23 and 24 Sept. were flown as mitigation to clear the 120dB zone prior to seismic activities. Survey and data recording procedures were identical to those described in the Chukchi Sea aerial survey methods section (Chapter 5).

Analyses of Aerial Survey Data

Mapping—This report includes maps showing the sighting locations of whales during aerial surveys in 2006. The survey area included the region from ~143°37’–145°58' W and ~69°56’–70°40' N.

Each sighting symbol on the maps presented later in this chapter represents a sighting of one or more individual whales. Sightings along formal transects (regardless of distance from trackline) are shown as filled (useable data) or “dotted” (non-useable data) symbols. Useable data refers to sightings and effort collected under good sighting conditions, (i.e., Beaufort wind force scale 4 or less, or sightability moderately impaired or better). Non-useable data refers to sightings and effort collected under poor conditions (i.e., Beaufort wind force scale 5 or more, or sightability seriously impaired or impossible). Non-useable data sightings, and the associated survey effort under poor conditions, were excluded from analyses of sightings per unit effort in this report. Incidental sightings, including sightings during “connect” legs between transects and during non-systematic “search” legs, are shown as open symbols, and are not considered during analyses.

Whales Per Unit Effort (Relative Abundance)—The maps described above provide much of the distributional information. However, they are difficult to interpret because survey effort and group sizes varied considerably within the study area; therefore, sightings were not a useful presentation of relative distribution or abundance. To account for this variability in survey effort and group size, we computed the number of sightings (groups and individuals) per unit effort.

We used the software program NRoute, supplemented by specially-written MapBASIC computer code, to determine the number of whale sightings and individuals, and the numbers of kilometers of transect survey coverage, within the survey area during useable effort and sightings. Sightings or individuals per unit effort were determined by dividing the number of sightings (or individuals) seen during the survey by the number of kilometers of “transect” coverage in that survey.

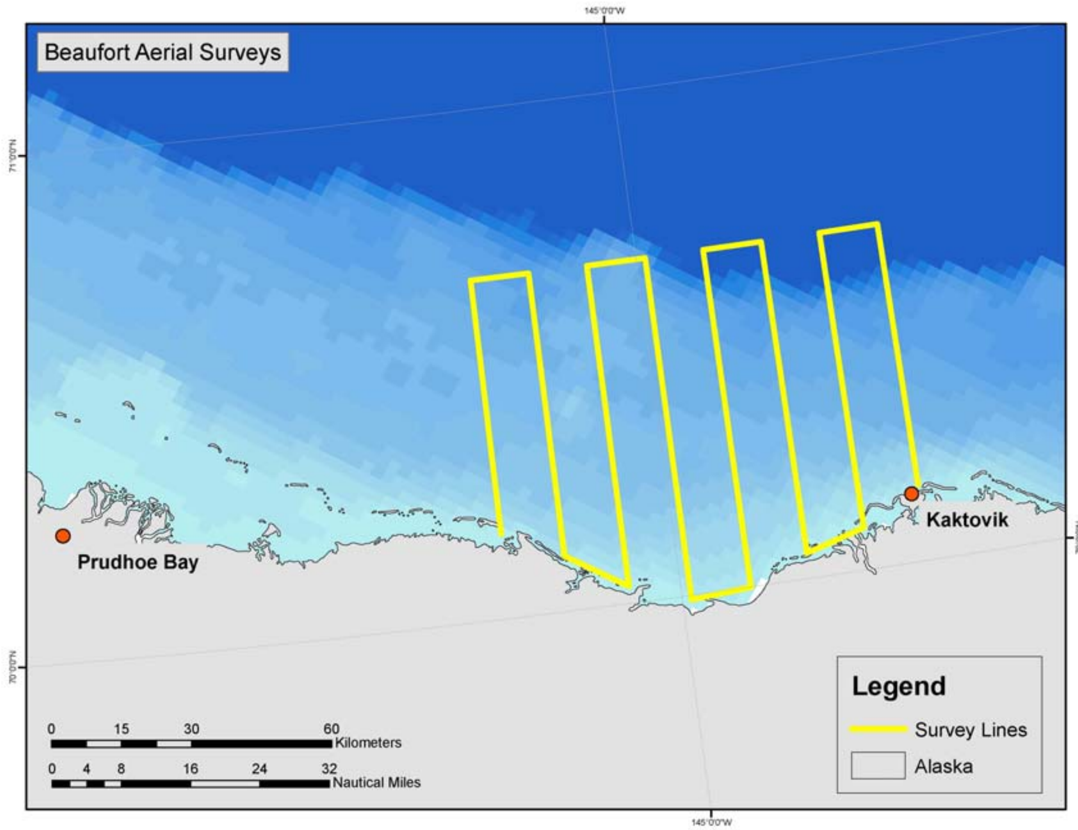

FIGURE 8.1. Approximate location of transect lines for aerial surveys of marine mammals in Camden Bay, Alaska 2006.

Estimated Number of Whales Present—Line Transect methodology (Buckland et al. 2001) was used to estimate densities and numbers of animals present in the study area. We used the DISTANCE program to calculate line transect estimates of the numbers of whales present for each survey when sufficient survey effort and sightings were available to justify the use of this methodology (Thomas et al. 2006, version 5.0, release 2). For the beluga whale estimates, when a number of sightings included clusters of animals, a cluster analysis was performed in the DISTANCE program. For the lateral distance factor, $f(0)$, we calculated inner truncation distances according to aircraft type and altitude. For a Twin Otter aircraft, the inner truncation distances were 100 m at 1000 ft and 300 m at 1500 ft. The outer truncation distances were calculated according to whale species seen during good sighting conditions (sea conditions between 0-4 and ice-cover between 0-5%) as in a previous study for the same general area (Thomas et al. 2002). For beluga whales the outer truncation distance was calculated at 1000 m, and for bowhead whales it was 2000 m. The availability bias factor, $g_a(0)$, which takes into account the effects of surfacing and dive behavior on the probability that an animal on or near the trackline will be at the surface while the surveyors are close enough to have a chance of detecting the animal, was calculated for each whale species (Thomas et al. 2002). For beluga whales, the $g_a(0)=0.58$ was calculated from surfacing and dive data in Martin and Smith (1992), and for bowhead whales, the $g_a(0)=0.144$ was taken from Thomas et al. (2002). The number of whales present was estimated for each survey when a minimum of two whales was sighted under good sighting conditions. The survey area encompassed 5658 km^2.

Distances from Shore—We further examined the distribution of whales by dividing the study area into a series of strips, each 10 km wide, oriented roughly parallel to the coast. This allowed a more detailed examination of the distribution and abundance of the whales at different distances from the shore. These analyses were restricted to useable effort and sightings to allow meaningful calculations of sightings and individuals per unit effort during different parts of the season. Thus, "zero" sightings or individuals in a particular strip range means that there were no sightings during useable effort, not necessarily that there were no sightings in those strips. Given the irregularities in the coastline, and the presence of islands along some parts of the coast, a "0 km from shore" reference point was established. Waters inshore of the 0 km line (also referred to as –5 km band) were shallow nearshore waters, in some cases inside lagoons. Thus the first distance from shore band "(-5)-5 km" represented the areas inshore of the 0 km line out to 5 km offshore, resulting in this band being less than 10 km wide at times. The farthest distance from shore band (65-70 km) was only 5 km wide, and, due to the limited effort in this band, it was excluded from the distance-from-shore analyses.

Seasonal Occurrence—We examined the distribution and abundance of whales by 10-day periods from 26 Aug. to 24 Sept. to determine seasonal patterns in the data. These analyses were restricted to useable effort and sightings. Thus, "zero" sightings or individuals in a particular date range meant that there were no sightings during useable effort, not necessarily that there were no sightings on those dates.

Behavior—Habitat use and movement were assessed by the behavior, swimming speeds and headings of the whales during all surveys, including useable and non-useable data and off-transect sightings. The angular deviations of the headings were calculated according to Batschelet (1981).

Estimating Cetaceans Potentially Affected—NMFS practice in situations with intermittent impulsive sounds like seismic pulses has been to assume that "take by harassment" (Level B) may occur if cetaceans are exposed to received levels of sounds exceeding 160 dB re 1 μPa (rms) (NMFS 1995). The reaction threshold for toothed whales, including belugas, is unknown but presumably higher because of their poorer hearing sensitivity at low frequencies (NMFS 1995; Richardson et al. 1995; Richardson and Würsig 1997). The monitoring plan for 2006 called for estimates of the numbers of cetaceans observed within the 160 dB rms (and 180 dB rms) zone, and bowheads (particularly mother/calf pairs) observed within the 120 dB zones.

Received levels of seismic pulses from the four-airgun array onboard the *Henry Christoffersen* diminished below 160 dB re 1 μPa (rms) at a distance not exceeding 1.75 km (see Chapter 7; Table 7.1). Animals within the 160 dB area were therefore likely observable from the vessel, and since there were no aerial surveys on the day of the seismic activity due to weather conditions, the vessel observations were used to estimate cetacean "takes." For the 180 dB rms radius, the distance at which the seismic pulses diminished below 180 dB re1 μPa (rms) was 250 m. The MMOs on the vessels should have been able to detect all cetaceans that surfaced within 250 m of the vessel. The received levels of seismic pulses from the airgun arrays diminished below 120 dB re1 μPa (rms) at a distance not exceeding 22.2 km. All animals present within the 120 dB rms area could not be observed from the vessel, so the number of bowheads seen during the aerial surveys on the previous two days were used to estimate the number of bowheads that might have been exposed to ≥120 dB rms.

However, only two airguns were used during the seismic activities on 25 Sept., and the actual distances of the 120, 160 and 180 dB radii were reduced compared to the measured values in Table 7.1. The size of the radii for the various disturbance and safety zones for the two-airgun array actually used were not measured. Thus, results of the analyses of potential exposures of marine mammals to seismic impulses in this report, which are based on the size of the radii for the four-airgun array, are conservative.

Results

Ice Cover

From late August through September 2006, the pack ice in the Beaufort Sea was always present in portions of, or across the entire study area.

Monitoring Effort

Table 8.1 summarizes the useable aerial survey effort and whale sightings for each survey. A total of 3049 km of useable transect effort was collected, during which 60 sightings of whales or whale groups were made (Table 8.1, Appendix Table F.1). Details of survey effort and whale sightings including non-useable periods are available in Appendix F (Table F.1, Figure F.1 – F.5).

Total or partial aerial survey coverage was obtained on nine surveys (on nine different days) between 26 Aug. to 24 Sept. All or most of the surveys were completed on six days. Substantially reduced coverage of transects due to low clouds, precipitation, high sea conditions, or some combination of those factors was obtained on three surveys. Approximately 40%

Aerial surveys were flown on 23–24 Sept. to "clear" the 120 dB (rms) zone prior to the seismic activities to be conducted from the *Henry Christoffersen*. During the aerial survey on 23 Sept., 45 km of transect surveys were flown, of which 29 km were flown in useable effort and sighting conditions. There was one sighting of a bowhead whale during this survey (Figure 8.2). On 24 Sept., 171 km of transect surveys were flown, of which 139 km were flown in useable effort and sighting conditions. No whales were seen during this survey. Poor weather prevented complete surveys from being flown on either 23 or 24 Sept. In Figure 8.2, the 22.2 km radius for the 120 dB (rms) is depicted on the map, showing the area that would have been affected by seismic activity (using a four-airgun array) on 25 Sept. Transect surveys flown on the 23-24 Sept. inside the 120 dB (rms) area covered ~15% of the affected area.

Sighting Rates

Poor weather conditions precluded completion of all but one survey and on average 65% of the surveys were completed (Table 8.1). Bowhead whales were observed on 89% (eight of nine) of the surveys, and the highest sighting rate of 4.19 bowhead whales per 100 km of survey occurred on 6 Sept. (Table 8.1). Bowhead whales were observed in group sizes of one to four, with single whales being observed most frequently.

Beluga whales were observed on 44% (four of nine) of the surveys. The highest beluga whale sighting rate (8.76 beluga whale per 100 km of survey; Table 8.1) also occurred on 6 Sept. The high beluga whale sighting rate on 6 Sept. was due primarily to the large group sizes seen on that particular survey. Beluga whales were generally seen in group sizes of one to seven, but on 6 Sept. a group of 17 beluga whales was observed.

TABLE 8.1. Summary of aerial survey effort and sighting rates in the central Alaskan Beaufort Sea, 26 Aug. to 24 Sept. 2006. Sighting rates are based on useable sightings and effort.

				Bowhead Whale				Beluga Whale			
Date in 2006	Survey No.	Transect km	Percent of Survey Area	Sight-ings	Indivi-duals	Sightings/ 100 km	Individuals/ 100 km	Sight-ings	Indivi-duals	Sightings/ 100 km	Individuals/ 100 km
26-Aug	1	468	89	3	3	0.64	0.64	1	1	0.21	0.21
3-Sep	2	471	90	3	3	0.64	0.64	0	0	0.00	0.00
4-Sep	3	513	98	8	12	1.56	2.34	0	0	0.00	0.00
6-Sep	4	525	100	14	22	2.67	4.19	16	46	3.05	8.76
12-Sep	5	95	18	1	1	1.06	1.06	0	0	0.00	0.00
13-Sep	6	464	88	5	8	1.08	1.72	3	10	0.65	2.15
14-Sep	7	346	66	4	6	1.16	1.74	1	2	0.29	0.58
23-Sep	8	29	5	1	1	3.51	3.51	0	0	0.00	0.00
24-Sep	9	139	26	0	0	0.00	0.00	0	0	0.00	0.00
Total		3049	65	39	56	1.28	1.84	21	59	0.69	1.94

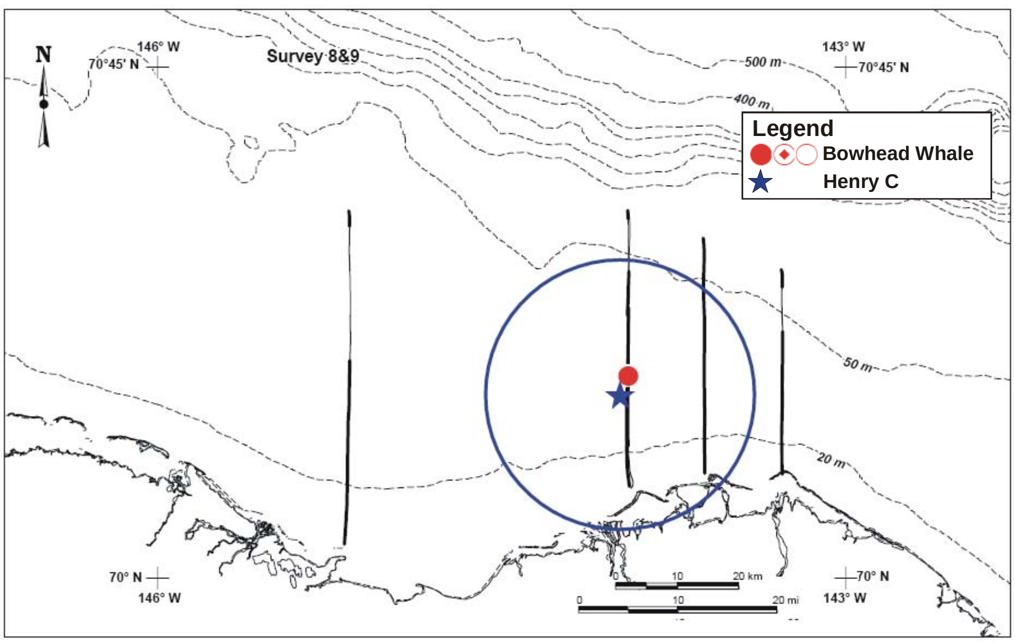

FIGURE 8.2. Aerial survey transects (black lines) flown on 23–24 Sept. 2006 in the central Alaskan Beaufort Sea. The third transect from the right was flown twice, once each on 23 and 24 Sept.; other transects were flown once. Blue star and circle depict the seismic patch (star) and a 22.2 km radius circle around the source location for the 25 Sept. 2006.

Distribution

During 2006, nearly all bowhead whales sighted during the surveys were found approximately 30 to 60 km from shore in waters 40–100 m deep, and four bowhead whales were sighted in waters 100–200 m deep (Figure 8.3). Only one bowhead was sighted in shallower water, and it was seen in ~10 m of water just east of Kaktovik.

Beluga whale sightings were primarily concentrated at the northern end of the transect lines along the 200 m depth contour, with a few scattered sightings in shallower waters from 30–40 m deep (Figure 8.4). No beluga whales were observed inside the 20 m depth contour which was generally > 10 km offshore.

Abundance

The numbers of bowhead whales present in the study area (5658 km^2) were estimated for six surveys, each of which was flown on separate days during the 2006 field season and had a minimum of two useable sightings (Table 8.2). Densities were not estimated for surveys with zero sightings, or for those with a single sighting. The estimates were based on line-transect methodology with allowance for low detectability of whales close to the trackline, the decrease in detectability with increasing lateral distance, and missed whales below the surface (see Methods and Thomas et al. 2002). Using the same criteria, beluga whale estimates were made for two surveys (Table 8.2)

The estimated number of bowhead whales within the study area ranged from 130 to a maximum of 649 bowheads (based on 17 sightings on 525 km of survey coverage on 6 Sept. 2006). The estimated number of beluga whales within the study area ranged 218 to 1198 belugas during the two surveys for which estimates were calculated (Table 8.2).

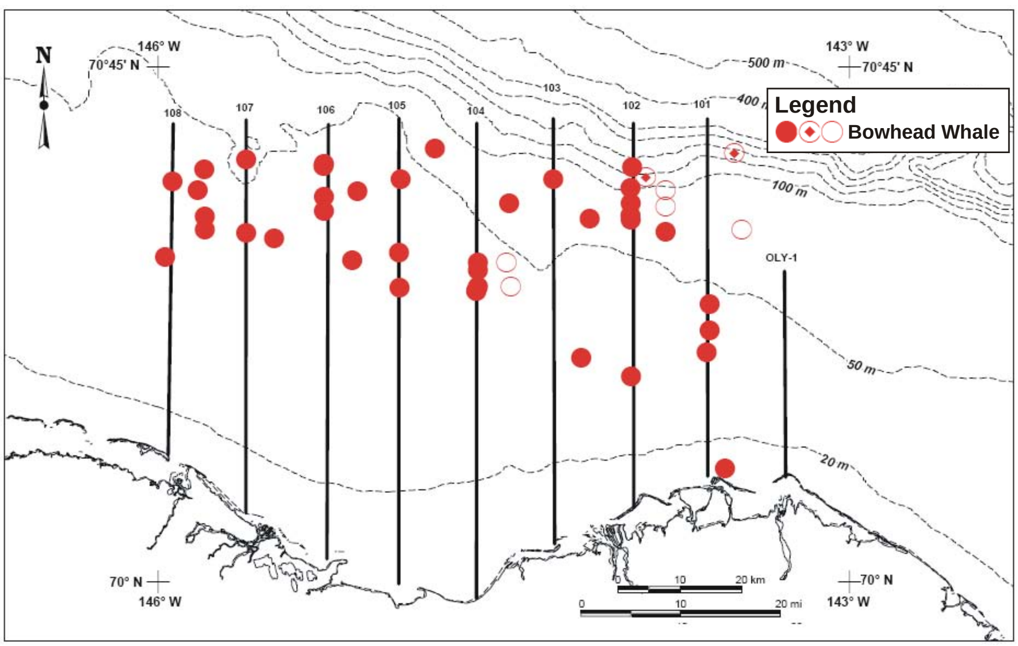

FIGURE 8.3. Locations of bowhead whale sightings during aerial surveys in the central Alaskan Beaufort Sea during Aug.–Sept. 2006. Solid symbols denote “useable” sightings, open symbols containing a dot denote “non-useable” sightings, and open symbols denote incidental sightings, including search and connect legs.

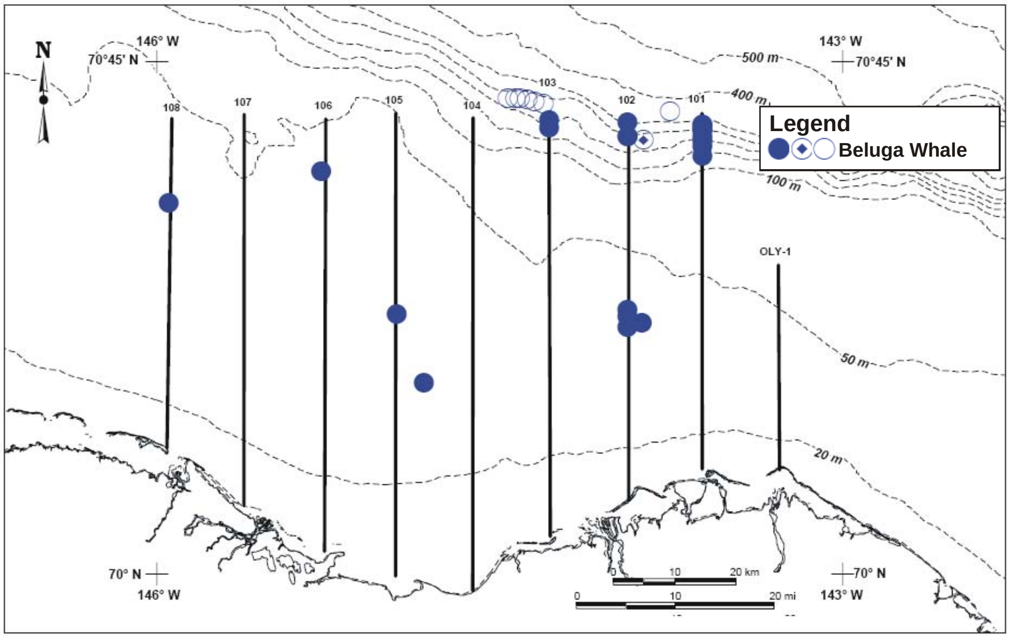

FIGURE 8.4. Locations of beluga whale sightings during aerial surveys in the central Alaskan Beaufort Sea during Aug.–Sept. of 2006. Solid symbols denote “useable” sightings, open symbols containing a dot denote “non-useable” sightings, and open symbols denote incidental sightings, including search and connect legs.

TABLE 8.2. Estimated numbers of whales in the central Alaskan Beaufort Sea study area, based on September surveys using line transect methods[a,b].

Date in 2006	Survey No.	Effort (km)	Whales seen on Trans[a]	Est. Whales /100 km[b]	S.E.[b]	Est. No. Whales[b]	S.E.[b]
A. Bowhead Whales							
26-Aug	1	468	3	2.30	1.52	130	86
3-Sep	2	471	3	2.29	1.82	130	103
4-Sep	3	513	12	8.28	3.60	469	204
6-Sep	4	525	17	11.47	5.86	649	331
13-Sep	6	525	8	6.10	3.48	345	197
14-Sep	7	346	2	2.05	1.57	116	89
B. Beluga Whales							
6-Sep	4	525	46	21.17	14.95	1198	846
13-Sep	6	525	10	3.85	4.17	218	236

[a] Excludes sightings between trackline and inner truncation distance (100-450 m, depending on aircraft altitude); also excludes sightings beyond outer truncation distance (1000-2000 m, depending on aircraft altitude, sea conditions, ice cover and species).

[b] Calculated by the DISTANCE program including use of f(0) and ga(0) correction factors to correct for submerged whales missed.

Distances from Shore

Bowhead and beluga whale distribution was determined for 10-km bands from shore considering only useable data. Survey coverage in each of the eight band widths was highly variable, ranging from 20 km in the 65–70 km band to 632 km in the 5–15 km band, resulting in potential overestimation of numbers where animals were encountered in the low effort bands (Figure 8.5E).

Peak numbers of bowhead sightings (18) and individuals (25) occurred in the band 45–55 km from shore (Figure 8.5A,B). In Figure 8.5C,D, the same data have been converted to sightings or individuals seen per 100 kilometers of aerial survey based on survey effort data from Figure 8.5E. When adjusted for survey effort, numbers of sightings (4.18 bowheads per 100 km) and individuals (5.81 bowheads per 100 km) per 100 km of survey were highest in the 45–55 km from shore band (Figure 8.5C,D). The sighting rate in the 65–70 km band was not calculated because the survey effort was too low to provide a reliable estimate.

Peak numbers of beluga whale sightings (9) and individuals (22) occurred in the band 55–65 km from shore (Figure 8.6A,B). In Figure 8.6C,D, the same data have been converted to sightings or individuals seen per 100 kilometers of aerial surveys based on survey effort data from Figure 8.5E. When adjusted for survey effort, numbers of sightings (4.41 belugas per 100 km) and individuals (10.78 belugas per 100 km) per 100 km of survey were highest in the 55–65 km from shore band (Figure 8.6C,D)

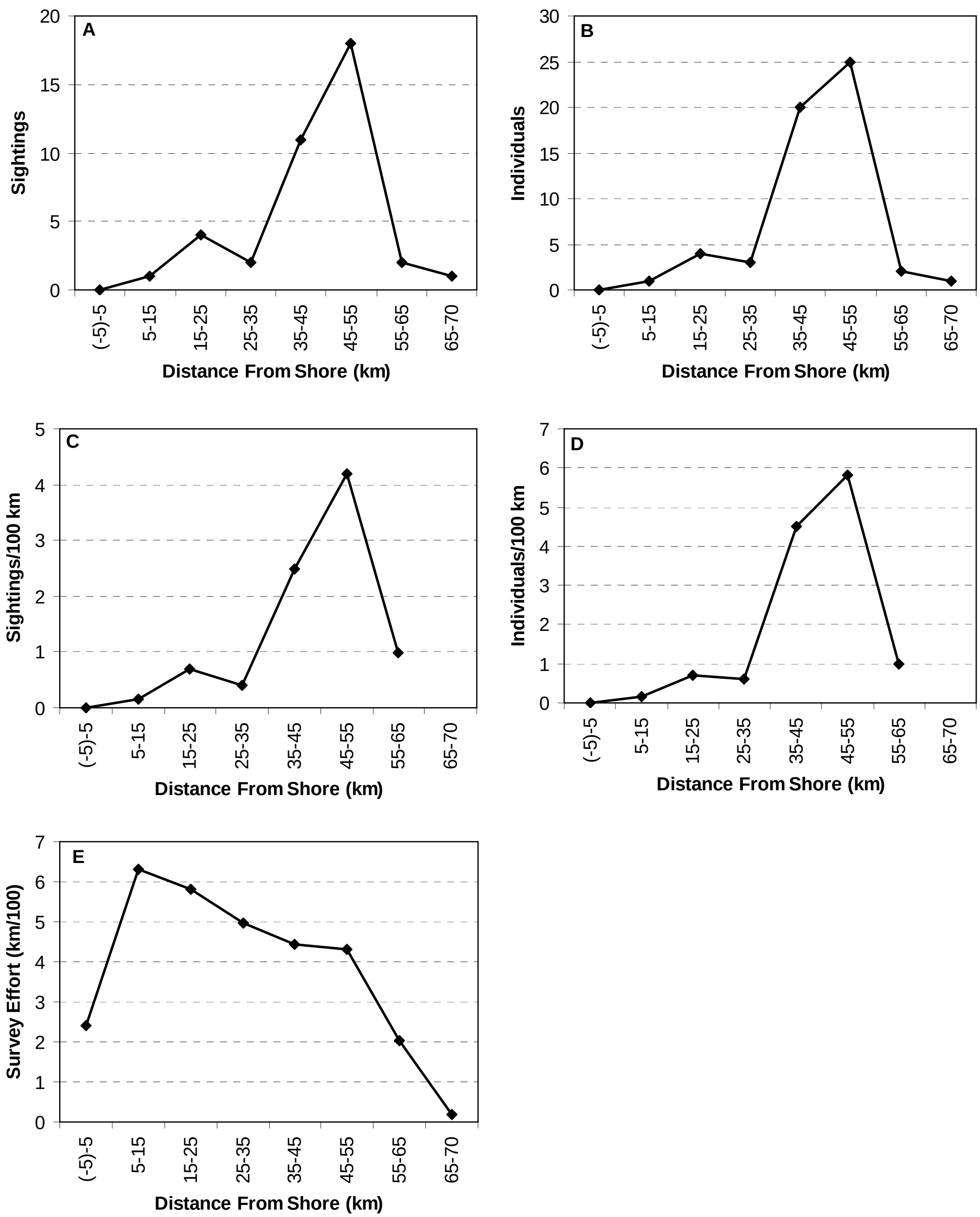

FIGURE 8.5. Distribution of bowhead whales vs. distance from shore (10-km bands). Based on useable aerial survey data in the central Alaskan Beaufort Sea, 26 Aug. to 24 Sept. 2006. ***(A)*** Sightings and ***(B)*** individuals by distance from shore, and ***(C)*** sightings and ***(D)*** individuals per 100 km of surveying, and ***(E)*** useable survey effort.

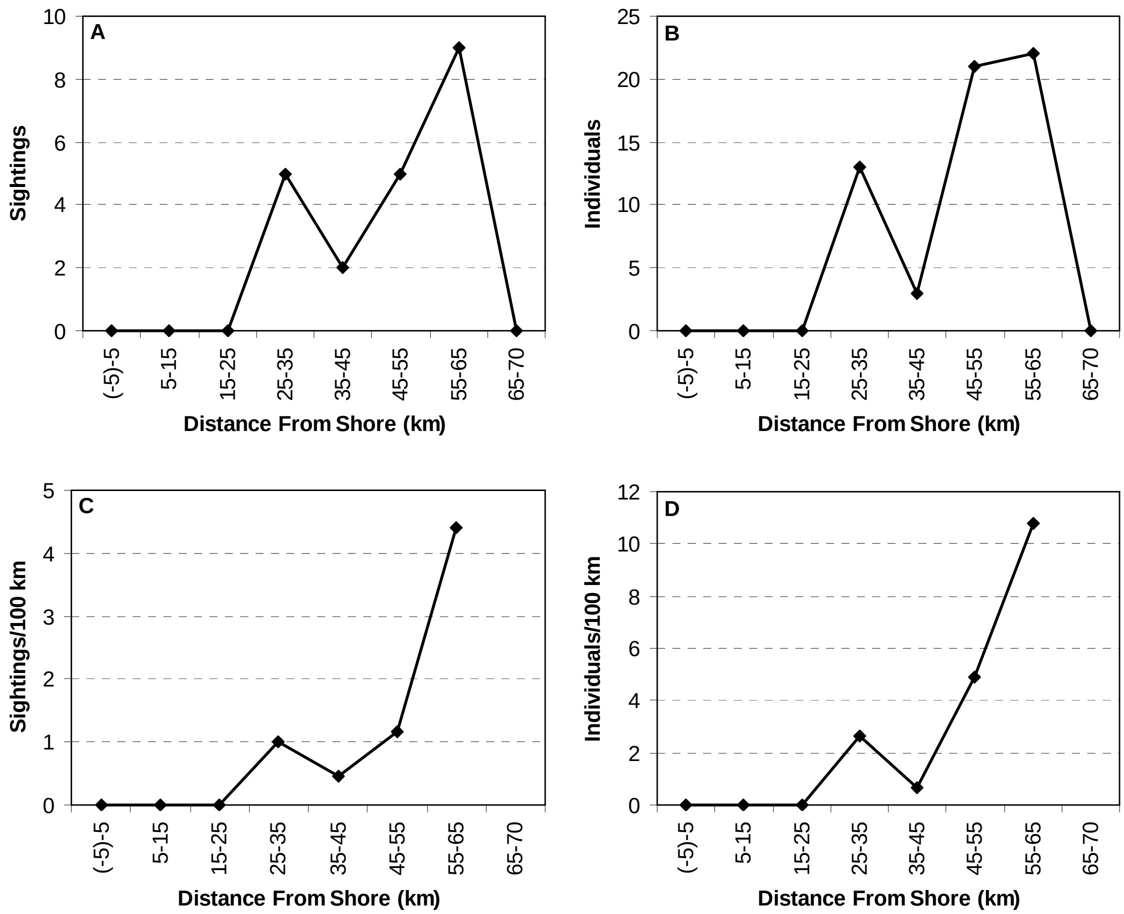

FIGURE 8.6. Distribution of beluga whales vs. distance from shore (10-km bands). Based on useable aerial survey data in the central Alaskan Beaufort Sea, 26 Aug. to 24 Sept. 2006. ***(A)*** Sightings and ***(B)*** individuals by distance from shore, and ***(C)*** sightings and ***(D)*** individuals per 100 km of survey. See Figure 8.5E for survey effort vs. distance from shore.

Migration Timing

The seasonal timing of whale sightings during the autumn is important in estimating the density of the whales that were in the area at different times of the year. Seasonal timing in 2006 was examined with useable data. Survey coverage during the four 10-day periods from 21–31 Aug. through 21–30 Sept. was highly variable, ranging from 167 to 1509 km of survey per 10-day period (Figure 8.7E).

Peak numbers of bowhead whale sightings (25) and individuals (37) were recorded during early-September (Figure 8.7A,B). When standardized for survey effort within the various 10-day periods, the peak rates (1.66 sightings/100 km and 2.45 individuals/100 km) were each recorded in early September (Figure 8.7C,D). The sighting rate in the 21–30 Sept. period was not calculated because the survey effort was too low to provide a reliable sighting rate.

Peak numbers of beluga whale sightings (16) and individuals (46) were recorded during early-September (Figure 8.8A,B). When standardized for survey effort within the various 10-day periods, the peak rates (1.06 sightings/100 km and 3.05 individuals/100 km) were each recorded in early September (Figure 8.8C,D).

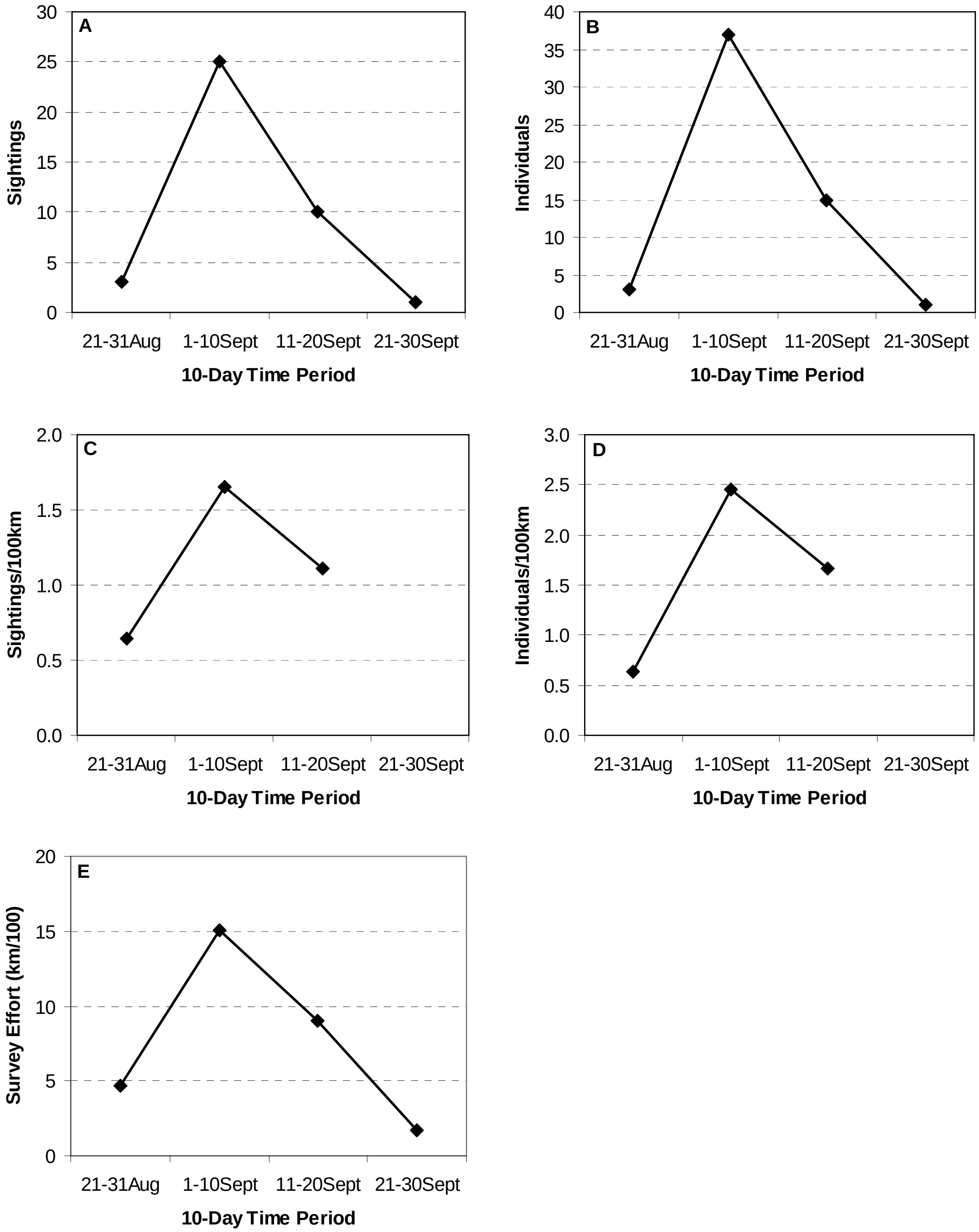

FIGURE 8.7. Seasonal pattern of bowhead whales in 2006. Based on useable aerial survey data in the central Alaskan Beaufort Sea during the autumn. Includes ***(A)*** sightings and ***(B)*** individuals by 10-day period, ***(C)*** sightings and ***(D)*** individuals per 100 km of survey, and ***(E)*** useable survey effort.

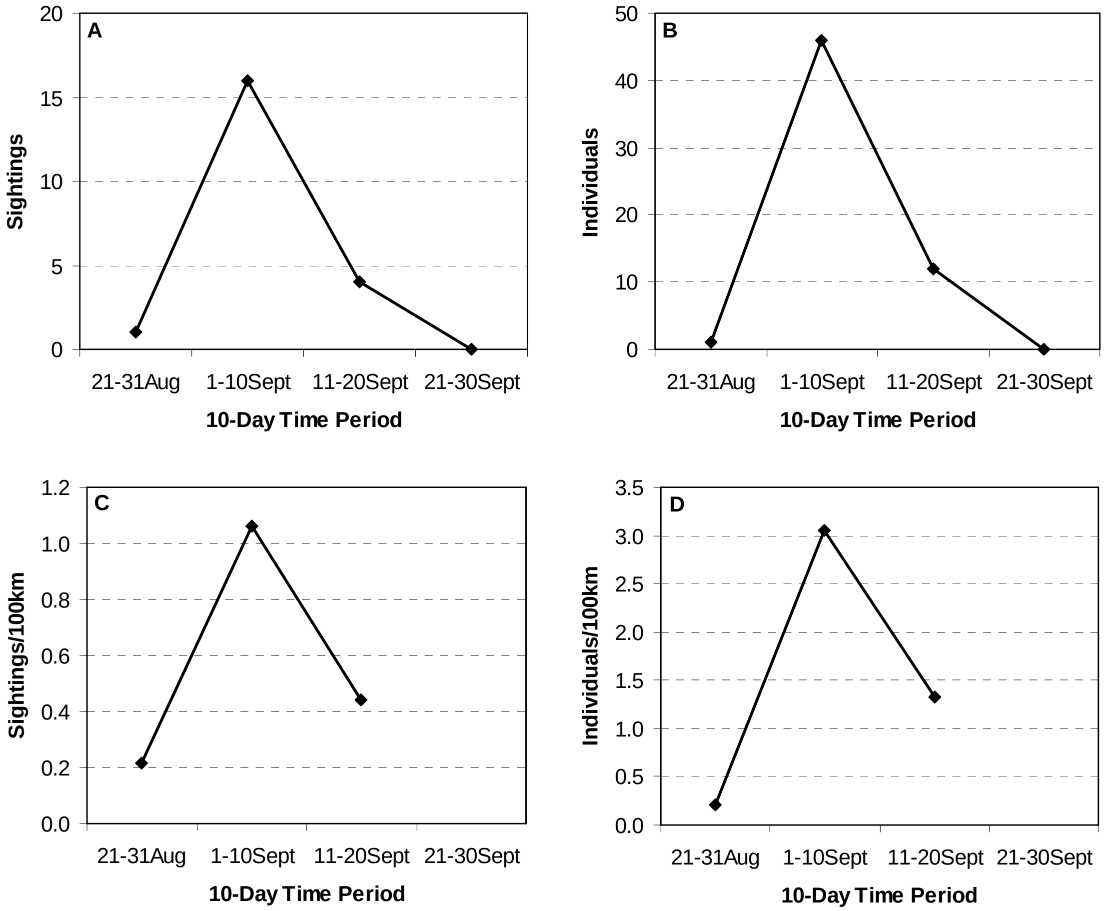

FIGURE 8.8. Seasonal pattern of beluga whales in 2006. Based on useable aerial survey data in the central Alaskan Beaufort Sea during the fall. Includes sightings ***(A)*** and individuals ***(B)*** by 10-day period, and sightings ***(C)*** and individuals ***(D)*** per 100 km of survey. See Figure 8.7E for survey effort vs. distance from shore.

Behavior, Swimming Speeds and Headings

The behavior, swimming speeds and headings of the whales during all surveys were analyzed to better understand whale activities in the study area. Behavioral analyses were not limited by the assumptions for other analyses which required use of only useable data, and both useable and nonuseable data were used in analysis of behavioral data. This included effort with poor sighting conditions and sightings during transit and connect segments.

The predominant behavior observed in bowhead whales was traveling, which was reported in 16 of 27 (59%) sightings (Table 8.3). Of the six sightings of traveling whales with a swimming speed recorded, three (50%) were traveling at medium speed and three at slow speed. The headings of 13 "traveling" bowhead individuals or groups included nine headings in the NW quadrant (270°-360°T) and four headings in other directions (Figure 8.9A). The vector mean heading was 302°T with an angular deviation of 71°T (P=0.06). The results suggest some bowheads were transiting the area, primarily in a westerly direction.

TABLE 8.3. Summary of behaviors of whales sighted in the central Alaskan Beaufort Sea during aerial surveys in 2006. Both useable and non-useable sightings are included.

	Number of Sightings					
	Bowhead Whale		Beluga Whale		Gray Whale	
Behav.	n	%	n	%	n	%
Feed	0	0	0	0	1	33
Travel	16	59	8	67	1	33
Rest	10	37	4	33	0	0
Dive	1	4	0	0	1	33
Total	27	100	12	100	3	100

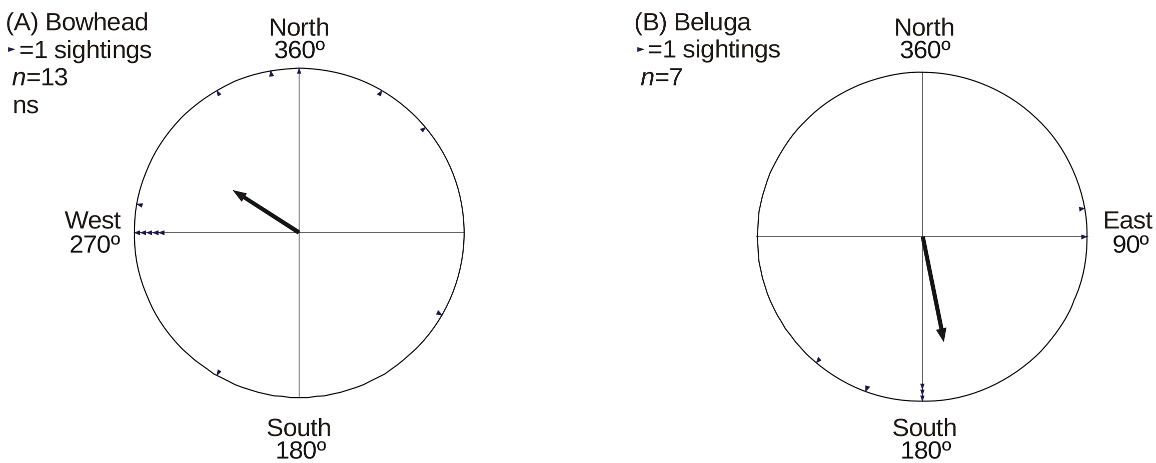

FIGURE 8.9. Headings of "traveling" whales in the central Alaskan Beaufort Sea study area, 24 Aug.–26 Sept. 2006, comparing ***(A)*** bowhead whales, and ***(B)*** beluga whales. Based on sightings during useable, non-useable, and search and connect data; each sighting counted once regardless of number of whales in group.

The predominant behavior observed in beluga whales was traveling, which was reported in eight of 12 (67%) sightings (Table 8.3). Of the six "transect" sightings of traveling whales with a swimming speed recorded, four (67%) were traveling at medium speed and two at slow speed. The headings of seven "traveling" belugas or groups included five headings in the S quadrant (90°-270°T) and two headings in an easterly direction (Figure 8.9B). The vector mean heading was 168°T with an angular deviation of 53°T. Sample size was too small to perform a meaningful test of directional trend.

Estimated Number of Cetaceans Present and Potentially Affected

The three received level criteria that were specified by NMFS as relevant in estimating cetacean exposure were:

- 180 dB re 1 μPa (rms), above which there is concern about possible effects on hearing
- 160 dB re 1 μPa (rms), above which avoidance and other behavioral reactions may occur

- 120 dB re 1 μPa (rms), above which there is concern that displacement of migrating bowhead whales, particularly cow/calf pairs, may occur (NMFS 2006)

180 dB Criterion—NMFS (1995, 1999) concluded that noise pulses from a seismic vessel might affect the hearing abilities of baleen whales if received levels exceed 180 dB re 1 μPa (rms). However, there is no direct evidence in the scientific literature that seismic sounds at these levels temporarily or permanently damage hearing of arctic marine mammals. The IHA issued for SOI's 2006 seismic program (NMFS 2006) called for immediate shutdown of airguns if cetaceans were detected within the 180 dB (rms) radius. Based on preliminary field measurements, the 180 dB zone extended ~330 m from the airgun source on the *Henry Christoffersen* when the four-airgun cluster was being used. The 330 m value was based on the preliminary field measurements and was more conservative than the final field measurement of 250 m for 180 dB re 1 μPa (Table 7.1). However, only two airguns were used during the site clearance on 25 Sept. and the actual 180 dB radius around that source was reduced compared to the final measured value of 250 m. The 330 m distance was used during calculations of possible exposure of whales to 180 dB rms, and thus estimates of exposure numbers are conservative.

MMOs working onboard the *Henry Christoffersen* saw no bowhead or beluga whales within (or beyond) the 180 dB (rms) zone on 8 Aug. or 25 Sept. when the airguns were operating. It is unlikely that an MMO would miss a whale within the 180 dB distance if it were at the surface, or if it were at the surface well beyond the 180 dB radius. Even if a whale were submerged within 330 m of the *Henry Christoffersen*, the MMO probably would have seen the whale earlier or later when it did eventually surface. Thus, the estimated number of bowhead and beluga whales exposed to sound pulses with received levels ≥ 180 dB re 1 μPa rms was zero during the sound source verification in Aug. and the site clearance activities in Sept. Furthermore, it is unlikely that a beluga would have been present in nearshore waters during this time, given the rarity of belugas in this area during summer and autumn.

160 dB Criterion—The NMFS criterion involving impulsive sounds such as those resulting from seismic activity has been to assume that a "take by harassment" may occur if cetaceans are exposed to received levels of sound that exceed 160 dB re 1 μPa rms. "Takes" of this type involve avoidance and other temporary changes in behavior that occur at distances well beyond those where there is any reasonable possibility of injury to the whales (Richardson et al. 1986, 1995:372ff; Ljungblad et al. 1988; NMFS 1995). Preliminary measurements of the sound pressure levels produced from the four-airgun array on the *Henry Christoffersen* indicated that the 160 dB (rms) radius extended ~2.22 km from the sound source, which was slightly greater than the final field measurement of 1.75 km (Table 7.1). The conservative 2.22 km distance was used during calculations of possible exposure of whales to 160 dB rms. As noted earlier, the two-airgun array was used during site clearance on 25 Sept., so the actual 160 dB radius on that date was substantially smaller than the 2.22 km assumed for analysis purposes.

MMOs working onboard the *Henry Christoffersen* saw no bowhead or beluga whales within the 160 dB distance on 8 Aug. or 25 Sept., when airgun operations were underway. We have no specific information on the probability that boat-based observers will sight a bowhead or beluga whale that is within 2.22 km of the vessel. However, given that traveling bowhead whales are below the surface a high proportion of the time, it is possible that a bowhead could have been within 2.22 km of the source vessel when the airguns were operating. However, bowheads were unlikely to have been in the area as early as 8 Aug., and those that are present in the general area at that time of year are typically seen well offshore in deep water (Moore et al. 2000). Also, during September 2006 the bulk of the bowhead migration was well offshore, some 20 km north of the seismic operations and in deeper water. It is also unlikely that a beluga whale was present during these times, given the rarity of belugas in nearshore waters in this area during late summer and autumn. Thus, it is unlikely that many (if any) bowhead or beluga whales were within

2.22 km of the shallow-hazards survey vessel during the brief period of airgun operations, and as noted above, the real 160 dB radius was substantially smaller than the 2.22 km used for analysis purposes.

120 dB Criterion—In 2006, NMFS specified that seismic activities could not be conducted if ≥4 bowhead cow/calf pairs were observed within the 120 dB re 1 μPa (rms) zone. It was assumed, based on very limited data where there was no change in behavior observed by Richardson et al. (1999), that exposures of cow/calf pairs to such levels of seismic sounds might cause avoidance of the area or other short-term changes in behavior. Measurements of the sound pressure levels produced from the four-airgun array on the *Henry Christoffersen* indicated that the 120 dB (rms) radius extended ~22.2 km from the sound source (Table 7.1).

One bowhead whale sighting was recorded during the surveys on 23 and 24 Sept. The area covered during survey represented ~15% of the 120 dB disturbance zone. Based on the aerial survey observations, 6.7 bowhead whales may have been within the 120 dB zone if the four-airgun array had been used. Since the actual seismic source was composed of a two-airgun array, the number of bowhead whales estimated to have been within the actual 120 dB zone was less than 6.7. Belugas would not be expected to occur as far south as the majority of the area ensonified to 120 dB (rms).

Summary

Aerial surveys of marine mammals in the Beaufort Sea were planned in support of vessel-based deep seismic exploration activities and shallow hazards surveys during 2006. The aerial surveys were originally intended to be flown during summer (July to late August) to collect information on species and densities of cetaceans present at that time of year. Fall surveys (late August to October) were planned to obtain detailed data on the abundance, distribution, and movements of marine mammals, particularly bowhead whales, within ~50 km to the east and ~70 km to the west of the primary seismic vessel, and to monitor the 120 dB radius for bowhead whales prior to and during seismic activities as required in the IHA. Logistical considerations precluded SOI from conducting deep seismic exploration in the Beaufort Sea in 2006, and aerial surveys were conducted only in support of the shallow hazards surveys.

Most of the geotechnical equipment used during the shallow hazard and site clearance activities produced low-level sound pressures that were not likely to impact marine mammals. A small four-airgun array was used for sound source measurement on 8 Aug. Only two of the airguns were used during the shallow hazards survey on 25 Sept. The safety and disturbance radii for the four-airgun array were relatively small and ranged between 0.089 and 1.75 km for the 190 and 160 dB zones, respectively (see Chapter 7).

Nine aerial surveys were flown between 26 Aug. and 24 Sept. The first seven were pre-seismic surveys intended to collect baseline data on the distribution and abundance of marine mammals in the project area. Surveys on 23 and 24 Sept. were flown to monitor the 120 dB zone prior to shallow hazard surveys on 25 Sept. Bowhead whales were sighted on eight aerial surveys and beluga whales on four aerial surveys. The estimated number of whales within the study area ranged from 0 to 649 for bowheads, and from 0 to 1198 for belugas. Bowhead and beluga whales were most abundant in early Sept. Moore et al. (1993b) also reported relatively high abundance of migrating bowhead whales in the central Beaufort Sea in early Sept., although similar sighting rates were reported for early Aug. Clarke et al. (1993) reported peaks in beluga whale sighting rates in the Beaufort Sea on 6 and 22 Sept.

Offshore distribution of bowhead and beluga whales may vary with ice cover. Treacy et al. (2006) reported that bowhead whales occur further offshore (primarily in slope waters) during years with heavy ice cover than during years with moderate and light ice cover. Whale distribution in 2006 would likely be considered similar to that of a moderate ice year (Treacy et al 2006). During the current surveys, most bowhead sightings were recorded in shelf waters although most of the survey area covered shelf waters < 100 m deep and did not extend far enough offshore to determine bowhead numbers in deeper slope waters. Moore (2000) reported that occurrence of bowheads in shelf waters in the Beaufort Sea was not unusual.

Moore (2000) reported that belugas in the Beaufort Sea selected deeper slope waters further offshore than bowheads. Most of the area covered in the current surveys was comprised of relatively shallow shelf habitats in waters < 100 m deep where most bowhead whales were sighted. However, a small portion in the northeast portion of the survey area was situated in slope waters > 100 m in depth where the greatest numbers of belugas and a few bowhead sightings were recorded (Figs. 8.3 and 8.4).

Based on the results of the aerial surveys and vessel-based observations, no whales were estimated to have been exposed to SPLs ≥180 dB (rms), and it is unlikely that any whales were exposed to SPLs ≥160 dB (rms). Vessel-based observers were not able to monitor the 120 dB (rms) zone. Based on the observation of one bowhead whale during the aerial surveys on 23 and 24 Sept., ~7 bowhead whales may have been exposed to SPLs ≥120 dB (rms). Most beluga whales were likely farther offshore than the extent of the 120 dB (rms) zone.

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9. MINERALS MANAGEMENT SERVICE AERIAL SURVEYS

Introduction

The Minerals Management Service (MMS) has funded a Beaufort Whale Aerial Survey Program (BWASP) in the Beaufort Sea during each year from 1979 to the present. The surveys were flown beginning in late Aug. or early Sept. and continued into mid-to late Oct. depending on the year. The results of past surveys are available in reports by MMS (Treacy 2000; Monnett and Treacy 2005). These surveys have provided long-term information on bowhead whale movement patterns during their migration through the Alaskan Beaufort Sea (Treacy et al. 2006) and are one of the longest continuous series of survey data available for any species in any region. Because these surveys cover a large geographic area, they do not provide detailed information on distribution and numbers of whales in specific geographic regions of the Alaskan Beaufort Sea, but they do provide information on movements and distribution over the entire Alaskan Beaufort Sea. The data presented here are interim data made available by Chuck Monnett of MMS in Anchorage for inclusion in this report.

Methods

Study Area

The MMS study area includes the Alaskan Beaufort Sea from the U.S. Canada border in the east to Point Barrow in the west, and from the coast to 72° N latitude.

Survey Procedures

The surveys were flown in a deHavilland Twin Otter at air speeds of 100–120 knots (185–220 km/h) and an altitude of 1500 ft (457 m) above sea level. The aircraft was equipped with a radar altimeter and a Global Positioning System (GPS). An onboard computer interfaced with the navigation system stored flight data (time and position) automatically for later analysis. Data reflecting marine mammal sightings, environmental conditions (e.g., weather, sea conditions, ice cover), and start and end points of transects and other survey segments, were entered manually into the computer. More details concerning the survey aircraft and other equipment used during MMS surveys are provided in the reports summarizing each year's data (Treacy 2000; Monnett and Treacy 2005).

Daily flight patterns were derived by dividing each MMS survey block into north–south strips 30 min of longitude wide or ~18.5 km or 10 n.mi. at this latitude. Start and end points were randomly selected for each survey. The selection of survey blocks to be flown on a given day was non-random and based on weather conditions where survey coverage had been obtained during recent days, etc.

Non-transect flight segments were identified as "Connect" and "Search" segments. Connect segments were the east–west (or similar) flights from the end of one transect to the start of another. Search segments were flights to or from the survey block where transects were flown, or non-random flights to find whales. Sightings during Connect and Search segments are plotted in figures within this chapter.

Results

Effort, Sightings and Distribution

The fall BWASP aerial surveys in 2006 provided good coverage of the bowhead migration in the first half of September and the first half of October, but poor coverage of the second halves of both months due to poor surveying weather. Table 9.1 shows the survey effort and numbers of bowhead whales sighted during transect surveys summarized by two-week period. The most effort, the largest numbers of sightings and the highest sighting rates were all obtained during the first survey period from 2-15 Sept. This coincided with the only extended period of good survey weather (clear days with low seas) during the fall of 2006.

Figures 9.1–9.4 show the transects surveyed and the distributions of bowhead sightings during each of the two-week survey periods. MMS suggested that the distribution of whale sightings changed significantly after a weather event on or around 8 Oct. Figure 9.5 shows the distribution of bowhead sightings throughout the entire MMS survey period from 2 Sept.–27 Oct. 2006 with different symbols for sightings that occurred before vs. after 8 Oct. Bowheads were scattered evenly throughout the area surveyed, except for a concentration of whales north of Point Barrow during the 2–15 Sept.. It appears that the majority of the migration was through waters 20–100 m deep, but some whales were sighted in both deeper and shallower waters. Sightings made during the first survey period (2–15 Sept.) appeared to be slightly farther offshore than during later periods.

Cow/Calf Sightings

Only four of 337 transect sightings of bowhead whales were of cow/calf pairs. The cow/calf sightings were distributed throughout the survey area, and all sightings were in water depths >~40 m.

TABLE 9.1. On transect effort and number of sightings and individuals for all bowhead whales and for cow/calf pairs during aerial surveys conducted in the Alaskan Beaufort Sea by MMS during fall 2007. Figures 9.1-9.4 include search and search connect sightings that are not included in this table.

		All Bowheads		Cow/calf		Sighting Rate
Period	Effort (km)	Sightings	Individuals	Sightings	Individuals	Indiv/km
2-15 Sept.	6659	65	251	1	3	0.038
16-29 Sept.	1581	5	10	0	0	0.006
30 Sept.-13 Oct.	3041	24	53	3	6	0.017
14-27 Oct.	873	5	23	0	0	0.026

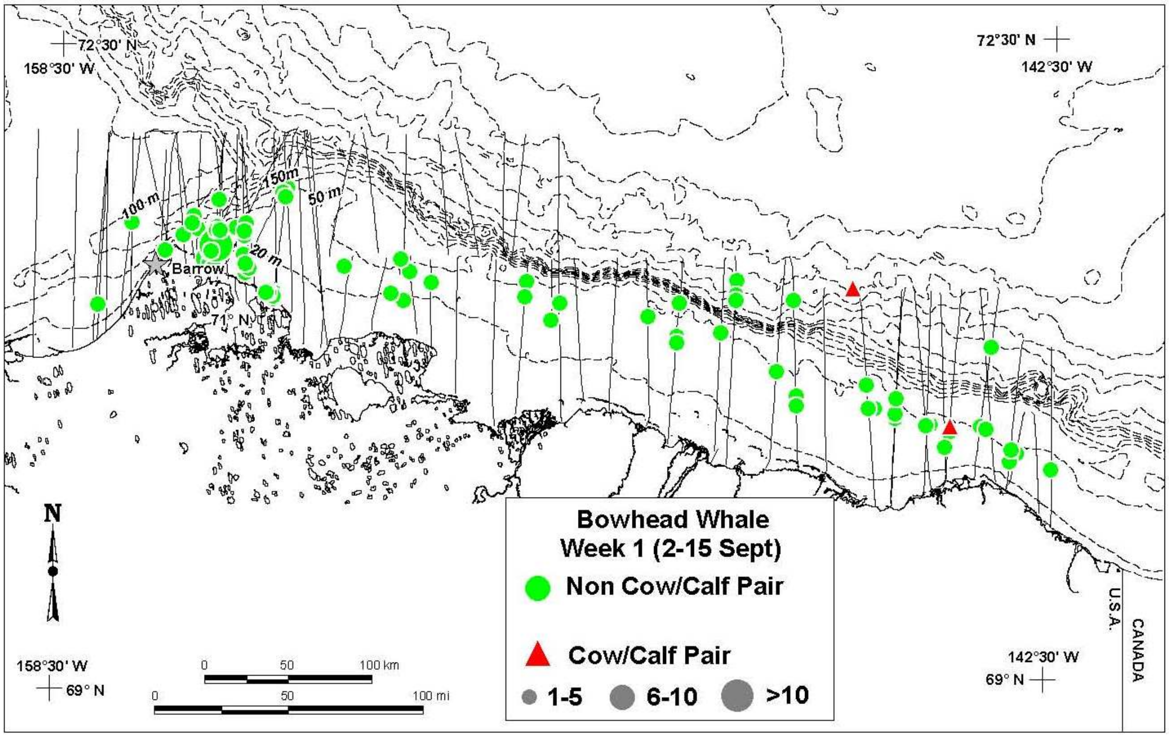

FIGURE 9.1. Transects surveyed and sightings of bowhead whales during aerial surveys conducted by MMS, 2–15 Sept. 2006.

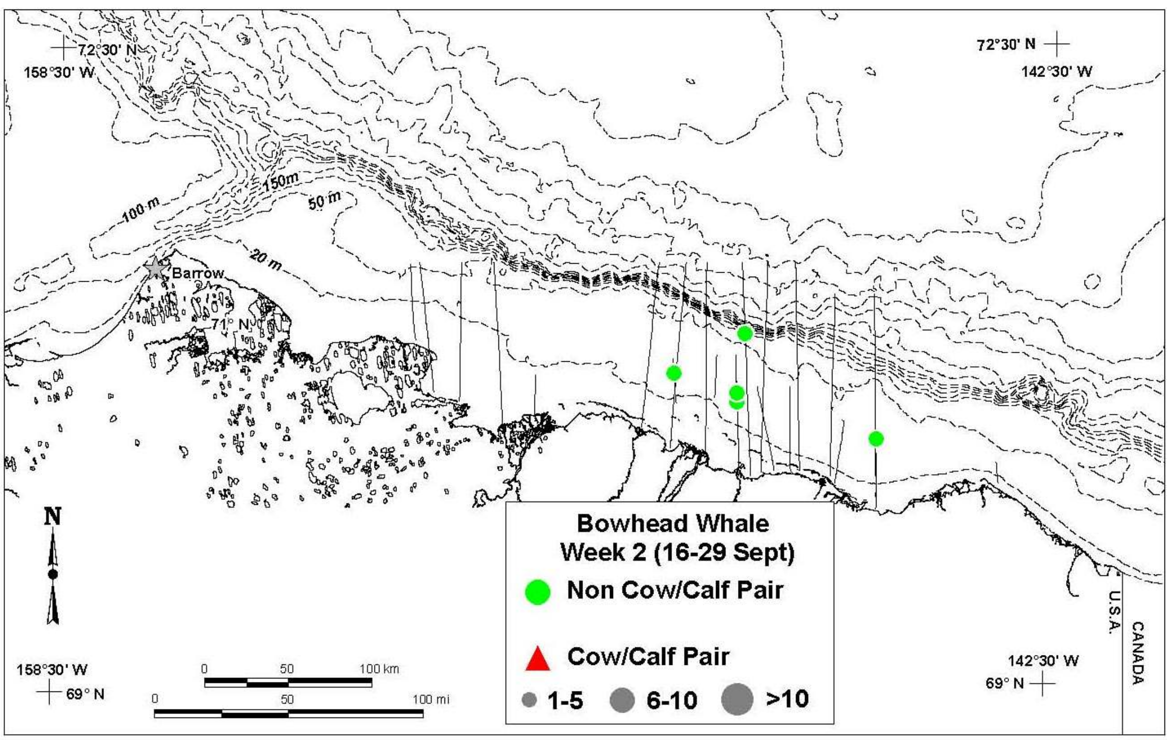

FIGURE 9.2. Transects surveyed and sightings of bowhead whales during aerial surveys conducted by MMS, 16–29 Sept. 2006.

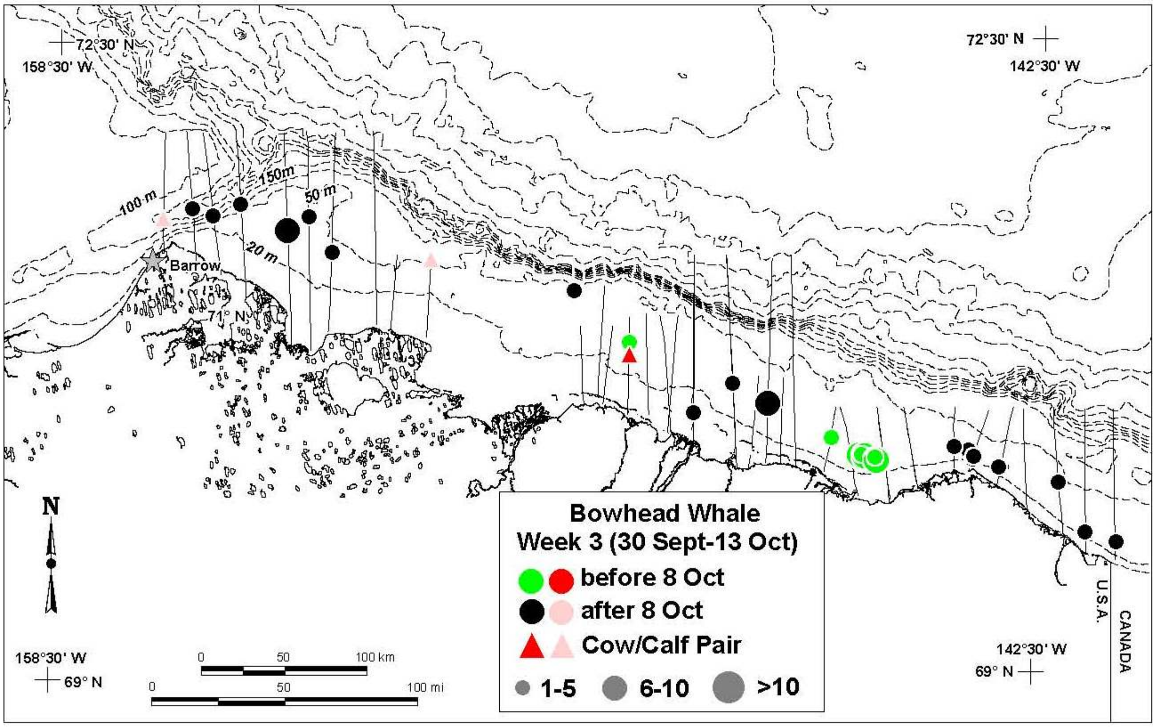

FIGURE 9.3. Transects surveyed and sightings of bowhead whales during aerial surveys conducted by MMS, 30 Sept–13 Oct. 2006. A major storm on 8 Oct. blew ice that was present before 8 Oct. out of the survey area.

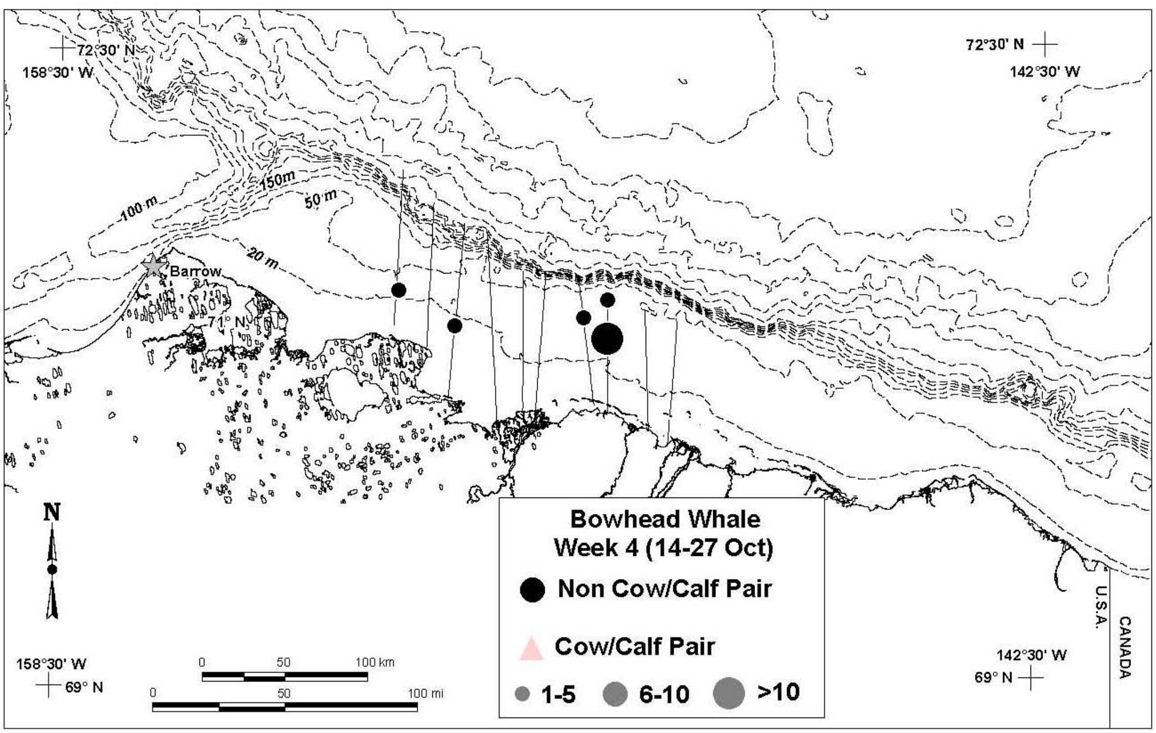

FIGURE 9.4. Transects surveyed and sightings of bowhead whales during aerial surveys conducted by MMS, 14–27 Oct. 2006.

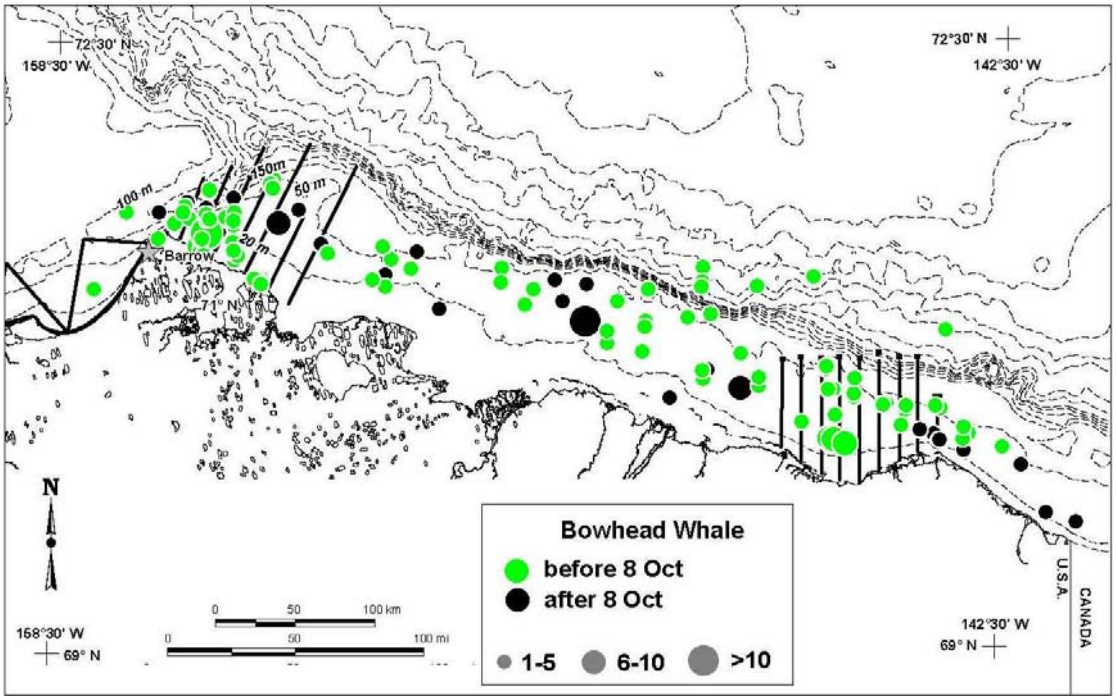

FIGURE 9.5. Combined sightings of bowhead whales during aerial surveys conducted by MMS for the entire survey period 2 Sept.–27 Oct. 2006. Transect lines from aerial surveys described in other chapters (see Chapters 5 and 8, and Appendix G). A significant weather event on and around 8 Oct. moved ice that was in the nearshore areas of much of the Beaufort Sea to other regions, potentially altering the distribution of bowhead whales.

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10. ACOUSTICS RESEARCH FOR STUDYING BOWHEAD MIGRATION, 2006[1]

Introduction

In recent years the potential for offshore oil and gas development in the Beaufort and Chukchi seas has raised concerns about the possible effects of offshore oil and gas development on marine mammals in general, and bowhead whales in particular. Bowhead whale, which is listed as endangered under the Endangered Species Act, is used as a subsistence resource by Native groups in coastal areas of the Beaufort and Chukchi seas. There has been concern that noise-producing activities associated with offshore oil and gas development may have the potential to deflect migrating bowhead whales further offshore, thus reducing their accessibility to Native hunters and requiring subsistence hunts to occur in more dangerous locations further offshore.

Recent studies have been conducted to determine underwater sound levels produced by industrial activities and the effects of industrial noise on migrating bowhead whales (e.g., Blackwell and Greene 2005, 2006; Greene et al. 2004). Acoustical studies have been conducted to determine the amount of deflection that may result along the southern edge of the bowhead migration corridor in response to oil production activities at Northstar Island located ~10 km (~5.2 n.mi) offshore of the Prudhoe Bay oil field. The approach to monitoring the bowhead migration has been to use special seafloor instruments to record the sounds of calling bowheads (Greene et al. 2004). The instruments, called "directional autonomous seafloor acoustic recorders" (DASARs) were configured in arrays of equilateral triangles comprising two overlapping hexagons north-northeast of Northstar Island. For every call, the received bearings were computed. With two bearings and the known spacing between the DASARs and the DASAR locations, the location of the calling whale could be triangulated and computed.

The two overlapping hexagons required ten instruments and were configured over a north-south extent of about 15 km (8 n.mi). If a nominal distance for "hearing" (receiving at a level above the ambient noise) is 10 km (5.4 n.mi), then whales calling from a north-south extent of 35 km (18.8 n.mi) should be received. The east-west extent of the DASAR array was about 12 km (6.5 n. mi), but because the migration direction is from east to west, whales would be detected when they approached within 20 km (10.8 n.mi) along their east-west traverse.

The current study was funded by SOI in support of potential future oil and gas exploration and development in offshore locations of the Beaufort Sea. The study was designed to investigate the possibility of using specially designed DASARs (called DASARbs) which were better configured to remain motionless on the seafloor, in combination with vertical arrays suspended in the water column to obtain better location data on migrating bowhead whales. By using array gain an eight-element vertical array could theoretically extend the detection range of a single station by a factor of 3 to 10, depending on what degree the ocean floor attenuates sound. Vertical arrays have been used to find distances to both submarines and whales by measuring how the received acoustic signal varies with depth. Specifically, the low-frequency sounds produced by a ship, submarine or a whale rarely travel directly to an acoustic receiver; instead, the sound reflects and refracts tens to hundreds of times from the ocean surface and bottom before reaching the receiver. As a consequence, a long-distance sound arriving at a particular

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sensor is composed of several propagation paths. Heuristically speaking, since each propagation path travels a different total distance, the effective travel speed of the sound along each path, or “group velocity,” varies. As a sound travels over great distances (more than 10 km), signals traveling along these propagation paths can separate in time, generating several distinct “images” of the sound in a spectrogram. If the group velocities of these “multipaths” can be estimated from knowledge of the water depth, ocean sound speed profile, and bottom composition, then the range to the source can be estimated. If a vertical array can be used to determine distance to a calling whale in combination with a bearing to the whale as determined by a DASARb, locations to calling bowhead whales may be calculated with data from only one DASARb, thus reducing the number of DASARbs required to determine whale locations and increasing the range at which whale locations can be determined.

Another purpose of the study was to determine the feasibility of using a machine-aided whale call detection system to increase efficiency during analyses of DASAR recordings of bowhead whale calls. In the past analysts have looked at spectrograms of every recorded minute, searching for visual clues of whale calls. When seen, the operator would mark the frequency-time space and listen to the sound, confirming that it was from a bowhead call. Although all the DASAR spectrograms for a single minute were displayed together, the analyst had to be vigilant and check for calls. Progress was slow when there were up to 10 calls in a single minute, and analysis became tedious when looking at periods without calls for as long as 20 hours, one minute at a time.

Objectives

There were three objectives of the acoustics research study:

- Develop a new model of the DASAR, which we called the DASARb, that would use readily-available directional sensors and be configured better for remaining motionless on the bottom during periods of high currents.
- Investigate the use of a vertical line array that would provide distance information to acoustic sources. Then, distance and bearing to a calling whale could be provided by a single DASAR for bearing and a vertical array for distance at any location of interest. The primary goal of the vertical array portion of this effort was to determine whether multipath modeling could be applied to bowhead whales in the Arctic environment to detect the animals out to distances of several kilometers. This portion of the effort was the responsibility of the Scripps Institution of Oceanography (SIO) in San Diego, CA.
- Develop machine-aided whale call detection to alleviate the labor-intensive analysis of all the recorded data to manually detect whale calls on each DASAR, determine the bearings, and finally the locations. It was not an objective to automate the detection process, but to present detection data to an analyst for times when a call was suspected, then have the analyst confirm or reject the detection. This development effort was also the responsibility of SIO.

Methodology

The technical approach and methods followed to achieve the three objectives are described in this section.

DASARb Development and Evaluation

The key requirements for the new DASAR design were for a low profile to resist motion in water currents and a new directional sensor. The original DASAR housing was 14 in high and 12 in in diameter, with the sensor suspended elastically about 8 in above. A latex “sock” stretched over an external frame protected the sensor from motion in any current. The housing was secured to a round, weighted frame 30 in in diameter with a triangular frame supporting the pressure housing. In the new design, the housing was 9 in high and 18 in in diameter with the sensor suspended elastically about 5 in above. The housing was secured to a weighted square frame 30 in on a side. The in-air weight was 115 lb and the in-water weight was 40 lb.

The concept for the new sensor was to use three-axis geophone elements for the directional sensors and a flexural pressure transducer for the omni-directional sensor (necessary to resolve the directional ambiguities from the geophone response patterns). Using a geophone element with a 28-Hz resonant frequency, critical damping, and spurious frequency response behavior at frequencies >500 Hz resulted in a frequency response essentially flat from about 20 Hz to 500 Hz, the range within which most bowhead calls occur. The vector sensor so constructed is ideally suited for this application where low-power consumption is imperative.

DASARs (old and new) are designed to be installed on the bottom with no surface expression, important to avoid entanglement with ice floes. A small Danforth anchor and chain were attached to a 100-m “tag line” of ground rope that was stretched out during deployment and attached to a corner of the frame. By noting the GPS coordinates of the Danforth anchor and the DASAR, it was straightforward to retrieve everything by using grapnel anchors and chain dragged over the center of the tag line. With an average of 11 DASARs deployed every year 2000-2004 and seven during the two years 2005-2006 (almost 80 units) in BP’s Northstar project, every unit has been retrieved. (Water depths range from 20 to 25 m, but similar retrievals have been effective in water 50 m deep.)

Figure 10.1 illustrates the DASARb assembly configuration. Figure 10.2 is a top-view photograph of a DASARb on the deck of *M.V. Henry Cristoffersen* after retrieval. One of the grapnel anchors with chain is in the picture. Figure 10.3 is the calibrated pattern of the two directional sensors in the new DASARb.

Vertical Array Development and Evaluation

As part of the Shell Investigatory Program (SIP), the Scripps Institution of Oceanography (SIO) arranged for the construction of two passive acoustic vertical arrays to be deployed concurrently with Greeneridge Science’s DASARb directional passive acoustic recorders. One vertical array (the "standard array") consisted of a pagisol-filled tube with eight hydrophones and two inclinometers spanning an 26 m (85 ft) aperture. The standard array was built under subcontract by Sonatech Inc., Santa Barbara, CA. (See Fig. 10.4). There was insufficient time for an original array design, so a design previously built by Sonatech was used. A second array (the “modular array”) consisted of five autonomous recorders that each recorded a single hydrophone signal. This modular array permitted the recorders to be deployed in an adjustable aperture and thus was deployable in water arbitrarily deep. The floatation used for both arrays consisted of six spherical 14 in diameter floats in a string-of-pearls arrangement that provided a cumulative buoyancy of 240 lbs. The array modules were built by SIO.

The standard array was suspended in the water using a combination of anchors and subsurface floatation (Fig. 10.5). A cumulative weight of 600 lb of anchor chain links was used as a clump weight to hold the assembly in position, although field experience eventually indicated that a 300 pound anchor could be used, along with less surface floatation. An additional Danforth anchor with 91 m (300 ft) of tagline was also attached to provide additional resistance to currents and to provide a recovery option in case of the failure of the acoustic release. A U-shaped link was welded onto the anchor to permit a 1.8-m (6-ft) sacrificial wire rope to connect to a CART acoustic release, which could support a static load of 1650 lb and a release load of 1100 lb. This 1.8-m (6-ft) spacing between the release and anchor was

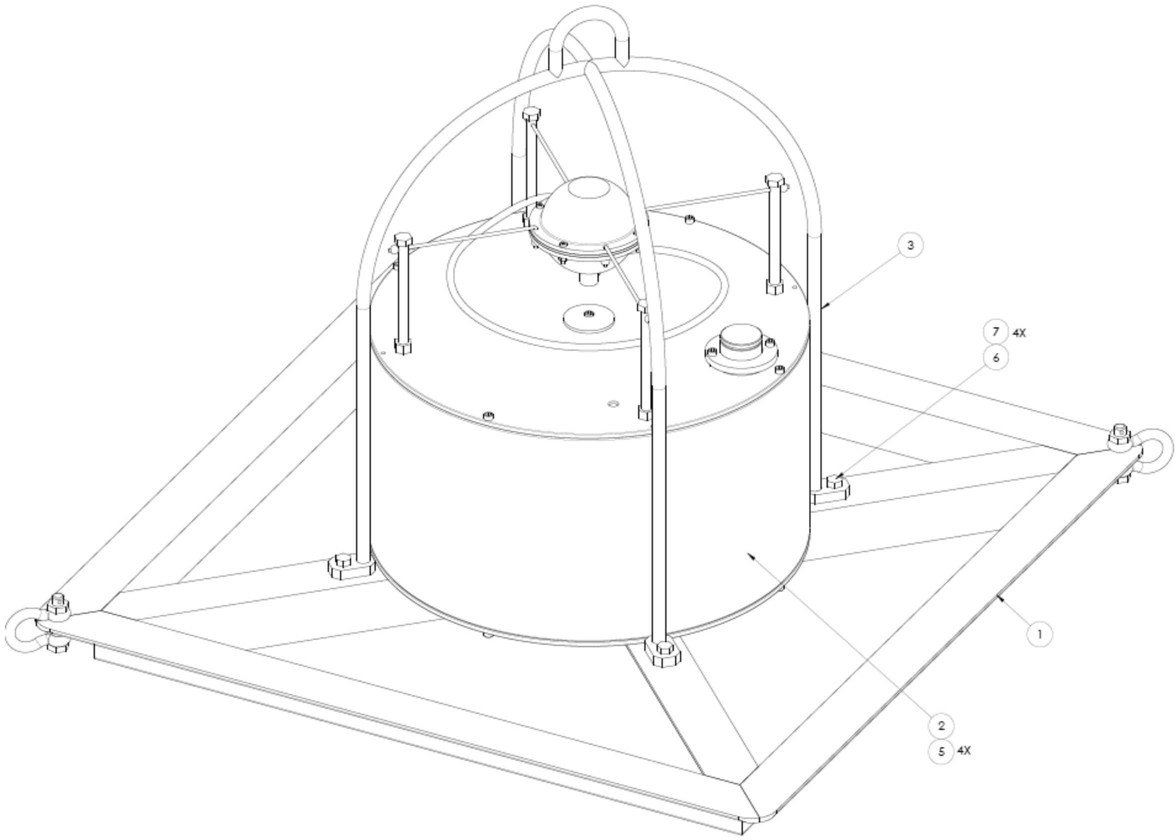

FIGURE 10.1. The assembly drawing for the DASARb. The small loop at the top is for the lowering line. The sensor is directly beneath the small loop and over the housing. The loop coming from the back-left of the sensor and disappearing beyond the sensor on the housing top is the tube with the electrical signal wires. The sensor is attached by four elastic strings to four vertical posts. The "knob" drawn on the right side of the housing holds the transponder transducer. A shackle on the left or right side of the frame is for attaching the tag line.

required in case a controlled deployment of the anchor to the ocean bottom became impractical, and the anchor would have to "free-fall" to the ocean floor. In these circumstances the 1.8-m (6-ft) spacing would have acted as a buffer to keep the cage from slamming into the ocean floor. The top of the release was attached to a swivel that in turn was attached to a 1.4-m (4.5-ft) tall cage that houses a pressure case with electronics and two sea-batteries. Four plastic floats made the entire cage assembly positively buoyant. Thus when the acoustic release was activated, the entire array would float to the surface. The 26-m (85-ft) standard array from Figure 10.4 is attached at its bottom via a shackle to the top of the cage, and at its top via a shackle to a 1.5 in rope that is knotted through six Trawlworks 714 floats (14 in dia, 39 lb buoyancy), thus spanning another 10 ft. The water depth required by such an array is 36.5-38 m (120-125 ft) if a minimum of 5.5 m (18 ft) clearance between the top float and the surface is required to avoid ice keels. This depth requirement was a consequence of the need to use a pre-existing array design of 26 m (85 ft) aperture, and also from a desire to maximize the amount of acoustic multipath that could be detected at frequencies below 200 Hz. Theoretical calculations suggested that a 150 Hz signal in 40 m (131 ft) deep water would produce 3 propagating modes, or multipaths, the minimum needed for a non-ambiguous range estimate.

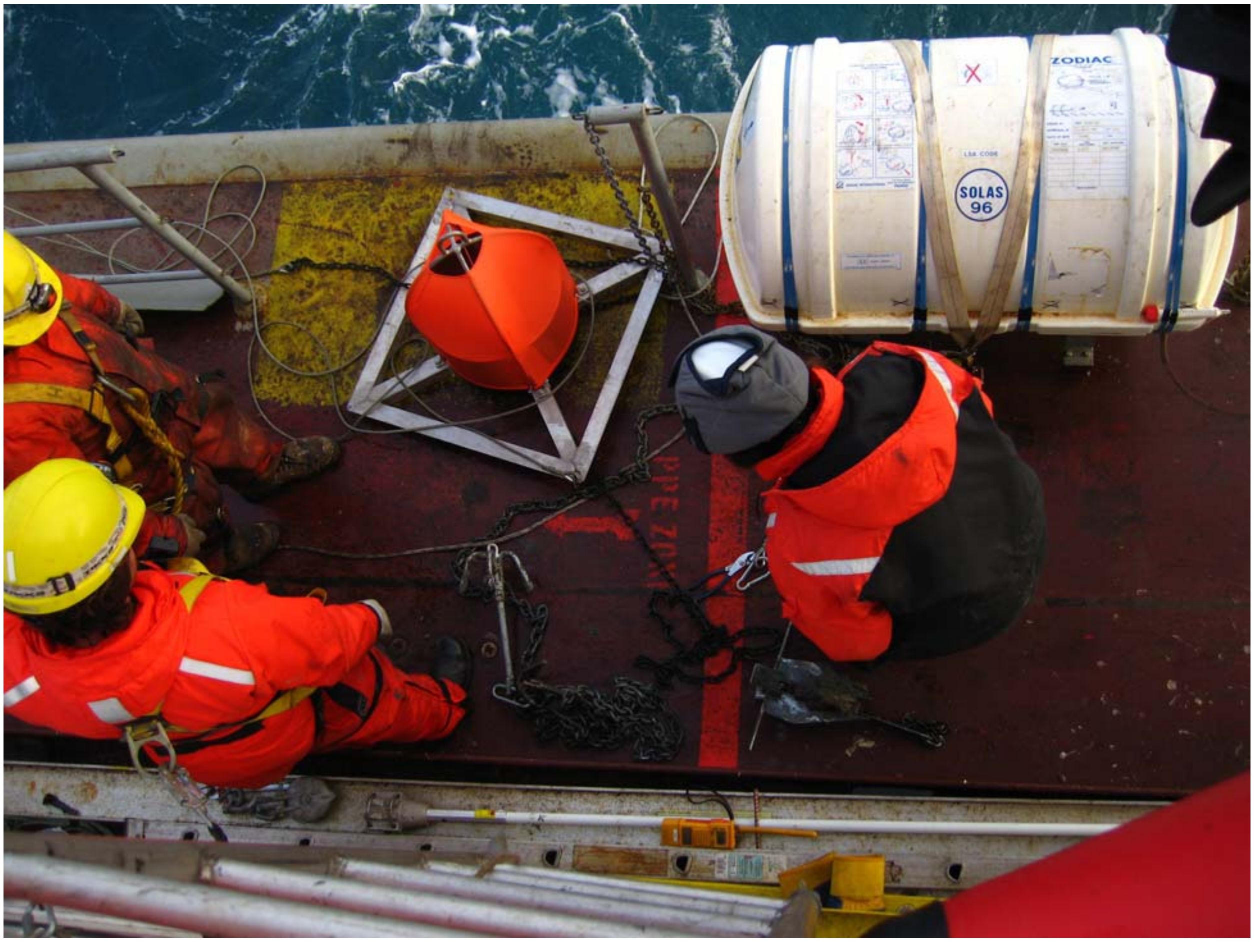

FIGURE 10.2. Photograph of a DASARb on deck after retrieval. Note the latex sock over the frame and a grapnel anchor and chain on the deck.

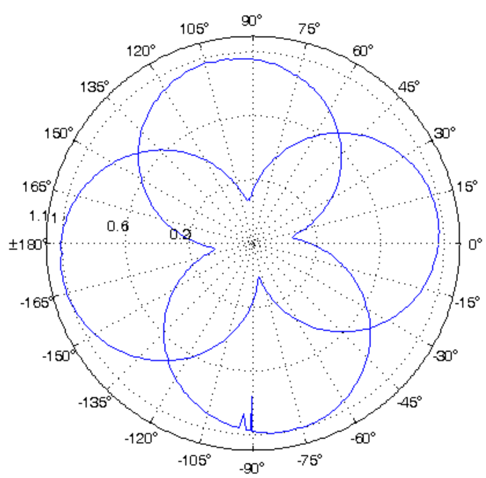

FIGURE 10.3. Azimuthal calibration responses of the two horizontal directional sensors. Note that the calibration setup was not aligned with the sensors' main response axes and that averaging filled in the response nulls. The "glitch" near -90° is from the calibration facility instrumentation.

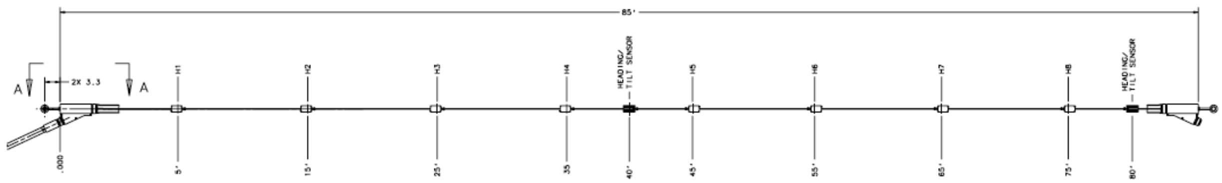

FIGURE 10.4. Detailed view of eight-element vertical array components and spacing (shown horizontally).

The modular array's deployment geometry was similar to that of the standard array except that a 500 lb. anchor was used, no cage assembly was needed, the array aperture was adjusted to 7.6 m (25 ft) instead of 26 m (85 ft), and four subsurface floats were used instead of six. The array aperture consisted of five pressure cases with recording electronics attached to a Vectran rope. The total vertical distance of the deployed modular array was 13.7 m (45 ft) from buoy tip to anchor bottom. When an extra 5.5 m (18 ft) is added to provide clearance between the subsurface floatation and ice keels, the minimum water depth required for a safe deployment becomes 19.2 m (63 ft). As events turned out, the modular array was deployed in water shallower than this, in circumstances where nearby ice floes had keels at least 6 m (20 ft) deep, with unfortunate results.

Machine-Aided Call Detection Development and Evaluation

Simple machine-aided detection algorithms in the past have used techniques like spectrogram correlation (Gillespie 2004) and matched-filtering (Urazghildiiev and Clark 2006) to flag calls in large acoustic data sets. However, these techniques were designed to detect particular "stereotyped," or non-varying, types of baleen whale calls and thus would miss a significant number of bowhead whale sounds in a dataset.

One component of this investigatory program seeks to develop a contour detection and tracing algorithm to trace frequency contours of arbitrary shape and duration, with an emphasis on flagging all possible calls, which implies accepting many false detections. In operation, all the data from all the DASARbs in a group would be processed automatically by computer to develop a log of call detection times. Then, with an analyst present, the actual data for a suspected call time would be displayed in spectrogram format for the analyst to confirm or reject. If confirmed, the analyst would assign a call type and the program would compute and store the call bearing. If detected on multiple DASARbs, a location would be computed and stored and the program would cycle on to the next detection time logged by the computer. False calls would be rejected swiftly and periods without calls would never be presented to the analysts. Some calls would inevitably be missed, but that happens with manual processing as well. If 80% of the actual calls present could be detected by computer for analysis, the process will still result in tens of thousands of call locations.

Bioacoustic software ***Ishmael*** (http://cetus.pmel.noaa.gov/cgi-bin/getinfo.pl?dirname=ishmael) provides a first pass of the acoustic data that serves as a basis for additional downstream processing. ***Ishmael*** provides three 'automated detection' routines for scanning raw acoustic data: spectrogram correlation, matched-filtering, and 'energy detection', or the summation of an equalized spectrogram over a prescribed frequency band. While spectrogram correlation has been used on a specific type of bowhead call (Mellinger and Clark 2000) neither the matched-filter nor spectrogram correlation is designed to detect arbitrary signals. Thus only the general 'energy detection' feature is used as the first stage of this more sophisticated analysis.

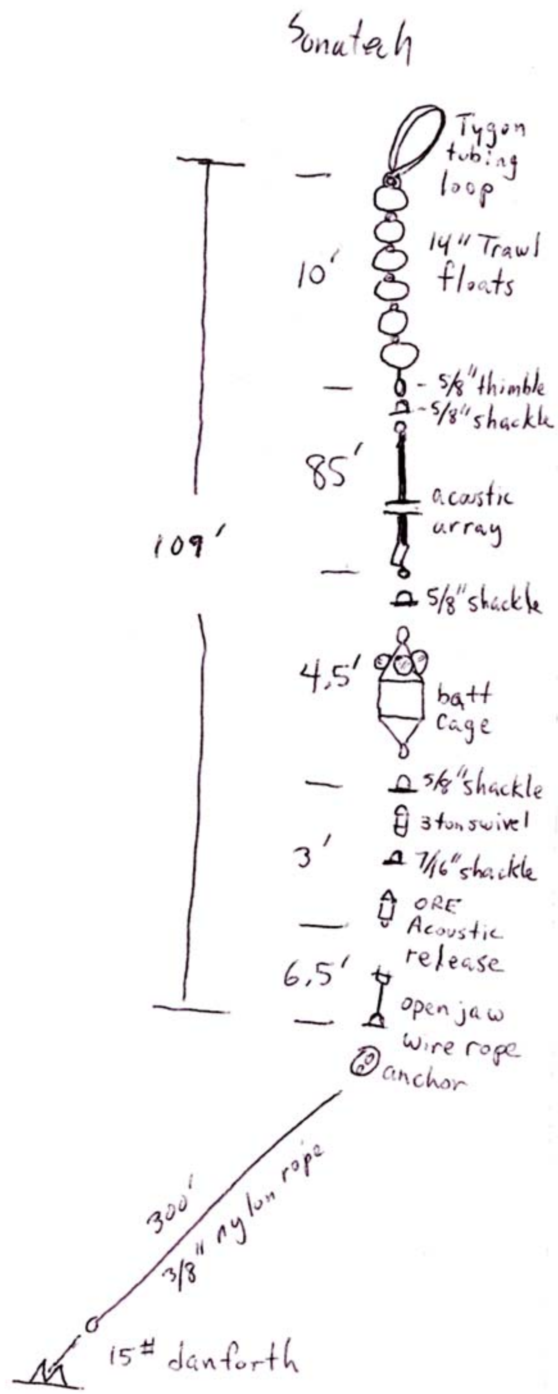

FIGURE 10.5. Exploded view of vertical array deployment geometry.

Ishmael has been configured to run the "energy detection" detector in batch mode, writing all detections to a MATLAB file for later analysis. Originally Ishmael was run only once, with the energy detection feature set to sum between 50 and 450 Hz. However, it was found that the program would miss narrowband calls at these settings, as the power over the bandwidth of a slightly-modulated FM sweep would be tiny compared to the noise contributions over the entire bandwidth. Thus ***Ishmael*** is run four times through each data set, each run focusing on the more limited frequency bands 50-150 Hz, 150-250Hz, 250-350Hz, and 350-450 Hz. These first-pass detections are then run through a second round of evaluation using a set of custom MATLAB scripts that will be described fully in a later section.

Field Operations

Ice conditions were particularly severe during summer 2006 near the coast off Prudhoe Bay. Beginning effort for installation on 5 September, it was not until 10 September that the first two DASARbs (B2 and B3) and the modular vertical array could be installed. This first installation was just northeast of West Dock (Fig. 10.6) in water 18 m (60 ft) deep. The modular vertical array was installed between B2 and B3, but it was caught by ice and carried away within two days. Ice prevented a complete calibration transmission sequence around the units. Units B1 and B4 were installed on 12 September at a site 20 km (10.8 n.mi) north-northeast of Cross Island in water 37 m (122 ft) deep. The standard vertical array was installed between the DASARbs with its subsurface float 6 m (20 ft) below the water surface. During the initial deployments a 600 pound anchor was used for the standard array, and a 500 pound anchor was used for the modular array.

Deployment of the Vertical Arrays

Alaska Clean Seas provided a 13 m (42 ft) “Bay Boat” to support the ocean deployments. A vertical array had never been deployed by the Alaskan Clean Seas Bay Boat before, so a great deal of discussion and safety review took place before attempting the deployment. Indeed, this may have been the first deployment of a vertical array in this region in over 20 years. The final procedure was as follows:

1. The anchor and cage assemblies were fastened to the port size of a Bay boat. The cage assembly consisted of cage, batteries, swivel, and acoustic release, while the anchor assembly consisted of anchor chain links, a welded-on U-link, 1.8 m (6 ft) wire rope attached through the U-link, and acoustic release drop link attached to other eye of wire-rope. The array and subsurface floatation were then laid out over the rest of the stern deck. A rope was run through the U-link as well, with the ends cleated to a sturdy point on a rail cleat.
2. The subsurface floats and 26 m (85 ft) array were fed out through the stern of the vessel, and then the cage assembly was lifted by the crane over the port gunwale and lowered into the water. The crane hook was attached to the cage by a sacrificial rope loop that was cut to release the cage, which floated on the surface, while the wire rope snaked back over the railing to the anchor assembly on deck.
3. Under full extension the on-board crane had 900 lbs of lifting capacity, so the 600 load anchor assembly could be safely lifted over the side using the 91 m (300 ft) tagline to control the swing of the assembly. As the anchor assembly was lowered into the water, the tagline was wrapped around a large post in the center of the deck, and the load was transferred to this line before the crane was released. With a little way on the vessel, the tagline was then used to lower the anchor and the array assembly to the bottom.
4. The rest of the tag line was paid out and the Danforth anchor lowered overboard.

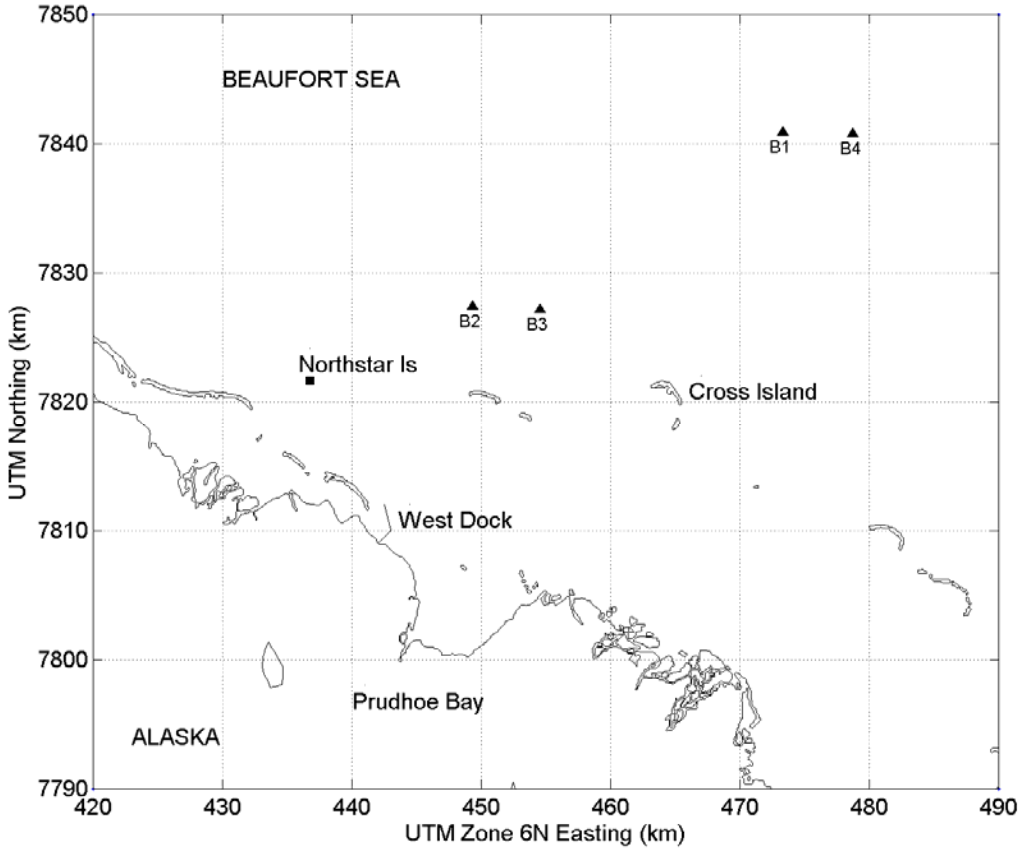

Figure 10.6. Map of DASARb installations off Prudhoe Bay. The water depth at B2 and B3 was 18 m (59 ft) and 37 m (121 ft) at B1 and B4. The modular vertical array was located between B2 and B3 and the standard vertical array was located between B1 and B4.

Retrieval of the Vertical Arrays

To retrieve the array the acoustic release was activated and the positively buoyant cage assembly floated to the surface, where it was grappled and lifted by the crane to the deck using various taglines. Once the cage was secured, the array and subsurface floatation were hauled on board and secured. The tagline and anchor were left on the ocean floor.

Deployment History of the Vertical Arrays

On 17:40 Sept. 12 the modular array was determined to have moved from its initial position. By using an acoustic transponder on the base of the array, the equipment was located stuck underneath a large ice flow 3 miles to the NW a couple of hours later. The equipment was located twice more on Sept. 13 and Sept. 16, moving on average one nautical mile a day NW. Attempts to relocate the array in early October by Greeneridge personnel were unsuccessful.

The standard array was recovered on September 16 when the field party realized that a combination of ice conditions, weather, and access issues would prevent another attempt at recovery before October and that the 5.5 m (18 ft) clearance between the subsurface floatation and ocean surface was likely to be insufficient to prevent ice floe capture.

Results

Results for the three objectives are described separately in this section.

DASARbs

The DASARb data were analyzed beginning on 12 September until retrieval began on 1 October. Analysis was done manually by the same method used since 2001 for the BP Northstar DASARs. The analysts viewed one-minute spectrograms for all four DASARs at a time analyzing calls detected visually and confirmed by the sound of the call, and located when detected at two or more DASARs unless the bearings did not intersect. Figure 10.7 presents the calls per hour vs time for the time span of the data. The figure illustrates how the call detection rate varies from day to day and within the days.

The locations are presented in the map of Figure 10.8. Remember that calls from near the baseline (almost on the east-west directions) cannot be located because the bearings are so close to one another that their intersection is indefinite. (This problem would be resolved by a third DASAR in a triangular array.) The dashed lines denote locations within ±15° of the baseline. Note that 16,442 calls were detected altogether, of which 13,428 were located. (Those located calls were detected on two or more DASARs.)

The two DASARs in shallower water (B2 and B3) detected 295 calls, of which 57 were detected by both units. These units were well to the south of the main migration corridor in 2006.

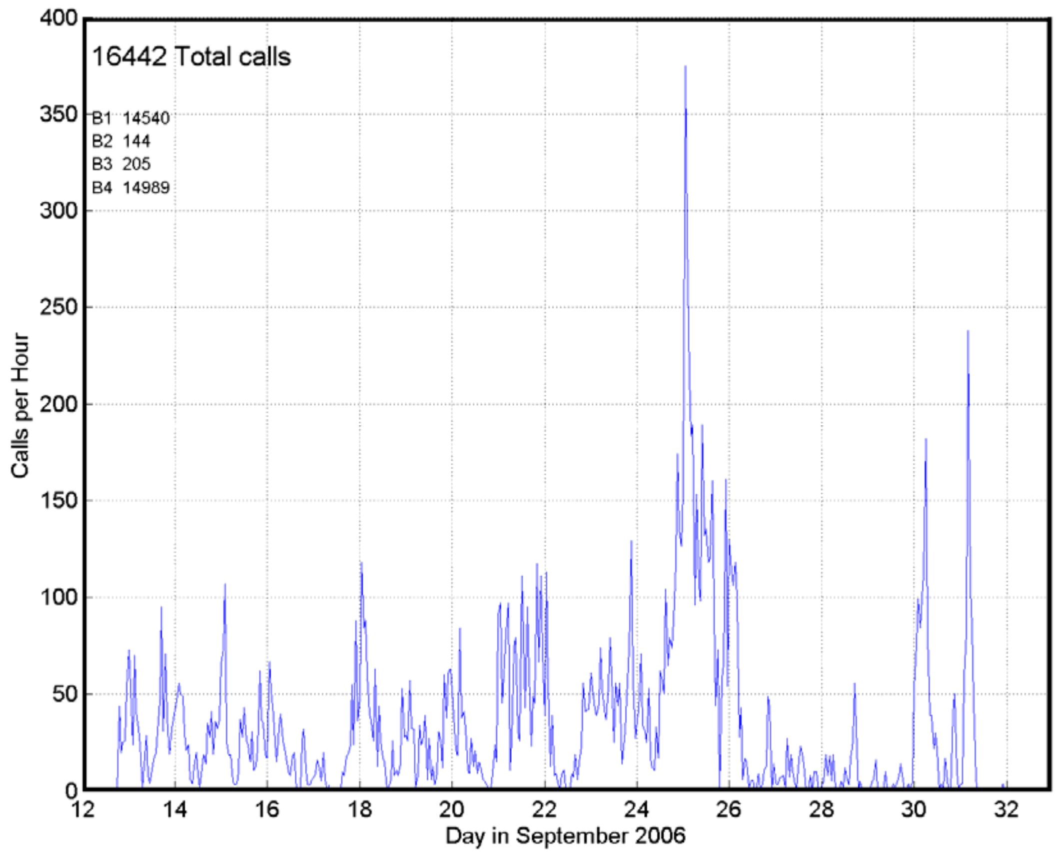

FIGURE 10.7. Calls per hour detected on all the DASARbs during the 20-day operating period.

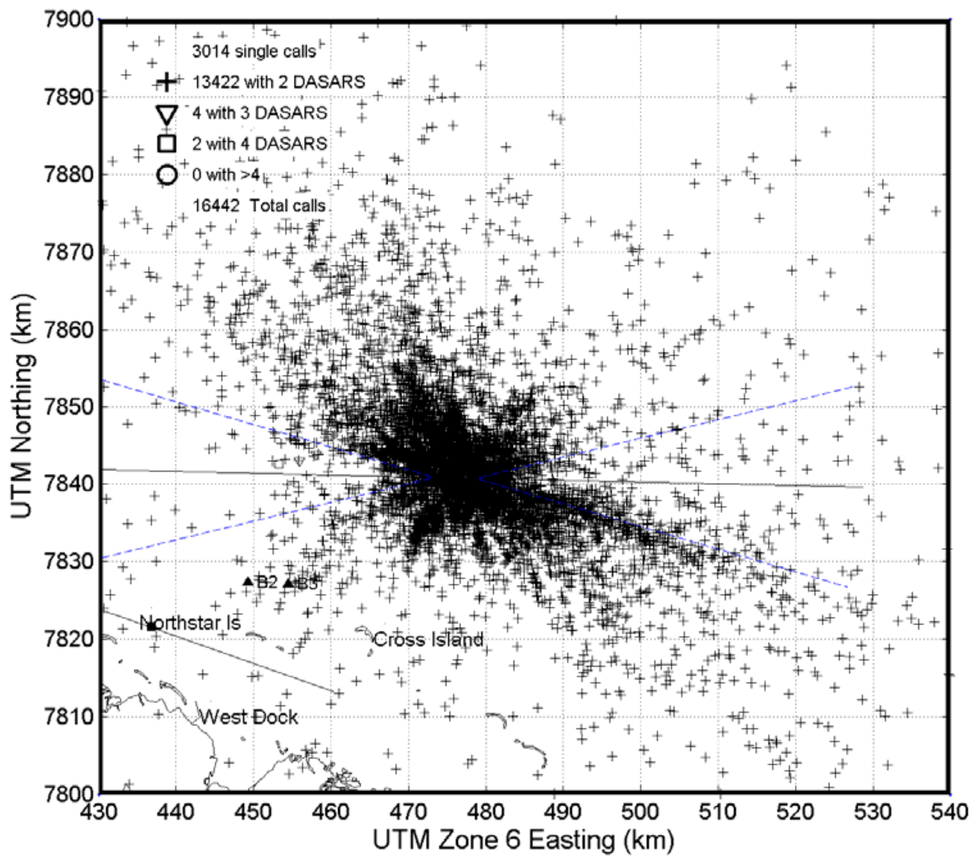

FIGURE 10.8. Map of call locations determined by triangulation from calls received by at least two DASARbs.

Vertical Arrays

The quality of the recordings from the vertical arrays was found to be contaminated by large amounts of electrical noise. After describing the nature of this contamination, this section will describe attempts to reduce this contamination, how calibration signals, airgun signals, and a whale call were detected in the data, and attempts to see if enough multipath information could be extracted from the noise to provide a ranging estimate.

Nature of Noise Contamination and Mitigation Efforts—The background noise of the electronics on the recording module by itself was determined to be about 2 mV rms, which roughly translates into an equivalent rms acoustic level of 128 dB re 1 µPa. Furthermore, when attached to the vertical array for an on-shore test the electronic noise increased to 3 mV rms and electrical spikes of 20 mV would occur every 20 msec or so. Assuming a white noise electrical background, a 3 mV rms electrical level would correspond to an acoustic pressure spectral density of 105 dB re 1 $\mu Pa^2/Hz$.

This electrical noise, particularly the electrical spikes, masked most acoustic signals recorded by the system. An initial review of the data could find no signs of calibration signals nor whale calls-only faint traces of airgun signatures.

Upon further investigation it was found that 90% of the non-acoustic 20 mV "spikes" typically lasted for only one sample (when sampled at 1 kHz), and had amplitudes that were far beyond any physical acoustic pressures. Thus a computer program was written to automatically replace data samples that were "spiking" with samples from a white noise distribution, improving the spectrogram quality considerably. Unfortunately this method of spike removal impacts the phase and spatial coherence of the data, which needed to be precise to permit accurate range estimates to be obtained. To improve the detection range of the array the data were also beamformed by summing all eight time series together. The combined actions of spike removal and beamformed has made it possible to detect a small number of signals, including whale calls.

Evidence of multipath effects in vertical structure of the signal—In this section three signals from the vertical array are discussed: a calibration signal from a J-9 transducer, an airgun signal, and a whale call. The key point of this section is that the signals display characteristic signs of multipath effects, indicating that with better quality data range and depth estimation of the signals could be achieved.

Soon after the vertical array was deployed on September 12, Greeneridge generated a calibration signal at 400 m (1312 ft) range from the array. Given an estimated rms source level of 150 dB re 1 µPa @ 1m and a water depth of 37 m (122 ft), one would expect a received sound level of (150-20*log10(37 m)-10*log10(400 m))=93 dB re 1 µPa. Figure 10.9 below shows the received calibration signal spectrum when the elements of the vertical array are beamformed, where the levels can be seen to lie between 85 and 95 dB re 1 µPa. Furthermore the spectrum level of the background electrical noise in this figure, about 85-88 dB re 1 µPa, lies around the same levels, consistent with a white electrical noise contamination rms amplitude of 2 mV over a 500 Hz bandwidth. In other words, the calibration signal is just barely discernable above the electrical contamination noise levels at 400 m (1312 ft) range.

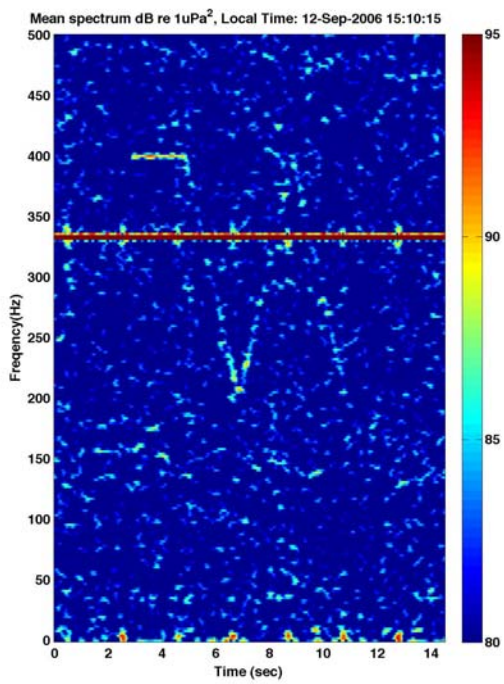

FIGURE 10.9. Spectrum of the calibration transmission sound obtained through beamformed vertical array data at distance 400 m (1312 ft).

Figure 10.10 shows the calibration transmission sound spectrum received by three individual hydrophones in the standard vertical array, as opposed to the beamformed result in Figure 10.9. Note that the power of the received signal seems to change with the receiver depth in the water, being weaker at shallow depths. This feature is characteristic of low-frequency acoustic multipath propagation in shallow water.

A more detailed way of viewing the structure of the signal with depth in shown in Figure 10.11. The left column describes the sound structure when the signal is present, and the right column describes the sound structure when the signal is absent. The top row shows the magnitude of the received signal as a function of frequency and hydrophone depth, and the bottom row shows the signal-to-noise ratio of the received sound field vs. frequency. One sees that the FM-modulated calibration signal has significant energy at the inflection points of 400 Hz and 200 Hz, and that the received levels vary with depth across the array, characteristic of multipath propagation. The 400 Hz signal in particular shows that the signal intensity is greatest at points 1/3 and 2/3 the depth of the water column, but much weaker at the surface, bottom, and mid-depth, a well-known characteristic of two-mode propagation in a waveguide.

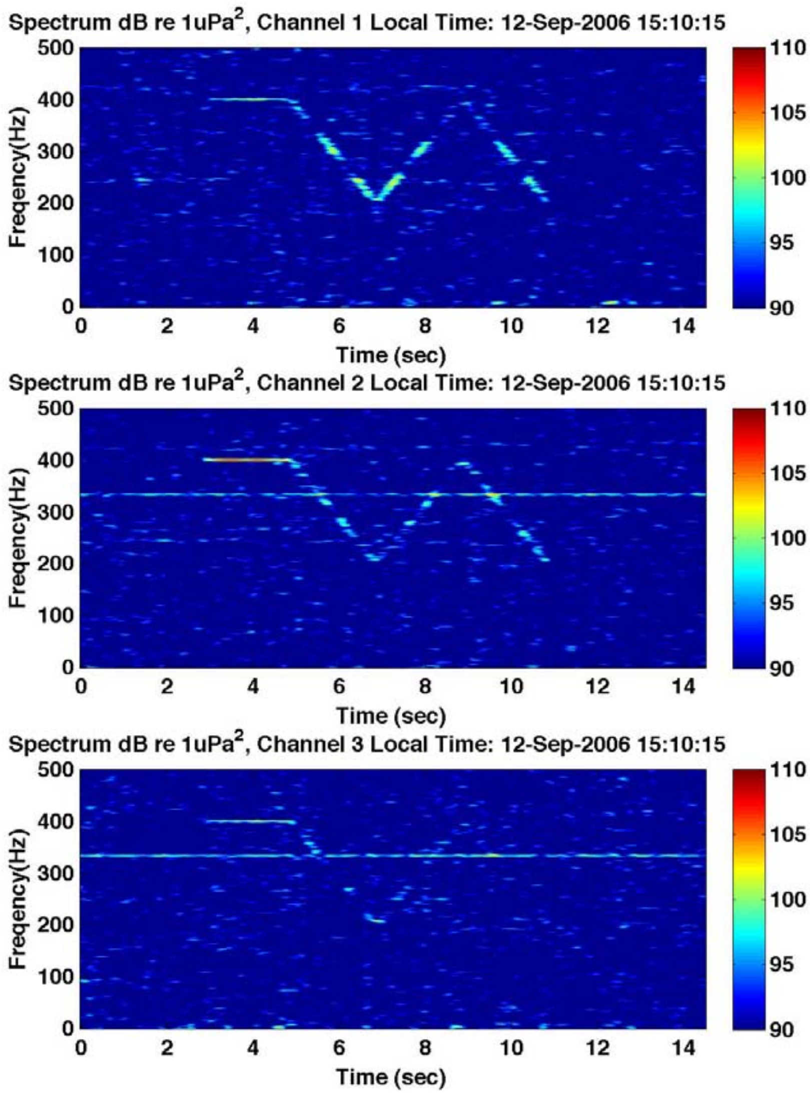

FIGURE 10.10. Spectrograms of the calibration sound from 400 m (1312 ft) for three of the individual hydrophone signals in the standard vertical array. The top subplot is from the deepest hydrophone, and the bottom subplot is from the shallowest.

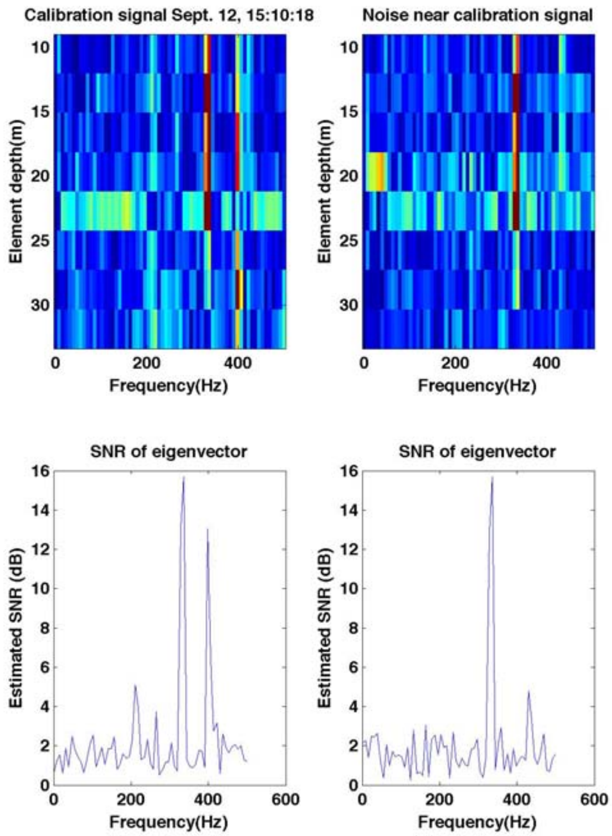

FIGURE 10.11: Vertical structure of the acoustic field in the presence and absence of the calibration signal. See text for explanation.

The next example shows a signal received from an airgun, believed to be recorded from a seismic vessel over 400 km (217 n.mi) away. Figure 10.12 displays a beamformed spectrogram of the signal, where it can be seen that the signal has significant energy between 75 and 300 Hz.

The vertical structure of this signal can be seen in Figure 10.13. Once again data with the airgun signal is shown in the left column, and data without the signal in the right. A 330 Hz electrical noise tone is visible on both plots. It's variation with depth is due to the fact that the gains of each channel are slightly different. The airgun vertical structure is quite visible below 200 Hz. Note that unlike the calibration signal, the airgun signal is most intense near the ocean floor. Also note that the vertical pattern is different than the electrical noise, indicating that gain alone cannot explain the discrepancy.

Finally, Figure 10.14 shows a whale call that was detected using data from the B1 DASARb as a reference, and Figure 10.15 shows the vertical structure of this call. Due to the narrowband nature and short duration of the call the vertical structure is more difficult to discern, but still seems to be present. Note that the signal-to-noise ratio of the processed data is quite good. Attempts to localize this call and the calibration signal will continue through March.

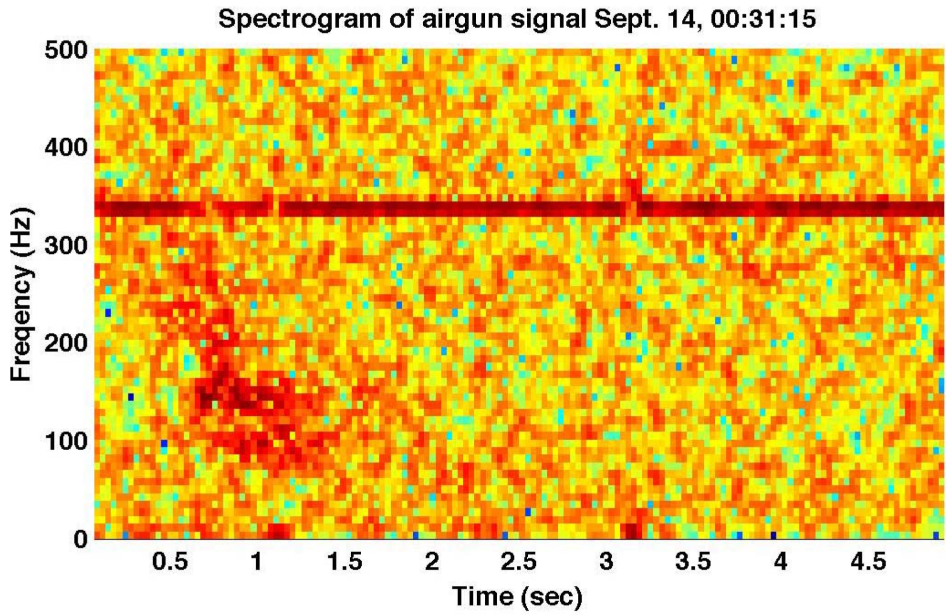

FIGURE 10.12: Spectrogram of beamformed airgun signal from standard vertical array. It is believed that this signal has propagated approximately 400 km (217 n.mi) to the DASAR.

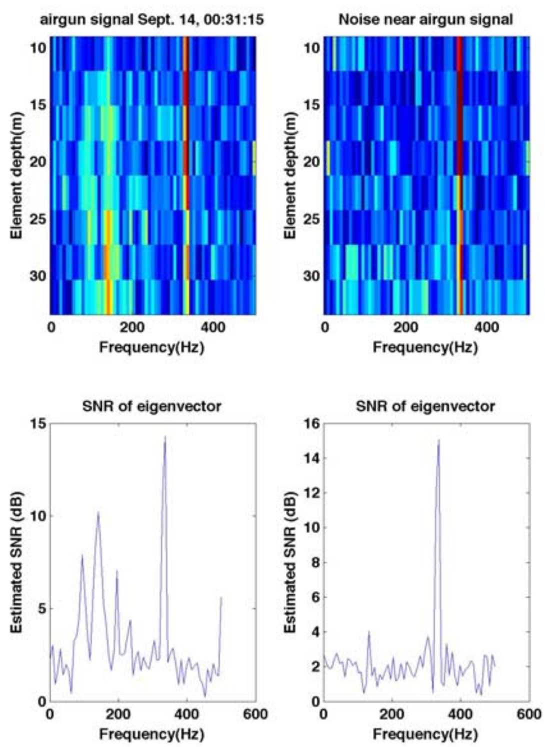

FIGURE 10.13: Vertical structure of acoustic field in the presence and absence of an airgun signal. See text for details.

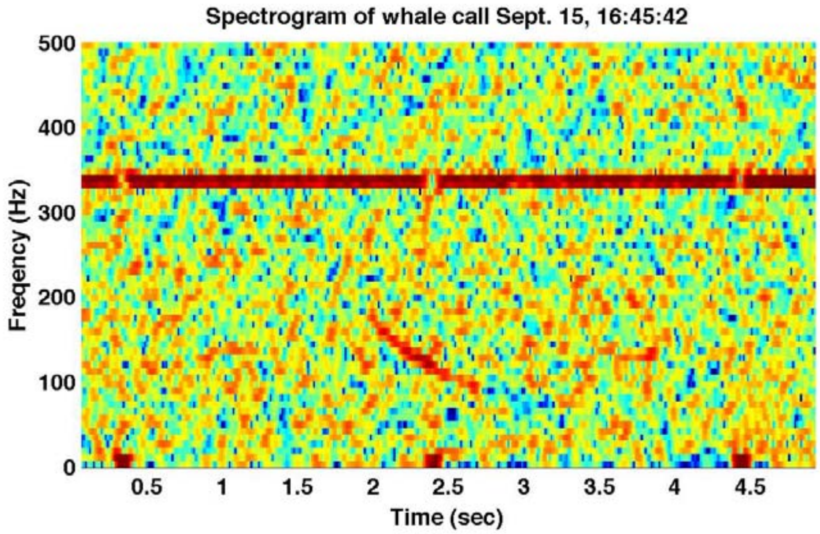

FIGURE 10.14. Spectrogram of whale call in beamformed vertical array data.

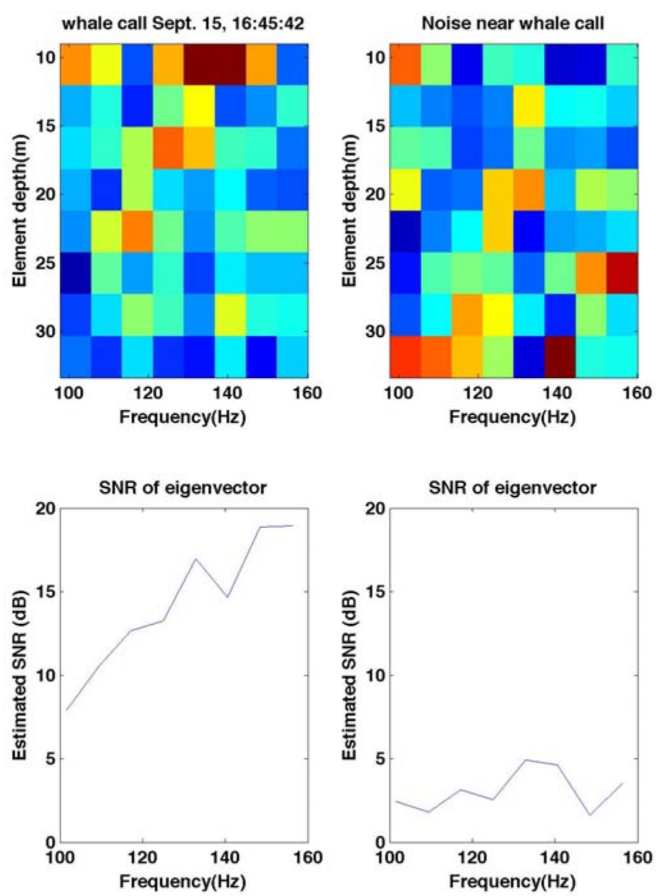

FIGURE 10.15. Vertical structure of acoustic field when a whale call is present (left) and absent (right).

Machine-Aided Call Detection

After preprocessing the raw binary data from DASARb station B1 (see Fig. 10.6), the public domain program ***Ishmael*** was first used to detect deviations from the mean background power spectral density across four frequency bands between 50 and 500 Hz. After being stored to hard disk, these first-order detections were then run through a new MATLAB-based contour tracer, which performs the following three steps: (1) identifies the time-frequency bins in a spectrogram that may be part of a FM-modulated signal; (2) attempts to connect flagged time-frequency bins into short segments, and (3) attempts to connect segments into longer contours. If the time-duration of these contours exceeds a threshold time, the routine flags the detection and stores the time and contour shape in a log. To date the routine is detecting about 80% of all calls logged by human operators, with a tradeoff of a large number of false detections.

A MATLAB program has been written to load the ***Ishmael*** output and to attempt to identify any contours present in each candidate detection. The program displays three dialog boxes in quick succession, then launches a set of additional MATLAB scripts.

Figure 10.16 illustrates the basic strategy of the contour tracing routine. The upper plot displays a spectrogram (time-frequency diagram) of a bowhead whale FM downsweep adjusted to equalize out background noise levels. The color scale of the image represents the signal-to-noise ratio of the image relative to the background noise levels. A peak detection routine marches through the spectrogram and at each moment in time identifies “peak” frequencies in the image. A “peak” is defined here as a frequency with an intensity value much greater than the intensity values of nearby frequencies. These “peak detections” are marked as yellow circles in the top plot. In the middle plot the program then attempts to connect the yellow circles to create contour segments. Finally, the bottom plot shows how the program attempts to connect individual segments (the magneta and blue lines in the middle plot) into a single contour. If the contour exceeds a certain minimum duration the detection is flagged as a potential bowhead call. The entire process required seven hours to run on 20 days of acoustic data.

Fourteen parameters have been identified to control how the entire program executes (Table 10.1). Default parameters have been chosen by running a small subset of bowhead calls through the routine and adjusting the parameters until all calls have been flagged. Thus at this stage the emphasis has been on detecting all potential calls, as opposed to reducing the likelihood of incorrectly flagging a detection as a call. However, two parameters have been defined for rejecting airgun acoustic signatures. Thousands of these pulses, which superficially resemble bowhead FM downsweeps, have occurred over a 24 hour period in the Shell data, so some means of rejecting these signals must be implemented to prevent the routine from being overwhelmed.

Figure 10.17 shows the result of running the routine over the entire Greeneridge data set collected by DASARb B1 between September 13 and October 2, 2006. Subplot (a) is a histogram of calls detected by a team of human analysts, presented as calls present per hour. The number of actual calls flagged in the data is 14,300. Subplot (b) shows a histogram of the output of the machine-aided algorithm, which has flagged 93,264 events as potential calls. At present the routine is often fooled by airgun sounds and motorboat noises, suggesting that some of the parameters in Table 1 still need to be optimized. Subplot (c) shows a histogram of calls logged by human analysts but missed by the algorithm. At present the routine detects 80% of all the calls located by the human operators (i.e., it misses 20% of the calls). Thus, this first attempt at developing an algorithm seems to be working for machine-aided call detection. Current work is focusing on understanding the features of the 20% of calls that are being missed, and adding an additional parameter to allow the routines to reject boat noise. Documentation describing the details of the MATLAB routines and how to execute the code has been created.

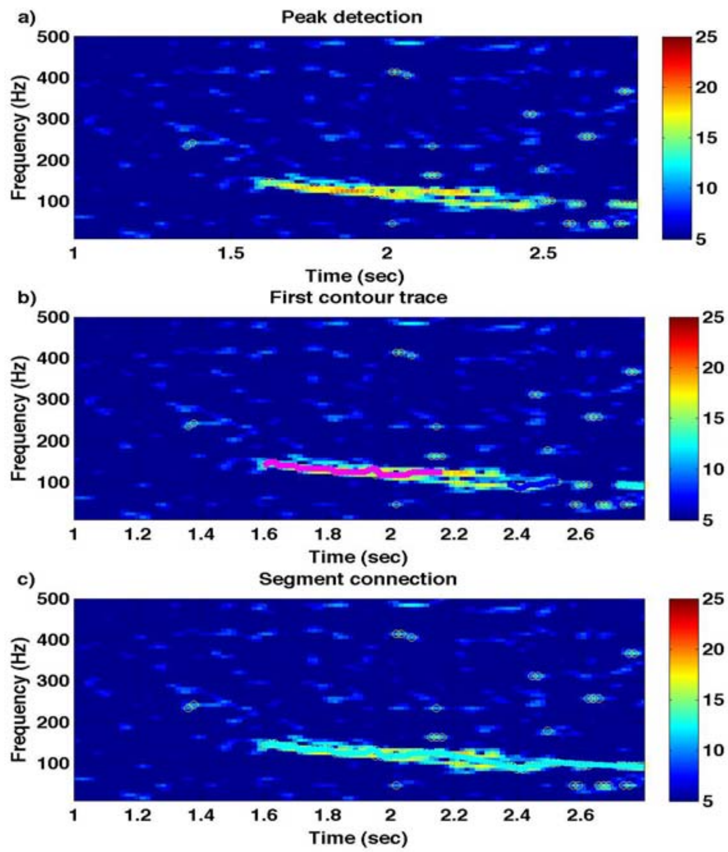

FIGURE 10.16. Following the *Ishmael* “energy detection” pass through the data, these three steps are performed on each of the first detections: (a) peak detection, (b) contour trace, and (c) segment connection.

Background Noise

In studying the received levels of known sounds, such as vessel or airgun sounds, it is useful to be able to compare them with the levels of the background noise. The BP DASARs northeast of Northstar Island (e.g., unit EB), the two Shell DASARBs southeast of the Northstar DASARs (units B2 and B3), and the two Shell DASARBs 25 km (13.5 n.mi) northeast of Cross Island provided sound data recorded continuously during their installation periods. (See Figure 10.6.) Computing one-minute averages of the sound pressure level every 4.37 minutes results in a time series of background noise levels. Those levels were sorted to determine the minimum, the 5th-percentile, the 50th-percentile, the 95th-percentile, and the maximum for the duration of the installation. Results were obtained for the narrowband spectral density levels, the one-third octave band levels, and the broadband levels from 10 to 450 Hz. Results are presented for unit EB north of Northstar, unit B2 southeast of the Northstar units, and unit B4 northeast of Cross Island. Table 1 presents the broadband results. Figures 10.17 and 10.18 present the broadband levels vs. time for units B2 and B4, respectively. Figures 10.19 and 10.20 present the distribution of the one-third octave band levels for the same two units. Figures 10.21 and 10.22 present the distribution of the spectral density levels for the same two units.

TABLE 10.1. Background noise level distribution for the broadband sound in the band 10–450 Hz.

	dB re 1 µPa		
Percentiles	Northstar EB	Shell B2	Shell B4
Minimum	76.8	86.7	83.3
5%	81.8	88.0	91.8
50% (median)	95.4	98.7	100.4
95%	108.4	110.4	109.0
Maximum	122.9	126.8	120.1

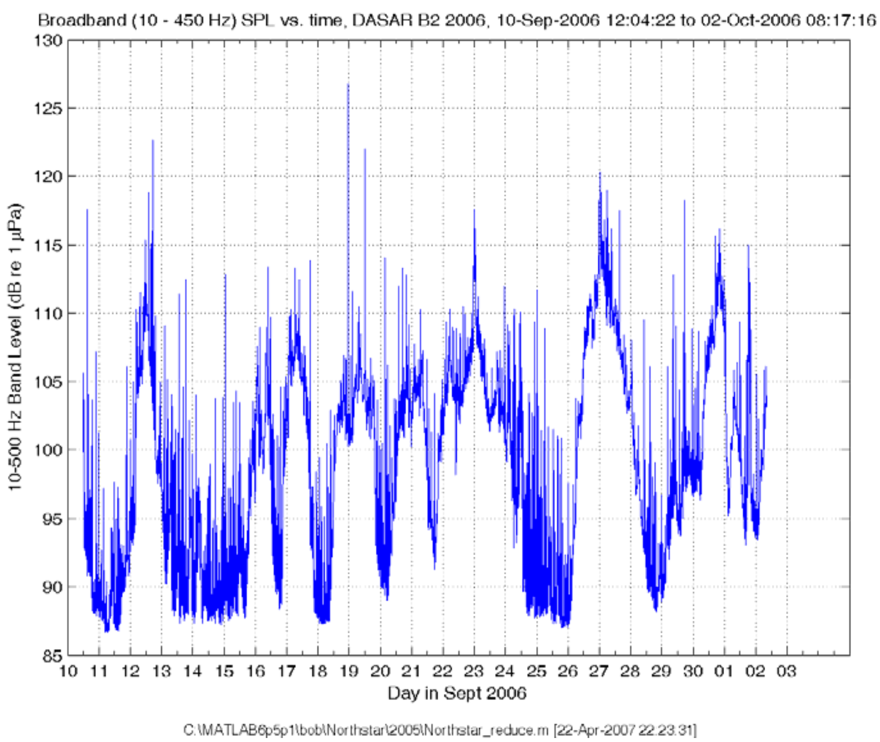

Figure 10.17. Broadband sound levels vs. time for unit B2

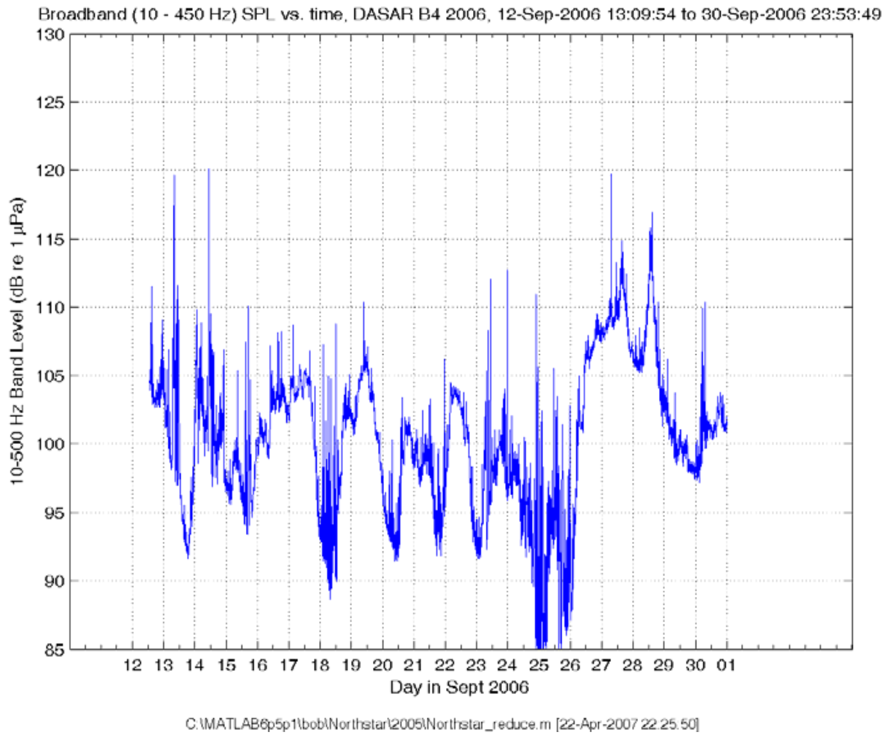

FIGURE 10.18. Broadband sound levels vs. time for unit B4.

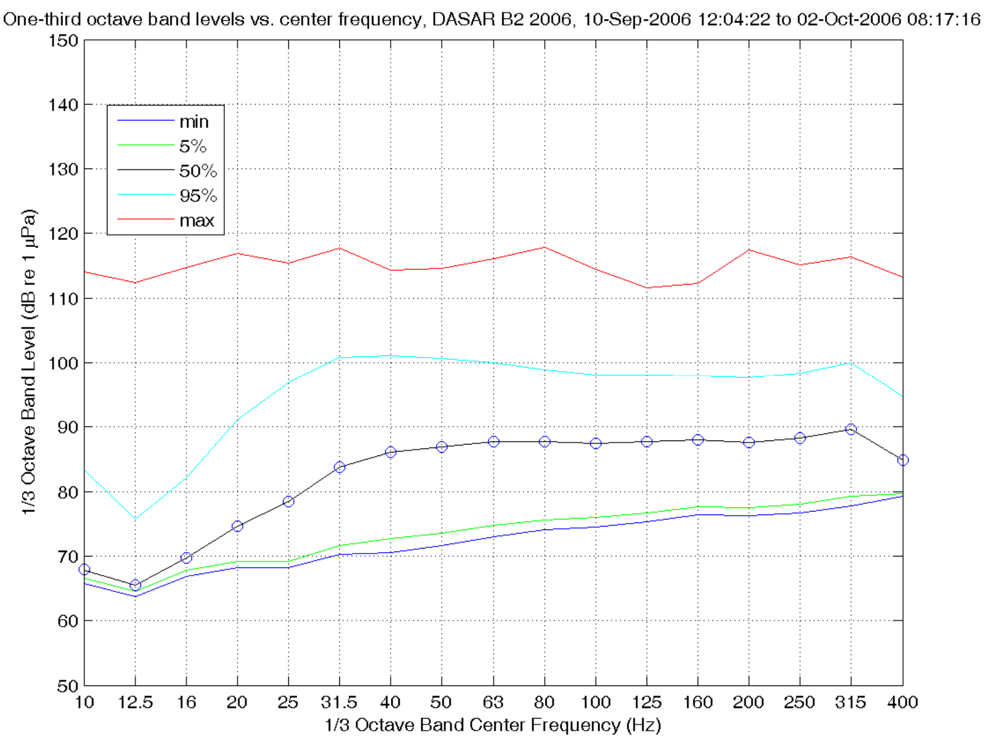

FIGURE 10.19. Statistical distribution of one-third octave band levels for unit B2.

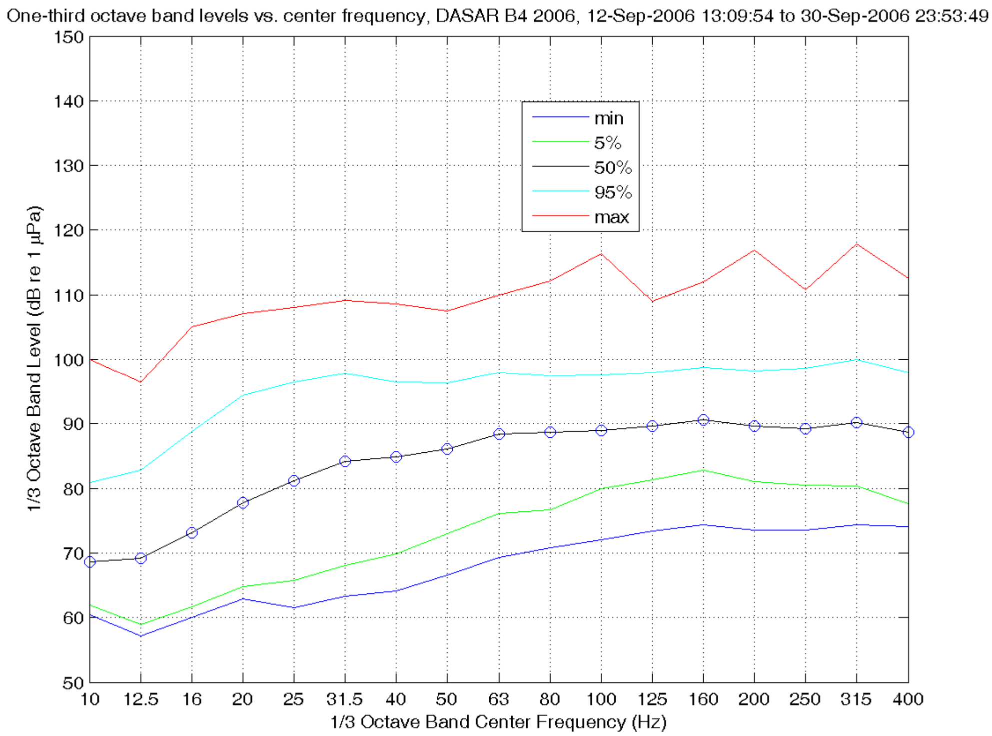

FIGURE 10.20. Statistical distribution of one-third octave band levels for unit B4.

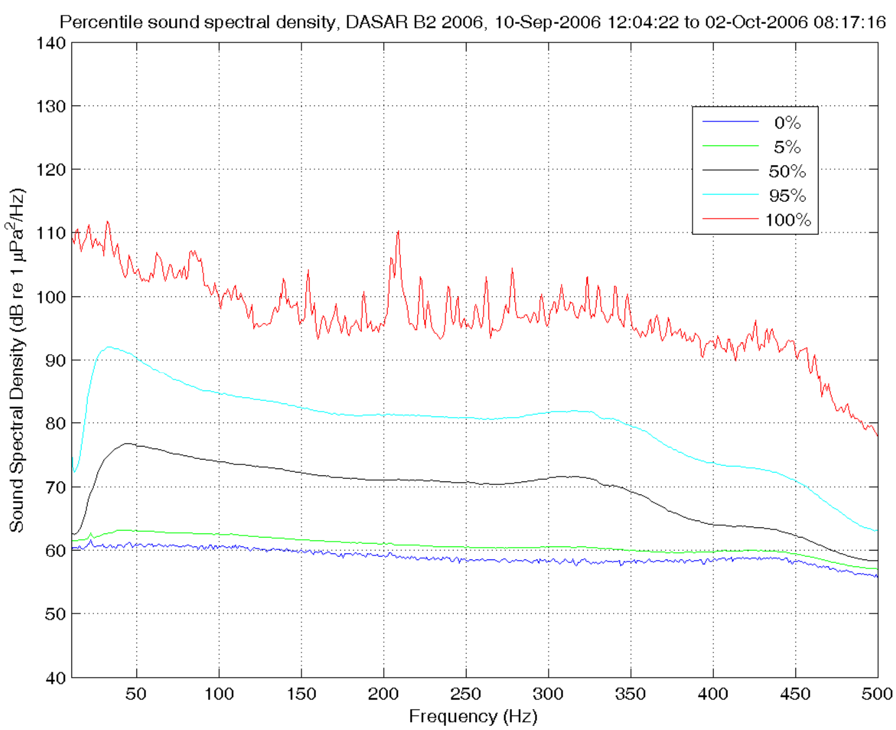

FIGURE 10.21. Statistical distribution of spectral density levels for unit B2.

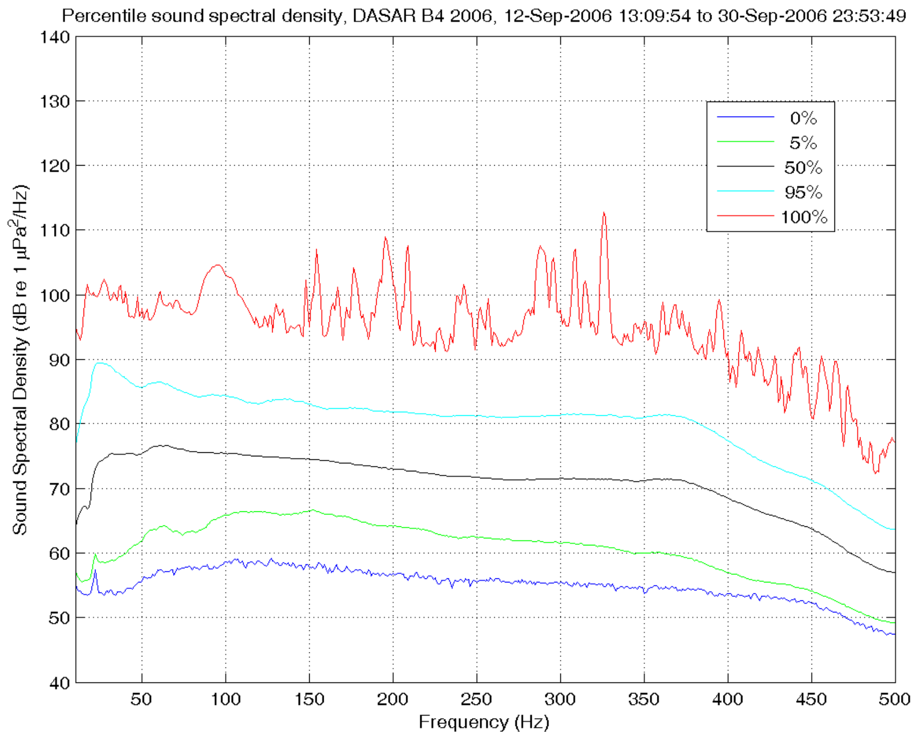

FIGURE 10.22. Statistical distribution of spectral density levels for unit B4.

Airgun Sounds from Seismic Survey in Canada

Airgun sounds from a seismic survey in Canada were recorded on the northern pair of DASARBs deployed for Shell (B1–B4 pair, see Fig. 1 above). Pulse amplitudes in all received pulses on 20 Sept. were similar. The pulse received at 14:43:01 on 20 September 2006 was analyzed and the results are listed below. Figures 10.24, 25, 26, and 27 illustrate some of these results.

- pre-event broadband background level: 78.2 dB re 1 µPa
- peak pressure (instantaneous maximum of the absolute sound pressure): 116.2 dB re 1 µPa
- sound exposure level (SEL, squared instantaneous sound pressure integrated over the pulse duration): 103.5 dB re 1 $\mu Pa^2 \cdot s$
- received pulse sound pressure level (SPL, squared pressure averaged over the pulse duration): 104.6 dB re 1 µPa
- pulse duration (time interval between the arrival of 5% and 95% of the total pulse energy): 0.778 s
- the distance between the DASAR which recorded this pulse and the seismic ship in Canadian waters was > 250 km (135 n.mi.). The bearing to the ship from the DASARB was 77° (between ENE and E).

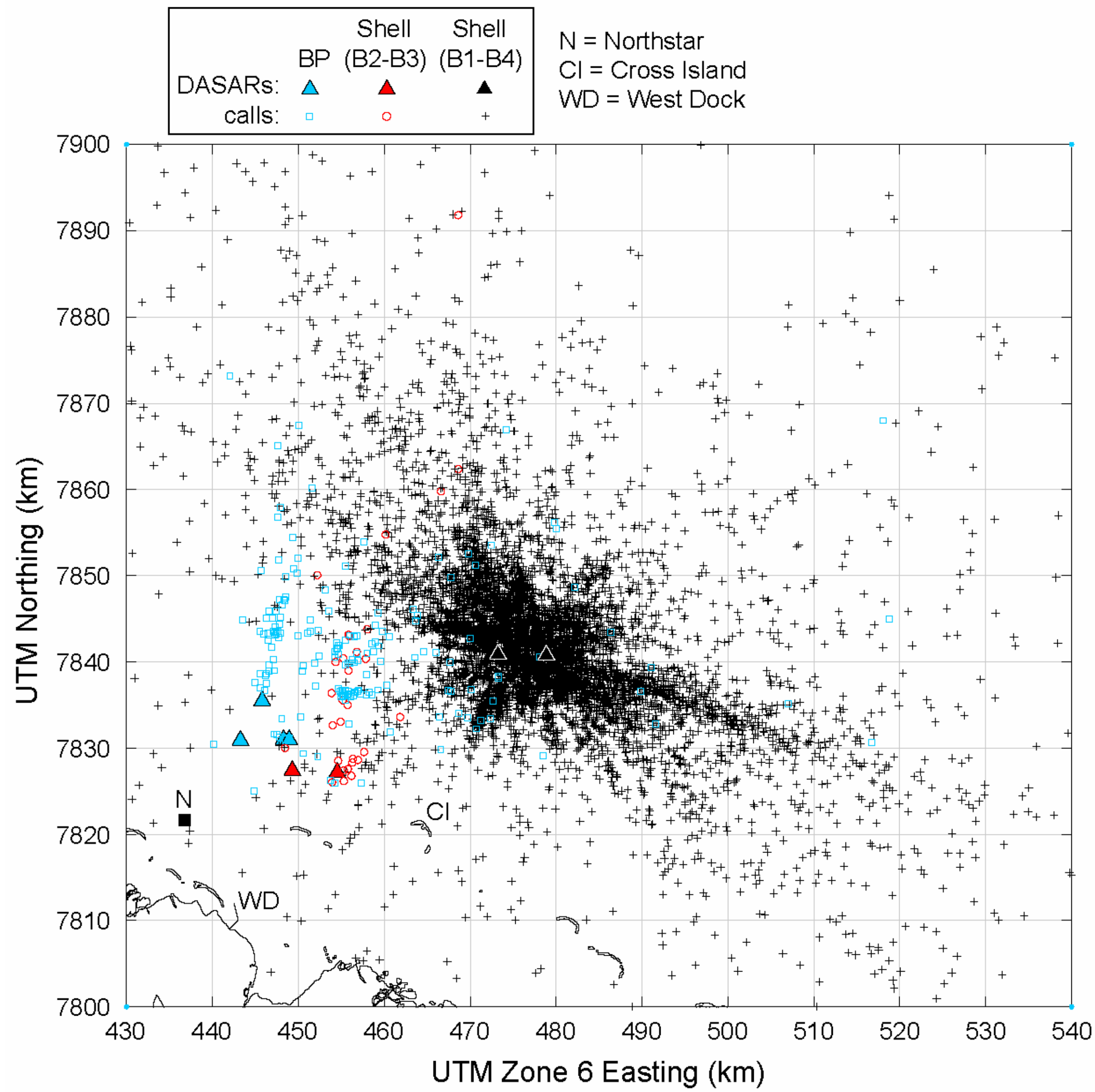

FIGURE 10.23. Composite map displaying the bowhead whale call locations for 2006 from three sites: the Northstar DASARs (BP), the Shell B2–B3 pair of DASARBs located just southeast of the Northstar DASARs, and the Shell B1–B4 pair of DASARBs located about 25 km (13.5 n.mi) North-northeast of Cross Island. The B1–B4 pair, being farther offshore, provided by far the greatest number of call locations. Note that no effort was made to match up calls detected by the Northstar and Shell DASARs, so there could be pairs of call locations which correspond to two slightly different position estimates of the same call.

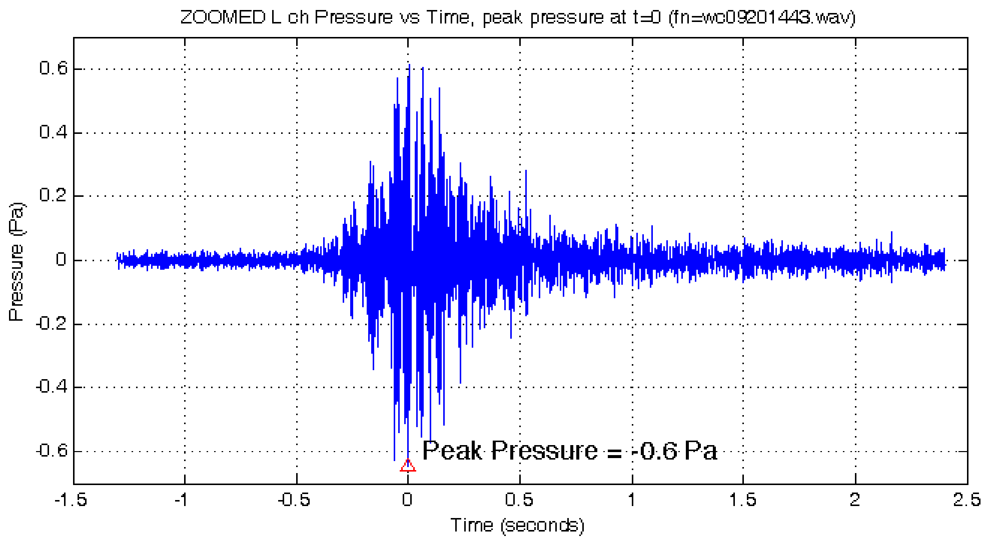

FIGURE 10.24. Sound pressure time series of seismic pulse at 14:43 on 20 September 2006.

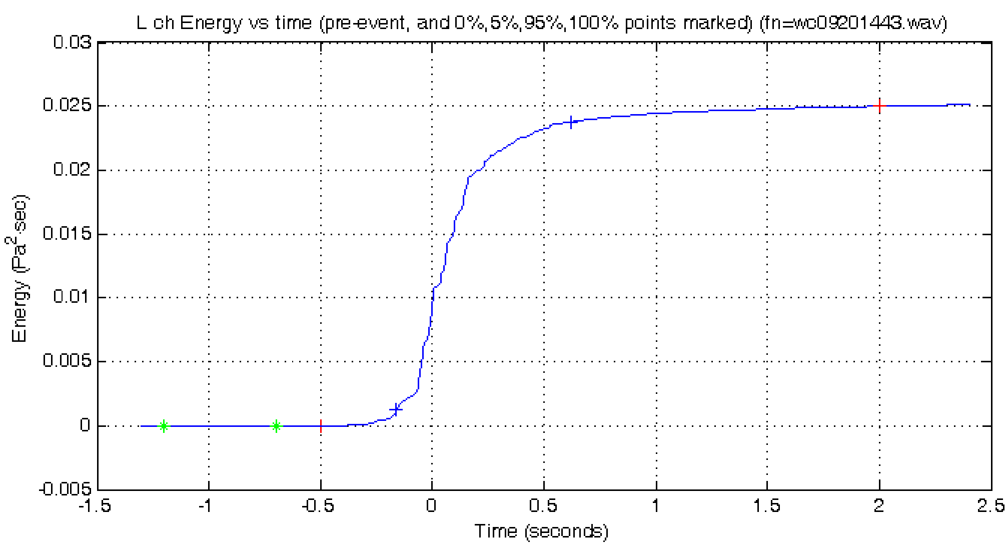

FIGURE 10.25. Energy versus time for seismic pulse at 14:43 on 20 September 2006.

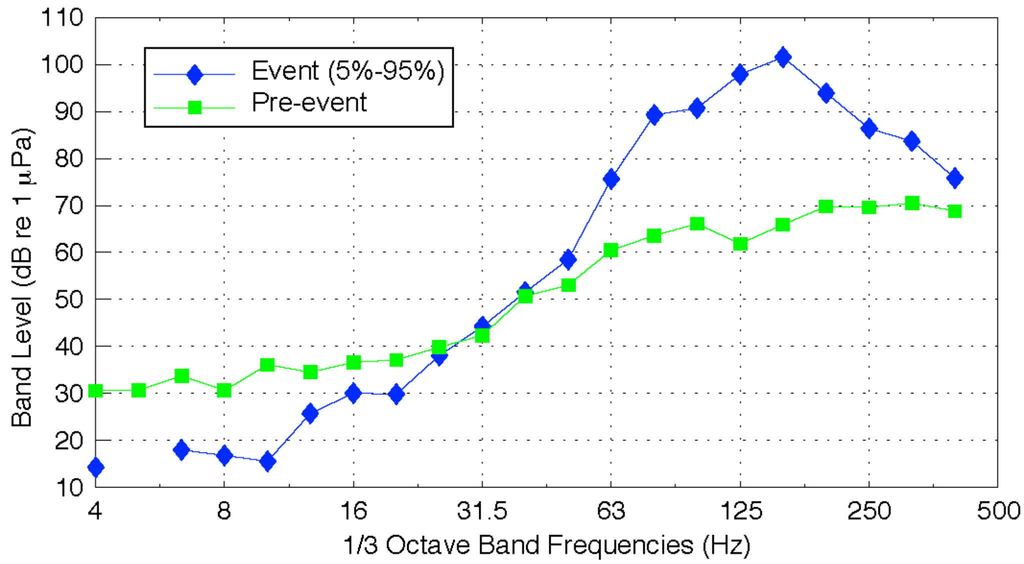

FIGURE 10.26. One-third octave band levels for seismic pulse at 14:43 on 20 September 2006. Levels for the pulse itself are shown as blue diamonds, and levels for a background sample preceding the pulse are shown in green squares.

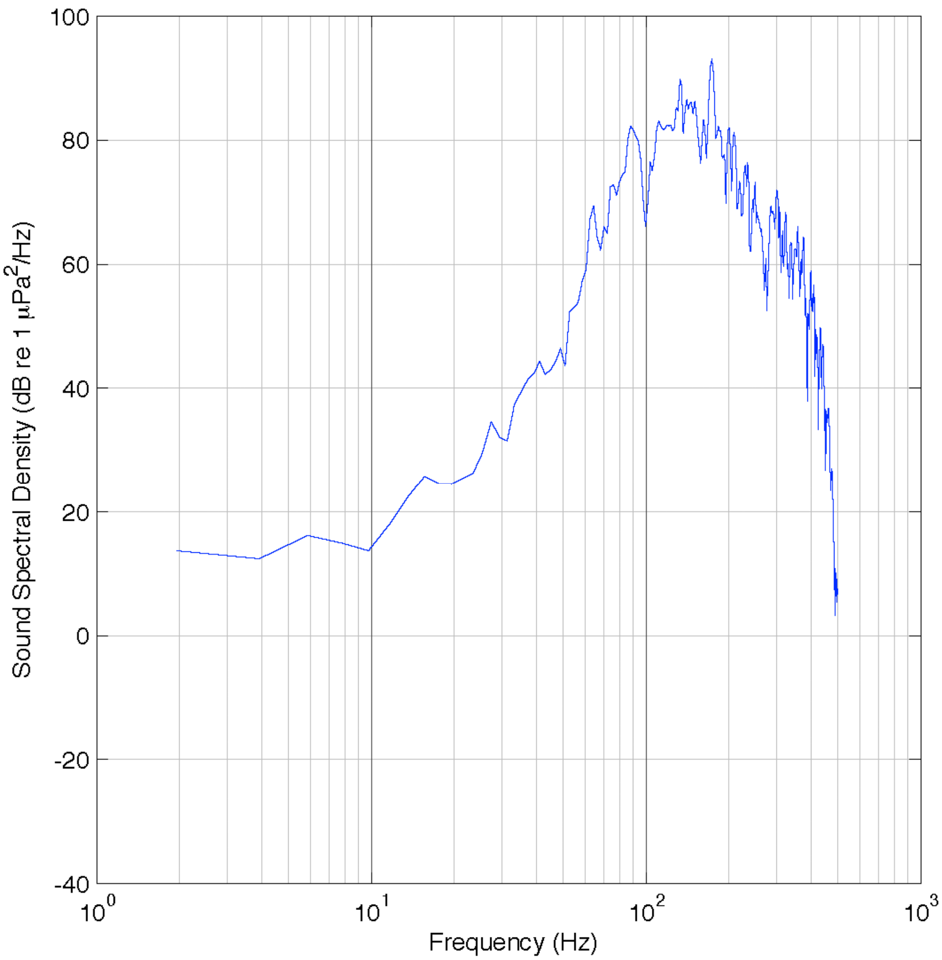

FIGURE 10.27. Spectral density levels for seismic pulse at 14:43 on 20 September 2006.

Conclusions and Recommendations

DASARb

The DASARbs performed as desired. These four units proved that they are ready for serious whale call location monitoring in the future. The *in situ* calibration transmissions following installation and preceding retrieval were not as strong as expected and must be monitored carefully in the future.

Vertical Arrays

Lessons from Vertical Array Deployments—The vertical array deployments represented the first attempt to deploy such systems in this area in over twenty years. Ice conditions were unusually heavy. Given these circumstances the odds of equipment loss were higher than what would be expected from deployments of established designs. A review of the circumstances suggests that some adjustments to the array configuration and deployment would significantly increase the odds of useful operation and recovery in future efforts. First, the subsurface buoy design for both arrays was a “string of pearls” arrangement that provided numerous potential grab points for a passing ice floe. Replacing this system with a single spar-type buoy would reduce the odds of capture by ice floes. This statement is supported by the fact that Greeneridge deployed surface sparbuoys in ice-covered regions in the past and did not lose any assemblies, even though some locations were ice covered at times. The sparbuoys submerged beneath the ice but returned to the surface when the ice floe passed.

Second, the target depth of the subsurface flotation, 4.5 m (15 ft), was too shallow for the unexpectedly large floes encountered in 2006. Consultations with Craig George of the North Slope Borough suggest that a 7.6 m (25 ft) foot clearance below the surface would provide more useful protection under such extreme conditions. Third, the Alaska Clean Seas organization has requested replacing the plagisol inside the array tube with castor oil for environmental regulatory reasons. Finally, results from the inclinometers and numerical modeling have determined that an anchor weight of 300 lbs. (instead of 600 pounds) would be adequate for future deployments, greatly simplifying the deployment logistics.

Despite these problems, the most expensive vertical array was safely recovered. Despite problems with electrical noise contamination, whale calls and airgun signals can be detected in the data, and evidence of multipath propagation has been observed. Attempts to localize the signals are continuing, although the procedure used to de-spike the data has probably disrupted the relative phase of the frequency components between the hydrophone elements, lowering the odds of an accurate ranging measurement for this data set. The electrical issues in the recording system are being addressed by a circuit board redesign, a data acquisition software review, and an adjustment in the gain of the array signals before they enter the acquisition system.

TABLE 10.2. Parameters of machine-aided detection routine.

Parameter	Units	Description
Fs	Hz	Sampling frequency (fixed)
Nfft	-	FFT size for base spectrogram
Ovlap	-	Fractional overlap of spectrogram FFT
SNRmin	dB	The dB level a time/frequency bin has to exceed the background level to be considered as part of a call
SNRBW (contour width)	Hz	A time/frequency bin must be a local maxima with respect to frequency, and frequency bins SNRBW Hz above and below the bin must be 4 dB below the peak value.
Eq. time	Sec	Amount of time used to estimate background noise levels from each call candidate time series. Used only if Eq_frac_update is set to 1.
Eq_frac_update	-	What fraction of the ambient background noise spectrum is updated for each call candidate. If 0, the background is never updated. If 1, the background spectrum is completely replaced for each call sample.
Pulse_percent	-	Fraction of frequency bins that must exceed SNRmin for airgun pulse rejection
Pulse Tclear	Sec	How much time proceeding and following an airgun pulse to ignore calls (removes reverberation)
Total duration	Sec	Minimum time length for a contour piece
Gap f	Hz	Maximum Hz a contour can change with each spectrogram time increment.
Gap t	Sec	Maximum sec a contour can break (maximum gap in a contour)
Seg total duration	Sec	When combining contour segments into a call, what is minimum time required for final call.
Seg gap f	Hz	When connecting contour segments, maximum frequency gap permitted between segments
Seg gap t	Sec	Maximum gap permitted when joining segments.

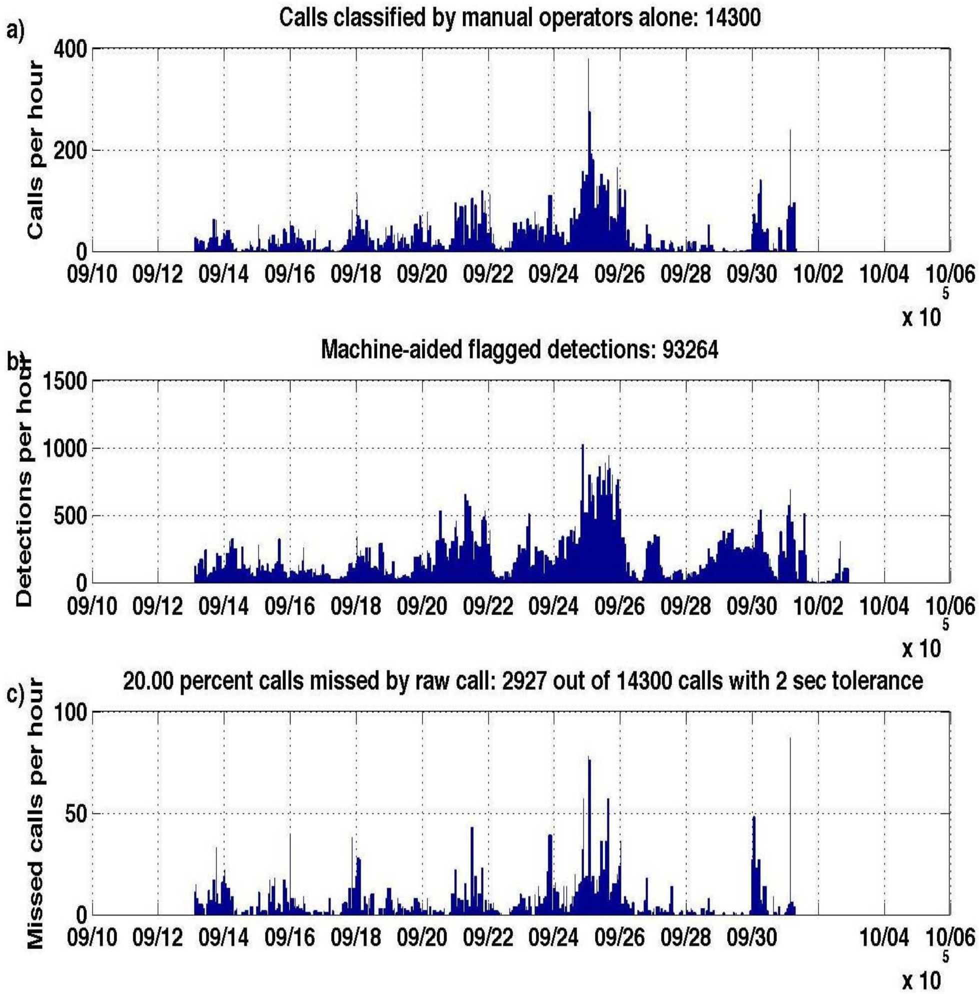

FIGURE 10.23. Comparison of manual and automated call detection results on the 2006 data recorded by DASARb B1.

Machine-Aided Call Detection

The machine-aided call detection algorithms need further development but progress to date shows that computer analysis can be a major aid to analysts. These routines will be improved with time as more experience is gained, with a particular emphasis on reducing false detections from airgun signals and boat-generated noise.

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11. OTHER INDUSTRY STUDIES [1]

Pioneer and FEX—Sound Source Characteristics of Barges [2]

Underwater acoustic source level measurements of vessels operating in the Alaska Beaufort Sea were conducted by JASCO Research for Pioneer Natural Resources Alaska, Inc. (Pioneer) and FEX LP (FEX) between 4 and 9 Sept. 2006. Source level measurements were performed on eight different vessels at various sites in the Alaskan Beaufort Sea beyond the barrier islands between Oliktok Point and West Dock (Figure 11.1). The measurements were stipulated by a North Slope Borough (NSB) ordinance (serial no. 75-6-50) for an Offshore Monitoring Program for the Oooguruk Development Project Area, and by a Conflict Avoidance Agreement between the operators and the Alaska Eskimo Whaling Commission (AEWC). Barging and related vessel traffic in 2006 supported both the Oooguruk drillsite (ODS) in Harrison Bay near the Colville River delta for Pioneer, and shipping of equipment and supplies from West Dock to Cape Simpson for FEX.

Results obtained from this study included broadband and 1/3-octave band source levels in the 10 hertz (Hz) to 20 kHz frequency range. The results were suitable for high-resolution computer simulation modeling of noise levels in the vicinity of working vessels. Both underwater and in-air sound levels were measured; however, this report presents only the underwater measurement data and associated analyses.

Ten separate source level sets were measured to capture source levels of eight different vessels (two vessels were monitored twice with different towing loads). Each measurement set included two or three separate measurements, in which the vessel passed a fixed recording station.

All underwater acoustic measurements were performed from the Alaska Clean Seas (ACS) boat *Mikelsen Bay* (base vessel). The base vessel remained stationary during the measurement periods while the measured vessels sailed past at standard transit speeds. During measurement runs on windy days, the base vessel was anchored to avoid excessive drifting; on calm days, anchoring was not necessary. In all cases, the base vessel engines were turned off during sound recordings so their noise would not contaminate the acoustic measurements. Details of the equipment used and the data analyses are contained in Zykov et al. (2007a).

The vessels for which sound measurements were made included the tugs *Kuparuk River*, *Kavik River*, and *Sag River*, the self-propelled barges M/V *Garret* and M/V *Stryker*, the response vessel *Gwyder Bay*, a small aluminum skiff, and the crew boat *American Pioneer*.

Two or three separate measurement passes were made for each of the eight vessels. Source levels from the different passes were generally in very good agreement; differences between passes at the same speed were typically within 2 dB. Broadband source levels from all measurements are provided below in Table 11.1.

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[1] Robert Rodrigues and Dale W. Funk, LGL Alaska Research Associates, Inc., Anchorage, Alaska.

[2] Summarized by LGL from a detailed technical report by JASCO Research Ltd. (Zykov et al. 2007a).

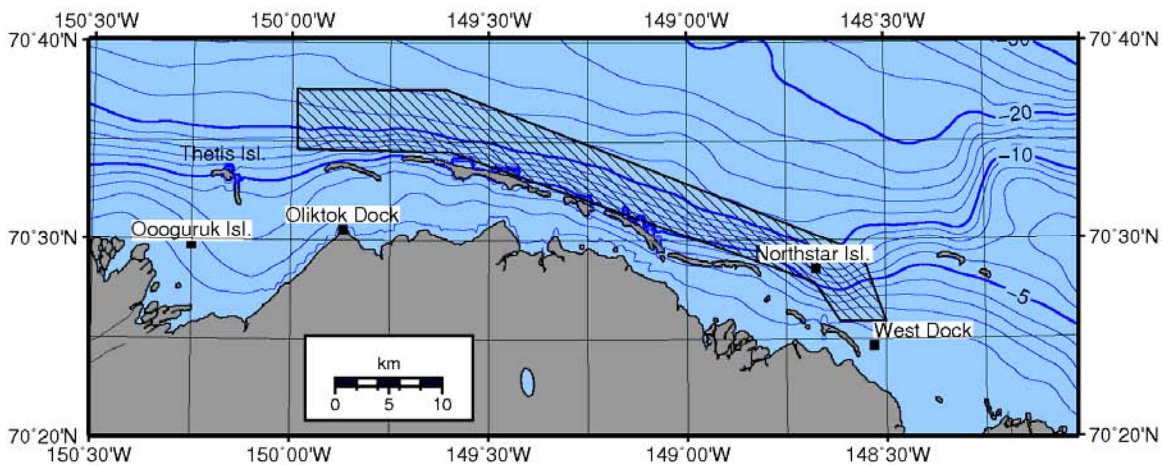

Figure 11.1. Study area for underwater source level measurements from vessels in 2006, Alaska Beaufort Sea (from Zykov et al. 2007a).

Table 11.1. Summary of broadband source levels for self propelled barges, tugs with barges, and other vessel types associated with industry activities in the Alaskan Beaufort Sea, 2006.

Vessel name	Type	Load Status	Speed (m/s)	Pass 1 SL (dB)	Pass 2 SL (dB)	Pass 3 SL (dB)
MV Garret	S/P barge	Unloaded	2.8	172.5	171.0	-
Sag River	Tug+barge	Unloaded	3.8	172.8	173.0	-
Kavik River	Tug+barge	Partial load	3.3	177.6	175.8	-
Kuparuk River	Tug+barge	Unloaded	4.5	181.2	182.9	-
MV Garret	S/P barge	Partial load	2.8	173.8	170.1	-
MV Stryker	S/P barge	Unloaded	2.8	162.6	162.8	-
Gwydyr Bay	ACS boat	n/a	8.3	167.9	167.8	168.4
Aluminum Skiff	16' aluminum	2 crew	9.7	165.0	167.6	164.9
Amer. Pioneer	Crew boat	2 crew	9.7	165.0	167.6	164.9
MV Stryker	S/P barge	Loaded	2.5 / 3.0	168.6*	174.0*	-

* Different vessel speeds

Broadband source levels of the three sister tugs *Kuparuk River*, *Kavik River* and *Sag River* with barges ranged from 172.8 to 182.9 dB re µPa at 1m. These lowest and highest levels were measured for the *Sag River* and the *Kuparuk River* respectively, both with empty barges. The main difference was that the *Kuparuk River* was sailing at 4.5 meters per second (m/s; 8.7 kts) while the *Sag River* was traveling slightly slower at 3.8 m/s (7.4 kts). The *Kavik River*, with a partially loaded barge traveling at 3.3 m/s (6.4 kts), had an intermediate source level of about 176 dB re µPa at 1 m. The higher source level of the *Kuparuk* relative to the sister tugs may have been due to its damaged propeller.

Measurements of four passes of the self-propelled barge *Garret* (two unloaded and two partially loaded) gave very similar levels over the range 170.1 to 173.8 dB re µPa at 1m. All four passes were at the same speed of 2.8 m/s (5.4 kts). Measurements of the *Garret's* unloaded sister vessel *Stryker* on the same day and sailing at the same speed gave source levels a full 10 dB less at 162.6 and 162.8 dB re µPa at 1m. The lower sound levels of the unloaded *Stryker* were apparent at all measured ranges from 20 to 500 m. Again, a probable cause of this difference could be a damaged propeller on the *Garret*. Measurements of the loaded *Stryker* were more than 5 dB greater than unloaded, at 168.6 and 174.0 dB at 2.5 m/s (4.9 kts) and 3.0 m/s (5.8 kts) respectively. The difference in the latter levels indicates a noticeable increase in source level, by 5 dB, with even a modest increase in speed.

The *Gwydyr Bay*, *American Pioneer* and the aluminum skiff had lower source levels than the tugs by approximately 5 to 15 dB. In general, these smaller boats produced higher frequency sound energy, which propagated better in the shallow water than did the low frequency sound from the tugs and self-propelled barges.

An important effect noticed in the measurements taken on 7-9 Sept. 2006 and not noticed in the earlier measurements (4-6 Sept. 2006), was the oscillatory nature of the sound level versus range plots. This effect was due to the passage of the vessel propellers through swells in the rougher sea conditions, which led to cycling of the output sound levels by up to 5-8 dB above and below the average sound levels. This effect could increase the maxima of local sound levels to a few kilometers in range, but it was probably mitigated at longer ranges by scattering of coherently reflected sound from the rougher sea surface. See Zykov et al. (2007a) for a more detailed discussion of the sound propagation in various 1/3 octave bands and broadband levels for each vessel.

Pioneer Natural Resources—Oooguruk Development Project [3]

Pioneer Natural Resources, Inc. (Pioneer) and its contractors conducted two studies related to marine mammals in support of its activities at Oooguruk Drilling Site (ODS) located in Harrison Bay near the Colville River delta. These studies included an acoustic study to measure industrial sounds resulting from activities related to the ODS, and aerial surveys designed to assess and report on the distribution of bowhead whales within 15-20 miles of the island during fall migration. The results of these studies are summarized below. See Zykov et al. (2007b) for a detailed report on the acoustic measurements at ODS, and Reiser et al. (2007) for details of the aerial surveys.

Acoustic Study

The acoustic study, which was part of an offshore monitoring program designed to address stipulations in the NSB ordinance for the Oooguruk Development Project Area, was conducted by JASCO and LGL. The goals of the acoustic study were to

- measure underwater sounds associated with construction activities on ODS and the attenuation with distance and direction from the island,
- characterize source sound levels from barging and support vessel activities and attenuation of these sounds with distance,
- assess ambient noise levels in the vicinity of ODS, and
- detect marine mammal vocalizations if present.

[3] Summarized by LGL from detailed technical reports by JASCO Research Ltd. (Zykov et al. 2007b) and LGL Reiser et al. 2007).

Three Ocean Bottom Hydrophones (OBH) were used to record ambient sound and sounds produced from island construction activity. OBH deployments were two-three days in duration, and three separate deployments of all three systems were performed from 2-10 Sept. Locations of OBHs varied among deployments and five deployment locations were chosen based on the NSB stipulations in the directions north and northwest of the ODS (Fig. 11.2). Deployment locations were ~ 1.6, 6.4, and 19.3 km (1, 4, and 12 mi) from the ODS.

The OBH systems were used to measure noise from ODS construction resulting from activities of a Deere 750J bulldozer, Caterpillar 330C and 345B excavators, a Caterpillar 966 loader, and a Terex HC275 crane. The OBH systems also measured noise from tugs and barges used at various times during the open-water period to haul construction equipment and supplies to the ODS.

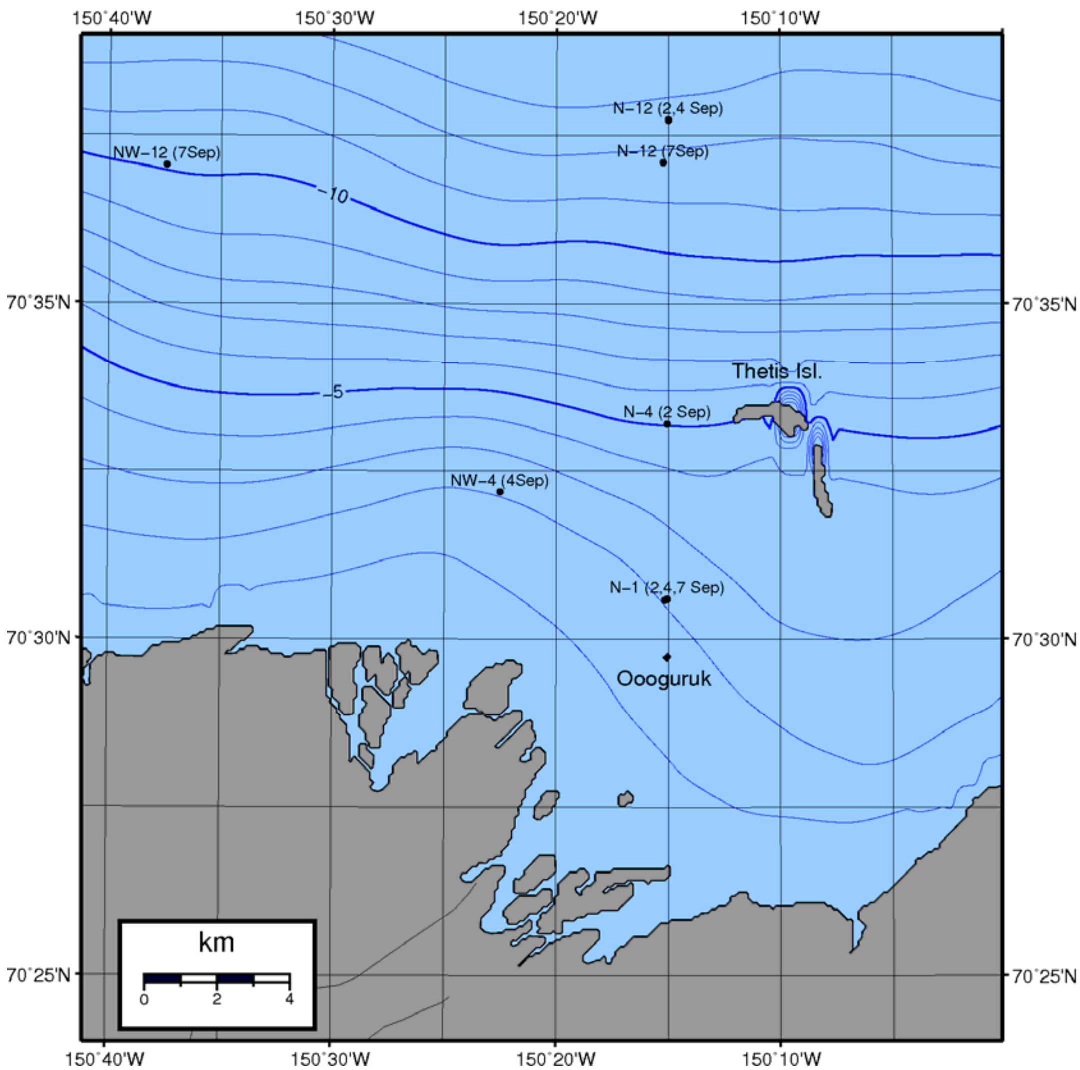

Figure 11.2. Location of Oooguruk Island and OBH deployment locations. Depth contours are in meters. (from Zykov et al. 2007b).

The closest range recorders (deployed at 1.6 km from the center of the ODS) detected intermittent low-frequency noise between 10 and 60 Hz attributed to heavy equipment operations on the ODS. The maximum absolute broadband level of these sounds was 92 dB re µPa. This noise was believed to propagate mainly through the seabed and consequently decayed rapidly with distance. It was not detected by the other OBH systems deployed at 6.4 and 19.3 km from the ODS. This was similar to the results of sound measurements at Northstar Island by Blackwell and Greene (2005a) who reported that broadband sound levels during construction and production activities reach background levels within 2-4 km from the island. However, background levels at Northstar during drilling were reached at 9.4 km (Blackwell and Greene 2005a).

Tug and barge traffic to the north of Thetis Island was recorded by the OBH systems deployed at 6.4 and 19.3 km from the ODS. Transit detections of three vessels (the tugs *Sag River* and *Kavik River* with barges, and self-propelled barge MV *Stryker*) were analyzed to determine spectral characteristics of the received noise and to estimate the distances at which vessel noise would attenuate to ambient levels. In shallow water (5 m OBH depth) the *Sag River's* noise reached ambient levels at about 2 km (ambient 95 dB re µPa broadband) and 3.5 km (ambient 80 dB re µPa in 100 Hz-1 kHz band). In deeper water, (13 m OBH depth) noise from the *Kavik River* reached ambient at about 7 km for both the broadband (ambient 94-96 dB re µPa) and 100 Hz-16 kHz (ambient 88 dB re µPa) bands. Three transits by the *Stryker* were captured on the deeper OBHs. Noise from this vessel when unloaded was detected above ambient to maximum ranges of 2.5 km (ambient 91 dB re µPa broadband) and 5.1 km (ambient 79 re µPa in band 100 Hz-1 kHz). When loaded, the *Stryker* was detected to a maximum range of 6.3 km (ambient 98 dB re µPa broadband) and 8.7 km (ambient 80 dB re µPa in band 100 Hz-1 kHz).

Ambient broadband (1 Hz – 16 kHz) noise levels in this environment varied between 80 dB re µPa and 110 dB re µPa, with strong positive correlation between apparent in-water sound levels and wind speed. The deeper (10-13 m) OBHs recorded minimum ambient levels as low as 90 dB re µPa. This level was significantly higher than the minimum level of 79 dB re µPa recorded on the shallower (2-5 m) OBHs. The difference in levels was attributed to attenuation of low-frequency, long wavelength acoustic energy due to limited propagation in the very shallow water. The 1-10 Hz frequency band added approximately 6-10 dB to the overall ambient broadband sound levels. The minimum measured ambient levels in the 10 Hz – 16 kHz band were 74 dB re µPa and 85 dB re µPa, respectively, for the shallow and deep OBHs.

OBH recordings were analyzed to search for marine mammal vocalizations. This analysis included manual viewing of expanded spectrograms of all pressure and spectral anomalies. In addition, sections of the audio signals were played back to listen for vocalizations however, none were identified. It is possible that very weak vocalizations could have been missed.

Aerial Surveys

The goal of Pioneer's aerial survey program in 2006 was to determine whether bowhead whales travel near enough to the ODS to detect industrial sounds produced from the facility construction and operation. Working closely with NSB scientists, Pioneer developed an aerial survey program to assess the distribution of bowhead whales within 15-20 miles (24 to 32 km) of the ODS during September 2006 (Reiser et al. 2007).

The survey was centered north of the ODS in Harrison Bay and encompassed an area approximately 580 km^2 (Figure 11.3). It consisted of four north-south transects, each of which was ~24 km in length and separated by ~9 km. The southern boundary of the survey area was located approximately 7 km north of the ODS at a latitude equivalent with the northern edge of Thetis Island. The area's northern boundary was approximately 31 km north of the development site and 24 km north of Thetis Island. The east and west boundaries spanned a distance of approximately 24 km. Water depth within this area of Harrison Bay just north of the barrier islands was from 2 to 10 m. This area represented the southern extent of summer pack ice within Harrison Bay during September 2006, and ice cover ranged from trace amounts to twenty percent during the survey period.

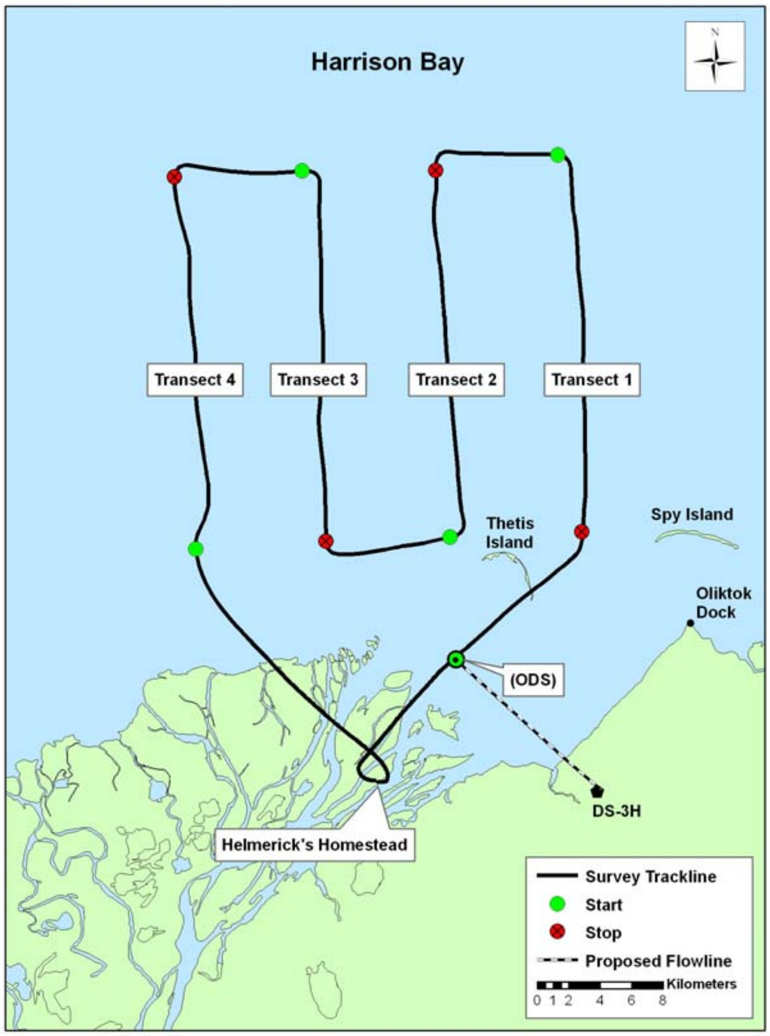

Figure 11.3. Aerial survey trackline showing locations of the four north-south oriented transects from the 12 Sept. 2006 survey. Surveys originated from Helmerick's Homestead on 7 and 12 Sept. 2006, from the ODS on 3 and 12 Sept. 2006, and from Kuparuk Construction Camp on 1 Oct. 2006; the actual transect grid (i.e. start / stop locations) remained constant throughout with the exception of 1 Oct. 2006 when weather prevented all four transects from being surveyed. (From Reiser et al. 2007).

Aerial surveys were flown from a Bell 412 helicopter used by Pioneer for logistical support at an altitude of ~457 m (1,500 ft) and an air speed of 185 km/hour or 100 knots. The preseason plan was to fly two surveys per week for the month of September. Weather conditions were expected to occasionally limit effort, as surveys were limited to 457 m or higher to prevent unauthorized harassment of marine mammals.

Surveys were conducted by two trained observers. Each observer recorded the time, visibility (subjectively classified as excellent, good, moderately impaired, seriously impaired or impossible), sea state (Beaufort Wind Force), ice cover (in 10ths) and sun glare (none, moderate, severe) at the start and end of each transect and at two-minute intervals along the transect.

Observers focused their search efforts to 1 km from their respective sides of the helicopter resulting in a 2 km-wide band of intensive coverage. Each observer carefully searched the transect area for evidence of bowhead whales, polar bears (*Ursus maritimus*), and seals (seals were typically unidentifiable to species from survey altitudes). For each marine mammal sighting, observers recorded the species when determinable, number, size/age/sex class when determinable, activity, heading, swimming speed category (if traveling), sighting cue, ice conditions (type and percentage), and inclinometer reading. The presence of boats was also noted. A sighting was considered *on-effort* if it occurred while the helicopter was on an established north-south oriented survey track and *off-effort* if it occurred while transiting between survey tracks.

Surveys were flown on 3, 7, 12, and 15 Sept., and 1 Oct. 2006. As was initially planned, four surveys were conducted during the first two weeks of September. Viewing conditions during the first four surveys were near optimal, and the four transects (~100 km total length) were completed without a weather-related interruption. Poor survey conditions in the second half September prevented further surveys until 1 Oct. when the fifth survey was conducted, although the presence of fog caused reduced sightability for over 60% of the survey length. Other Beaufort Sea aerial surveys in 2006 also experienced poor weather conditions during the latter half of Sept. (see Chapters 8 and 9).

No bowhead whales were observed during the five aerial surveys. Seals were observed during the first and fourth surveys. Eight seals were observed while on-effort on 3 Sept. (~1.9 seals/100 km of effort for all surveys combined). An additional two seals were seen while traveling between transects. A single seal was observed off-effort on the 15 Sept. 2006 survey. A polar bear was observed off-effort on an ice flow approximately 5 miles north and east of the ODS between Thetis and Spy Islands during the 3 Sept. 2006 survey.

There was no evidence from the aerial survey data to suggest that bowhead whales traveled within 20 miles of the ODS in substantial numbers. Survey data from other studies indicated that large numbers of bowheads were in the greater region at the time of the Pioneer surveys, and the fall whaling season was successful in Kaktovik, Nuiqsut and Barrow. Underwater acoustic recordings made during the same period as Pioneer's aerial surveys did not detect any whale vocalizations. Historical survey data (Moore 2000; Treacy et al. 2006) is consistent with these findings and supports the hypothesis that bowhead whales prefer deeper water than the area within 20 miles of ODS.

BP (Northstar)—Acoustic Studies 2006 [4]

Introduction

Since 2000, the autumn migration of the bowhead whale has been monitored acoustically north of Northstar Island for a nominal 30 days per year during the month of September. This monitoring has occurred during construction through the production period. Every year since 2001, continuous underwater recordings were obtained close to Northstar Island to determine the levels and frequency composition of sounds produced by the island and associated vessels. From 2000 to 2004, whale calls were monitored continuously by an array of Directional Autonomous Seafloor Acoustic Recorders (DASARs), deployed 6.5–21.5 km (4–13.4 mi) NNE of Northstar. After retrieval of the instrumentation, the whale calls recorded by the DASARs were localized by triangulation. The key objective of the monitoring in 2001–2004 was to estimate the offshore displacement of the southern edge of the bowhead migration corridor, if any, at times when higher-than-average levels of underwater sound were being emitted from Northstar Island and its associated vessels. Overall, the offshore distance of the apparent southern (proximal) "edge" of the migration corridor was significantly ($P < 0.01$) associated with industrial sound output each year. The best estimates of the offshore deflection of the southern part of the migration corridor at times with high Northstar sound ranged from a low of 0.66 km (0.41 mi) in 2003 to a high of 2.24 km (1.39 mi) in 2004.

Based on the results achieved in 2001–2004, BP, the Science Advisory Committee (SAC) appointed by the North Slope Borough to review the work, and the team of scientists conducting the study concluded that monitoring as carried out in 2001–2004 did not need to be repeated every year. The 2006 effort discussed here is similar to that carried out in 2005, and is a modified effort compared to those in 2001–2004. Results from 2001–2004 are summarized in Greene et al. (2002, 2003), and Blackwell et al. (2006a,b). Results from 2005 are summarized in Blackwell et al. (2006c). This discussion of the 2006 study with references to the preceding years is summarized from the report by Blackwell et al. (2007).

The specific objectives in 2006 were as follows:

- to measure near-island sounds about 450 m (1476 ft) north of Northstar using DASARs (one primary DASAR whose data were to be analyzed plus two spares for backup), and to compare the amplitude and frequency composition of the sounds with similar data collected in previous years.
- to install a small array of DASARs in three of the locations used in previous years (see below), analyze the data from one of these units to count whale calls as in previous years, and compare the whale counts at the chosen DASAR with whale counts obtained at the same location in 2001–2005.

After the end of the 2006 field season, BP decided to analyze whale calls from all DASARs that were deployed in the offshore array (instead of counting whale calls from only a single DASAR, as was originally planned). The additional analyses added three main objectives to the two original objectives listed above:

[4] Summarized by LGL from a detailed technical report by Greeneridge Sciences, Inc. (Blackwell et al. 2007).

- obtain whale call counts from all three offshore DASAR locations in 2006, and compare the counts with whale call counts obtained at the same locations in 2001–2005.
- obtain bearings to whale calls and localization of calls, if possible. A comparison of the bearings or locations obtained in 2006 with those obtained in previous years should provide information on the distribution of the calling whales, i.e., the proportion of calls originating offshore vs. inshore of the locations of the DASARs deployed in 2006.
- compare the types of calls recorded at the DASAR locations used in 2006 with the call types recorded at the same locations in previous years.

Methods

Directional sensors from DIFAR (Directional Frequency and Recording) sonobuoys were used, along with digital recording equipment and batteries, to construct Directional Autonomous Seafloor Acoustic Recorders (DASARs). For a complete description, see Greene et al. (2004). The DIFAR sensor includes a compass, two horizontal orthogonal directional sensors, and an omnidirectional pressure sensor to sense an acoustic field. DASARs record at a sampling rate of 1 kHz onto a 25.38-GB disk drive. This allows for continuous sampling for up to 45 days and spans an acoustic range up to 500 Hz, adequate for bowhead vocalizations.

In 2001–2004, DASARs were deployed at 10 locations 6.5–21.5 km (4–13.4 mi) NNE of Northstar (see Fig. 11.4, filled triangles, open diamonds, and open square). In 2005, DASARs were deployed at three of the locations used in 2001–2004: WB, CC (2 DASARs) and EB. In all years, the DASARs recorded continuously for the entire field season, usually late August/early September until late September/early October (range 24 to 35 days). Whale calls were tallied on all DASAR records. When a whale call was recorded by two or more DASARs in 2001–2004, a position for the calling whale was obtained by triangulation, using the DASAR bearing information. In 2005 bearings were obtained only for EB (the other DASARs having moved on the seafloor during their deployment), so no whale call positions were calculated.

A continuous record of sounds from Northstar Island and its attending vessels was also obtained by deploying several redundant recorders ~450 m (1476 ft) north of the island's north shore (see Fig. 11.4, open triangle). One minute of data was used every 4.37 min (or ~330 times per 24-h day) to calculate mean broadband and one-third octave band levels, and spectrum levels. One-third octave band levels were also used to define an Industrial Sound Index (ISI). The ISI was determined from the sum of the mean-square sound pressures in the five one-third octave bands centered at 31.5, 40, 50, 63, and 80 Hz, i.e., including frequencies from 28 to 90 Hz. These five one-third octave bands contain most of the industrial sound energy emanating from Northstar (Blackwell 2003).

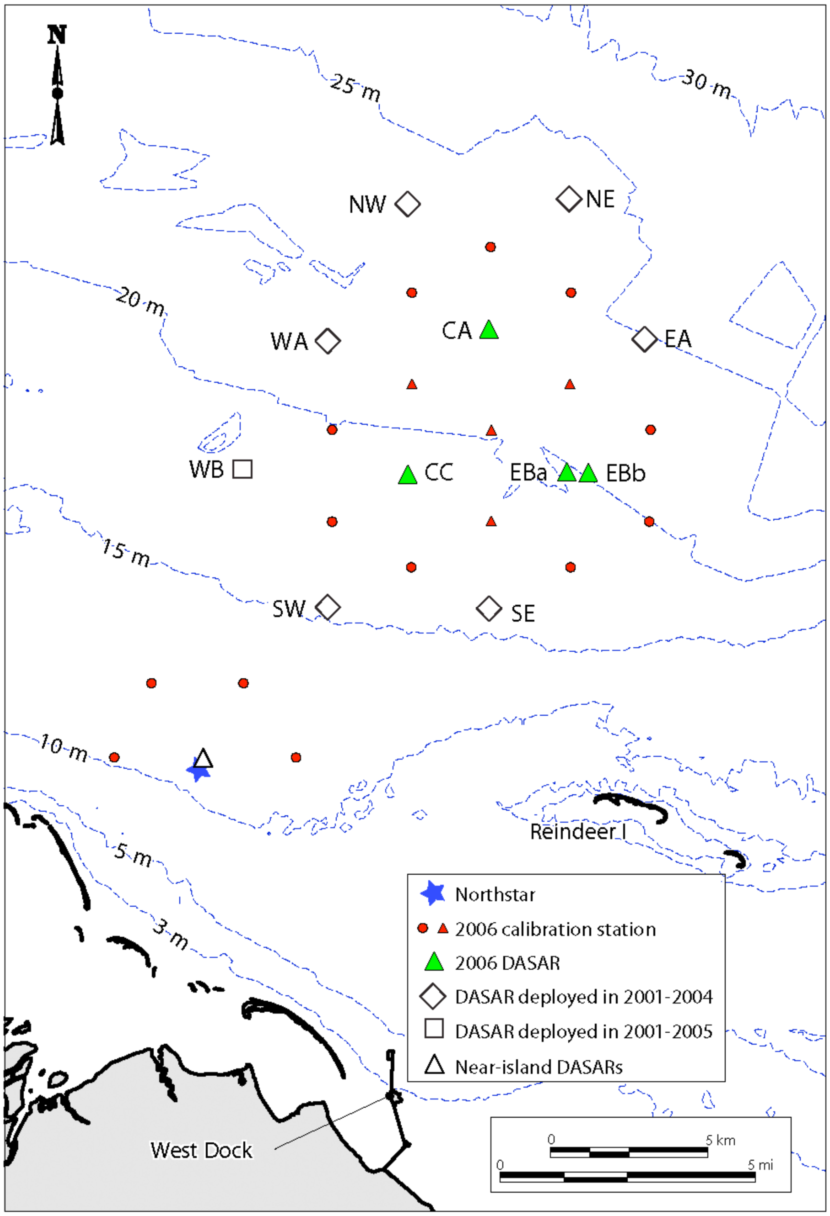

FIGURE 11.4. Locations of four array DASARs, 17 calibration stations, and three near-island DASARs (see Fig. 2.2) with respect to Northstar Island, September 2006. DASAR locations used in 2006 are shown with green triangles. In 2005, locations used were limited by ice, and included WB, CC, and EB. All DASAR locations (including those identified by empty diamonds and squares) were used in some or all of 2001–2004. On 29 Aug. 2006, calibrations were performed at the four locations surrounding Northstar Island. On 7 Sept., calibrations were performed at the locations indicated by red triangles. On 24 Sept., calibrations were performed at all mapped calibration locations.

On 29 Aug. 2006, three near-island DASARs (NSa, NSb, and NSc) were deployed ~410 m, 410 m, and 465 m (1345–1525 feet) northeast of Northstar's north shore (Fig. 11.4). Water depth was about 13 m. Ice and fog prevented further deployment until 7 Sept., when DASARs were deployed at locations EB (2 DASARs), CC, and CA, at distances 11.5–16.6 km (7.1–10.3 mi) NNE of Northstar Island (Fig. 11.4). After DASAR deployments on both 29 Aug. and 7

Sept., an acoustic transponder in each DASAR was interrogated to confirm that each DASAR was operating nominally. All seven DASARs recorded continuously at a 1 kHz sampling rate until they were retrieved on 25 Sept. 2006.

Each DASAR contained a magnetic compass and clock. However, to provide greater precision in times and bearings if used, the DASAR clocks and orientations were calibrated by projecting test sounds at known locations and known times, and receiving these sounds via the DASARs.

Whale call data from all four offshore DASARs (EBa, EBb, CC, and CA) were analyzed in the same way as they have been in the past (2001–2005, see Greene et al. 2002, 2003; Blackwell et al. 2006a, 2006b, 2006c). As in previous years, recordings obtained while the acoustic crew's vessel was in the DASAR array were not analyzed. Whale calls were tallied on all offshore DASARs by examining all DASAR records simultaneously, minute by minute, to count calls and to determine call types.

During the whale call classification process, the bearing from each DASAR to each detected call was determined automatically. In 2006, all DASARs were stable on the seafloor (this had not been the case in 2005), so a bearing was obtained for each call and whale positions were obtained for those calls detected by at least two DASARs. Bearings in 2006 were compared with those from all previous years (2001–2005).

Results

All DASARs functioned throughout their deployment. The sound levels recorded by the three near-island DASARs (NSa, NSb, and NSc) were in close agreement. DASAR NSc was used for data analyses, as this DASAR had the most stable compass bearings over its deployment. The signals from DASAR NSc were analyzed to determine the broadband (10–450 Hz) level of underwater sound based on a one-minute analysis every 4.37 minutes. The combined results are presented in Figure 11.5B for the period 31 Aug.–24 Sept. 2006. The range of broadband levels shown for 2006, 90–131 dB re 1 μPa, is similar to that reported for 2002, 2003, 2004, and 2005: 90–135, 90–137, 92–133, and 88–136 dB re 1 μPa, respectively.

Broadband levels close to Northstar are determined by a combination of two factors: sound-generating industrial activities at and near Northstar (including associated vessels) and wind speed, which determines ambient sound levels. Figure 11.5A shows mean hourly wind speed as recorded by the Northstar weather station[5]. The lowest levels in Figure 11.5B are indicative of the quietest times in the water near the island, and generally correspond to times with low wind speeds. Conversely, times of high wind speed (e.g., 12, 17, or 22 Sept.) usually correspond to increased broadband levels in the DASAR record (Fig. 11.5B). However, there are many additional times with elevated broadband levels that do not correspond with periods of high wind speed. Data from previous years have shown that most of the peaks not related to high wind speed are attributable to industrial sound, and most often to vessel activity from Bay class boats, tugs, and barges (Blackwell and Greene 2006). The hovercraft is not a major sound source near Northstar Island (Blackwell and Greene 2005b).

[5] Northstar weather data are available at http://www.resdat.com/mms/

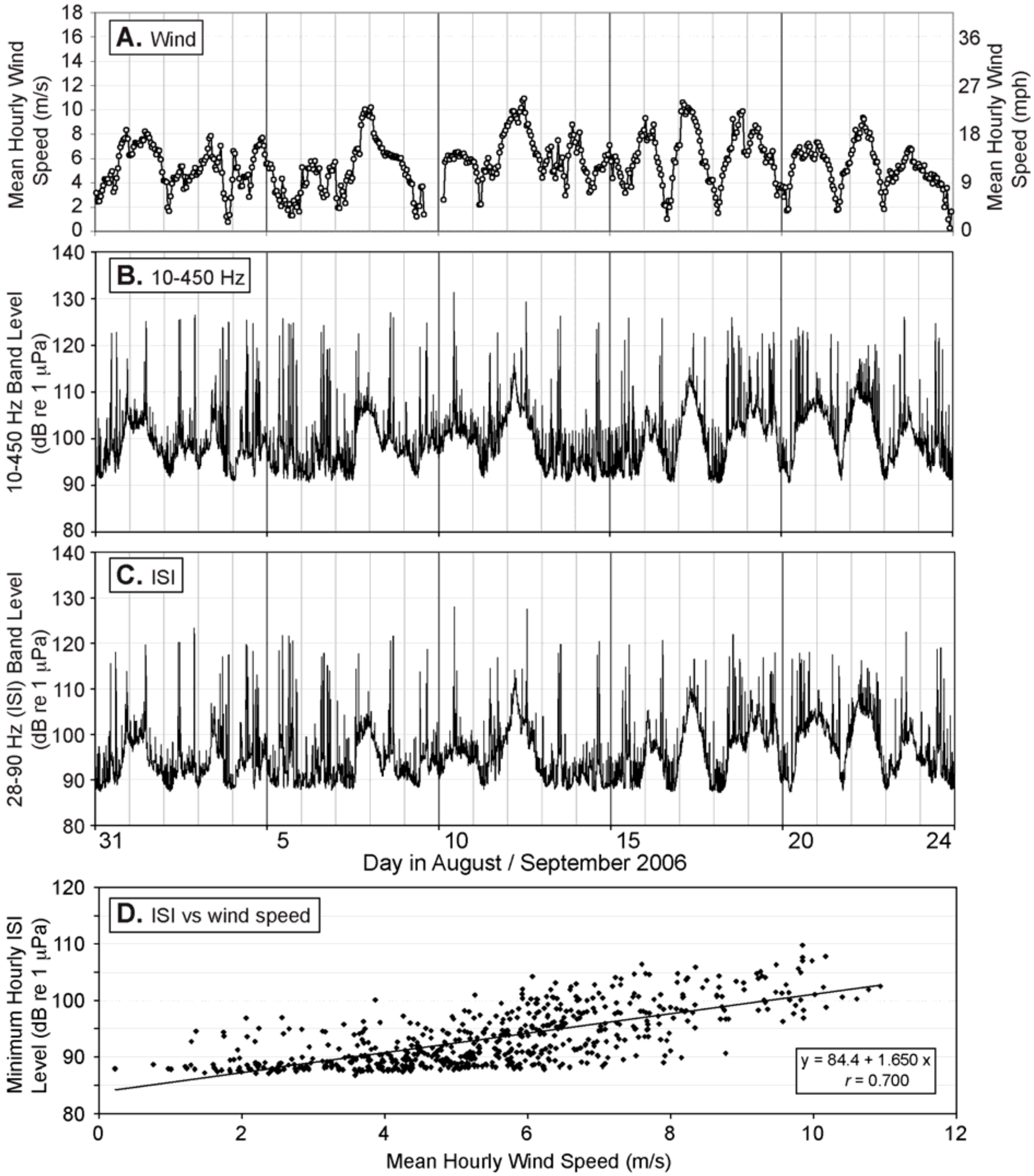

FIGURE 11.5. Variation in levels of underwater sound near Northstar in relation to date/time and wind speed, 31 Aug.–24 Sept. 2006. ***(A)*** Mean hourly wind speed as recorded by the Northstar weather station. Note that this weather station does not record north winds correctly, as the wind vane is shielded by a building in that direction. ***(B)*** Broadband (10–450 Hz) levels of underwater sound near Northstar vs. time, as recorded by DASAR NSc. This recorder was deployed 465 m (1525 ft) north of Northstar. ***(C)*** Corresponding ISI band level (~28–90 Hz) from DASAR NSc. ***(D)*** Minimum hourly ISI level versus mean hourly wind speed for 2006.

The sum of sound components in the frequency range 28 to 90 Hz is defined as the *Industrial Sound Index* (ISI). The ISI for the 2006 study period is shown in Fig. 11.5C as a function of time. As in previous years the ISI was closely related to the overall 10–450 Hz level, but the ISI tended to be a few decibels lower (as a consequence of excluding sound components at frequencies 10–28 Hz and 90–450 Hz.). Direct comparison of the two values showed that 1-min ISI values were, on average, 4.2 dB below 10–450 Hz broadband values in 2006. This difference was 5.7 dB in 2005, 5.0 dB in 2004, and 5.7 dB in 2003. As in previous years, when wind speed was high so were average broadband and ISI levels (Fig. 11.5D).

Specific Island Sound Sources

Vessels—As has been the case since 2004, personnel and goods were transported to the island with the hovercraft and, when weather conditions precluded its use, with helicopters. In addition, ACS vessels and tugs[6] (usually accompanied by a barge) made trips to Northstar.

- The *hovercraft* made a total of 141 round trips to Northstar during the 32 days for which we have information (30 Aug.–30 Sept.), or on average 4.4 trips/day. (All references to "trips" in this subsection refer to round trips.) This is 2.8 and 7.3 times the mean number of daily trips in 2005 (1.6 trips/day) and 2004 (0.6 trips/day). Mechanical problems prevented use of the hovercraft on 19–20 Sept. As in previous years, the arrivals and departures of the hovercraft at Northstar were not detectable on DASAR NSc's sound pressure time series (e.g., Fig. 11.5B).
- *Tugs and barges* made 29 trips to Northstar in 30 days, i.e., an average of ~1 trip/day. This is higher than in 2005 (0.5 trips/day) and 2004 (0.4 trips/day), but still below the average barge traffic in 2003 (1.6 trips/day).
- *ACS vessels*[7] (excluding the vessel used by the acoustics crew) made 31 round trips to Northstar in 32 days, an average of ~1 trip/day. This is three times the number of daily trips in 2005 (0.33 trips/day), and about 1.5× the number of daily trips in 2004 (0.7 trips/day).

Round trips to the island by tugs and ACS vessels combined (including the ACS "Bay" boat used for the acoustic work) accounted for >85% of all the large "spikes" in DASAR NSc's sound pressure time series (Fig. 11.5B). Figure 11.6 shows broadband (10–450 Hz) sound levels as recorded at the near-island recorders in 2001–2006. In all years, vessels operating near Northstar (excluding the hovercraft) had a strong influence on overall sound levels. The number of "vessel spikes" in the sound pressure time series steadily decreased from 2001 through 2004, remained about the same in 2005, and showed an increase in 2006.

Underwater Sounds Offshore at DASAR EB

Figure 11.7 shows broadband (10–450 Hz) levels of sound as recorded offshore at DASAR EB in 2001–2006. DASAR EBa was 15 km (9.3 mi) northeast of Northstar (Fig. 11.4). During calibrations on 24 Sept. 2006, no health checks to determine the status of the equipment were performed, so the vessel never got closer than ~2 km from DASAR EBa, which explains

[6] These were the *Kuparuk River* (made >75% of trips), *Kavik River*, *Siku*, and *Sinuk.*

[7] These were all trips by "Bay" boats, which are 12.8 m (42 feet) long aluminum-hulled OSRVs (oil spill response vessels).

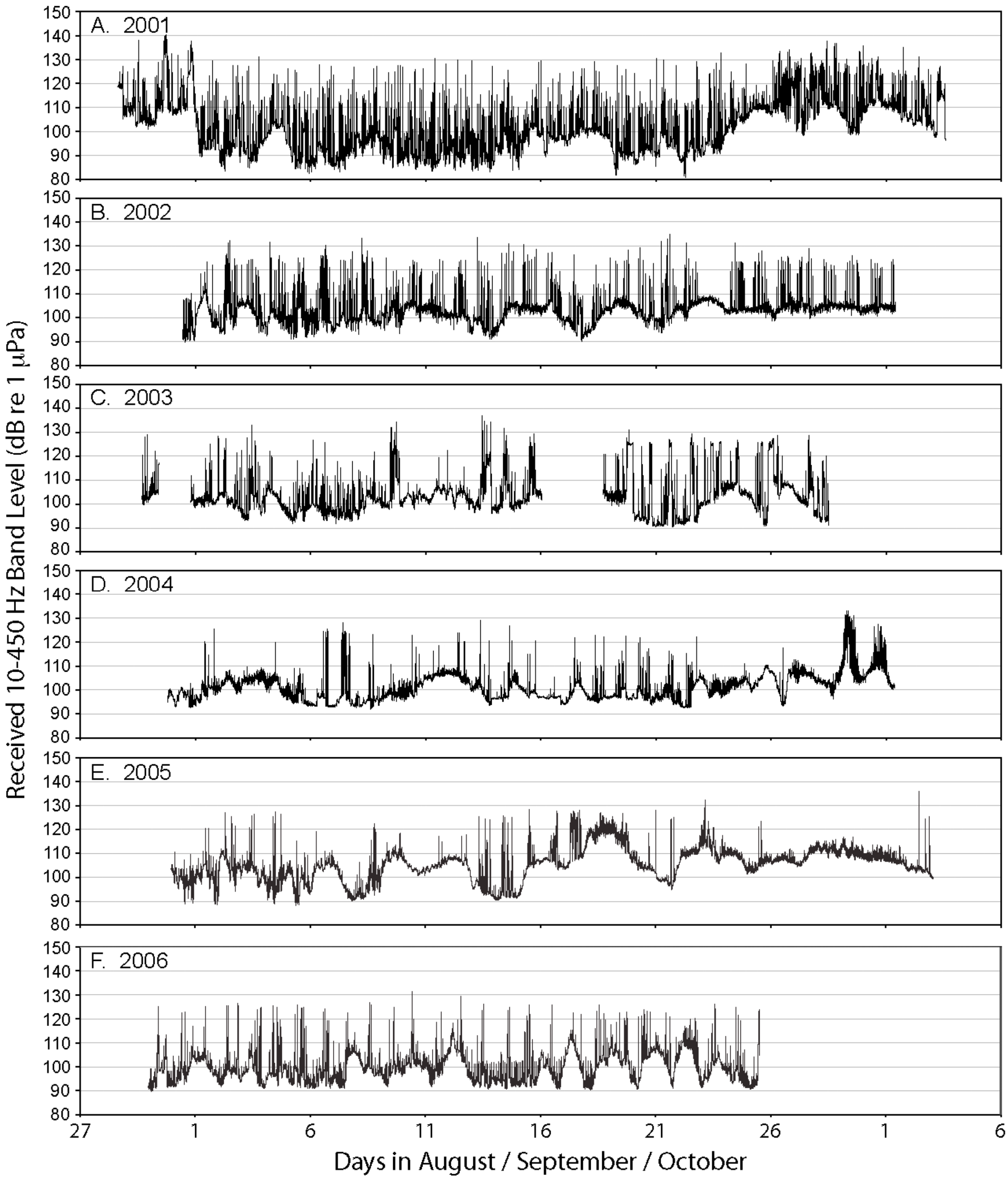

FIGURE 11.6. Sound pressure time series (10–450 Hz band level) for the 2001–2006 seasons, as recorded by the near-island recorders—a cabled hydrophone in 2001, 2002, and the first part of 2003, and a DASAR for the second part of 2003, and all of 2004, 2005, and 2006.

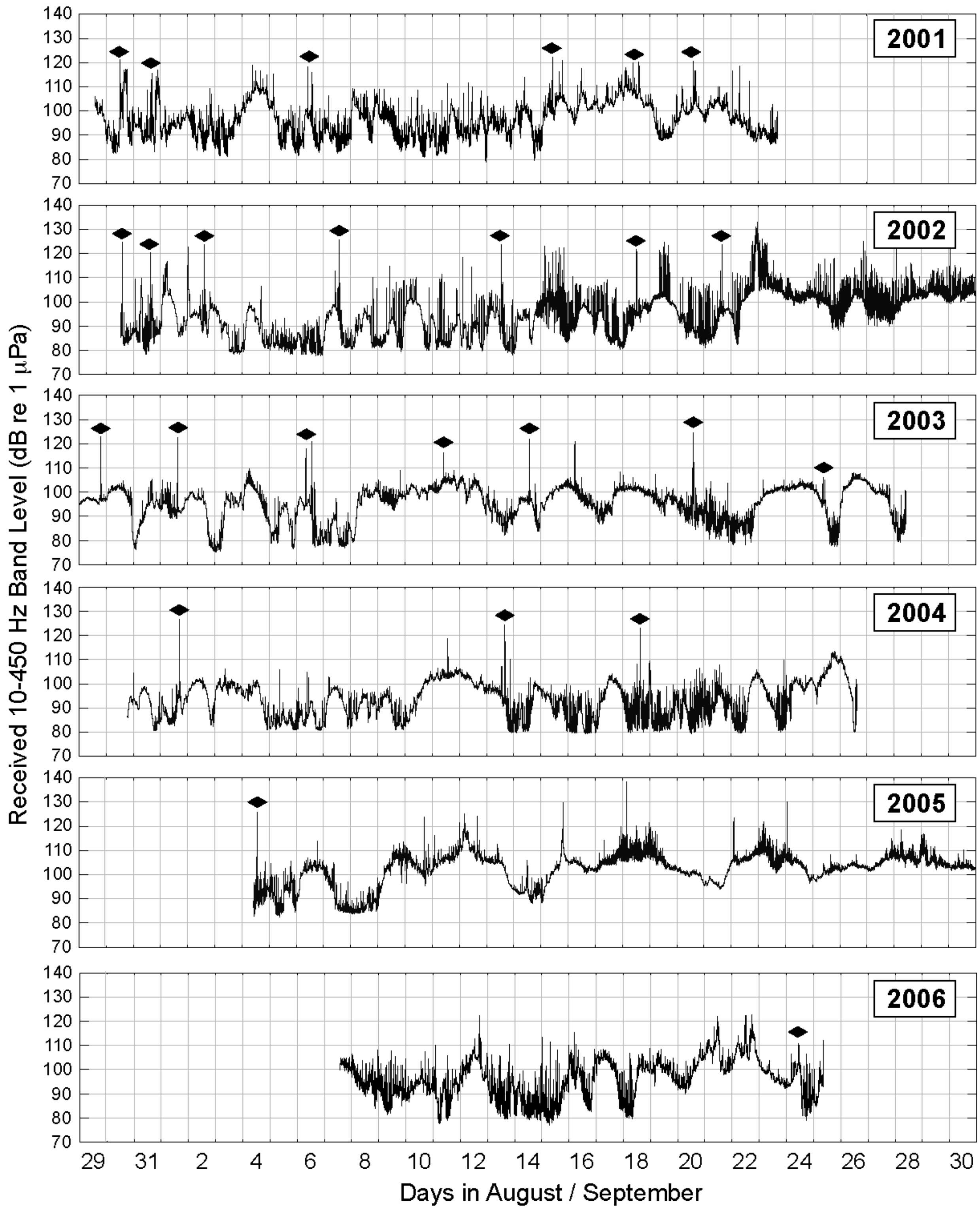

FIGURE 11.7. Broadband (10–450 Hz) sound pressure levels (SPLs) vs. time as recorded by DASAR EB in 2001–2006. Diamonds indicate spikes (brief periods of higher-level sound) created by the acoustic crew's vessel during servicing of the DASAR array.

the small size of the spike (Fig. 11.7). The vessel was also traveling more slowly than usual because of the ice. Baseline8 levels of sound at DASAR EB are mainly a function of sea conditions, and therefore wind speed. Wind-induced sound levels in 2006 were lower than in 2005 and comparable to the levels obtained in 2001–2004.

Number of Whale Calls Detected

A total of 1509 calls were detected on the records of DASARs CC, EBa, EBb, and CA combined during the 7 Sept. to 25 Sept. period in 2006 (another seven calls were heard only by the near-island DASARs). This is the lowest seasonal call count for these DASARs for the period 2001–2006, but it should also be noted that 2006 was the year with the fewest days of recordings offshore. Table 11.2 compares call counts in the different years. In 2006, there were two DASARs at location EB (EBa EBb), so to allow meaningful comparisons with previous years we have included only one of the EB DASARs (EBa) in Table 11.2. (EBa was chosen over EBb because EBa was closest to the EB locations of previous years.) Also, to allow comparison of 2006 values with all previous years, Table11.2 shows only counts for DASARs EB and CC. (CA could not be deployed in 2005 due to ice.) The mean number of calls detected per day was calculated using only days when both recorders were functioning normally (2001: 14 out of 35 days; 2002: 23 out of 24 days; 2003: 30 out of 30 days; 2004: 27 out of 33 days; 2005: 29 out of 29 days; and 2006: 18 out of 18 days). The percentages of calls detected at CC and EB add up to more than 100% because some calls were heard by both DASARs. However, when expressed as a number of calls per day, the 2006 number was slightly higher than the 2005 number for the same DASARs (Table 11.2).

[8] The ***baseline*** refers to the lower edge of an “envelope” around the plotted sound pressure time series.

TABLE 11.2. Comparison of bowhead whale call counts via DASARs EB (EBa in 2006) and CC (CCa in 2005) combined in 2001–2006. Also shown for each year are mean number of calls detected per day (considering only days when both DASARs were operating), and percentages of those calls detected at each of the two DASAR locations. See text for details.[a,b]

			Percentages of calls detected	
Year	Total calls detected at EB and/or CC	Mean # calls per day [a, b]	EB	CC
2001	1542	110	97.2	9.3
2002	4775	208	90.2	43.0
2003	26,401	895	82.3	62.6
2004	31,903	1182	83.1	72.8
2005	1020	35	62.5	56.5
2006	677	38	49.0	57.0

[a] Mean number of calls per day for individual DASARs EB and CC were as follows: **2001**, 107 and 10, respectively; **2002**: 187 and 90; **2003**: 737 and 560; **2004**: 982 and 915; **2005**: 22 and 20; **2006**: 18 and 21. For each year, these values consider days when both of these DASARs were operating.

[b] In **2000**, the DASAR array was 1 n.mi. farther north than in 2001–2006, with no functional DASAR near EB. The recorders closest to DASAR CC were SW1 located 1850 m north of CC, and SW2 ~4650 m southwest of CC (Greene et al. 2001). SW1 recorded 1177 calls over 11.7 days, or 100 calls per day; SW2 recorded 1012 calls over 5.7 days, or 177 calls per day.

Figure 11.8 compares the daily number of calls detected by DASARs EB and CC combined in 2006 with those of previous years. In 2001, most of the calls were detected in the first part of the season, before 15 Sept., whereas in 2002, 2003 and 2004 most of the calls were detected after 15 Sept. (This is the later part of the field season but the middle part of the bowhead migration period, which extends until mid- to late-October.) The two years with the largest call counts (2003 and 2004) showed three peaks (Fig.11.16): a small peak in early September, a second peak in mid-September, and a third (and largest) peak on 21 Sept. Similarly, 2005 and 2006 exhibited several peaks over the course of the season: 7, 14, and 20 Sept. in 2005, and 11 and 23 Sept. in 2006. One must keep in mind, however, that sample sizes in 2005–2006 and 2003–2004 differ by nearly two orders of magnitude.

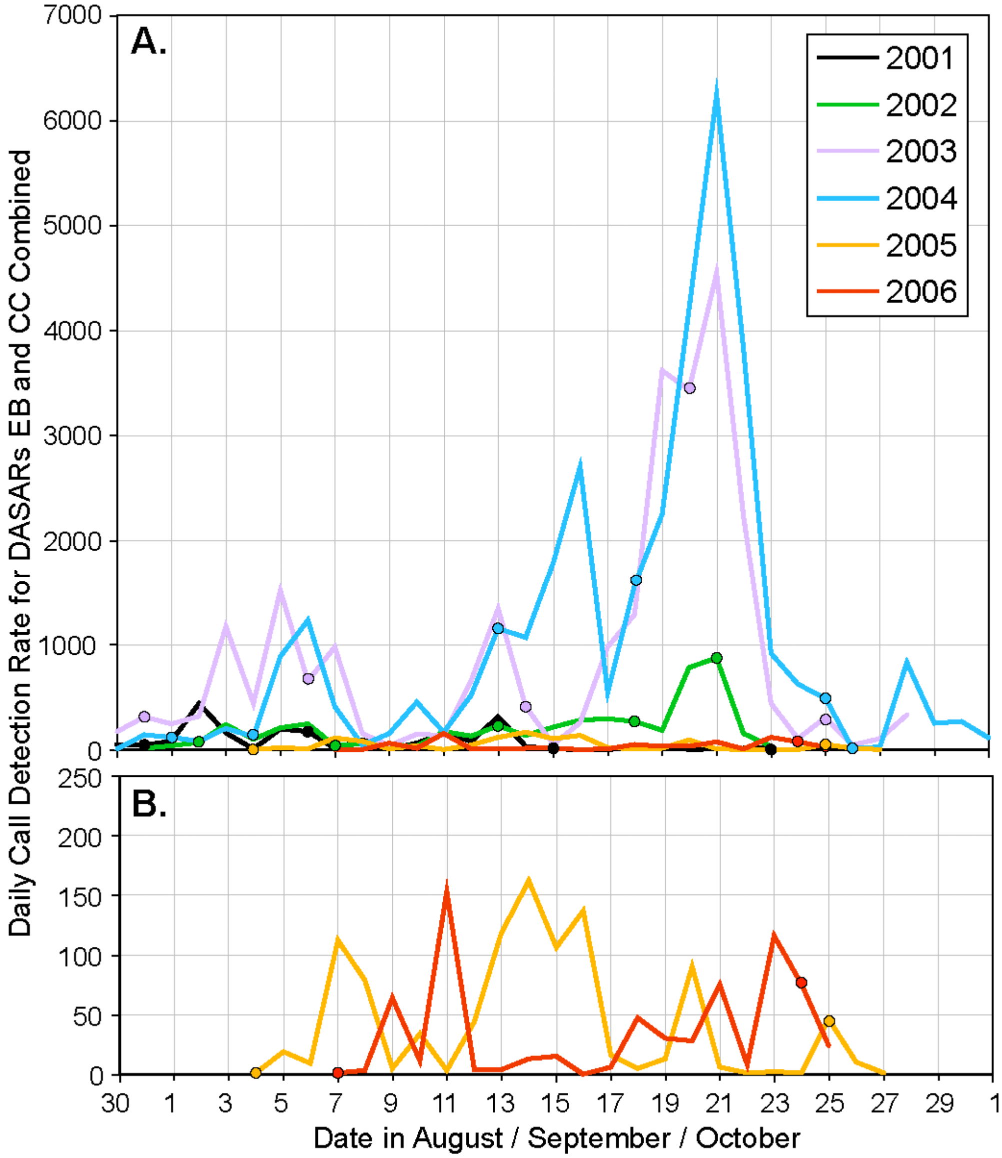

FIGURE 11.8. Daily number of bowhead calls detected by DASARs EB and CC combined for the entire 2001–2006 seasons. ***(A)*** 2001–2006, and ***(B)*** 2005 and 2006, on an enlarged scale. Daily counts marked with a dot indicate days when the acoustic vessel went into the area of the DASAR array to service the DASARs. In 2002–2006, the calls detected at those times were not counted, and those days are therefore "incomplete." In 2001, all calls were counted, regardless of the presence or absence of the acoustic vessel.

In 2006 there were a total of 1887 separate call detections at the four offshore DASARs. DASAR CA detected close to twice as many calls as the other three DASARs: 773 (41.0%), versus 386 (20.5%) via CC, 332 (17.6%) via EBa, and 396 (21.0%) via EBb. Location information was available for 214 of the 1509 calls detected by one or more of the four array DASARs. The estimated locations of whale calls in 2006 are shown in Fig. 11.9.

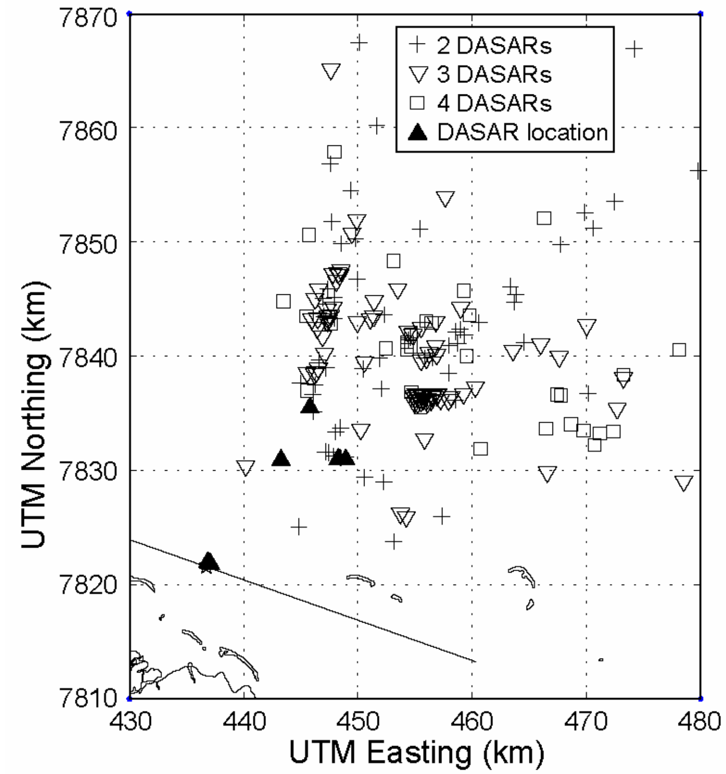

FIGURE 11.9. Estimated locations of all whale calls detected by two, three or four offshore DASARs in 2006. Northstar Island is located near the southwestern DASAR.

Considering all six seasons (2001–2006), vector mean bearings from offshore DASARs EB, CC, and CA to the whale calls detected by these DASARs were most often in the range NNW through N to E, indicating an offshore distribution. Figure 11.10 shows the percentage distribution of all bearings obtained via DASAR EB in each year from 2001 to 2006. The bearings for each year were grouped into thirty-six 10° bins centered on multiples of 10° (i.e., 355°–4.99°, 5°–14.99°, etc.). The number of bearings in each bin is expressed as a percentage of the total number of call bearings determined via DASAR EB for that season. These plots emphasize the preponderance or rarity of bearings in certain directional sectors. For example, the 2002 plot shows that bearings in the range 140°–310° were rare that season, whereas bearings in the range 85°–105° were most common. In terms of their general orientation, DASAR EBa's bearings in 2006 were similar to those in 2001. The 2006 season was similar to 2005 in the presence of ice and the low whale call counts, but the distribution of the bearings was quite different (Fig. 11.10).

Figure 11.10 shows that in 2001–2004 and 2006 the vast majority of bearings from DASAR EB to calls were in the 20°–120° range, i.e., ~NNE to ESE. This is not what we would expect if the whale calls were omnidirectional and the whale calling rate was constant as they swam through the DASAR array past Northstar. This skew towards the east was also seen in DASARs CC and WB in 2001–2004 (not shown), except for DASAR WB in 2001, for which the skew was in the opposite direction (40% of bearings were in the 265°–275° range). It is unlikely that the DASARs would have a bias towards picking up signals from the east if the calls are equally strong "ahead of" and "behind" the predominantly westbound whales. There is some equally indirect evidence of call directionality for bowheads migrating in spring (Clark et al. 1986). The remaining hypothesis, that there is some difference in whale behavior to the west vs. east of the DASARs, has recently received some support. Based on an analysis of bowhead calls in 2001–2004, Blackwell et al. (in prep.) showed that calling rates were significantly higher to the east of Northstar than to the west, with the boundary between "east" and "west" being a line going from Northstar through the center of the DASAR array as deployed in those years, i.e. through DASARs SW, CC, CA, and NE (see Fig. 11.4).

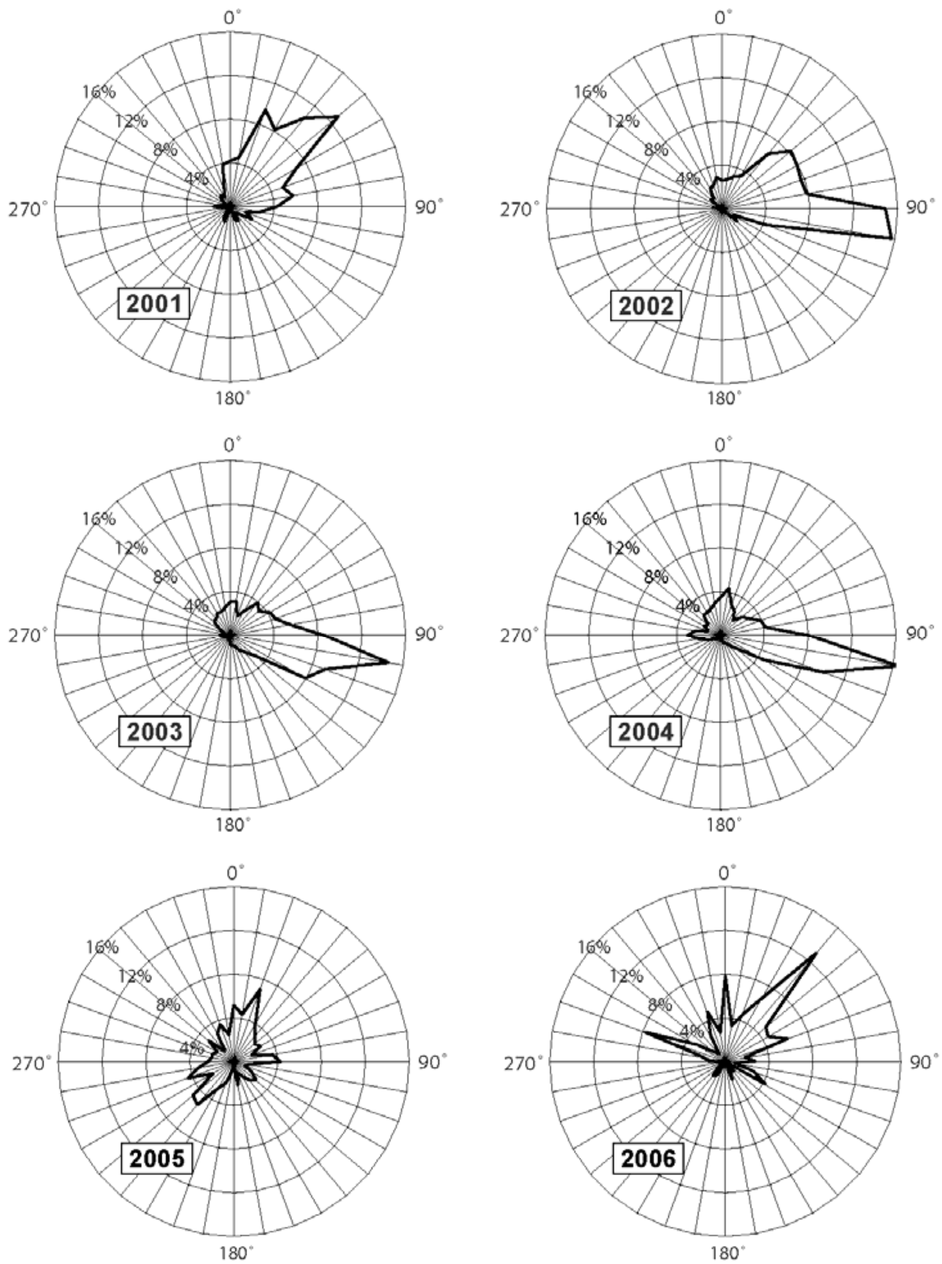

FIGURE 11.10. Directional distribution of bearings to bowhead whale calls detected via DASAR EB in 2001–2006. Results for each 10° sector are expressed as a percentage of all bearings obtained via DASAR EB that year. Sample sizes vary widely, from ~330 in 2006 to ~26,500 in 2004.

Discussion

<u>*Underwater Sounds at Northstar*</u>

Figure 11.6 shows that boat traffic to Northstar Island in 2006 increased compared to 2005. Both tugs and ACS “Bay” boats made more daily round trips to the island, on average, than in 2004 or 2005. Round trips to the island by the hovercraft also increased, with ~3 and ~7 times more trips in 2006 than in 2005 and 2004, respectively. While cruising, hovercraft cause short increases in sound levels underwater that do not register on the sound pressure time series, as recorded by the near-island recorders (Blackwell and Greene 2005b). For that reason, the hovercraft does not count as a major sound source around Northstar, and only the tugs and ACS vessels must be considered. The increased vessel traffic at Northstar in 2006 was probably related to increased maintenance activities or other projects on the island. Also, the weather was so poor (because of wind) during the 2005 open-water season that some island activities may have been postponed until 2006.

Figure 11.6 also shows that after three yearly increases in mean wind speeds (2001–02, 2002–03, and 2004–05), 2006 was a calm year with few days of stormy weather. As a result, 2006 data reflected the lowest and second-to-the-lowest 50th and 95th percentile levels of sound since the beginning of the island sound monitoring in 2001. The maximum percentile level was also amongst the lowest in 2006, but this does not have much significance since maximum levels are mainly determined by boats.

In 2006, broadband (10–450 Hz) sound levels recorded 15 km (9.3 mi) from Northstar at the DASAR EBa location (Fig. 11.7) were unremarkable. From 2001–2004 and in 2006 fluctuations in minimum sound levels due to sea conditions generally had a periodicity of ~1–5 days. In contrast, in 2005 high sea conditions kept minimum ambient levels higher than normal for extended periods, up to two weeks. For 2006, the sound pressure time series shown in Fig. 11.7 contains very few spikes of the type we usually associate with the passage of a vessel. This certainly has to do with the pack ice, which covered the area of the array to some extent for all, or nearly all of the deployment period, and therefore limited boat traffic. The presence of ice also helps explain the small size of the spike created by the acoustic vessel on 24 Sept. during calibrations, as travel speed among ice floes was much reduced compared to that in open water conditions.

<u>*Whale Calls and Locations*</u>

The fall migration of bowhead whales has been monitored acoustically offshore of Northstar Island since 2001. In the first four years (2001–2004) the procedure was roughly the same. In 2005 it was changed on the basis of the results obtained during 2001–2004, and the 2006 season was the second year of the modified effort, which was designed to allow comparisons with data collected in previous years. However, the two recent years with a modified monitoring effort also happen to be years with ice conditions that were very different from those experienced in the first four years of the study. This makes it more difficult to compare data collected with the original (2001–2004) and modified (2005–2006) procedures.

The location of the bowhead whale migration corridor varies annually, and it may have tended to be farther offshore or more scattered in 2005 and 2006 compared to some previous years. Treacy et al. (2006) reported that bowheads migrated nearer shore during years with light ice cover and further offshore during heavy ice year. Since 1982, systematic aerial surveys have been done by or for the MMS off the north coast of Alaska during the autumn migration period of bowhead whales. Their data showed that, in 2004, bowhead whales were sighted on average closer to shore than in previous years (1982–2001; Monnett and Treacy, 2005). Early in the 2005 season (early September), MMS aerial surveyors sighted bowheads north of the area of drifting ice, i.e., several to many miles north of Northstar. Later in the 2005 season, very few flights could take place because of the poor weather conditions. Thus sample sizes over the season were low, and it may not be possible to meaningfully compare distances from shore in 2005 vs. previous years (C. Monnett, MMS, pers. comm.). When available, the MMS aerial survey data for 2005 and 2006 will be useful in documenting the overall position and width of the migration corridor in 2005 and 2006 compared to 2001–2004.

The distribution of bearings to whale calls from DASAR EB in 2006 (Fig. 11.10) was most similar to that in 2001 and quite different from that in 2005, the other year with low call counts. In 2006 calls were mainly coming from the NE, with 51% of calls in the 0–90° quadrant (N to E). The distribution of call locations, shown in Fig. 11.9, has one striking feature: the complete lack of detected calls west of Northstar's longitude, and the very low number anywhere west of the DASARs. This is very different from the distribution of calls in 2002, 2003, and 2004 (see Fig. 9.4 for 2002, Fig. 7.21 for 2003, and Fig. 8.18 for 2004, all in Richardson [ed.] 2006), but somewhat reminiscent of the distribution of calls in 2001 (Fig. 9.3 in Richardson [ed.] 2006). In 2001, like 2006, the total number of calls detected was low, and the proportion of those that were west of Northstar's longitude was very low.

As was hypothesized for the 2005 season, it is likely that the presence of ice in 2006 was important in causing the low call counts. Ice coverage along the coast extended offshore of Northstar, with a band of denser ice surrounded on both sides (N and S) by less dense ice. The ice conditions did not change much during the course of the 2006 field season, and it is conceivable that most migrating bowheads would avoid the ice and migrate in open water ~25 n.mi. (~46 km or 29 mi) from shore when near our study area. Using aerial survey data, Moore (2000) and Treacy et al. (2006) have shown that bowheads tend to select shallow inner-shelf waters close to shore during years with moderate and light ice, and deeper slope habitat farther from shore in heavy ice conditions.

The Nuiqsut whale hunters on Cross Island are always a good source of information on the abundance of bowhead whales during the fall migration. For the 2006 whaling season (2–22 Sept.) the whalers reported that very few whales (~4) were seen during scouting days in early Sept., when ice confined the whalers within the barrier islands. Starting on 10 Sept. the whalers were able to reach the open water beyond the barrier islands, where they saw more whales. The whalers thought that the presence of ice pushed the migration farther north than in years with open water conditions. Nevertheless, they caught their quota of four whales, whereas in 2005 they were never able to get north of the pack ice and caught only one whale.

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12. DISCUSSION, CONCLUSIONS, AND ASSESSMENT OF POTENTIAL EFFECTS OF SEISMIC ACTIVITIES ON MARINE MAMMALS IN THE CHUKCHI AND BEAUFORT SEAS[1]

Introduction

This report has described the results of studies conducted for the 2006 Joint Monitoring Program (JMP) in the Chukchi and Beaufort seas. Studies included an acoustic program using arrays of bottom-founded recorders deployed along the Alaskan Chukchi Sea coast, dedicated vessel-based surveys with and without passive acoustic monitoring (PAM) in the MMS Chukchi Sea Planning Area, and an aerial monitoring program over the nearshore waters and Chukchi Sea coastline between Pt. Hope and Barrow, Alaska. Shell Offshore Inc. (SOI) also conducted some limited acoustic studies and aerial monitoring in the Beaufort Sea in the general area of their operations. In 2006, sea-ice conditions in the Beaufort Sea limited SOI's operations to shallow hazards surveys and other site clearance activities. Acoustic studies conducted by SOI were primarily used to test newly developed equipment for monitoring marine mammals (primarily bowhead whales) and industrial sounds in the Beaufort Sea. Aerial surveys in the central Beaufort Sea were limited to nine surveys due to weather and changes in SOI's planned seismic program.

These studies contribute to the body of knowledge about marine mammals in the Chukchi and Beaufort seas and form the basis for longer term data sets to address potential disturbance of marine mammals by industrial activities. The dynamics of the physical environment in the Beaufort and Chukchi seas create high temporal and spatial variability in conditions that affect marine mammals. While the Chukchi Sea is relatively shallow and uniform in depth, the presence of currents and movements of sea ice alter the suitability of particular areas for marine mammals over variable time scales. The extent and persistence of sea ice in the Chukchi Sea have shown wide variability over the past decade and may be especially important for determining habitat use by walruses, polar bears, beluga whales and other marine mammals. Similar dynamic patterns occur in the Beaufort Sea although there the sea floor depth is much less uniform with deeper water occurring relatively close to shore where the continental shelf transitions to the Arctic Basin.

The spatial and temporal variability in the environment of the Chukchi and Beaufort seas drives large scale movements of many of the marine mammal species that inhabit these areas. These movements lead to wide seasonal variation in habitat use and marine mammal abundance, and to a large degree determine the timing of subsistence hunts of these resources by native people in the area.

This high degree of variability in both the physical and biological aspects of the Chukchi and Beaufort seas makes it challenging to characterize and assess the patterns of marine mammal movement, behavior and abundance, and the potential effects of anthropogenic activities on those patterns. This is particularly true with the limited data set currently available from a single year of studies.

There have been numerous previous studies on marine mammals in the Beaufort Sea over the past two decades focusing on bowhead whales, beluga whales, seals, and polar bears. Industry research and monitoring programs have contributed greatly to our understanding of impacts to marine mammals from oil and gas exploration and production. Various government entities including the Minerals Management Service (MMS) and the U.S. Fish and Wildlife Service (USFWS) have also funded long-term research in the area. In the Chukchi Sea far fewer studies have been conducted in recent years. Many of the data sets

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[1] Dale W. Funk, Robert Rodrigues, Darren S. Ireland, and William R. Koski, LGL Alaska Research Associates, Inc.

are 20 years old, or more, making the 2006 data important for improving the understanding of marine mammal use of the in the Chukchi Sea. Any discussion and conclusions described here should be viewed in the framework of this limited data set which encompasses only one year of data collected across a large area. Interpretation of broad patterns from a single year of data is inherently limited.

Marine Mammal Monitoring in the Chukchi Sea

The JMP used vessel, aerial and acoustic techniques to collect data on the density and distribution of marine mammals in the Chukchi Sea from early July through mid-November 2006.

Five vessel-based surveys using three on-duty observers were designed to estimate densities of marine mammals in the offshore MMS Chukchi Sea Planning Area at locations away from active seismic operations, i.e., at locations where it was assumed there would be little disturbance to marine mammals. These surveys were conducted from July into October (with two surveys occurring in September). As described in Chapter 4, persistent sea ice in the MMS Planning Area greatly affected the surveyed locations. This resulted in much of the survey effort occurring closer to shore and to the pack ice than was planned.

Additional vessel based data were collected during monitoring from the operating seismic ships, chase boats, and various support vessels used during seismic operations. These observations generally occurred over a more limited area as much of the seismic survey activity was located in relatively small blocks within the MMS Planning Area. Later in the season, observations from the GXT seismic ship and support vessel were somewhat wider ranging within the MMS Planning Area.

Aerial surveys were conducted over nearshore waters and the coastline of the Chukchi Sea between Barrow and Pt. Hope at (approximately) biweekly intervals for most of the period from mid-July through mid-November. Surveys began shortly after the annual spring beluga whale hunt by the village of Pt. Lay. Logistical constraints near the end of July prevented surveys from being flown from late July until late August. Despite this gap, these data provided insight into timing of movements and relative abundance of marine mammals along the Chukchi Sea coast during summer and fall 2006.

Acoustic studies were conducted along the Chukchi Sea coast using bottom-founded recorders. Five recorders were deployed off each village (Cape Lisburne, Pt. Lay, Wainwright, and Barrow). The five recorders in each area were deployed perpendicular to the coastline from ~5 to 50 n.mi. (9.3 to 92.6 km) offshore. These recorders provided information on the received sound levels from seismic survey activities at various distances from shore, as well as marine mammal vocalizations at those locations.

The design of the aerial and acoustic studies and the impact of ice on the vessel-based surveys skewed the results of these studies toward nearshore locations and limited the amount of data collected farther offshore in the MMS Chukchi Sea Planning Area. Vessel-based results reflect both the areas where seismic work was occurring and the location of the ice pack during the early part of the season.

Cetaceans

Cetacean seasons were defined according to the typical bowhead migration period in the Chukchi Sea, with the early season lasting from July through 25 Sept., mid-season from 25 Sept. through 25 Oct., and late season from 25 Oct. through Nov. (R. Suydam, NSB, pers.com.). Useable cetacean sightings from all vessels combined were greatest in the early season from July through 25 Sept. when the gray whale was the most frequently recorded cetacean species. The detection rate for cetaceans was generally greater from most vessels during non-seismic periods suggesting localized avoidance of seismic survey activities by cetaceans. Harbor porpoises were seen more commonly than expected based on previous studies. In a few cases, species uncommon to the area were documented, such as one fin whale sighting, but in general, the species present and their relative abundances were similar to what has previously been reported for the area (USDOI MMS 2007).

Gray Whales — The gray whale was the most common cetacean species sighted during the early season from seismic and support vessels combined (43 sightings, 146 individuals; Chapter 3). Vessel-based sightings of gray whales declined during the mid-season and all gray whale sightings during the mid-season were from support vessels (9 sightings, 19 individuals). However, based on aerial survey data in the Chukchi Sea (Chapter 5) gray whale sighting rates were slightly higher during the mid-season compared to the early season suggesting continued use of study area during that time. Gray whale sighting rates were highest during the nearshore sawtooth aerial surveys in July when most sightings were of traveling whales, and during the coastline aerial surveys from Aug. to Oct. when most sightings were of feeding whales (Chapter 5). This suggests that in July gray whales may have been moving into the Chukchi Sea and that from August to October they were actively feeding in the study area. Moore et al. (1986) observed inter-annual variability in gray whale abundance with peak abundance occurring in July (1982), Aug. (1983), and Sept. (1984). Gray whales were sighted only once during the late season (in late Oct.). No gray whales were seen during November surveys.

Most of the gray whale sightings during aerial surveys were concentrated in the band within 5 km of shore where few vessel based observations were made. Gray whale use of nearshore habitats was consistent with previous observations (Moore and DeMaster 1998; Moore et al. (2000b)) which reported that gray whales in the Chukchi Sea selected coastal and shoal waters. The northeastern-most of the known recurring feeding areas frequented by gray whales are located in the northeastern Chukchi Sea southwest of Barrow (Clarke et al. 1989). Gray whales routinely feed in the Chukchi Sea during summer. Moore et al. (2000b) reported gray whales summering in the Chukchi Sea clustered along the shore primarily between Cape Lisburne and Point Barrow. In autumn, gray whales clustered near shore at Point Hope and between Icy Cape and Point Barrow, as well as in offshore waters northwest of Point Barrow at Hanna Shoal and southwest of Point Hope. Seismic survey activities and vessel operations generally occurred farther offshore and the reduced number of gray whale sightings from vessels during the mid- and late seasons compared to the early season is likely a result of vessel locations.

Bowhead Whales — The Bering-Chukchi-Beaufort (BCB) stock of bowhead whales migrates north from wintering areas in the Bering Sea through the Chukchi Sea in early-spring (April-May) and arrives in the summering areas in the eastern Beaufort Sea and Amundsen Gulf in June-July. Most of the bowhead whales that winter in the Bering Sea are thought to migrate to the Beaufort Sea during this period. Bowhead whales return to the Chukchi Sea in the fall as they migrate back to the Bering Sea, in at least some cases via feeding grounds along the northeast coast of Chukotka (Sept.-Oct.; Moore and Reeves 1993). Observations from vessels indicated that, in 2006, bowhead whales were most common during the mid-season (25 Sept.-25 Oct.; 18 sightings, 25 individuals) although nearly as many whales were recorded during the early season (9 sightings, 18 individuals). No bowheads were recorded from vessels during the late season (26 Oct. through Nov.). Sighting rates for bowheads during aerial surveys were greatest during the early and late seasons, and few bowheads were recorded during the mid-season. The relatively higher numbers of bowhead observations during the mid- (from vessels) and the late (from aircraft) seasons likely resulted from the movement of bowhead whales through the Chukchi Sea during their fall migration. The mid- and late seasons extend from 26 Sept. through Nov. which includes the period during which fall migrating bowheads typically pass through the Chukchi Sea (Moore and Clarke 1993).

Moore (1992) reported 26 sightings of bowhead whales during July and Aug. in the northeastern Chukchi Sea from 1975 to 1991 and suggested that some bowhead whales may summer in the Chukchi

Sea rather than moving into the Beaufort Sea. In 2006, bowhead whales were observed during aerial surveys in the Chukchi Sea every month except August when few surveys were flown. Whether bowhead whales observed during July remained in the Chukchi Sea for the entire summer is uncertain given the paucity of aerial surveys during August. The whales sighted in July also may have been late spring migrants that continued to move along their migratory path to the Beaufort Sea.

Acoustic recorders placed along the Chukchi Sea coast detected many bowhead whale vocalizations (Chapter 6). Bowhead whales were recorded in the fall by the arrays at Barrow, Wainwright, and Pt. Lay, but not at Cape Lisburne where the three recorders farthest offshore could not be recovered. The array near Barrow detected bowhead whales on each recorder. Detections decreased from Pt. Barrow to Pt. Lay, and a shift in detections relative to the coast occurred from Wainwright, where there was a uniform distribution in detections, to Pt. Lay, where there were mostly inshore detections.

Aerial and vessel survey data from 2006 indicated an increase in bowhead whale abundance during the fall, as would be expected based on the known migration pattern. However, aerial survey data indicated that peak bowhead whale abundance in the study area occurred in Nov., with most sightings in the Pt. Franklin area. This late pulse of whales along the Chukchi Sea coast was somewhat unexpected, since past ship-based surveys in Sept. and Oct. of 1992 and 1993 did not record any bowhead sightings on the western coast of Alaska between Point Hope and Barrow (Moore et al. 1995). However, little prior information was available on bowhead movements in the Chukchi Sea during November. Recent satellite tagging data confirm earlier evidence that at least some bowhead whales continue their westward migration across the northern Chukchi Sea to the Russian Chukchi Sea before migrating south toward the Bering Sea (Mate et al. 2000; Quakenbush 2007; Fig. 12.1). The reduction in call detections at the acoustical arrays from Barrow to Pt. Lay also suggests a possible dispersal of bowheads as they migrated southwest (or west) through the Chukchi Sea. No bowhead whales were seen from seismic or support vessels during Nov. monitoring.

Beluga Whales — Beluga whales were not reported by vessel-based MMOs during periods with useable (or unuseable) conditions (Chapter 3). Beluga whale sighting rates during aerial surveys were similar during the early and late seasons with relatively few beluga observations during the mid-season. Beluga whale sighting rates and numbers of individuals were highest during the early season in nearshore areas within 5 km of shore. However, acoustic recorders deployed along the coast detected only five groups of beluga whales on 285 recorder-days. These detections occurred from mid-July to late Aug.

During June and July, beluga whales congregate in lagoons and nearshore waters along the Chukchi Sea coast, especially Omalik and Kasegaluk Lagoons near Point Lay (Huntington et al. 1999; Suydam et al. 2001; NMFS 2006). Consistent with this, the largest congregation of beluga whales was observed on 9 July during the first survey, when 295 belugas were counted in a single sighting during the coastline survey. There was high variability in the numbers of beluga whales observed along aerial transects from July through Nov. Beluga whale sighting rates were lowest in Aug. and steadily increased through Nov. with most whales recorded farther offshore during the mid- and late seasons. This was consistent with the observations of Clarke et al. (1993) and Moore (2000) who reported that beluga whales were distributed over a wide range and utilized offshore habitats during fall migration through the Chukchi Sea.

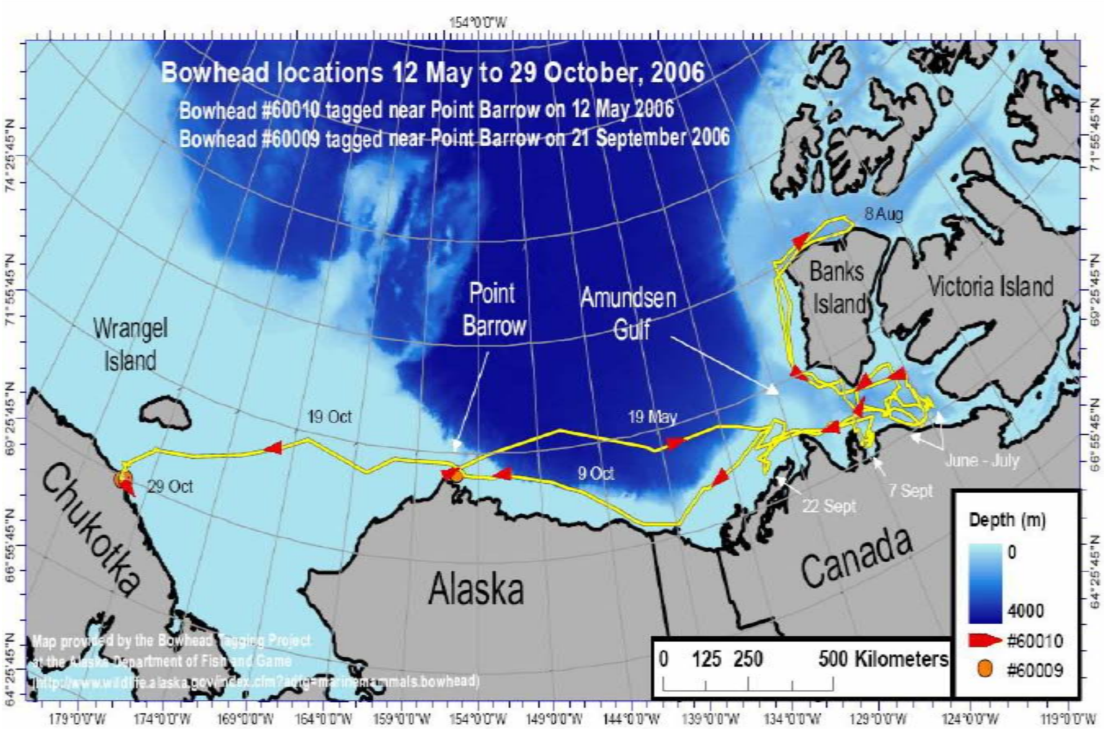

FIGURE 12.1. Bowhead locations during 12 May to 29 October 2006 from satellite telemetry. Arrows show track for whale 60010. The tag for whale 60009 only transmitted intermittently, at Barrow and several weeks later along the Chukotka coast. Data are from Quakenbush (2007) and available online at http://www.iwcoffice.org/_documents/sci_com/SC59docs/SC-59-BRG12.pdf

Satellite tracking of eastern Chukchi Sea beluga whales from 1998 to 2002 indicated that by Aug. some beluga whales moved north of Barrow into the northern Chukchi and Beaufort seas (Suydam et al. 2001, 2005; NMFS 2006). Some of the tagged whales moved into the Canadian Beaufort Sea suggesting overlap between the Eastern Chukchi Sea and the Beaufort Sea stocks. The whales moved back south into the Chukchi Sea by Oct., but were generally farther offshore during their return when compared to their July distribution (Suydam et al. 2001, 2005). The few beluga whale sightings recorded in Aug. and early-Sept. 2006 during aerial surveys (Chapter 5) support the hypothesis that most of the beluga whales occurring in early summer along the northeast Chukchi coast do not spend the late summer in that area, although relatively few surveys were flown during August. However, acoustic detections of beluga whales along the coast indicated that some beluga whales remained in the Cape Lisburne area in Aug. The detection rate during aerial surveys (Chapter 5) increased in Oct. and Nov. when beluga whales would be expected to return to the Chukchi Sea. More of these late-season sightings occurred in a band 30-39 km band from shore rather than along the shoreline. Some of the beluga whales seen during Oct. and Nov. may have been from the Beaufort Sea stock, given the much larger size of that population (39,258, Angliss and Outlaw 2007) compared to the Chukchi Sea population (3710, Angliss and Outlaw 2007).

Pinnipeds

Pinniped seasons were based on changes in weekly pinniped detection rates over the course of the field season with the early season defined as July through 28 Aug., mid-season from 29 Aug. though

8 Oct. and late season from 9 Oct. through Nov. (Chapter 3). The greatest number of pinniped sightings was recorded during the mid-season for both non-seismic (670 sightings, 837 individuals) and seismic (294 sightings, 336 individuals) periods. No pattern of pinniped avoidance of seismic surveys was evident; no pattern in pinniped detection rate in relation to seismic state was evident. Most walruses were seen in relatively large groups hauled out on the ice, although a number of walruses in smaller groups were recorded in open water. The number of walrus sightings was similar in the early and mid-seasons (5 and 7 respectively), but the number of walrus individuals was much greater in the mid-season (780) than in the early season (57) due to large numbers of walruses hauled out on ice. The amount of effort and numbers of walrus detections were too low to make comparisons of walrus detection rates for seismic and non-seismic periods.

Pinnipeds were also documented during the aerial surveys (Appendix F), but generally were not identified to species due to the altitude of the aircraft. Numerous seals were sighted throughout the study period (Appendix E). Useable sightings of walruses were made during 20% (5 of 25) of the coastline aerial surveys. Walruses were seen along most of the coastline between Barrow and Point Hope during the early season when their sighting rate was highest (0.91 walruses per 100 km of survey). Walrus sighting rates along the coastline decreased to zero during the mid-season and then increased to 0.07 walruses per 100 km of survey in the late season. Further offshore on the sawtooth surveys the walrus sighting rate and numbers of individuals were greatest during the early season when pack ice was more prevalent in and near the study area and declined substantially during the mid- and late seasons (Chapter 5).

Pinniped densities calculated from vessel-based observations ranged from ~0.07 to 0.61 pinnipeds/km^2. We know of no other vessel-based densities for pinnipeds in the Chukchi Sea. Densities reported for ringed and bearded seals by Bengtson et al. (2005), based on aerial surveys in the eastern Chukchi Sea, ranged from 0.07 to 0.14 bearded seals/km^2, and 1.62 to 1.91 ringed seals/km^2. No correction factor was applied to the bearded seal densities and actual bearded seal densities may be greater than that reported by Bengtson et al. (2005). Although the density reported by Bengtson et al. (2005) for ringed seals alone was greater than the densities reported here for all pinnipeds, the Bengtson et al. (2005) aerial surveys were conducted earlier in the year (May/June) than the current surveys, primarily over pack ice, and cannot be considered equivalent to the current vessel-based surveys.

Polar Bears

Five sightings of polar bears (4 useable and 1 non-useable) were reported from vessels in the pack ice, all during non-seismic periods (i.e., during periods uninfluenced by seismic activities). No polar bears were reported during aerial surveys along the Chukchi Sea coast and over nearshore waters. Polar bears occur in most ice covered seas of the Northern Hemisphere including the coastal waters of the Bering, Chukchi, and Beaufort seas. Over most of their range their distribution is primarily limited to locations near sea ice. Sea ice disappears from most of the Chukchi Sea during summer and polar bears migrate north with the drifting pack ice (Garner et al. 1990, 1994; Amstrup 2000). Therefore the low numbers of polar bears seen during the surveys in the Chukchi Sea were not surprising.

Marine Mammal Monitoring in the Beaufort Sea

Industry operations in the Beaufort Sea were limited by sea-ice coverage to shallow hazards surveys and site-clearance work by SOI. Aerial surveys were limited to only 9 surveys flown over SOI's operations in the Camden Bay area. Acoustic studies conducted by SOI were primarily used to test newly developed equipment for monitoring marine mammals (primarily bowhead whales) and industrial sounds in the Beaufort Sea. At the request of the "SNACS" project investigators, some aerial surveys of the established "Study of the Northern Alaska Coastal System" survey lines near Barrow were flown to collect information on bowhead distribution and use in an area where oceanographic and biological data had been collected earlier in 2006 and in 2005.

Cetaceans

***Beluga whales* —**The westward migration of beluga whales through the Alaskan Beaufort Sea begins in Aug. (Moore and Reeves 1993). Beluga whales were sighted in the Camden Bay area during four of the nine surveys conducted from 26 Aug. through 24 Sept. 2006. Poor weather conditions limited surveys in mid- to late Sept. and no surveys were conducted in Oct. Peak beluga abundance during the study period occurred during early-Sept. Beluga whales were also reported in the SNACS survey area near Barrow during early Sept. (Appendix G). Past studies have reported peak beluga abundance in the central Alaskan Beaufort Sea in early-Oct. (Miller et al. 1999).

Beluga whales in the Camden Bay area were predominantly observed far offshore with peak detection rates 55 to 65 km from shore (Chapter 8). As in past studies (Miller et al. 1999; Moore et al. 2000a), beluga whales were generally found farther offshore than bowhead whales. Similar results were seen in the SNACS survey area near Barrow (Appendix G) where most beluga whale sightings (n = 219; 75%) occurred at distances > 50 km from shore. Only 73 beluga whales were documented within 50 km of shore. Beluga whales were typically observed in water > 100 meters (m) or 305 feet (ft) deep, although they were also observed within the 50 m isobath (Chaper 8).

***Bowhead whales* —** The BCB stock of bowhead whales migrates eastward through the central Alaskan Beaufort Sea in spring (April to mid-June), and arrives in summering areas in the Canadian Beaufort Sea and Amundsen Gulf in May-July. Most bowheads do not return to the Alaskan Beaufort Sea until fall (late Aug. to late Oct. or possibly later; Moore and Reeves 1993; Miller et al. 2002), although a few bowheads may remain in the northeastern Chukchi Sea during summer (Moore 1992). Bowhead whales were present in the Camden Bay area throughout the 2006 aerial survey period, 26 Aug. - 24 Sept. During the 2006 aerial surveys (Chapter 8), the highest numbers of bowheads were seen on 6 Sept. (17) and peak bowhead abundance in the study area apparently occurred during early Sept. Near Prudhoe Bay, where bowhead calls were monitored from 7 to 25 Sept. in 2006, maximum call detection rates occurred on 9, 11 and 23-24 Sept. (Blackwell et al. 2007a). Peak migration near Kaktovik is usually around 18 Sept. (Figure 12.2) with the majority of whales passing Kaktovik from about 3 to 25 Sept. (Miller et al. 2002).

Most bowhead whale sightings during 2006 were in the northern one-third of the survey area with the greatest proportion in a band 45-55 km from shore in waters 40 to 100 m deep. Bowhead whale distribution in the Alaskan Beaufort Sea during late summer and autumn varies with ice conditions (Moore 2000; Treacy et al. 2006). Bowhead whales tend to occur farther offshore in years of heavy ice conditions (95% CL: 67.2-79.6 km) compared to years of moderate (95% CL: 44.8-53.8 km), or light (95% CL: 30.0-32.4 km) ice conditions (Treacy et al. 2006). During the Beaufort Sea aerial surveys, 0-40% ice conditions were recorded on the southern ends of the transect lines, and open water on the northern ends of the lines. Most bowhead sightings were recorded in shelf waters shoreward of the shelf break, although little of the survey area was beyond the shelf break (Fig. 12.3 and Chapter 8). A similar distribution was reported during the 2006 BWASP surveys which extended from the shore to locations beyond the shelf break (Chapter 9). Acoustic monitoring near Prudhoe Bay suggested that the bowhead migration in Sept. 2006 tended to be farther offshore than at most times in 2001-2005, possibly related to the greater amount of ice in nearshore waters during 2006 (Blackwell et al. 2007a). Based on the results of the two aerial surveys plus the acoustic data, bowhead distribution in early-autumn of 2006 appeared consistent with that expected during a year with moderate ice conditions (*cf.* Treacy et al. 2006).

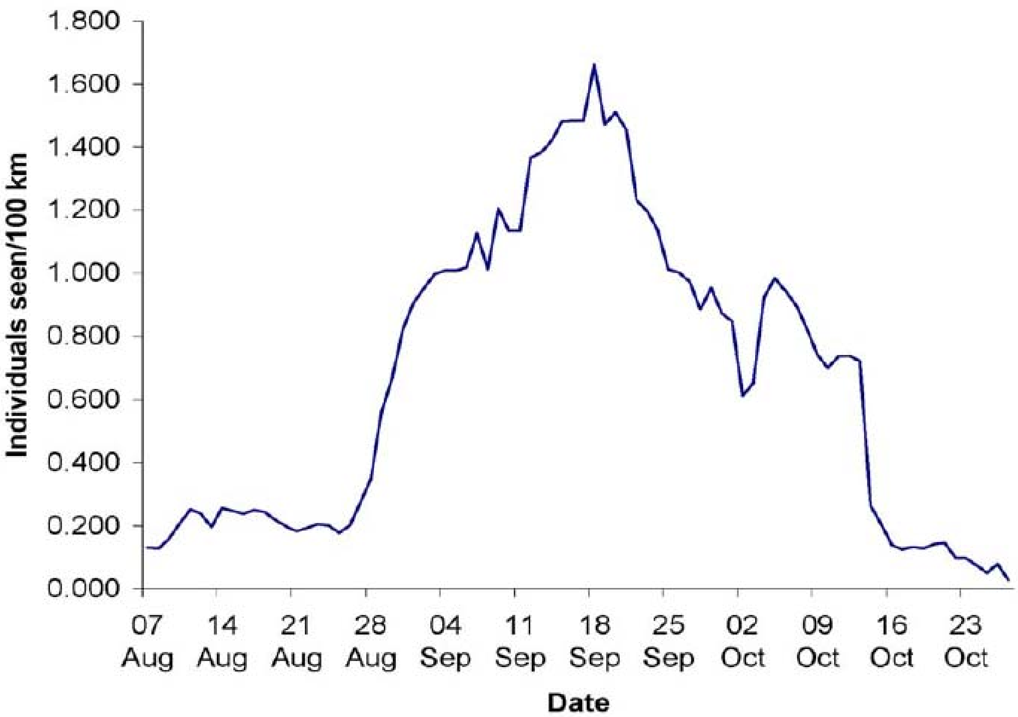

FIGURE 12.2. Plot of 10-day moving average of bowhead abundance (individuals seen/100 km) during aerial surveys in the eastern Alaskan Beaufort Sea, 7 Aug.-27 Oct., 1979-2000. The study area extended from Flaxman Island to the Canadian border (from Miller et al. 2002).

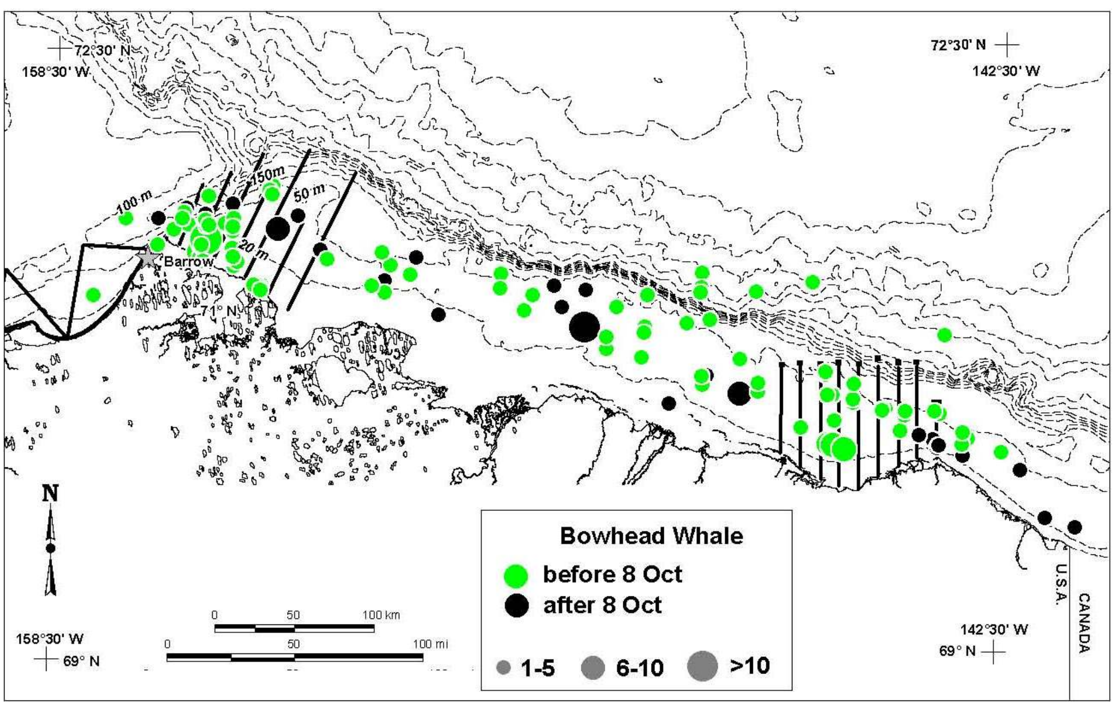

FIGURE 12.3. Combined sightings of bowhead whales during aerial surveys conducted by LGL and MMS for the entire survey period (2 Sept.-27 Oct. 2006). Transect lines from other aerial surveys described in this and other chapters are shown. A weather event on 8 Oct. moved ice that was in the nearshore areas of much of the Beaufort Sea to other regions, potentially altering bowhead whale distribution.

The BWASP aerial surveys conducted by MMS in 2006 provided extensive coverage of the bowhead migration in the first half of Sept. and the first half of Oct. However, poor weather conditions limited coverage during the second halves of both months. The most effort, the largest numbers of sightings, and the highest sighting rates were all obtained during the first survey period from 2-15 Sept. Figure 12.3 shows the distribution of bowhead sightings throughout the entire MMS survey period from 2 Sept.-27 Oct. 2006. This Figure shows sightings before and after 8 Oct. with different symbols. It was suggested by MMS that the distribution of whale sightings changed significantly after a weather event on or around 8 Oct caused changes in ice distribution. Bowheads were scattered evenly throughout the area surveyed except for a concentration of whales near and east of Point Barrow during the 2–15 Sept. period. It appears that the majority of the migration was through waters 20–100 m deep but some whales were sighted in both deeper and shallower waters. Sightings made during the first survey period (2–15 Sept.) appear to be slightly farther offshore than during later periods.

Pioneer Natural Resources (PNR) conducted aerial surveys in Harrison Bay near the Oooguruk Drilling Site (ODS; see Chapter 11). However, no whales were observed during the five surveys. In general, only a few whales have been reported in Harrison Bay during BWASP surveys over many years.

Acoustic monitoring of whales occurred near Northstar Island as part of BP's monitoring program and for a limited amount of time as part of a test deployment of DASARb recorders by SOI (see Chapter 10). The latter ("DASARb") recorders were deployed north and east of Cross Island in 37 m of water. Figure 12.4 shows the locations of the recorders deployed for both projects and a composite of the whale calls that were localized from the Northstar DASARs and the Shell DASARbs.

The fall migration of bowhead whales has been monitored acoustically offshore of Northstar Island since 2001 (Blackwell et al. 2007b). However, ice conditions in 2005 and 2006 were very different from those experienced in the first four years of the study (2001-2004). The location of the bowhead whale migration corridor varies from year to year and it may have tended to be farther offshore or more scattered in 2005 and 2006 compared to some previous years.

It is likely that the presence of ice in 2006 was important in causing the low call counts from the Northstar DASARs (see BP acoustic studies in Chapter 11). Ice coverage along the coast extended offshore of Northstar in 2006, with a band of denser ice surrounded on both sides (N and S) by less dense ice. The ice conditions did not change much during the course of the 2006 field season and it was thought that most migrating bowheads would avoid the ice and migrate in open water ~25 n.mi. (~46 km or 29 mi) from shore when near the Northstar study area. This was confirmed by the large number of whale calls recorded by the Shell DASARb recorders that were positioned farther offshore. This is also consistent with the 2006 aerial surveys in Camden Bay during which migrating bowheads were most abundant in the band 45-55 km offshore (Chapter 8).

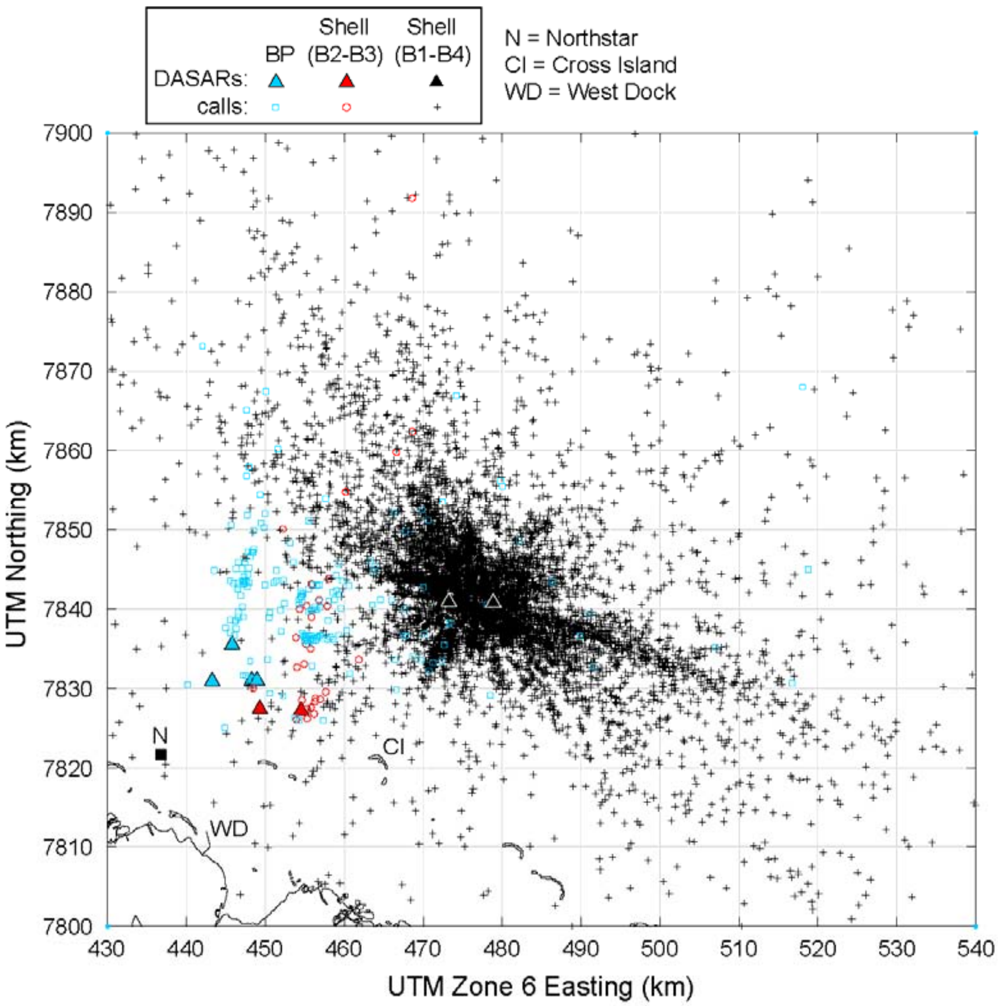

FIGURE 12.4. Composite map displaying the estimated bowhead whale call locations for 2006 as determined by three groups of recorders: the Northstar DASARs (BP; Blackwell et al. 2007a), the Shell B2–B3 pair of DASARBs located just southeast of the Northstar DASARs, and the Shell B1–B4 pair of DASARBs located about 25 km north-northeast of Cross Island. The B1–B4 pair, being farther offshore, provided by far the greatest number of call locations. Note that no effort was made to match calls detected by the Northstar and Shell DASARs, so some calls could be represented by pairs of symbols at two slightly different estimated positions. Localization accuracy is highest close to the DASARs and diminishes with increasing distance (Greene et al. 2004).

Pinnipeds and Polar Bears

Vessel based monitoring in the Beaufort Sea was conducted only from the *Henry Christofferson*, which was conducting shallow-hazards surveys for SOI. A total of 451 individual marine mammals (primarily seals) were seen in 412 groups from the vessel as it traveled through mostly nearshore waters. No cetaceans were sighted from the vessel. Sightings during useable periods included 320 seals and 4 polar bears. There were three sightings of polar bears: one of a single adult bear (on an ice floe feeding on a dead seal), a mother and cub (that entered the water as the vessel approached), and a single bear swimming in the offshore region.

The estimated pinniped density in the Beaufort Sea in 2006, based on observations from the *Henry Christoffersen*, was ~0.36 seals/km^2. Seal density in 2006 was similar to seal density in 1996 (0.30

seals/km^2) reported by Harris et al. (2001) during monitoring of seismic activities in the Beaufort Sea. Seal densities in 1996 and in 2006 were generally greater than during similar monitoring studies 1997-2001. The similar seal densities in 2006 and 1996 were likely related to heavier ice conditions in those years than during the other monitoring years.

Potential Interactions of Industry and Other Human Activity in the Chukchi and Beaufort Seas

Chukchi Sea

Industry activities in the Chukchi Sea during the open water period were primarily associated with the three seismic operations in the MMS Planning Area. In addition to those programs some barges, research vessels, and various small boats were also operating during summer and fall.

Seismic Operations

SOI commenced operations in the Chukchi Sea in July 2006. The seismic airguns were first fired during sound source measurements on 21-22 July. Measurements of the sounds produced by the airguns are presented in detail in SOI's 90-day report (Patterson et al. 2007). Due to heavy ice cover in the MMS Planning Area, sound source measurements were somewhat delayed and made south of the area originally intended. Seismic acquisition began on 27 July and continued through most of the field season until 19 Sept. Ice conditions and other operational considerations precluded continuation of the exploration program or transition of the program into the Beaufort Sea. SOI completed ~5297.4 km (3291.7 statute mi) of seismic survey lines in the Chukchi Sea in 2006.

CPAI also began their seismic program in the Chukchi Sea in July 2006. CPAI's seismic contractor began deploying seismic acquisition equipment on 23 July. Initial sound source measurements were made on 24 and 25 July. Details of these measurements are presented in Ireland et al. (2007a). Acquisition of seismic data began on 27 July and continued through most of the field season until 12 Oct. Ice conditions and other operational considerations precluded continuation of the exploration program, and seismic activities were then terminated. CPAI completed ~16,028 km (9959 statute mi) of seismic survey line (roughly, over an area of 7766 km^2) in the Chukchi Sea in 2006; the surveyed area covered ~5.6% of the total lease sale area (137,594 km^2).

GXT conducted operations in the Chukchi Sea briefly in Aug. 2006, and then in Oct.-Nov. 2006. The sound source measurements were made on 20-21 Aug. Details of these measurements are presented in Ireland et al. (2007b). The GXT seismic vessel, the *Discoverer*, departed the Chukchi Sea after completion of the sound source measurements. The *Discoverer* returned to the Chukchi Sea on 7 Oct. to conduct seismic exploration activities and deployed seismic equipment on 12 Oct. Seismic acquisition began on 13 Oct. and continued until 11 Nov. when the *Discoverer's* airguns and streamer were retrieved. GXT completed a total of ~4707 km (2924 statute mi) of seismic survey line in the Chukchi Sea in 2006.

The geographic region where the seismic surveys occurred was located in the proposed 2002–2007 MMS Chukchi Sea Planning Area. Since the Chukchi Sea seismic program was conducted as a pre-lease activity, the exact locations of operations are confidential. The seismic data acquired in 2006 will be used to identify leases on which companies may bid in a forthcoming competitive lease sale. However, in general, seismic acquisition occurred in the Chukchi Sea well offshore from the Alaska coast in OCS waters averaging greater than 40 m or 131 ft deep and outside the polynya zone.

As indicated by the dates of operation of each company's seismic program, SOI and CPAI conducted portions of their operations in different locations in the Chukchi Sea at the same time. Operations of both companies began on 27 July 2006 and continued through 19 Sept. when SOI terminated their operations in the Chukchi Sea. At that point only CPAI was operating in the Chukchi Sea and they continued until 6 Oct. Seven days after CPAI ended their operations, GXT began working in the Chukchi Sea and was the only seismic program operating until acquisition was terminated on 11 Nov. Only on 21-22 Aug. during the GXT sound source measurements were all three of the programs active in the Chukchi Sea at the same time.

SOI and CPAI seismic vessels both acquired seismic data (used their full airgun arrays) for part or all of the day on 53 of the 55 days from 27 July to 19 Sept. On the other two days, only one of the vessels acquired seismic data. CPAI acquired seismic data on 20 days during the period from 19 Sept. through 12 Oct. after which they departed the Chukchi Sea. GXT conducted seismic activities in the Chukchi Sea for 27 days from 13 Oct. until they ended their operations on 11 Nov. 2006. Based on these numbers there were 102 days when at least one seismic vessel was actively acquiring data in the Chukchi Sea between 27 July and 11 Nov. 2006. On 53 days two vessels were operating their airguns and all three vessels operated on two days. There was no seismic survey activity on 6 days.

During the period that two seismic ships were actively acquiring data, a greater area was ensonified than when only one ship was working. Therefore, the total area within the Chukchi Sea that marine mammals might avoid as a result of increased sound levels would be the sum of the “zones of avoidance” around each operation, provided that there was no overlap of those areas. Incidental Harassment Authorizations (IHAs) issued to the seismic exploration companies restricted how close the vessels could operate to each other. Two vessels were not allowed to actively acquire data within 15 n.mi. (27.8 km) of each other.

Although seismic source vessels did not operate within 15 n.mi. of each other, there could have been overlap of the ensonified areas around the two operating seismic vessels at some times when both sources were operating. Given that seismic airgun sounds are impulsive rather than continuous, there would be few locations where sound pulses were received from both operations simultaneously. At most locations the sound pulses would arrive sequentially and alternatively from one seismic ship and then the other. Thus, at most times the received levels of sounds would not exceed the level of the sounds from the closer of the two operations. However, the number of pulses received per unit time (the pulse repetion frequency) would be greater in the region of overlap than in areas ensonified by a single operation. Figure 12.5 shows sound signatures from two seismic sources as recorded at the pop-ups near Point Lay on 15 Sept. (see Chapter 6). There would have been a small number of locations and times where pulses from two operations would arrive at or near the same time. In these few occasions the sound pulses would add incoherently (with random phase). At most, when pulses from each source were received simultaneously with the same root-mean-square pressure level, the combined sound pressure level would be 3 dB higher. When the received levels of the overlapping pulses differ by 10 dB or more, their combined level will be less than 1 dB greater than the level of the stronger pulse.

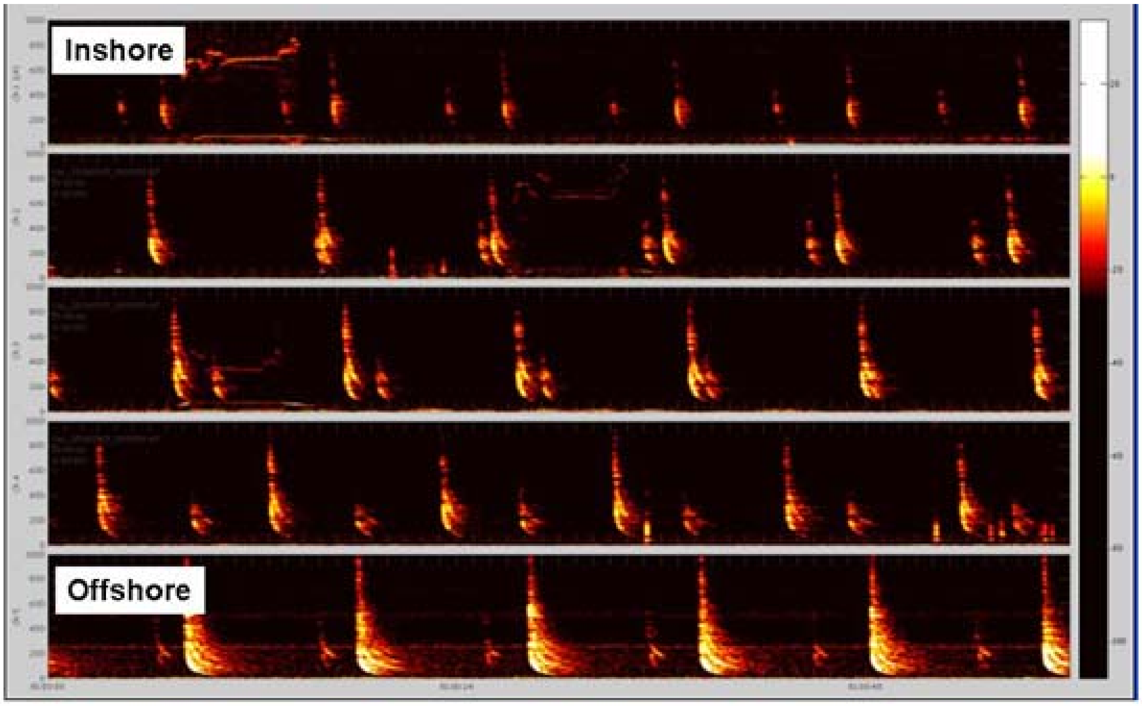

FIGURE 12.5 Five-channel spectrogram for 15 Sept. 2006 at 00:00:00 local time when two seismic sources were active. Data were collected on five BRP autonomous seafloor recorders deployed off Pt. Lay, Alaska. Frequency scale (vertical), 0–1000 Hz; Time scale, 0–60 s. Order of panels is from inshore (top panel = PU #97 at *ca.* 4 n.mi. offshore in 16 m water depth) to offshore (bottom panel = PU#63 at *ca.* 55 n.mi. offshore in 41 m water depth).

Arrays of bottom-founded acoustic recorders deployed along the Alaskan Chukchi coast indicated that sound levels reaching the offshore and inshore recorders were as high as ~130 dB re 1 μPa (rms) during active seismic periods. Figure 12.6 shows a sample of received sound levels at recorders #2 and #5 from all four sites combined along the Chukchi Sea coast, plotted in relation to distance from the seismic ship. Received levels tended to be higher at recorder #5 located ~50 n.mi. (92.6 km) offshore compared to those at recorder #2 located ~10 n.mi. (18.5 km) offshore. Most measurements decreased to about 120 dB at a distance of ~50-60 km, although there was substantial variability in the measurements. A similar pattern was evident when comparing received levels at recorders #2 and #5 at individual sites, e.g. off Point Lay and Wainwright (Figs. 12.7 and 12.8). Airgun sounds were detected on the second recorder of the array, located 10 n.mi. (18.5 km) offshore, on 77% of the days off Point Lay, 59% of the days off Wainwright, 53% of the days off Cape Lisburne, and only 4% of the days near Barrow.

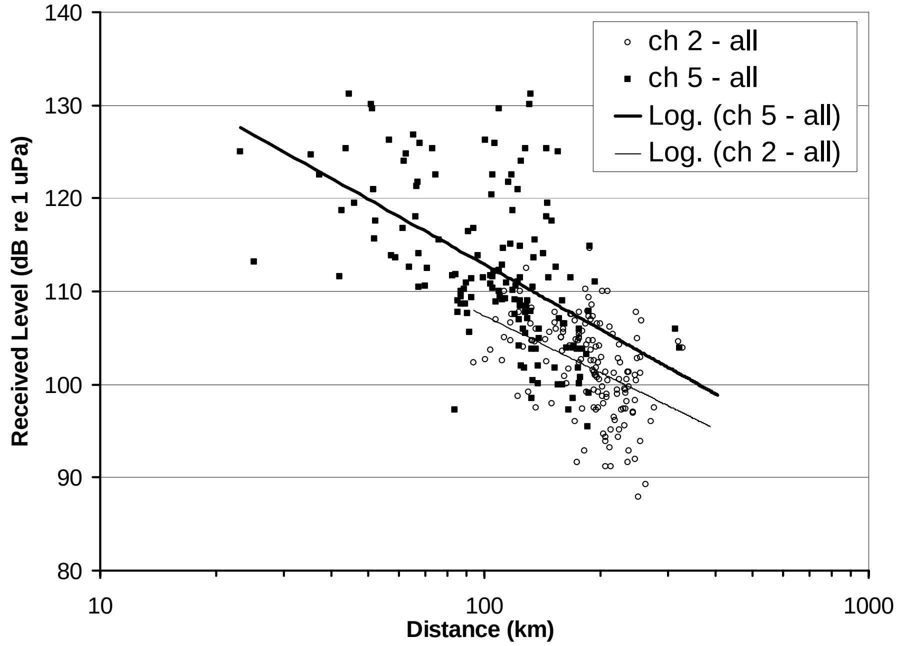

FIGURE 12.6. Average received sound levels (rms) for seismic pulses detected by recorders #2 and #5 (10 n.mi. and 50 n.mi. offshore, respectively) of all Chukchi-Sea arrays as a function of the average distance from a seismic source. Data are from selected periods of time (1 – 3 h in duration) between 12 Sept. and 6 Oct. when one or both vessels were operating airguns. Sound source varied from the full array, 16 or 24 airguns, to mitigation power, 1 or 2 airguns, on the *Patriot* and *Gilavar*, respectively.

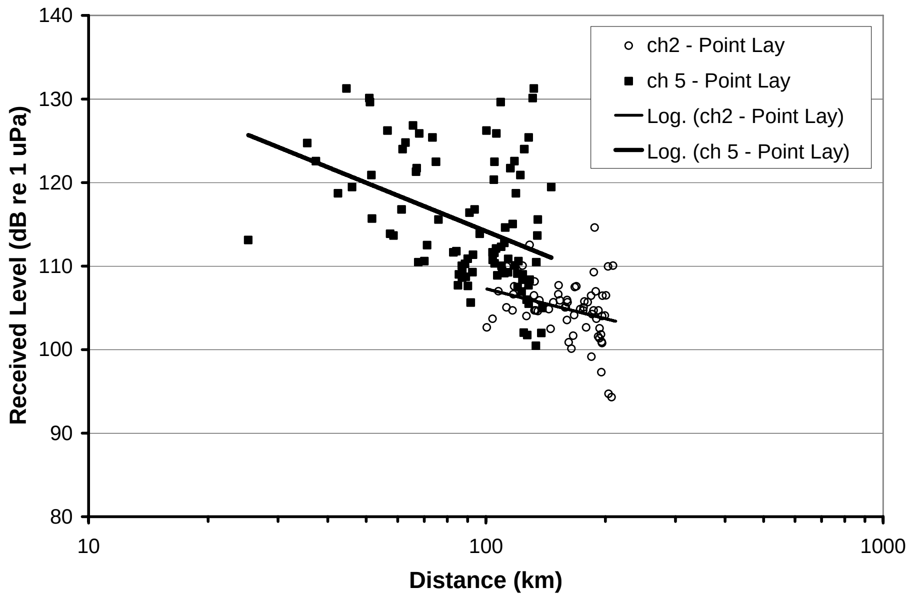

FIGURE 12.7. Average received sound levels (rms) for seismic pulses detected by recorders #2 and #5 (~10 n.mi. and ~50 n.mi., respectively) off Pt. Lay as a function of the average distance from a seismic source. Data are from selected periods of time (1 – 3 h in duration) when one or both vessels were operating airguns. Sound source varied from the full array, 16 or 24 airguns, to mitigation power, 1 or 2 airguns, on the *Patriot* and *Gilavar*, respectively.

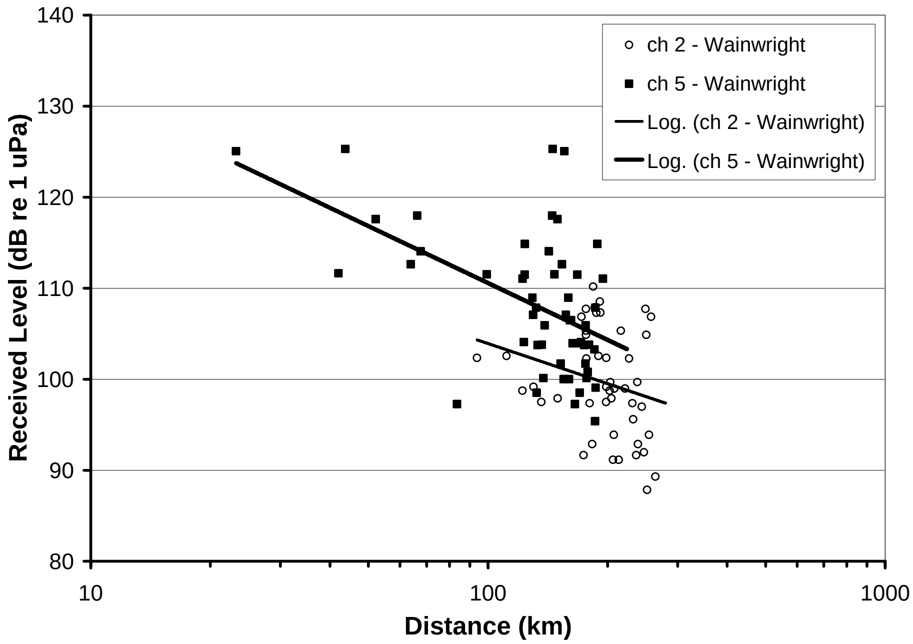

FIGURE 12.8. Average received sound levels (rms) for seismic pulses detected by recorders #2 and #5 off Wainwright as a function of the average distance from a seismic source. Data are from selected periods of time (1 – 3 h in duration) when one or both vessels were operating airguns. Sound source varied from the full array, 16 or 24 airguns, to mitigation power, 1 or 2 airguns, on the *Patriot* and *Gilavar*, respectively.

Received levels of seismic pulses at the recorders were similar to or higher than ambient noise levels which were recorded during the period between seismic pulses at recorders 2 and 5 off Cape Lisburne, Point Hope, and Wainwright (Figs. 12.9 and 12.10). Most ambient noise levels recorded at the #2 recorder ranged between ~90 and 100 dB (Fig. 12.9) whereas levels of ambient noise averaged several dB higher at the #5 recorder (Fig. 12.10). The seismic vessels were generally closer to the "offshore" recorders (#5 recorders) than to the nearshore recorders (#2 recorders), and the higher ambient levels recorded at #5 recorders may to some degree have resulted from the contribution of vessel noise to the recordings of ambient noise in offshore waters. However, the main reasons for higher noise levels farther offshore were probably related to differing proximity to ice and greater fetch and wave height offshore. Received levels of seismic pulses at the #2 recorders ranged between ~90 and 110 dB re 1 µPa (rms) and were generally lower than levels at the #5 recorders which ranged between ~100 and 130 dB.

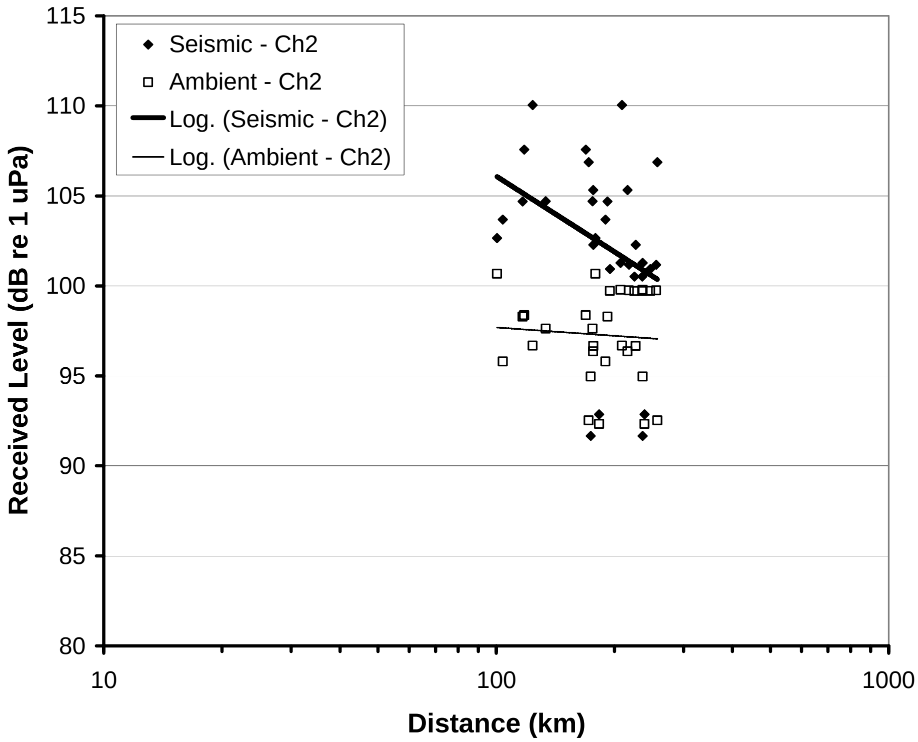

FIGURE 12.9. Average received sound levels (rms) during seismic pulses (seismic) and between seismic pulses (ambient) from recorders #2 off Cape Lisburne, Point Hope and Wainwright on 19 Sept. as a function of the average distance from a seismic source. Data are from selected periods of time (1 – 3 h in duration) when one or both airgun arrays from the two vessels were operating. Sound source varied from the full array, 16 or 24 airguns, to mitigation power, 1 or 2 airguns, on the *Patriot* and *Gilavar*, respectively.

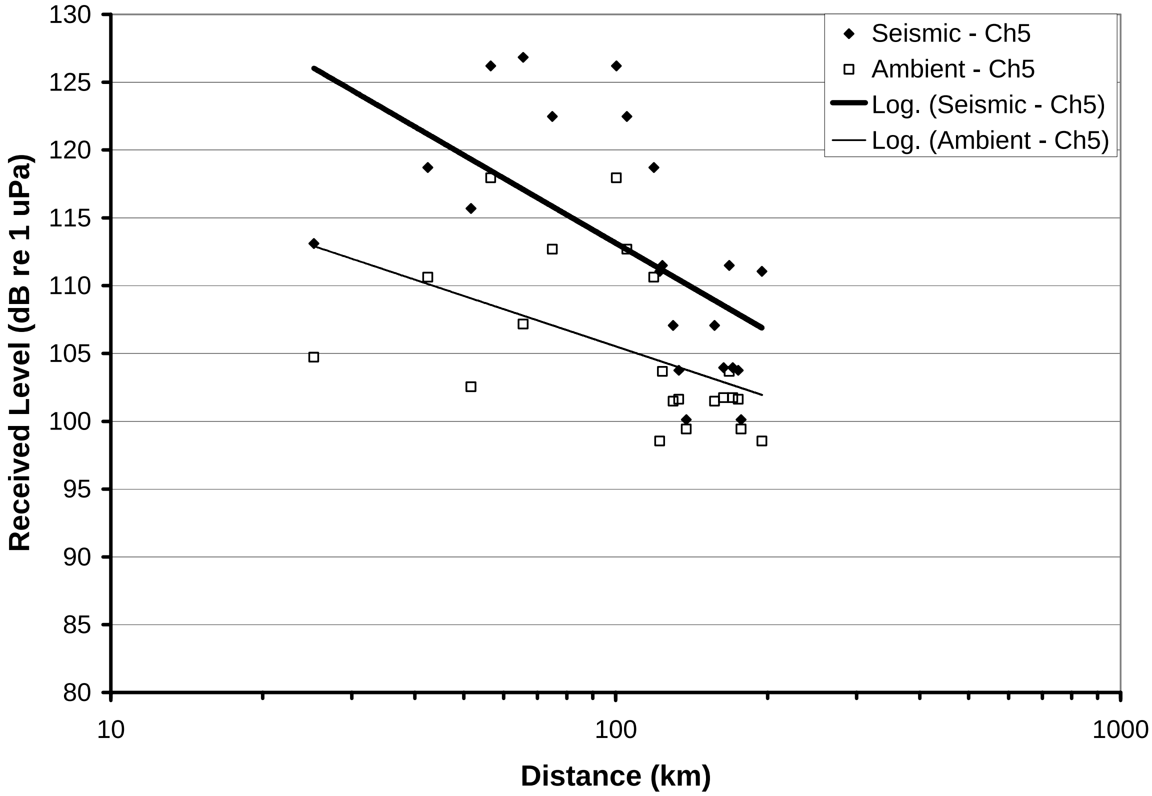

FIGURE 12.10. Average received sound levels (rms) during seismic pulses (seismic) and between seismic pulses (ambient) from recorders #5 off Cape Lisburne, Point Hope and Wainwright on 19 Sept. as a function of the average distance from a seismic source. Data are from selected periods of time (1 – 3 h in duration) when one or both airgun arrays from the two vessels were operating. Sound source varied from the full array, 16 or 24 airguns, to mitigation power, 1 or 2 airguns, on the *Patriot* and *Gilavar*, respectively.

Received levels at recorder #5 for all sites and recorder #2 at Barrow, Wainwright and Point Lay from the full airgun array of the *Patriot* were greater than those from the single airgun used for mitigation (Fig. 12.11). The received levels diminished with distance from the source for both the full airgun array and the mitigation airgun. The levels decreased to below 120 dB (rms) at ~40 km for the mitigation gun and ~60-70 km for the full array.

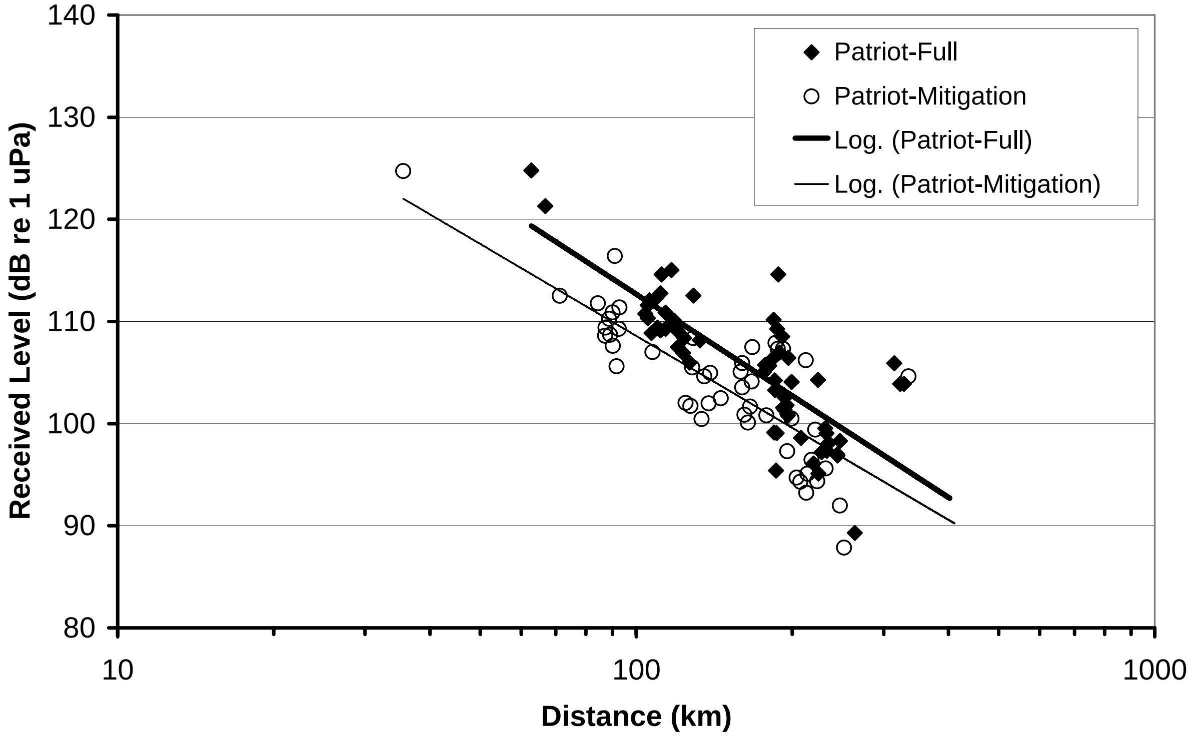

FIGURE 12.11. Average received sound levels (rms) at recorder #5 for all sites and recorder #2 at Barrow, Wainwright and Point Lay during seismic pulses for the full array (16 airguns) and from the mitigation gun (1 airgun) on the *Patriot* as a function of the average distance from a seismic source.

<u>*Vessel traffic*</u>

In addition to the seismic vessels operating in the Chukchi Sea, various other vessels supported the seismic operations. In general, these included a chase boat associated with each of seismic vessels (the *Kilabuk*, the *Torsvik*, and the *Octopus*), a support boat (the *Gulf Provider*) and a crew change boat (the *Peregrine*).

Sound levels from these support vessels were measured and reported in the 90-day reports from each of the operators. While the source levels of the routine vessel operations do not typically approach the source levels produced by the seismic airgun arrays at times when pulses are being received, these smaller vessels may produce a substantial amount of sound, particularly if a number of vessels are operating in a relatively small area such as a harbor or bay. Also, vessels produce continuous sound whereas an airgun array produces sound for only a fraction of a second every several seconds (i.e., duty cycle 100% vs. <5%). Sounds from all of these vessels operating would contribute to the total in-water sounds.

Additional vessels operating independent of the seismic program included barges, research vessels, and various small boats. Vessel traffic not associated with the seismic programs for which information was available primarily involved barges as described in Chapter 2. The barges supplied fuel to the seismic and support vessels but were not actively involved in the seismic exploration. In addition, at least two barges transited the Chukchi Sea enroute to the Beaufort Sea and then passed through the Chukchi

Sea again on the return voyage. Several other research vessels also operated or transited through the Chukchi Sea during 2006.

Beaufort Sea

Oil Exploration, Construction, and Production Activities

As described in Chapter 2, a number of independent oil exploration, construction and production operations occurred in the Beaufort Sea during the open water period of 2006. These operations did not interact directly, but their operations overlapped temporally. In general, all of these projects potentially increased in-water sound through increased vessel traffic in the areas of operation.

In the Beaufort Sea, operations by SOI were limited by sea ice to shallow hazards surveys and site clearance work. Airguns were used during sound source measurements done on 8 Aug., and on one additional day (25 Sept.) for shallow hazards surveys. During the sound source measurements on 8 Aug., a cluster of four 70 in^3 airguns was used. Two 70 in^3 airguns were used during the site clearance survey on 25 Sept. The site clearance surveys with airguns and the measurements of the airgun sound radii were confined to small specific areas within defined OCS lease sale blocks in the Camden Bay area. Camden Bay is about 60 miles east of the nearest other industry activity that was occurring during this time period, and any effects of the sound associated with the airgun and ancillary activities on these two dates would likely have been restricted to an area within a few km around the vessel. The potential impacts to marine mammals from these activities on 8 Aug. and 25 Sept. are described in detail in SOI's 90-day report (Patterson et al. 2007) and are summarized in Chapters 7 and 8.

In addition to this work the *Henry Christoffersen* conducted various types of site clearance surveys between 8 Aug. and 2 Oct. on an intermittent basis as allowed by ice and weather conditions. These operations, which involved higher-frequency, shorter-range acoustic sources, were located in specific nearshore areas ranging from east of Kaktovik west to Thetis Island near the Colville River delta. Site clearance survey activities occurred on ~23 days during this period.

Some interaction of SOI operations with construction occurring at Pioneer's ODS in Harrison Bay may have occurred while SOI's site clearance activities were being conducted near Thetis Island. Such interaction would have occurred on only a few days during the open water period. Work in the Thetis Island area involved only low energy sound sources that diminish to background levels a few km from the source (Patterson et al. 2007). Similarly, broadband sound levels emanating from the ODS were measured at about 92 dB re 1 μPa at a distance of 1.6 km (1mi), and received levels decayed rapidly with increasing distance (Chapter 11). Acoustic recorders deployed 4 and 12 miles from the ODS were unable to detect sounds from the island.

Similarly, some of the site clearance activity and vessel operations of SOI occurred in the vicinity of BP's oil production operations at the Northstar Island. Numerous types of activities are required to support oil production at Northstar. These activities are summarized in Chapters 2 and 11. While SOI activities around Northstar may have contributed to in-water sounds in the area, acoustic measurements made near Northstar reported that levels of low-frequency sound near Northstar in September 2006 were similar to those in other years during which measurements were made (Blackwell et al. 2007a summarized in Chapter 11). Background sound measurements made with SOI's DASARb recorders reported a median value of 98.7 dB re μPa and 100.4 dB re μPa for recorders B2 and B4 respectively, with maximum values of 126.8 dB re μPa and 120.1 dB re μPa respectively. Northstar recorder EB had similar background sound measurements with a median of 95.4 dB re μPa and maximum of 122.9 dB re μPa (Chapter 11).

Vessel Traffic

Various types of barge traffic in support of industry activities occurred in the Beaufort Sea between Barrow and Kaktovik during the 2006 open-water period. The types of vessel traffic, general location of vessel routes, the number of round trips, and the timing of barge traffic are discussed in Chapter 2. Barge activities in the Beaufort Sea were conducted primarily in support of land-based exploratory drilling by FEX LC near Cape Simpson, island construction at ODS offshore of the Colville River delta by Pioneer Natural Resources (PNR), oil production activities at Northstar Island by BP Exploration, and various construction activities at Kaktovik and Lonely by Marsh Creek LLC. Barge traffic in the Beaufort Sea in 2006 began in late July and continued into Oct.

Barge routes in the Beaufort Sea were generally near the coast and barges often transited inside the barrier islands (Fig. 12.12). The primary barge routes for industry activities were between West Dock and various locations including Northstar, Cape Simpson, Lonely, and Kaktovik and some traffic extended into the Canadian Beaufort Sea (Fig. 12.13). Other barge traffic that carried general cargo or fuel included several round trips between Barrow and Kaktovik, and several vessels transited the entire Alaskan Beaufort Sea during the 2006 open-water period. Localized barge traffic in support of PNR's ODS occurred primarily between Oliktok Point and ODS, although some barge traffic to ODS also originated at West Dock (Fig. 12.13). Localized barge traffic also occurred between West Dock and BP's Northstar Island.

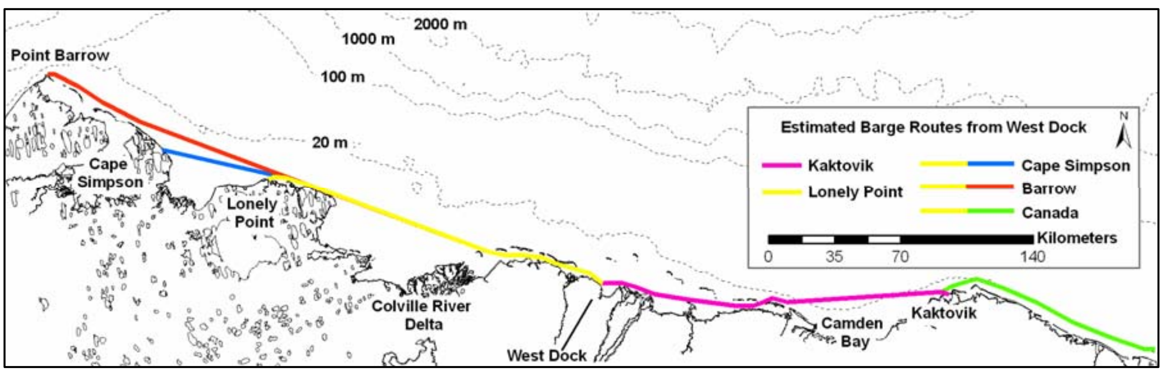

FIGURE 12.12. General location of barge traffic routes in the Alaskan Beaufort Sea between Barrow and the Canadian border, 2006.

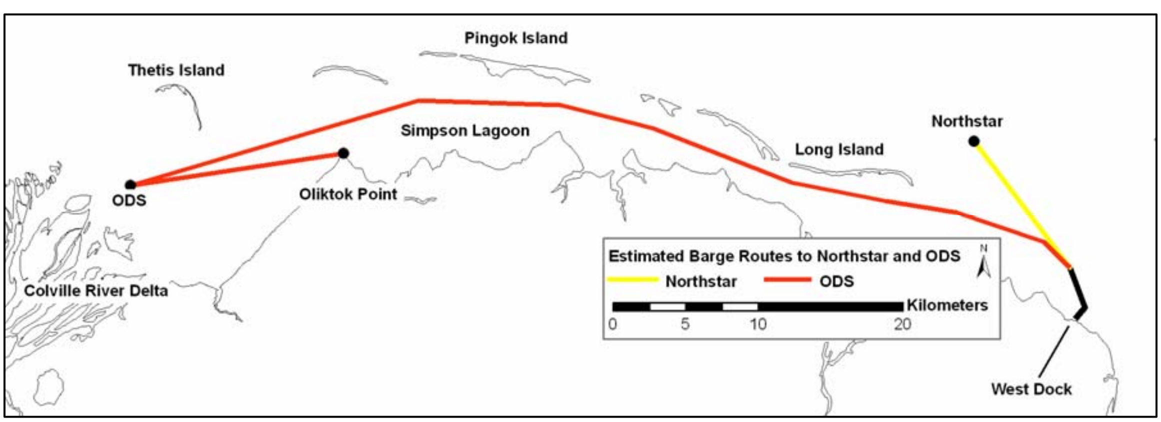

FIGURE 12.13. General location of barge routes from West Dock to Northstar Island and ODS, and from Oliktok Point to ODS, 2006.

There was little monthly fluctuation in localized barge traffic for the ODS project near the Colville River delta during the 2006 open water period (Table 12.1). The monthly number of barge round trips from Oliktok Point to ODS ranged from 9 to 11 during July through Oct. The underwater sound produced by construction activities on the island and by barge traffic in support of ODS activities was measured by Zykov et al. (2007). Island-based construction sound was <90 dB re 1 μPa and was recorded daily at the OBH located 1.6 km (1 mi) from the island. These sounds could not be heard at recording stations located 6.3 and 19.3 km (4 and 12 mi) from the island. Underwater noise from tugs and self-propelled barges reached ambient levels from ~3.5 to 8.1 km (2.2 to 5 mi) from the sources.

Most barge traffic between West Dock and Northstar Island occurred during Aug. and Sept. when 25 round trips occurred during each month (Table 12.1). Barge round trips to Northstar Island were less numerous in July (10 trips) and Oct. (4 trips). Barge traffic in support of Northstar and the ODS likely had little effect on marine mammals although, for 2001–2004, McDonald et al. (2006) reported apparent minor deflections (and/or changes in calling behavior) of migrating bowhead whales offshore of Northstar Island at times when industrial sound levels near the island were higher than average.

TABLE 12.1. Number of barge round trips in support of major industrial groups in the Beaufort Sea, 2006.

		Pioneer			Marsh Creek	
Month	FEX	Oliktok/ODS	West Dock/ODS	BP	Kaktovik	Lonely
July	1	9	0	10	0	0
August	24	10	3	25	4	0
Sept	5	11	2	25	4	8
October	0	9	2.5	4	0	0

The long distance barge activities between Barrow and the Canadian border in support of activities at Cape Simpson, Lonely and Kaktovik would likely have had a greater potential to cause disturbance to marine mammals than the more localized barge traffic near ODS and Northstar Island. This barge traffic occurred over a broad portion of the Beaufort Sea coast and had the potential to affect marine mammals along the entire route, particularly from Camden Bay eastward.

Barge traffic to locations west of West Dock (Barrow, Cape Simpson and Lonely) occurred more frequently in Aug. than Sept. (Table 12.2). Only one round trip to this area occurred during July and there was no activity in Oct. Barge traffic to Kaktovik in support of activities by Marsh Creek occurred only in Aug. and Sept.

We estimated the number of km of barge traffic that occurred by month east and west of West Dock in 2006, excluding the localized traffic in support of ODS and Northstar. Far more km of barge traffic occurred west of West Dock than east of West Dock (Table 12.2). More barge traffic occurred in Aug. than any other month. The number of km of barge traffic in Aug. was over twice that in Sept. The number of km of barge traffic east of West Dock was ~20% of traffic to the west of West Dock.

TABLE 12.2. Approximate number of kilometers of barge traffic by month occurring in the Beaufort Sea east and west of West Dock. The estimate does not include localized barge traffic near ODS and Northstar Island.

Month	West of West Dock	East of West Dock
July	244	0
August	6807	1230
September	3350	1044
October	0	0
Total	**10401**	**2274**

Subsistence Whaling

Subsistence whaling activities for bowhead whales in the Beaufort Sea in 2006 were successful. Fall whaling activities in the Beaufort Sea occurred at Kaktovik, Cross Island by Nuiqsut whalers, and Barrow. Based on available information, the subsistence bowhead whale hunts in the Beaufort Sea in 2006 went well and all three villages were able to reach their quotas.

During autumn, bowhead whales were harvested in the Beaufort Sea during a relatively narrow window of time for each village (Table 12.3) and whalers did not appear to have difficulties in reaching their quotas. The seismic survey activities that occurred in the Beaufort Sea in early Aug. to measure sound propagation from the airguns onboard the *Henry Christoffersen* occurred well before the fall bowhead hunt at any location and would not have affected the subsistence hunt. The only other airgun activity in the Beaufort Sea occurred in Camden Bay west of Kaktovik on 25 Sept. This occurred well after completion of the subsistence whale hunt in this area and also would not have affected the 2006 whale hunt.

Galginaitis (2007) reported that the effort expended in 2006 by whalers from Nuiqsut who were whaling at Cross Island was greater than in each of the previous three years (2003-2005). The whalers indicated that ice conditions apparently affected the distribution of whales requiring more effort and longer trips. Heavy ice conditions limited the whaler's ability to reach open water beyond the barrier islands during the early part of the season. Once the ice conditions moderated, the whalers were able to harvest the whales beyond the barrier islands. During scouting trips early in the season the whalers reported seeing non-whaling vessel traffic inside of the barrier islands, but no non-whaling vessel traffic was noted in the open water outside of the barrier islands during the hunts. Non-whaling vessel traffic in the Beaufort Sea did not appear to impact the subsistence hunt at Cross Island and any increased effort by the whalers likely resulted from heavy ice conditions rather than vessel disturbance. Most barge and other vessel traffic in the Beaufort Sea was likely routed inside the barrier islands and probably did not affect the bowhead subsistence hunts further offshore. The numbers of bowhead whales harvested in the Beaufort Sea in 2006 were similar to the numbers harvested in previous years (Table 12.4).

TABLE 12.3. Dates on which first and last whales were harvested during spring and fall subsistence bowhead whale hunts by coastal villages in the Alaskan Chukchi and Beaufort Seas, 2006. Data from Suydam et al. (2006).

Village	First Whale	Last Whale	Total
Barrow (spring)	11 May	18 May	3
Wainwright (spring)	10 May	11May	2
Barrow (fall)	25 September	3 October	19
Nuiqsut (fall)	13 September	18 September	4
Kaktovik (fall)	5 September	16 September	3

Spring hunts for bowheads also occurred in the Chukchi Sea at Pt. Hope, Wainwright, and Barrow. Seismic survey activities in the Chukchi Sea in 2006 did not begin until mid-July, well after completion of the spring hunts. Non-whaling vessel traffic also did not occur until after completion of the spring subsistence hunt. Heavy ice conditions during the spring affected the ability of whalers to access bowheads in 2006. Pt. Hope was unsuccessful, and Wainwright and Barrow had lower than average success (Table 12.3). Fall whaling for bowhead whales is not typical for Wainwright and no whales were sighted by whalers during scouting trips from Wainwright in the fall of 2006.

In addition to the bowhead hunt at Wainwright, subsistence whaling also occurred at Point Lay where beluga whales were harvested. This hunt occurred on 13 July when 28 beluga whales were landed. This was also prior to any seismic survey activities in the Chukchi Sea, which did not occur until 21 July when sound measurements of SOI's airgun array were recorded.

TABLE 12.4. Number of bowhead whale landings by year at Wainwright, Barrow, Cross Island (Nuiqsut) and Kaktovik, 1993-2006.

Year	Wainwright	Barrow	Cross Island	Kaktovik
1993	5	23 (7)	3	3
1994	4	16 (1)	0	3
1995	5	19 (11)	4	4
1996	3	24 (19)	2	1
1997	3	30 (21)	3	4
1998	3	25 (16)	4	3
1999	5	24 (6)	3	3
2000	5	18 (13)	4	3
2001	6	27 (7)	3	4
2002	1	22 (17)	4	3
2003	5	16 (6)	4	3
2004	4	21 (14)	3	3
2005	4	29 (13)	1	3
2006	2	22 (19)	4	3

1 Compiled in USDI/BLM (2003) from various sources.

2 Numbers given for Barrow are "total landings/autumn landings". From Burns et al. (1993), various issues of Report of the International Whaling Commission, Alaska Eskimo Whaling Commission, J.C. George (NSB Dep. Wildl. Manage.), Suydam et al. 2004, 2007, 2007.

3 Cross Isl. (Nuiqsut) and Kaktovik landings are in autumn. Data compiled in USDI/BLM (2003) and Koski et al. (2005) from various sources.

Potential Effects of Industry Activities on Marine Mammals in the Chukchi and Beaufort Seas

Chukchi Sea

Bowhead Whales

Industry seismic activities in the Chukchi Sea began on 27 July. It is unlikely that any Beaufort Sea bound bowhead whales were exposed to, or disturbed by, seismic activities during their spring migration through the Chukchi Sea, which for the most part is completed by early June. Small numbers of bowhead whales may remain in the northern Chukchi Sea through the summer (Moore 1992; Rugh et al. 2003; Chapter 5), and bowhead whales that may have remained in summer could have been exposed to seismic sounds in the Chukchi Sea then. However, most bowhead whales would not have returned to the Chukchi Sea until after SOI had completed their seismic program in the Chukchi Sea, on 19 Sept. Therefore, most bowhead whales would have been exposed to sounds from no more than one seismic operation when they returned to the Chukchi Sea during fall 2006. (CPAI's seismic operations continued to 6 Oct., and GXT's occurred from 13 Oct. to 11 Nov.). Most bowhead whales that encountered airgun sounds from operations in the Chukchi Sea would have been migrating. Depending upon the location of the seismic vessel, some feeding whales near Barrow may also have been exposed, but at relatively long distances from the sound source. Acoustic recordings made in the Barrow area indicated that seismic sounds were near background levels and unlikely to have impacted feeding whales near Barrow. Received levels in the feeding area near Barrow would have been lower than those at the recorders.

The response of bowhead whales to seismic surveys can be quite variable depending on the activity of the whales (e.g., migrating vs. feeding vs. socializing). Bowhead whales on their summer feeding grounds in the Canadian Beaufort Sea showed no obvious reactions to pulses from seismic vessels at distances of 6–99 km and received sound levels of 107–158 dB on an approximate rms basis (Richardson et al. 1986). Subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon analysis, but were not noticeable to observers at the time the data were collected. Bowheads usually showed strong avoidance responses when seismic vessels approached within a few kilometers (~3–7 km) and when received levels of airgun sounds were 152–178 dB on an approximate rms basis (Richardson et al. 1986, 1995; Ljungblad et al. 1988). This work and a more recent study by Miller et al. (2005) found that feeding bowhead whales tended to tolerate higher sound levels than did fall migrating bowhead whales before showing an overt change in behavior.

Fall migrating bowhead whales in the Alaskan Beaufort Sea were more responsive to noise pulses from a distant seismic vessel than are summering feeding bowheads. In 1996–98, a partially-controlled study of the effect of Ocean Bottom Cable (OBC) seismic surveys on westward-migrating bowheads was conducted in late summer and autumn in the Alaskan Beaufort Sea (Miller et al. 1999; Richardson et al. 1999). Aerial surveys showed that some westward-migrating whales avoided an active seismic survey boat by 20–30 km, and that few bowheads approached within 20 km. Received sound levels at those distances were only 116–135 dB re 1 μPa (rms). The specific distance at which deflection began could not be determined from the available data, but some whales approaching from the east apparently began to deflect from their migration path at ~35 km from the airguns. In contrast, at times when the airguns were not active, many bowheads moved into the area close to the inactive seismic vessel. Avoidance of the area within ~20 km of the seismic operations did not persist beyond 12–24 h after seismic shooting stopped.

Based on the 1996–1998 (mainly 1998) study of migrating bowhead whales, relatively low levels of airgun sound (e.g., ≥120 dB re 1 μPa rms) are considered by NMFS (2007) to have the potential to cause disturbance to bowhead whales. There has been concern that bowhead whales subjected to sound pressures ≥120 dB rms may be deflected from the migration routes and may thus be less accessible to subsistence hunters. For this reason the IHAs issued to SOI, CPAI, and GXT required monitoring of the 120 dB zone after 25 Sept. in the Chukchi Sea.

Few data have been obtained subsequent to the 1996-1998 study to replicate (or otherwise) the observation that migrating bowhead whales avoid areas with relatively low received levels (≥120 dB re 1 μPa rms) of airgun sound. During a recent cooperative effort by the Alaska Department of Fish and Game, the Alaska Eskimo Whaling Commission, the North Slope Borough, and the Minerals Management Service, a bowhead whale was tracked from the Barrow area in the spring to the Canadian Beaufort Sea, and then westward through the Beaufort Sea to Barrow (Fig. 12.1; Quakenbush 2007). The tracked whale eventually continued west past Barrow in mid-Oct. and through the northern Chukchi Sea to the Chukotka coast south of Wrangel Island. As the whale passed Barrow moving westward it came into close proximity with the eastward moving GXT seismic vessel *Discoverer* on 15 and 16 Oct. 2006, and was within the 120 dB radius around the operating airgun array (Fig. 12.14). Levels up to 120 dB rms are expected to occur as much as ~58 km fore and aft and ~167 km to the side of the operating airgun array—see GXT 90-day report (Ireland et al. 2007). Within the limits of uncertainty regarding the specific closest point of approach of the whale to the operating seismic vessel, the seismic survey activity from the *Discoverer* did not appear to cause a deflection in the bowhead's migration route.

Gray Whales

Gray whales were sighted regularly along the Chukchi Sea coast during aerial surveys in 2006. However, relatively few gray whales were sighted from vessels except when the vessels were close to shore. The locations of the whales sighted, along with the acoustic measurements from bottom recorders, indicate that gray whales would have been exposed intermittently to seismic sounds while feeding or traveling along the coast between Pt. Hope and Barrow. From 27 July through 19 Sept., gray whales present in the Chukchi Sea would have been exposed to the combined effects of two active seismic programs. The cumulative effect of the two programs was likely experienced in the total number of seismic pulses received (nearly double that of a single program) and only occasionally in an ~1–6 dB increase (or decrease) in the strength of the received levels of (overlapping) seismic sounds relative to the levels noted above.

Malme et al. (1986, 1988) studied the responses of feeding eastern gray whales to pulses from a single 100 in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Malme at al. (1986) estimated that an average pressure level of 173 dB occurred at a range of 2.6–2.8 km from an airgun array with a source level of 250 dB (0-pk) in the northern Bering Sea. Similarly, studies of western gray whales on their summer feeding grounds off Sakhalin Island demonstrated considerable tolerance of an operating seismic vessel offshore of the feeding area (Johnson et al. 2007). However, there were some subtle behavioral responses (Gailey et al. 2007) and some movement of whales within the feeding area in apparent response to strong airgun sounds (Yazvenko et al. 2007).

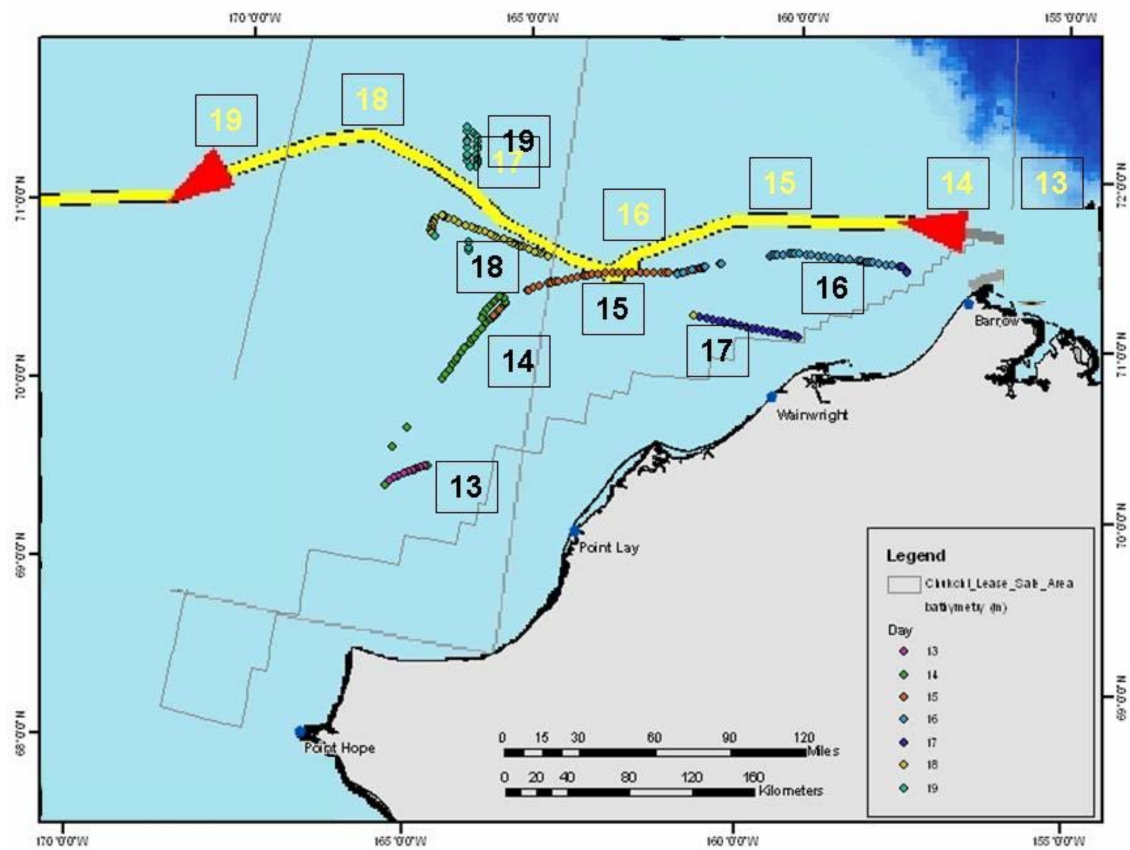

FIGURE 12.14. Tracklines of satellite-tagged bowhead whale (yellow track) and GXT seismic vessel *Discoverer* (dotted track) from 13 to 18 Oct. 2006 showing closest point of approach on 15-16 Oct. Data are from Quakenbush (2006) for the bowhead trackline and from GXT for *Discoverer* trackline. Numbered boxes indicate the dates for whale and vessel locations, respectively.

These findings from the summer feeding grounds were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast. Malme and Miles (1985) concluded that, during migration, avoidance occurred for received levels of about 160 dB re 1 μPa and higher, on an approximate rms basis. For a 4000-in³ airgun array operating off central California, the 50% probability of avoidance was estimated to occur at a CPA distance of 2.5 km where the received level would be ~170 dB re 1 μPa (rms). During the study of migrating gray whales, some behavioral changes were noted at received sound levels of 140 to 160 dB (rms), and it was believed that initial deflection probably began at considerably lower received levels, when the sounds were barely above the background noise level.

Given the relatively high tolerance of gray whales to airgun sounds on summer feeding grounds in the Bering Sea (Malme et al. 1986, 1988) and off Sakhalin island (Yazvenko et al. 2007), it is unlikely that gray whales would have been disturbed sufficiently by the low levels of sound recorded in coastal areas in 2006 to have moved away from a feeding area. Reactions to the highest levels of received seismic sounds along the coast would likely have been no more than short-term behavioral responses.

Gray whale use of waters farther from shore in the fall may have been affected by ongoing seismic activity. After 19 Sept. whales would have been exposed to only one active seismic program. If shoals within the Lease Sale Area (where gray whales have been observed during aerial surveys) are important feeding habitat, those animals using the area may also have been affected. Whales may have been temporarily displaced from those areas and may have been forced to use less optimal feeding habitat. In Chapter 3 we estimated that ~740 gray whales may have been exposed to received levels of airgun sound ≥170 dB re 1 μPa (rms) if they did not move away from the source vessel. Malme et al. (1986) estimated that ~50% of feeding gray whales would move away from a seismic vessel when sound levels were ~173 dB, with a few showing avoidance at received levels ≥163 dB and others tolerating levels somewhat greater than 173 dB. If so, ~ 370 gray whales may have been temporarily displaced from feeding areas by seismic survey activities in the Chukchi offshore area during 2006. The Sakhalin Island study showed that feeding gray whales that do show local displacement generally remain within the overall feeding area. As the seismic program moved, sound levels in the area would return to background levels and whales could reoccupy preferred feeding areas.

Beluga Whales

Based on aerial surveys along the Chukchi Sea coast (Chapter 5) and on the 2006 acoustic studies (Chapter 6), small numbers of beluga whales from the eastern Chukchi Sea stock were likely still in the Chukchi Sea when seismic survey activities began in late July. No beluga whales were observed during aerial surveys along the coastline in Aug. or Sept., though there were few surveys in August. However, small numbers of belugas were recorded in the nearshore waters offshore of the coastline (sawtooth surveys; Chapter 5) during this time and there were acoustic detections of beluga whales on a few days in July and August near Cape Lisburne.

Beluga whales returning through the Chukchi Sea during the fall migration may have encountered ongoing seismic operations. Whales encountering the operating seismic vessel may have altered their course to maintain some nominal distance from the sound source. Effects of seismic exploration and other industry activities on most toothed whales are generally thought to be less than on baleen whales. Beluga whale hearing sensitivity peaks between 10 and 100 kHz and most of the sounds produced by vessels and seismic activities are at much lower frequencies that are less prominent to belugas. Nonetheless, airgun pulses are strong enough, and extend up to sufficiently high frequencies, to be audible to belugas 10s of kilometers away (Richardson and Würsig 1997). Although belugas are not likely to react to barely-detectable airgun pulses at those long distances, there is evidence that, in summer, belugas in the Beaufort Sea tend to avoid operating seismic vessels out to distances of 10 km or more (Miller et al. 2005). In general, beluga whales moving along the Chukchi coast probably did not receive airgun pulses strong enough to elicit overt disturbance, but belugas farther offshore probably would avoid the area around an active seismic vessel.

Pinnipeds

In addition to the whales that would, at times, have been exposed to seismic and vessel activities in the Chukchi Sea during summer and fall 2006, ringed, spotted, and bearded seals and Pacific walruses were also present along the coast and offshore. Previous monitoring work in the Alaskan and Canadian Beaufort seas indicates that seals show no more than limited avoidance of active seismic operations (Miller et al. 1999, 2005; Harris et al. 2001; Moulton and Lawson 2002).

During the open-water period, the highest densities of ***ringed seals*** are most often found within the margin of the pack ice edge. Seismic source vessels towing long streamers cannot operate close to ice because of the risks to equipment towed behind the vessels. However, lower densities of ringed seals also occur in open-water areas where seismic operations occurred. Some ringed seals present in areas of the Chukchi Sea where seismic surveys were ongoing may have been displaced from the area immediately around an operating airgun array; however seal detection rates were often higher during periods of seismic activities than during non-seismic activities, suggesting that many seals were not displaced far (if at all) by seismic noise. Evidence from previous studies in the Beaufort Sea indicates that ringed seals are not likely to move away from sounds produced by seismic surveys at distances >100–200 m.

Ringed seals (and other seals) that did not move from areas receiving strong seismic sounds may have been exposed to varying levels of impulsive sounds periodically for an extended period of time as the seismic vessel moved back and forth through the area. No specific data are available describing the potential for long durations of exposure to impulsive sounds to cause impairment (temporary or permanent) in pinniped hearing. However, there is increasing evidence that seal hearing may be more susceptible to impairment by strong sounds as compared with the hearing of belugas and dolphins (Kastak et al. 2005).

Spotted seal foraging habits are not well understood. Lowry et al. (1998) placed satellite tags on spotted seals at haulouts along the Chukchi Sea coast and reported that spotted seals spent about 16% of their time at haulouts. Seals likely spent a significant portion of the remaining 84% of the time feeding. Chukchi Sea spotted seals traveled as far as 1000 km during foraging trips and they traveled to the Russian coast and used haul-out sites there during feeding expeditions (Lowry et al. 1998). In 2006, exposure to industry activities may have occurred in offshore areas of the Chukchi Sea. Limited information from prior monitoring studies in the Beaufort Sea indicates that spotted seals occasionally occur close enough to operating seismic vessels to be visible to observers on the source vessel (e.g., Moulton and Lawson 2002). There is no specific information to suggest that spotted seals show greater avoidance of seismic vessels than do ringed seals. Other than the nearshore aerial surveys, no industry activity occurred in coastal areas where disturbance to haulouts would have been possible, (During aerial surveys, the aircraft remained at an altitude of 1000 to 1500 ft to minimize disturbance to haulouts.) Underwater sound levels reaching haulout areas were probably near ambient according to measurements made in nearshore waters along the Chukchi coast (Chapter 6). Therefore, it is very unlikely that large areas, either offshore or nearshore, were made unavailable to these seals by seismic surveys occurring in the Chukchi Sea.

Bearded seals in the Chukchi Sea are more likely to be found in close proximity to the margin of the pack ice than in the open-water areas where most seismic work took place. Individuals present near active seismic surveys likely moved away to some limited extent (Harris et al. 2001). Continual or repeated industry activities in a localized area may have displaced some animals from the area, but there is no specific evidence of this.

Walruses use the floating pack ice as a platform from which to forage as long as it remains over relatively shallow waters (<80 m deep), which was the case during much of 2006. Because of their close association with ice (which seismic vessels avoid), few walruses were likely to be affected by the combined industry activities in the Chukchi Sea. Those walruses that encountered seismic surveys or support vessels may have moved away to some limited extent. During aerial surveys of the nearshore Chukchi Sea, walruses were most abundant during July and Aug. and sighting rates dropped off substantially from late Aug. though mid-Nov. Walruses were generally much more abundant offshore during the sawtooth surveys and along the immediate area of the coast.

No ***polar bears*** were observed from seismic source vessels in the Chukchi Sea at any time during the season. A few sightings of polar bears were made from support vessels transiting through areas with high concentrations of pack ice west of Barrow, far from ongoing seismic operations. When polar bears are in the water, they are very near the surface where sounds from seismic sources tend to be lower due to pressure release effects (Greene and Richardson 1988). Their habit of swimming at the surface also makes polar bears relatively easy to observe from a vessel. The direct effects of industry activities in the marine environment on polar bears were, at most, very limited in 2006.

Beaufort Sea

The safety radii for cetaceans and pinnipeds during shallow hazards work were small compared to the safety radii for the deep seismic activities, given the relatively small size of airgun system used during the former. No cetaceans or pinnipeds were observed by MMOs onboard the *Henry C.* during use of the airgun array (Chapter 7). Given the small safety radii, and the fact that airgun operations were limited and occurred during periods with good visibility, it is not likely that any marine mammals were within the respective safety radii during airgun operation. Based on the densities of marine mammals estimated from observations during non-seismic periods, we estimated that 8 pinnipeds might have been exposed to sound levels of ≥190 dB re 1 μPa (rms) if there was no avoidance of the seismic activities. MMOs would likely have been able to observe any cetaceans within the relatively small safety radius and it is not likely that any cetaceans were exposed to sound levels of ≥180 dB.

The airgun calibration measurements and the shallow hazards survey probably temporarily displaced a few seals from the immediate area, but were unlikely to have had any greater effects. Ice was relatively heavy in the Beaufort Sea at the time of the shallow hazards survey. The MMS BWASP data and call locations from the SOI DASARb recorders suggest that most bowheads migrated well off shore in 2006. Therefore, few bowheads were likely to be affected by the sound produced by the *Henry C.*, even at the 120 dB level. Calibration measurements showed that the ≥120 dB (rms) level extended ~22 km from the vessel when four airguns were operating. The 120 dB distance would have been considerably less during the one day of airgun operations in September, when only two airguns were used. Bowheads were most abundant in the band 45-55 km offshore and only one bowhead was recorded within the 120 dB zone during the aerial surveys prior to the seismic activity on 25 Sept. Extrapolation of the aerial survey data suggests that ~7 bowheads may have been within the 120 dB zone during the seismic activities. Beluga whales were probably far offshore and unlikely to have been exposed to sound levels of ≥ 120 dB during the airgun activity (Chapters 8). There is, in any event, no evidence or likelihood that belugas would be affected by airgun sounds at a received level of 120 dB (rms).

Based on evidence from 2001–2004, it likely that a small deflection of bowhead whales migrating in the southern edge of their migration corridor may have occurred when they passed the Northstar development at times when above-average levels of underwater sound were being emitted. Whales reaching the Northstar area during their westward migration would have already passed activities in Camden Bay and could potentially have been exposed to seismic operations conducted in the Canadian Beaufort Sea in 2006.

It does not appear that barge traffic in the Beaufort Sea in 2006 had significant impacts on marine mammals. Green and Negri (2006) reported that ~15% of the seals observed by MMOs onboard barges between West Dock and Cape Simpson displayed strong reactions (described as sudden dives characterized by tail slaps or violent splashes) to barge presence. Most seal reactions were recorded as mild and involved changes in swimming direction or sliding off ice floes. No whales were observed by MMOs between West Dock and Cape Simpson during the barge activities. In retrospect, that was to be expected because most bowhead as well as beluga whales migrated much farther offshore (Fig. 9.1) than the barge routes (Fig. 12.12, 12.13), and much of the barge activity occurred in Aug. before most bowhead and beluga whales were likely to be migrating through the area. No whales were seen during Sept. and early Oct. aerial surveys that extended to ~30 km north of the ODS in Harrison Bay (Reiser et al. 2007). Gray whales occur in nearshore areas, but are not common in the Beaufort Sea. Small numbers of gray whales have been reported along the coast of the Alaskan and Canadian Beaufort Sea in summer

(Rugh and Fraker 1981; Miller et al. 1999; Treacy 2000) and a few gray whales were observed during the 2006 aerial surveys (Chapter 8). Thus, a few gray whales may have encountered barge traffic.

A few polar bears were sighted in the Beaufort Sea during industry activities, either swimming or on ice. No seismic survey activity, and little other vessel activity, occurred in ice-covered waters where polar bears are most abundant. The direct effects of industry activities in the marine environment on polar bears were, at most, very limited in 2006.

Potential Cumulative Impacts

Cumulative effects to a species or a group of species may result from the accumulation of impacts of all previous, current, and future activities that have the potential to affect the species or species group on a population level. MMS (2007) identified past, present, and potential future human activities and possible naturally occurring phenomenon that may incrementally affect and thus have cumulative impacts on bowhead whales in the Chukchi and Beaufort seas. Many factors that have the potential to affect bowhead whales also have the potential to affect other marine mammal species. Past, present and potential future actions that have the potential to impact marine mammals in the Chukchi and Alaskan Beaufort seas include

- historic commercial whaling;
- past, current, and future subsistence hunting;
- previous, current, and near-term future oil- and gas-related activity;
- previous, current, and near-term future non-oil and gas industrial development;
- past, current, and near-term future research activities;
- recent, current, and future marine vessel traffic and commercial fishing;
- pollution and contaminants; and
- Arctic climate change.

Hunting

Commercial whaling from 1848 to about 1915 caused severe depletion of the BCB bowhead whale population. Woody and Botkin (1993) estimated that the historical population for the BCB bowhead population was likely between 10,400 and 23,000 animals prior to commercial whaling, and that about 1000 to 3000 whales remained in 1914. Commercial hunting was discontinued around 1915 and the current BCB bowhead population has recovered to approximately the lower limits of the historical population estimates. The most recent population estimates (2001) suggest that the BCB bowhead population may contain over 10,500 whales with confidence intervals ranging from 8200 to 13,500 (George et al. 2004; Zeh and Punt 2005). The annual growth rate in recent decades has been estimated as 3.4%, with 95% confidence interval 1.7 to 5%. If the annual growth rate has remained near 3.4% since 2001, the current population is likely on the order of 12,900.

The growth of the BCB bowhead whale population has continued in spite of annual Native subsistence hunts from coastal villages in Alaska and Russia. Subsistence hunts have been conducted for several thousand years and far fewer whales have been taken annually compared to commercial hunting activities in the mid-late 19^{th} century. There is no evidence that past and current subsistence hunts have affected bowhead whales at the population level. Subsistence hunts for bowhead whales are regulated and managed under the authority of the International Whaling Commission (IWC) which establishes quotas for the numbers of whales that may be taken during the subsistence hunts. For the period 2002-

2007, a block quota of 280 bowhead strikes will be allowed, of which 67 (plus 15 un-harvested whales from the previous year) could be taken each year (Angliss and Outlaw 2007). This quota includes an allowance of 5 whales to be taken by Chukotka Natives in Russia. Although quotas have increased in recent years and current technology has increased the efficiency of subsistence hunts, the BCB bowhead population is expected to remain sustainable under the quota system regulated by the IWC.

Subsistence hunts for beluga whales occur annually at Point Lay on the Chukchi Sea coast and opportunistically at other locations in Alaska. The subsistence harvest of beluga whales from the Eastern Chukchi Sea stock averaged 65 whales annually in 1999-2003 (Angliss and Outlaw 2007). The most recent estimate of the size of the Chukchi Sea beluga population is 3710 whales. However, recent evidence (Suydam et al. 2001) suggests overlap of the summer range of this population with that of the much larger Beaufort Sea population estimated at nearly 40,000 whales (Angliss and Outlaw 2007). Subsistence harvest of beluga whales in the Chukchi Sea does not appear to affect this stock on a population level, although subsistence hunting of other beluga whale stocks may have had population level impacts (Mahoney and Sheldon 2000).

Native communities also conduct subsistence hunts for other marine mammal species including ringed, bearded, and spotted seals, and the Pacific walrus. Seals are much less high-profile species than bowhead whales and subsistence hunts for seals are less regulated. There are no current estimates of the numbers of ice seals (ringed, bearded, and spotted seals) taken annually during subsistence hunts. The Alaska Department of Fish and Game collected subsistence data on annual seal harvests based on information collected prior to 2000 (Angliss and Outlaw 2007). The estimates for annual subsistence harvests of ringed, bearded and spotted seals in Alaska were 9567, 6788, and 5265, respectively. The current world population estimates for each of these seal species is in the hundreds of thousands although reliable estimates for Alaskan populations are unavailable. Current levels of subsistence harvests are not expected to affect these populations.

The size of the Pacific walrus population is not known with certainty. Pacific walruses have been hunted commercially in the past and it is likely that the population has fluctuated markedly (Angliss and Outlaw 2007). The actual numbers of walruses currently harvested during subsistence hunts are unknown. The USFWS bases their current estimate of the annual Pacific walrus harvest on the average number of walruses harvested during the 5-year period 1996-2000 resulting in an annual estimated harvest of 5789 animals. Although there are no current estimates of the size of the Pacific walrus population, it likely numbers around 200,000 animals and the current level of harvest is not expected to impact the Pacific walrus at the population level.

Environmental Change

The potential effects of climate warming on marine mammals in the Chukchi and Beaufort seas may vary among species. The current warming trend has increased sea water temperature, and reduced the size of the polar ice cap (IPCC 2007). The potential effects of this warming trend may be global in nature and may affect marine mammals in the Chukchi and Beaufort seas in numerous ways. A protracted open-water period during the summer may result in increased shipping/vessel traffic that may have the potential to cause disturbance to marine mammals. Increasing sea temperatures could result in changes in the distribution of marine mammal prey species which could result in changes in the distributions of marine mammals. MMS (2007 and references therein) suggested that some of these environmental changes may actually be beneficial to bowhead whales by producing more favorable conditions. However, some species that depend on ice during part of their life cycle may be much more susceptible to the negative impacts of a reduced ice pack. Ice seals and Pacific walruses rely on the pack ice for hauling out at locations near food sources and some seals give birth and wean pups on ice. Some seals and Pacific walrus feed primarily on benthic invertebrates and are restricted to relatively shallow depths for feeding. A receding ice pack could preclude bearded seals and walruses from accessing suitable feeding areas with adjacent ice habitats for hauling out. Polar bears hunt for ringed and bearded seals on the ice pack. A reduction in the size of the ice pack and of seal abundance may force more frequent use of terrestrial habitats by polar bears and may also cause bears to swim more, possibly increasing the risk of drowning (Monnett and Gleason 2006). It is not clear how a shrinking ice pack will affect species associated with ice habitats such as ice seals, walrus, and polar bear, but it is likely that impacts resulting from the current trend will negatively affect these species.

Increasing sea temperatures could also result in changes in the distribution of commercial fish species which could result in expansion of the commercial fishing industry into the Beaufort and Chukchi seas. An expanded fishing industry could result in the potential for increased vessel collisions with marine mammals and marine mammal entanglement of fishing gear. Increased disturbance to marine mammals from vessels could result in temporary displacement from preferred habitats.

Research Activities

Vessel-based research has the potential to cause temporary disturbance to marine mammals. Vessel-based research has been conducted to investigate the impacts of climate change on biological, physical, and geochemical processes in the Arctic in recent years. Studies summarized by Richardson et al. (1995) show that vessel activities can cause temporary avoidance of specific areas by bowhead whales. Aircraft overflights also can cause transient disturbance to some marine mammals, although aerial surveys for marine mammals are generally conducted at altitudes sufficiently high that marine mammal responses are minimal or absent. Patenaude et al. (2002) reported little reaction of beluga and bowhead whales to fixed-wing aircraft at relatively low altitudes ranging from 60 to 460 m. However, beluga and bowhead whale reactions to low-level helicopters was greater than for fixed-wing aircraft and consisted of various changes in behavior.

Some other types of research activities, particularly those involving transmission of underwater sounds, also have some potential to affect marine mammals. Such activities could include geophysical research not associated with the oil industry (e.g., Haley 2006); oceanographic cruises, which routinely involve use of various types of sonars; deployment of oceanographic instruments that commonly include acoustic communication links and/or sensors; and deployment of low-frequency acoustic sources for long-distance ocean monitoring (e.g., Gavrilov and Mikhalevsky 2006). Most work of these types is not directly connected to the offshore oil and gas industry.

Offshore Oil and Gas Industry

Noise from exploration activities of the offshore oil and gas industry, including both seismic surveys and exploratory drilling activities, along with offshore production activities, also can disturb marine mammals at times. Many cetaceans are known to avoid seismic surveys noise whereas there is less avoidance by some pinniped species (e.g., Harris et al. 2001). Migrating bowhead whales deflect from their fall migration route to avoid some types of seismic and drilling noise (LGL and Greeneridge 1987; Richardson et al. 1999; Schick and Urban 2000). How quickly bowheads return to their original paths is unknown. Nonetheless, seismic programs have operated in the Alaskan Beaufort and/or Chukchi seas since the late 1960s with more than 10,000 line miles being shot in some years (Fig. 12.15). In addition, there was much seismic surveying within the summer range of bowheads in the Canadian Beaufort Sea during the 1970s and early-mid 1980s (Richardson et al. 1987), and again in recent years (Miller et al. 2005). This seismic survey activity was coincident with an increase in the bowhead whale population, which continues to grow at a rate of ~3.4% per year based on recent estimates.

Intensive multi-year acoustical studies during the fall bowhead whale migration at Northstar Island, an offshore oil production island in the Alaskan Beaufort Sea, suggested an offshore displacement of some migrating bowhead whales associated with noise from construction and production (McDonald et al. 2006). The industrial noise associated with the apparent deflection resulted primarily from support vessels (Blackwell and Greene 2006). However, the apparent deflection effect was subtle and only evident after intensive statistical analysis. At past and current levels of industry activity, noise disturbance associated with industrial activities such as seismic surveys, exploratory drilling, and offshore oil production likely have not affected any marine mammal species in the Chukchi and Beaufort seas at the population level.

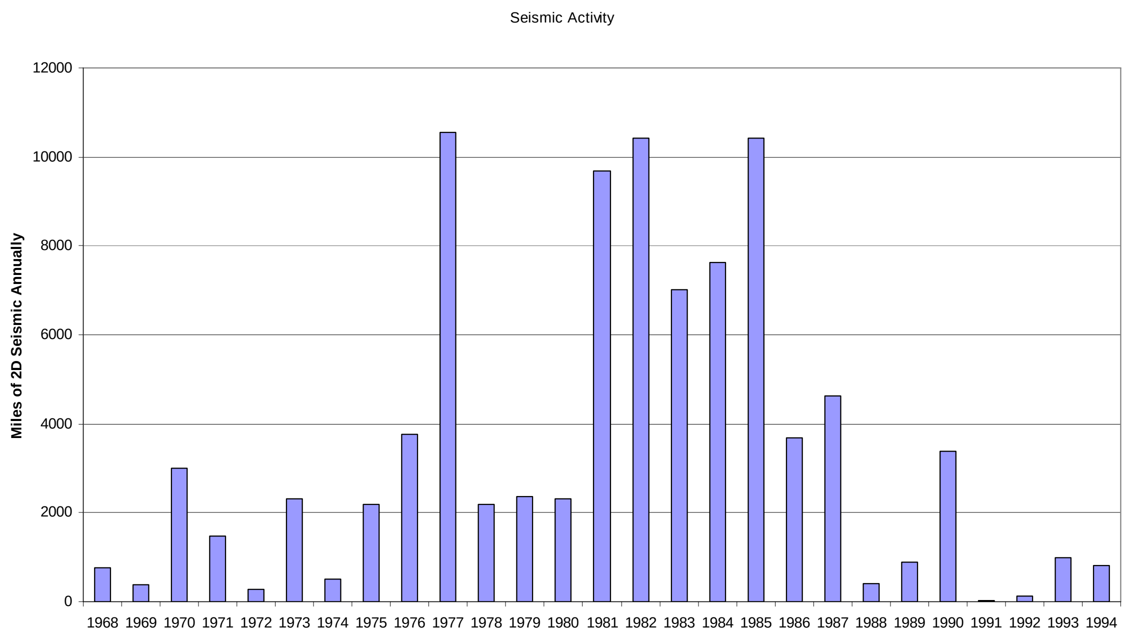

FIGURE 12.15. Miles of 2-D seismic survey activity in the Alaskan Beaufort and Chukchi seas from 1968 through 1994. Additional 3-D seismic was shot in the Alaskan Beaufort Sea during 1996-2001 using ocean bottom cables (OBC).

Collision with vessels has the potential to cause injury and death to marine mammals. Collision with seismic vessels in the Chukchi and Beaufort seas has not appeared to be a significant source of injury or mortality to cetaceans or other marine mammals.

Pollution and Contaminants

The potential for pollution and contaminants to impact marine mammals and other vertebrate species has been of concern to wildlife managers for many years. Pollution of marine environments may result in increased levels of mortality due to toxic effects or increased levels of disease (Gulland and Hall 2007). Tertiary consumers near the top of the food chain are at greater risk than consumers at lower levels due to concentration of contaminants as they progress through the food chain (Wilson et al 2005). Bowhead whales are secondary consumers that feed primarily of euphausiids and copepods, and the levels of most metals and other contaminants in bowheads appears to be relatively low (MMS 2007).

Beluga whales and other cetaceans in the Arctic appear to have lower levels of some contaminants than do cetaceans from other locations (Norstrom and Muir 1994). Levels of various types of contaminants in arctic seals and walruses have also been measured (Nakata et al. 1998; Fisk et al. 2002). Some studies have indicated that marine mammals in the Russian Arctic may have higher levels of contaminants that those in the Canadian Arctic (Nakata et al. 1998; Wilson et al. 2005). The effects of current and future exposure of marine mammal populations in the Chukchi and Beaufort seas to various types of contaminants are unknown.

Future offshore oil exploration and development in the Chukchi and Alaskan Beaufort seas will increase the potential for an offshore oil spill which could contaminate marine mammal food sources. Ingestion of contaminated food sources could be lethal to limited numbers of individuals, and seals and polar bears directly exposed to spilled oil could be killed. The potential impacts of an oil spill would depend on the size and location of the spill, the time of year that the spill occurred, and the ability of industry to respond. As is the case for current offshore oil exploration and development, for future offshore oil activities the oil industry would be required to have extensive oil spill response capabilities which would help to reduce impacts from any spill that did occur.

Future Trends

Impacts to marine mammal individuals and populations would potentially increase with expanded exploration and development of oil and gas in the Alaskan Beaufort and Chukchi seas. It is not possible at this point in time to predict the level of industry interest in future lease sales or the extent of exploratory seismic surveys and drilling that may occur in the Chukchi and Alaskan Beaufort seas in the future. It is also not possible to predict how many new developments might occur from that exploration. However, it is likely that at least some current prospects would be developed or at least explored to a greater extent. As additional exploration and development occurs the potential for impacts caused by industrial sounds in the marine environment will rise as will the potential for vessel collisions with marine mammals due to increased ship traffic in the area. Without proper mitigation such impacts could affect marine mammal individuals and result in a decrease in the availability of marine mammals for subsistence use by villages along the coast of Alaska. It appears unlikely that populations of marine mammals would be affected at current levels of exploration although it remains unclear how other types of impacts like changes in temperature and ice across the Arctic may ultimately affect these populations and their ability to adapt to additional human influence in their habitats.

Cumulative impacts result from the accumulation of incremental effects resulting from various types of anthropogenic and naturally occurring events. While it is sometimes possible to determine the effects of specific activities or events on individuals or groups of marine mammals, it is often difficult to determine what the effects (if any) may be at the population level. Even when data are available suggesting or showing that marine mammals respond to particular anthropogenic stimuli, similar changes often occur in response to numerous environmental variables, further complicated by naturally occurring cycles in population abundance or distribution. Projections of the potential effects of future activities or naturally occurring events on marine mammal populations in the Chukchi and Alaskan Beaufort seas are even more speculative than determining the effects of current activities making accurate determination of cumulative impacts difficult.

Summary and Conclusions

The JMP in the Chukchi and Beaufort seas in 2006 included an acoustic program using arrays of bottom-founded recorders deployed along the Alaskan Chukchi Sea coast, dedicated vessel-based surveys with and without passive acoustic monitoring (PAM) in the MMS Chukchi Sea Planning Area, and an aerial monitoring program over the nearshore waters and coastline of the Chukchi Sea between Pt. Hope and Barrow, Alaska. In addition to the studies conducted in the Chukchi Sea, SOI also conducted some limited acoustic studies and aerial monitoring in the Beaufort Sea in the general area of their operations. In 2006, sea-ice conditions in the Beaufort Sea limited SOI's operations to shallow hazards surveys and other site clearance activities. Acoustic studies conducted by SOI in the Beaufort Sea were primarily used to test newly developed equipment for monitoring marine mammals (primarily bowhead whales) and industrial sounds. Weather and changes in SOI's planned seismic program limited the number of aerial surveys in the central Beaufort Sea to nine.

These studies contribute to the body of knowledge about marine mammals in the Chukchi and Beaufort seas and form the basis for longer term data sets to address potential disturbance of marine mammals in the area by industrial activities. There have been a number of studies on marine mammals in the Beaufort Sea over the past two decades focusing on bowhead whales, beluga whales, seals, and polar bears. Industry monitoring programs have contributed greatly to understanding of impacts to marine mammals from oil and gas exploration and production. Various government entities including the MMS and the USFWS have also funded major research programs in the Alaskan Beaufort Sea. In the Chukchi Sea, far fewer studies have been conducted in recent years. Many of the data sets were collected 20 or more years ago, making additional collection of data important for understanding the current abundance and distribution of marine mammals in the Chukchi Sea.

Vessel surveys conducted in 2006 included dedicated surveys designed to estimate densities of marine mammals in the offshore MMS Chukchi Sea Planning Area at distances from active seismic operations where the behavior and distribution of marine mammals were expected to be undisturbed. These surveys used three on-duty observers, which was not possible on other vessels. Additional data were collected during monitoring of marine mammals from the operating seismic ships and chase boats, and opportunistic sightings from the various support vessels during seismic operations. Results from all of these efforts indicated that, in general, marine mammals occur at relatively low densities in much of the Chukchi Sea during the open water period from mid-July through mid-Nov. In one case, a species uncommon to the area was documented (fin whale), but in general, the species present and their distributions and densities were similar to what has previously been reported for the area. Towed PAM systems were used on some of the dedicated vessel surveys and on one of the chase boats that accompanied the seismic vessels as an additional way to detect marine mammals, but no marine mammals were detected by the PAM systems.

Aerial surveys over the nearshore waters and along the coastline of the Chukchi Sea between Barrow and Point Hope documented the presence and movements of marine mammals along the coast. Surveys began shortly after the annual spring beluga whale hunt by the village of Pt. Lay. Surveys early in the field season documented large numbers of beluga and gray whales, and few bowhead whales. Bowhead whales seen in the Chukchi Sea early during the field season were possibly late northward migrants or could have been whales that remained in the Chukchi Sea throughout the summer. There are no known feeding areas in the Alaskan Chukchi Sea that are frequented consistently by bowhead whales in present times, but there has been speculation that some animals may remain in the area throughout the summer. Walruses were frequently sighted along survey transects early in the season and near Pt. Hope during late season surveys as they migrated back to the Bering Sea wintering ground. Numerous seals were also documented by the aerial surveys but generally were not identified to species due to the altitude of the aircraft. In general, the numbers and distribution of marine mammals along the Alaskan coast were similar to what would be expected based on previous studies.

Bottom-founded acoustic recorders at four locations near villages from Pt. Hope to Barrow were used to conduct acoustic studies along the Chukchi Sea coast. Five recorders were deployed at each site at locations ranging from ~5 to 50 n.mi. (~9.3 to 92.6 km) offshore. Sound measurements collected by arrays of bottom-founded acoustic recorders along the Alaskan Chukchi coast indicated that sound levels reaching the offshore recorders were as high as ~130 dB re 1 μPa (rms) during periods of active seismic surveying. The received levels were highly variable depending upon the distance of the ship from the recorder and diminished to ~110 dB when the seismic ships were ~100-150 km away. Broadband levels of background sound were also variable ranging from ~90 dB to ~110 dB (Chapter 6).

Seismic sounds heard on the second recorder of each array, located 10 n.mi. (18.5 km) offshore, were distinguishable on 77% of the days off Point Lay, 59% of the days off Wainwright, 53% of the days off Cape Lisburne, and only 4% of the days near Barrow. Received sound levels at recorder #2 (10 n.mi. or 18.5 km offshore) and recorder #5 (50 n.mi. or 92.6 km offshore) of each array, plotted as a function of distance from the operating airgun array, indicated that the recorder 50 n.mi. offshore received substantially higher levels of sound than did the recorder closer to shore, as expected. All measurements of received levels at the recorders 10 n.mi. from shore were near ambient levels, ~90 to 110 dB.

In the Beaufort Sea, operations were limited by sea ice to shallow hazards surveys and general site clearance work. Airguns were only used on two days, once during sound source measurements completed early in the season and once during shallow hazards work near the end of Sept. Aerial surveys in support of SOI's operations in the Beaufort Sea were also limited by environmental conditions and by the reduced industry program, with only 9 surveys being flown over a month-long period. Marine mammals in the area of the surveys were seen in typical numbers. Acoustic studies in the Beaufort Sea were used primarily to test new bottom-founded recorders. These studies were successful in detecting whale calls but the deployment period was short. In general, there was no evidence that SOI's operations in the Beaufort Sea had any appreciable effects on the marine mammals in the area. Additionally, the whale hunts at Kaktovik, Cross Island, and Barrow were all successful, suggesting that there was likely no impact on the subsistence hunt from industry activities.

The studies conducted as part of the JMP provide a first year of data toward what is anticipated to be a long term data set. Compilation of these data will assist in later integration of these studies and will provide the basis for a broad-based assessment of industry activities and their impacts on marine mammals in the Chukchi and Alaskan Beaufort seas. Such an assessment will provide Industry and Government the data needed to better manage the resources in the area and will contribute information for assessing potential effects of cumulative increases in activity in these areas.

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APPENDIX A.

TABLE A.1. Useable[a] visual observation effort in hours from the different vessel groups within the Chukchi Sea, Offshore and Nearshore, subdivided by Beaufort Wind Force[b] and seismic activity. Note that effort is different for cetaceans, pinnipeds, and ursids, partly due to the differences in their post-seismic periods and partly due to their different vessel proximity criteria (both are factors for useability). For more details, see *Methods* in Chapter 3.

	Nearshore								**Offshore**							
Beaufort Wind Force	**0**	**1**	**2**	**3**	**4**	**5**	**blank**	***Total***	**0**	**1**	**2**	**3**	**4**	**5**	**blank**	***Total***
Effort in h																
Vessel Group A																
Non-seismic																
Cetaceans	0	0.4	2.3	3.8	0	0.4	0	***6.9***	0	12.9	32.1	84.2	86.9	46.8	4.4	***267.3***
Pinnipeds	0	0.4	2.3	3.8	0	0.4	0	***6.9***	0	15.0	34.8	91.9	93.9	52.7	4.4	***292.9***
Ursids	0	0.4	2.3	3.8	0	0.4	0	***6.9***	0	14.0	33.8	90.8	91.9	51.8	4.4	***286.8***
Seismic																
Cetaceans	0	0	0	0	0.5	0	0	***0.5***	0.8	17.8	62.9	156.3	269.1	209.1	0	***716.1***
Pinnipeds	0	0	0	0	0.5	0	0	***0.5***	1.1	19.3	75.9	200.2	349.9	267.9	0	***914.3***
Ursids	0	0	0	0	0.5	0	0	***0.5***	1.1	19.3	75.9	200.2	349.9	267.9	0	***914.3***
Vessel Group B																
Non-seismic																
Cetaceans	4.4	17.3	29.5	31.8	12.5	9.7	0	***105.2***	29.0	121.6	254.7	154.5	133.5	91.9	0	***785.2***
Pinnipeds	4.4	19.3	30.4	32.3	12.5	13.7	0	***112.5***	31.5	150.9	301.6	191.7	153.1	104.2	0	***933.0***
Ursids	4.4	19.3	30.4	32.3	12.5	13.7	0	***112.5***	31.5	130.8	259.1	157.6	149.1	98.4	0	***826.5***
Seismic																
Cetaceans	0	0	0	0	0	0	0	***0***	3.2	67.5	121.2	119.8	119.6	60.3	0	***491.7***
Pinnipeds	0	0	0	0	0	0	0	***0***	9.7	108.4	206.9	236.9	231.5	94.1	0	***887.6***
Ursids	0	0	0	0	0	0	0	***0***	9.7	108.4	206.9	236.9	231.5	94.1	0	***887.6***
Vessel Group C																
Non-seismic																
Cetaceans	0	0	0	0	1.2	0.5	0	***1.7***	0	4.9	17.6	22.4	14.5	14.5	0	***73.8***
Pinnipeds	0	0	0	0	1.2	0.5	0	***1.7***	0	5.9	20.7	22.4	15.0	15.6	0	***79.4***
Ursids	0	0	0	0	1.2	0.5	0	***1.7***	0	4.9	18.1	22.4	14.5	14.5	0	***74.3***
Seismic																
Cetaceans	0	0	0	0	0	0	0	***0***	0	7.5	10.1	16.5	7.6	6.0	0	***47.7***
Pinnipeds	0	0	0	0	0	0	0	***0***	0	8.7	12.1	16.9	7.6	6.2	0	***51.6***
Ursids	0	0	0	0	0	0	0	***0***	0	8.7	12.1	16.9	7.6	6.2	0	***51.6***

Note: Totals are of unrounded values.
[a] See *Useability Criteria* in *Methods* in Chapter 3.

[b] Beaufort Wind Force scale: 0 is < 1 knot (<1 mph); 1 is 1-3 knots (1-3 mph); 2 is 4-6 knots (4-7 mph); 3 is 7-10 knots (8-12 mph); 4 is 11-16 knots (13-18 mph); 5 is 17-21 knots (19-24 mph).

TABLE A.2. Useable[a] visual observation effort in hours, from the different vessel groups within the Chukchi Sea, Offshore and Nearshore, subdivided by total number of observers, seismic activity, and the different species groups. Note that effort is different for cetaceans, pinnipeds, and ursids, partly due to the differences in their post-seismic periods and partly due to their different vessel proximity criteria (both are factors for useability). For more details, see *Methods* in Chapter 3.

	Nearshore				**Offshore**			
Total number observers	**1**	**2**	**3**	***Total***	**1**	**2**	**3**	***Total***
Effort in h								
Vessel Group A								
Non-seismic								
Cetaceans	5.2	1.7	0	***6.9***	194.6	71.8	0.9	***267.3***
Pinnipeds	5.2	1.7	0	***6.9***	214.0	78.0	0.9	***292.9***
Ursids	5.2	1.7	0	***6.9***	210.8	75.1	0.9	***286.8***
Seismic								
Cetaceans	<0.1	0.5	0	***0.5***	431.6	278.7	5.8	***716.1***
Pinnipeds	<0.1	0.5	0	***0.5***	563	343.9	7.5	***914.4***
Ursids	<0.1	0.5	0	***0.5***	563	343.9	7.5	***914.4***
Vessel Group B								
Non-seismic								
Cetaceans	52.1	25.9	27.1	***105.2***	552.6	96.5	136.2	***785.2***
Pinnipeds	57.8	27.6	27.1	***112.5***	689.3	106.0	137.7	***933.0***
Ursids	57.8	27.6	27.1	***112.5***	591.4	98.6	136.4	***826.5***
Seismic								
Cetaceans	0	0	0	***0***	378.9	106.6	6.2	***491.7***
Pinnipeds	0	0	0	***0***	749.7	129.1	8.8	***887.6***
Ursids	0	0	0	***0***	749.7	129.1	8.8	***887.6***
Vessel Group C								
Non-seismic								
Cetaceans	1.7	0	0	***1.7***	73.8	0	0	***73.8***
Pinnipeds	1.7	0	0	***1.7***	79.4	0	0	***79.4***
Ursids	1.7	0	0	***1.7***	74.3	0	0	***74.3***
Seismic								
Cetaceans	0	0	0	***0***	47.7	0	0	***47.7***
Pinnipeds	0	0	0	***0***	51.6	0	0	***51.6***
Ursids	0	0	0	***0***	51.6	0	0	***51.6***

Note: Totals are of unrounded values.
[a] See *Useability Criteria* in *Methods* in Chapter 3.

TABLE A.3. Numbers of useable[a] sightings (number of individual marine mammals) in the Chukchi Sea, nearshore region, from the different vessel groups between Jul. 10 and Nov. 12, 2006. Sightings are sub-divided by season (early, mid, late). See *Methods* in Chapter 3 for definitions of these data categories. There were no useable sightings during seismic periods within the Chukchi nearshore region.

	Non-Seismic								
	Vessel Group A			Vessel Group B			Vessel Group C		
Species	**Early**	**Mid**	**Late**	**Early**	**Mid**	**Late**	**Early**	**Mid**	**Late**
Cetaceans									
Unidentified Whale	0	-	-	2(3)	1(1)	-	-	0	0
Odontocetes									
Harbor Porpoise	0	-	-	1(3)	0	-	-	0	0
Mysticetes									
Bowhead Whale	0	-	-	0	7(9)	-	-	0	0
Gray Whale	0	-	-	12(27)	2(2)	-	-	0	0
Minke Whale	0	-	-	1(1)	0	-	-	0	0
Total Cetaceans	***0***	***-***	***-***	***16(34)***	***10(12)***	***-***	***-***	***0***	***0***
Pinnipeds in Water									
Unidentified Pinniped	0	0	-	1(1)	1(1)	0	-	-	0
Odobenids									
Pacific Walrus	0	0	-	0	2(3)	0	-	-	0
Phocids									
Bearded Seal	0	0	-	2(2)	28(28)	2(2)	-	-	0
Phoca sp.	1(1)	0	-	0	67(86)	5(5)	-	-	0
Unidentified Seal	2(2)	0	-	10(10)	126(135)	0	-	-	1(1)
Total Pinnipeds in Water	***3(3)***	***0***	***-***	***13(13)***	***224(253)***	***7(7)***	***-***	***-***	***1(1)***
Pinnipeds on Ice									
Odobenids									
Pacific Walrus	0	0	-	2(31)	0	0	-	-	0
Ursids									
Polar Bear	0	0	-	0	0	0	-	-	0

[a] See *Useability Criteria* in *Methods* in Chapter 3.

TABLE A.4. Number of useable detections (sightings), useable[a] effort in km and calculated detection rate (number of detections per 1000 km) for all vessel groups in the Chukchi Sea, Nearshore, sub-divided by (A) Non-seismic, and (B) Seismic periods. There was no seismic effort from vessel groups B or C within the nearshore region.

	Early			Mid			Late			All		
Vessel group	**# Det.**	**Effort (km)**	**Det. rate/ 1000km**	**# Det.**	**Effort (km)**	**Det. rate/ 1000km**	**# Det.**	**Effort (km)**	**Det. rate/ 1000km**	**# Det.**	**Effort (km)**	**Det. rate/ 1000km**
A. Non-seismic												
Vessel Group A												
Cetaceans	0	125.6	0.0	-	-	-	-	-	-	N/A	N/A	N/A
Pinnipeds in Water	3	85.2	35.2	0	40.5	0.0	-	-	-	N/A	N/A	N/A
Pacific Walrus in water	0	85.2	0.0	0	40.5	0.0	-	-	-	N/A	N/A	N/A
Pinnipeds on Ice	0	85.2	0.0	0	40.5	0.0	-	-	-	N/A	N/A	N/A
Pacific Walrus on ice	0	85.2	0.0	0	40.5	0.0	-	-	-	N/A	N/A	N/A
Ursids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	125.6	0.0
Vessel Group B												
Cetaceans	**16**	**1156**	**13.8**	10	713.3	14.0	-	-	-	N/A	N/A	N/A
Pinnipeds in Water	13	712.8	18.2	224	991.7	225.9	7	260.1	26.9	N/A	N/A	N/A
Pacific Walrus in water	0	712.8	0.0	0	991.7	0.0	0	260.1	0.0	N/A	N/A	N/A
Pinnipeds on Ice	2	712.8	2.8	0	991.7	0.0	0	260.1	0.0	N/A	N/A	N/A
Pacific Walrus on ice	0	712.8	0.0	0	991.7	0.0	0	260.1	0.0	N/A	N/A	N/A
Ursids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**0**	**1964.6**	**0.0**
Vessel Group C												
Cetaceans	-	-	-	0	17.8	0.0	0	9	0.0	N/A	N/A	N/A
Pinnipeds in Water	-	-	-	-	-	-	1	26.8	37.3	N/A	N/A	N/A
Pacific Walrus in water	-	-	-	-	-	-	0	26.8	0.0	N/A	N/A	N/A
Pinnipeds on Ice	-	-	-	-	-	-	0	26.8	0.0	N/A	N/A	N/A
Pacific Walrus on ice	-	-	-	-	-	-	0	26.8	0.0	N/A	N/A	N/A
Ursids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	26.8	0.0
B. Seismic												
Vessel Group A												
Cetaceans	-	-	-	0	2.5	0.0	-	-	-	N/A	N/A	N/A
Pinnipeds in Water	-	-	-	-	-	-	0	2.5	0.0	N/A	N/A	N/A
Pacific Walrus in water	-	-	-	-	-	-	0	2.5	0.0	N/A	N/A	N/A
Pinnipeds on Ice	-	-	-	-	-	-	0	2.5	0.0	N/A	N/A	N/A
Pacific Walrus on ice	-	-	-	-	-	-	0	2.5	0.0	N/A	N/A	N/A
Ursids	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	2.5	0.0

Note: N/A means not applicable.

[a] See *Useability Criteria* in *Methods* in Chapter 3.

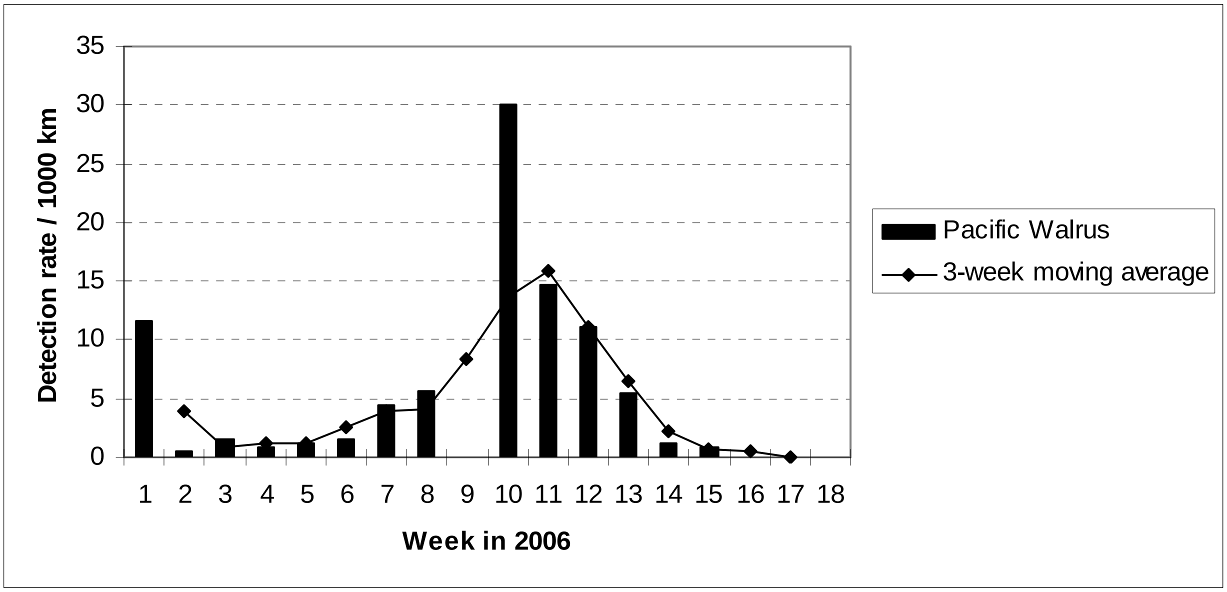


FIGURE A.1. Pacific walrus detection rates (# useable sightings per 1000 km) by week and 3-week moving average detection rates in the Chukchi Sea, offshore region, during non-seismic periods, pooling data from all vessels. To see the corresponding effort by week and 3-week moving totals, refer to Figure 3.1 in Chapter 3.

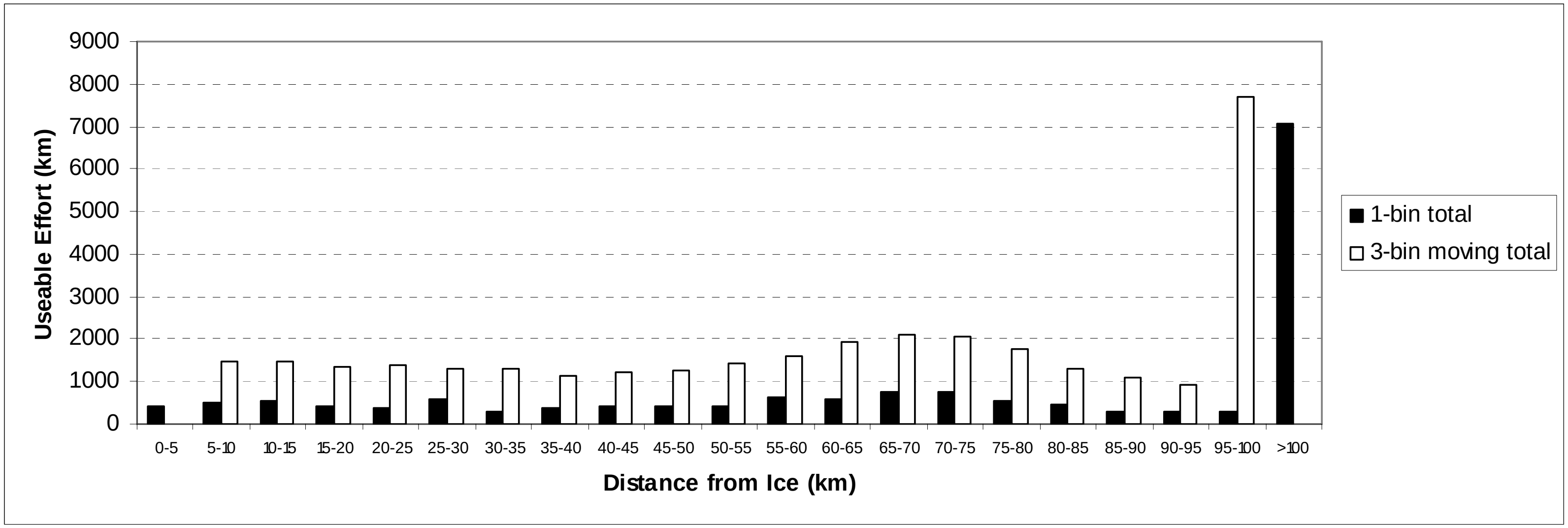


FIGURE A.2. Useable pinniped effort in kilometers with distance from ice including all pinniped seasons. Data is from the Chukchi Sea, offshore region, during non-seismic periods, pooling data from all vessels.

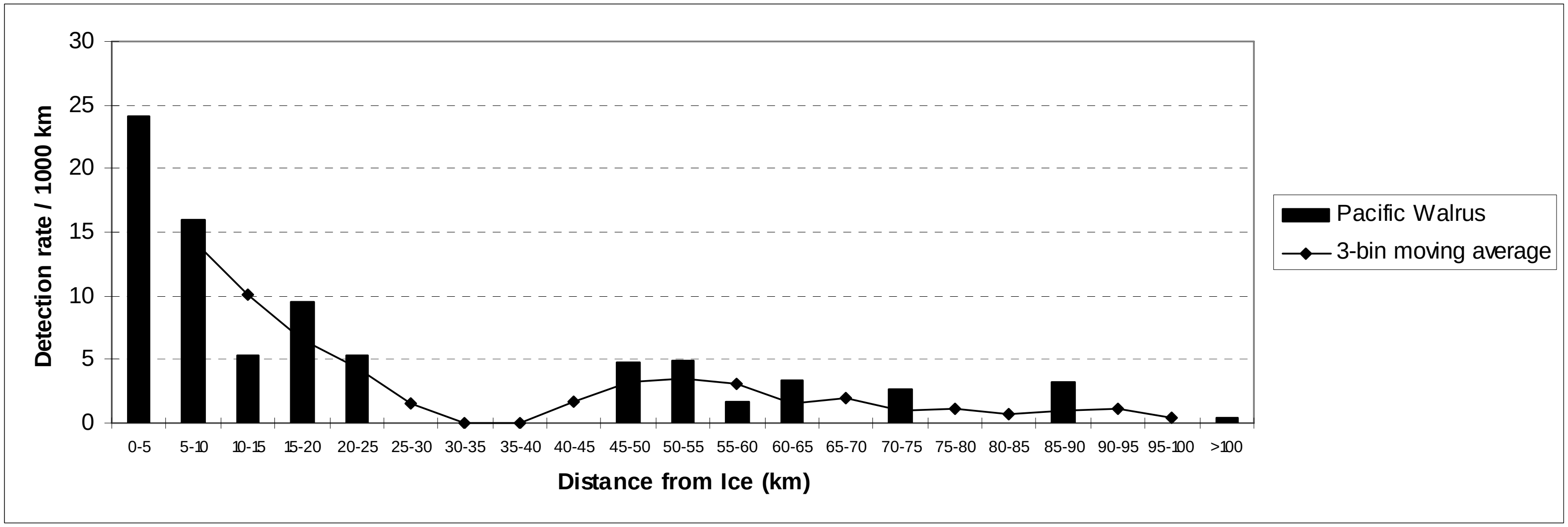


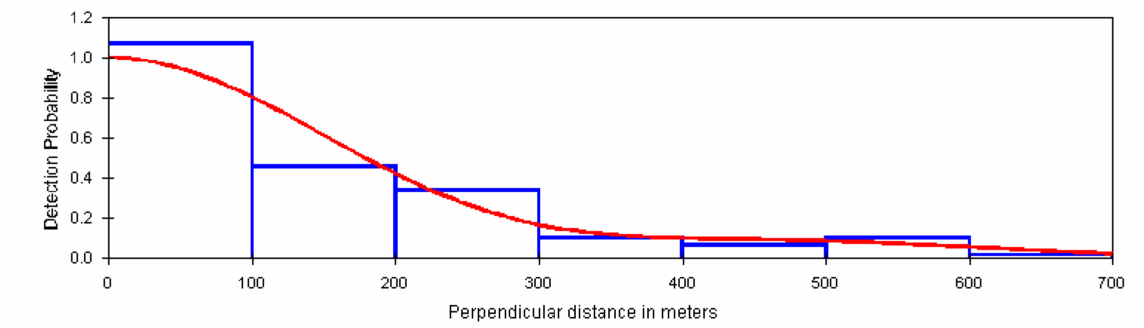
FIGURE A.3. Detection rates for Pacific walrus (# useable sightings per 1000 km) with distance from ice including all seasons. Data is from the Chukchi Sea, offshore region, during non-seismic periods, pooling data from all vessels.

APPENDIX B

Calculation of f(0)

f(0) values were estimated for each subset of the data, with subsets defined based on species group (cetaceans and pinnipeds), vessel groupings, offshore and nearshore, number of observers, season, and ice cover category (near ice and open water). Only "useable" sighting data as collected during the specified combination of conditions as defined in Chapter 3 were used to calculate *f*(0) values.

For each subset of data, the probability density functions and *f*(0)s associated with the observed distribution of lateral distances were calculated with the program DISTANCE (Thomas et al. 2006, version 5.0, release 2). The model selected was half-normal (with cosine polynomial). This model was selected based on minimizing Akaike's Information Criterion (AIC; Akaike 1973). *f*(0) was calculated without right truncation because the raw data were screened to remove outliers before input to DISTANCE. Outliers were defined as pinnipeds seen >3.7 km and cetaceans seen >5.5 km from observers. An example output is shown below (Fig. B.1).



VisualEffort='Y' AND UseableSighting='Y' AND FirstSighting='Y' AND VesselGroupNonSeismic='B' AND Sea='Chucki Sea' AND NearshoreOffshore='Offshore' AND SeismicExposure='NotExposed' AND UseableEffortPinnipeds='Y' AND SpeciesGroup1 = 'Pinniped' AND SeasonPinnipeds='bMid' AND TotalOBS='3' AND Angle >= 0; N=127, width=700

	Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine					
m	2.0000				
LnL	-769.79				
AIC	1543.6				
AICc	1543.7				
BIC	1549.3				
Chi-p	0.65511E-03				
f(0)	0.46355E-02	7.29	125.00	0.40138E-02	0.53535E-02
p	0.30818	7.29	125.00	0.26685	0.35591
ESW	215.72	7.29	125.00	186.79	249.14

FIGURE B.1. Output from the DISTANCE program. The *f*(0) value from this analysis is highlighted in Table B.2.

Tables B.1–B.3 show the *f*(0) values that were estimated directly from DISTANCE in bold typeface. Those values were applied to the sightings and effort data during those specific periods and in those specific areas to compute densities from the survey data. During some periods, there were not enough sightings to provide reliable estimates of *f*(0) for all observer combinations. During many of those periods, we were able to obtain *f*(0) values for either 1, 2 or 3 observers and we scaled the missing *f*(0) values for a specific number of observers based on the ratios of *f*(0) values for 1, 2 and 3 observers during

TABLE B.1. *f*(0) values used to correct survey data collected in the offshore Chukchi Sea. Also shown is the number of "useable" sightings (*n*) entered into the DISTANCE program and the 95% Confidence Intervals (C.I.) of the *f*(0) estimate. Numbers in bold typeface are computed from survey data and numbers in regular typeface are prorated based on *f*(0) values from the mid- season pinniped surveys in offshore, open-water areas. See Chapter 3 for "useable" criteria and temporal, habitat and geographic breakdown.

	Early-season								Mid- season				Late-season			
	Near Ice				Open Water				Open Water				Open Water			
			95% C.I.				95% C.I.				95% C.I.				95% C.I.	
Vessel group	***n***	***f*(0)**	**Lower**	**Upper**	***n***	***f*(0)**	**Lower**	**Upper**	***n***	***f*(0)**	**Lower**	**Upper**	***n***	***f*(0)**	**Lower**	**Upper**
A. Non-seismic																
Vessel Group B																
Cetaceans																
1, 2 & 3 observers	57	**1.625**	1.207	2.188	57	**1.625**	1.207	2.188	57	**1.625**	1.207	2.188	57	**1.625**	1.207	2.188
Pinnipeds in Water																
1 observer	70	**2.878**	2.411	3.435	27	**7.879**	5.333	11.64	485	**4.233** [a]	4.053	4.420	23	**5.378**	0.234	123.4
2 observers	11	2.300	N/A	N/A	15	6.296	N/A	N/A	40	**5.607**	4.278	7.349	1	7.275	N/A	N/A
3 observers	0	1.902	N/A	N/A	6	5.205	N/A	N/A	127	**4.636**	4.014	5.354	62	**8.475**	6.890	10.43
A. Seismic																
Vessel Group B																
Cetaceans																
1, 2 & 3 observers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pinnipeds in Water																
1 observer	36	**7.704**	6.049	9.813	161	**6.892**	6.132	7.745	245	**10.727**	9.908	11.61	N/A	6.892	N/A	N/A
2 observers	N/A	5.607	N/A	N/A	N/A	5.508	N/A	N/A	23	**3.522**	2.229	5.567	N/A	5.508	N/A	N/A
3 observers	N/A	4.636	N/A	N/A	N/A	4.554	N/A	N/A	13	5.000	N/A	N/A	N/A	4.554	N/A	N/A

Note: N/A means not applicable.

Note: *n* is the number of sightings with distance and bearing data (which are needed to compute *f*(0)), and may differ from the number of "useable" sightings presented elsev

[a] The *f*(0) values collected during these surveys were during exceptionally good conditions with low sea states. If sea states were similar during all surveys during this period the f(0) for one observer would have been 7.942 (see text for an explanation of this calculation).

TABLE B.2. *f*(0) values used to correct survey data in the nearshore Chukchi Sea during non-seismic periods for vessel group B. See notes to table B.1.

	Mid-season			
Vessel group	***n***	***f*(0)**	**95% C.I. Lower**	**Upper**
A. Non-seismic				
Vessel Group B				
Cetaceans				
1, 2 & 3 observers	57	**1.625**	1.207	2.188
Pinnipeds in Water				
1 observer	38	**5.480**	3.797	7.909
2 observers	N/A	3.866	N/A	N/A
3 observers	176	**2.772**	2.428	3.165

the mid-season, open-water period. For example, the 2 observer value for near ice in the early-season in Table B.1 was obtained by dividing the 1 observer value for near ice (2.878) by the 1 observer value for mid-season open water (7.016) and multiplying that value by the 2 observer value for mid-season (5.607). The derivation of the 7.016 (instead of 4.233) for 1 observer during mid-season open water is described in the next paragraph. For seasons or areas where sample sizes did not allow calculation of a *f*(0) for any combination of observers, we used the *f*(0) for the most similar conditions where *f*(0) values were obtained.

TABLE B.3. *f*(0) values used to correct survey data in the nearshore Beaufort Sea during non-seismic periods. See notes to Table B.1.

	All Seasons and Ice			
Vessel group	***n***	***f*(0)**	**95% C.I. Lower**	**Upper**
A. Non-seismic				
Henry Christofersen				
Pinnipeds in Water				
1 observer	282	**4.814**	4.376	5.297
2 observers	N/A	3.847	N/A	N/A
3 observers	N/A	3.181	N/A	N/A

The mid-season open-water data provided the largest sample of survey data to examine the effect of the number of observers on the detection rates of marine mammals during the 2006 surveys. It was important to establish the relationship between *f*(0) and the number of observers on watch because different numbers of observers were used on different vessels or at different times on the same vessels. Observations needed to be standardized across other factors to examine the effects of those factors (ie. ice cover and season on marine mammal distribution). If the sighting data were not standardized for the number of observers, any differences found could be due to differences in the number of observers on watch and not the factor being considered. *f*(0) values from the survey data for one, two and three observers are shown in Table B.1. Unexpectedly, one observer saw a higher proportion of the animals near the vessel than two observers and about the same as three observers based on the *f*(0) corrections for missed animals.

Table B.4 shows the survey effort broken down by Beaufort state for times when one, two and three observers were present. During periods when one observer was on watch the Beaufort states were much calmer (i.e., a much higher proportion of effort was during Beaufort states 0 and 1) than when 2 or 3 observers were watching. Figure B.2 shows the effect of sea state on detection rates for one, two and three observers. As during many earlier studies, detection rates are much higher during calm seas. Therefore, one-observer *f*(0) data cannot be directly compared to the two and three observer data. To make the data comparable, we calculated a revised sighting rate for one observer by multiplying the observed sighting rate for each Beaufort state for one observer times the effort by three observers for that Beaufort state category and then summed the components to obtain a theoretical sighting rate for one observer. Based on the ratio of the overall revised sighting rate for one observer to the sighting rate for three observers, it was estimated that the *f*(0) value for one observer would have been 7.016 if sea state conditions were the same for one and three observers. When estimating *f*(0) for one, two or three observers using *f*(0) values from one of these categories, we assumed that *f*(0) values would be in the ratio of 7.016 with one observer to 5.607 with two observers to 4.636 with three observers. However, when calculating numbers and densities of animals using the mid-season data of one observer, we used the *f*(0) of 4.233 from the survey data because it best represents the detection probability function present during those surveys.

Table B.4. Survey effort (linear km) during each Beaufort state for crews of 1, 2 and 3 marine mammal observers in the offshore Chukchi Sea during the mid-season period for pinnipeds.

Beaufort State	Number of observers 1	2	3	Total Effort
0	274.3	9.8	9.2	293.4
1	567.5	80.4	65.5	713.5
2	505.7	83.0	453.7	1042.5
3	584.8	105.9	316.8	1007.5
4	290.6	113.4	554.3	958.3
5	434.3	452.8	154.1	1041.2
0 to 5	2657.2	845.4	1553.8	5056.4

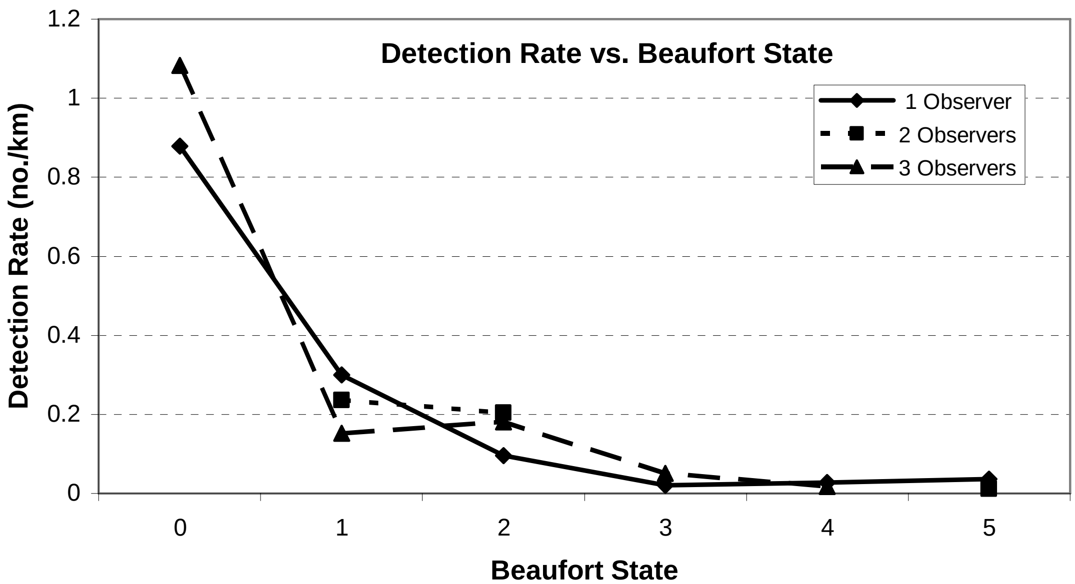


Figure B.2. Detection rates of pinnipeds versus Beaufort state for crews of one, two and three marine mammal observers. Based on non-seismic periods; "useable" pinniped sightings and effort; vessel group B; Chukchi Sea offshore; and during the pinniped mid-season. Detection rates are not shown for categories with less than 5 sightings.

Calculation of g(0)

As noted above, there are two components of $g(0)$ that were estimated separately. To distinguish the two components of $g(0)$, we will refer to

$g_a(0)$ when we refer to corrections for availability bias, *i.e.*, for mammals not at the surface due to their diving behavior,

$g_d(0)$ when we refer to corrections for detectability bias, *i.e.*, for animals at the surface that are missed by the primary observer, and

$g_{a,d}(0)$ when corrections account for both biases.

In this analysis, estimates of $g_a(0)$ were included when estimating numbers of all species. However, these estimates of $g_a(0)$ are in many cases very preliminary and approximate, as specific studies to estimate $g_a(0)$ have not yet been done for many of the species encountered, or when they have, they have not been done for the time of year when our surveys were conducted. We used $g_a(0)$ and $g_{ad}(0)$ estimates from Barlow and Sexton (1996), Barlow and Gerrodette (1996), and Forney and Barlow (1998) for a few species or species groups for which those values have been derived for ship surveys. For the main cetacean species encountered in our survey area, surfacing and dive data shown in Table B.5 were used to approximate $g_a(0)$ for each species based on vessel speed and whale behavior. For example, for beluga whales, the $g_a(0)$=0.42 for the source vessels (Table B.5) was calculated from data in Martin et al. (1993), and for feeding bowhead whales (i.e., their main activity during summer), the $g_a(0)$=0.165 for the dedicated survey vessel (Table B.5) was taken from data in Thomas et al. (2002).

In some cases, the only available data on surfacing and dive behavior were obtained from studies conducted outside the Beaufort Sea on the same species. In these cases, the data used were from periods when marine mammal activities would be similar to those of the species while they were in the Chukchi Sea. For example, for feeding gray whales we used data from feeding gray whales in the Bering Sea (Würsig et al. 1986). For species for which neither $g_a(0)$ values nor surfacing and dive data were available data, we used $g_a(0)$ values from closely related species.

Estimates of $g_d(0)$ have been made for most species or species groups during ship surveys. The $g_d(0)$ values used during this study were obtained from the reports and publications listed above. If $g_d(0)$ was not available, we assumed that it was 1.00.

***Calculation of Availability Bias*.—**The calculation of $g_a(0)$ values in Table B.4 is described here. If all surfacings of a marine mammal are of duration *s*, all dives are of duration *u*, and the duration of potential detectability as the survey vessel travels past the whale location is *t*, the probability that a whale will be at the surface while it can be seen is

$$g_a(0) = \frac{s}{s+u} + \frac{t}{s+u} = \frac{s+t}{s+u}$$

(Eberhardt 1978). Here, $s/(s+u)$ is the probability that the whale will be at the surface when its location first comes into visual range, and $t/(s+u)$ is the probability that the whale will surface while its location is in visual range.

We calculated *t* for two vessel speeds because the speed of the survey vessels varied substantially between seismic source vessels and other vessels. While conducting seismic, the source vessels maintain a relatively constant speed of ~7.4 km/h (4.0 kts) to maximize the quality of seismic data that are acquired. Based on the truncation distance for cetacean sightings from the dedicated surveys (~2.0 km), an area being searched for cetaceans would be in view for t=~78 s at a ship speed of 7.4 km/h. The chase boats and other survey vessels during this study traveled at a median speed of 9.2 kts (17.0 km/h), and so we calculated a *t* of ~34 s for the other survey vessels.

***Calculation of Detectability Bias.*—**The proportion of pinnipeds detected along the trackline [$g_d(0)$] is expected to vary according to the number of observers. When three observers are on duty, one observer can "guard" the trackline and most pinnipeds should be seen; however, with one observer attempting to monitor the same area as three, many pinnipeds will be missed. We used our data from periods with one, two and three observers on duty to estimate the proportion of sightings missed by one and two observers assuming that three observers saw all pinnipeds along the trackline or that $g_d(0)$=1.00 for three observers. Assuming that $g_d(0)$=1.00 is probably a minor underestimation of the detection probability along the trackline and so overall detection probabilities may be slightly low. However, readers are reminded that

TABLE B.5. $g_a(0)$ values for cetaceans. Shown are the data sources, and assumptions used when calculating $g_a(0)$.

Species Activity	Data source	Time in view (s)	Distance ahead (km)	Vessel speed (km/h)	Mean surfacing time (s)	Mean dive time (s)	$g_a(0)$
Bowheads- ship							
Feeding	Thomas et al. (2002)	97.3	2.0	7.4	76.6*	520	0.250*
Traveling	Thomas et al. (2002)	97.3	2.0	7.4	93.7	832	0.206
Feeding	Thomas et al. (2002)	42.3	2.0	17.0	76.6*	520	0.165*
Traveling	Thomas et al. (2002)	42.3	2.0	17.0	93.7	832	0.147
Gray Whale - ship							
Feeding	Wursig et al. (1986)	97.3	2.0	7.4	53.4	191	0.616
Traveling	Mallonee (1991)	97.3	2.0	7.4	62.4	145	0.769
Feeding	Wursig et al. (1986)	42.3	2.0	17.0	53.4	191	0.391
Traveling	Mallonee (1991)	42.3	2.0	17.0	62.4	145	0.504
Beluga Whale - ship							
All behavior	Martin et al. (1993)	97.3	2.0	7.4	392	773	0.420
All behavior	Martin et al. (1993)	42.3	2.0	17.0	392	773	0.373
Harbor Porpoise - ship							
All behavior	Laake et al. (1997)	97.3	2.0	7.4	36.0	127	0.818
All behavior	Laake et al. (1997)	42.3	2.0	17.0	36.0	127	0.480
Killer Whale - ship							
All behavior	Erikson (1978)	97.3	2.0	7.4	38.5	382	0.323
All behavior	Erikson (1978)	42.3	2.0	17.0	38.5	382	0.192
Fin Whale - ship							
All behavior	Stone et al. (1992)	97.3	2.0	7.4	54.6	201	0.595
All behavior	Stone et al. (1992)	42.3	2.0	17.0	54.6	201	0.379
Minke Whale - ship							
All behavior	Folkow & Blix (1993)	97.3	2.0	7.4	41.2	173	0.645
All behavior	Folkow & Blix (1993)	42.3	2.0	17.0	41.2	173	0.389

* Corrected for short dives.

our $f(0)$ corrects for animals missed due to the reduced probability of sighting an animal relative to its lateral position from the trackline. The following procedure was used to compute $g_d(0)$ for one and two observers:

- The density of pinnipeds was estimated using three-observer data for the mid-season, open-water period, vessel group B in the Chukchi Sea using the "useable" effort, sightings, and $f(0)$ value highlighted in yellow in Table B.1 (4.636) for that period. The assumption was made that $g_a(0)$=1.00 and $g_d(0)$=1.00.
- The density of pinnipeds as estimated above was entered into the density calculation equation for the two-observer data for the same period assuming that $f(0)$=5.607 and $g_a(0)$=1.00. The equation was solved for $g_d(0)$ which is 0.720 in Table B.6.

TABLE B.6. $g_a(0)$, $g_d(0)$ and $g_{ad}(0)$ values for marine mammals during vessel based surveys in the Chukchi and Beaufort seas, July to October 2006.

Vessel group	$g_a(0)$ 1-16	$g_a(0)$ 16+	$g_d(0)$ 1-16	$g_d(0)$ 16+	$g_{ad}(0)$ 1-16	$g_{ad}(0)$ 16+
Source Vessels (speed 4.0 kts)						
Cetaceans (all observers)						
Bowhead						
feeding	0.250	1.000	0.902	1.000	0.226	1.000
migrating	0.206	1.000	0.902	1.000	0.186	1.000
Gray Whale						
feeding	0.616	1.000	0.902	1.000	0.556	1.000
migrating	0.769	1.000	0.902	1.000	0.694	1.000
Fin Whale						
feeding	0.595	1.000	0.902	1.000	0.537	1.000
Minke Whale						
feeding	0.654	1.000	0.840	1.000	0.549	1.000
Beluga Whale						
all behaviors	0.420	1.000	0.840	1.000	0.353	1.000
Killer Whale						
all behaviors	0.323	1.000	0.561	1.000	0.181	1.000
Harbor Porpoise						
all behaviors	0.818	1.000	0.768	1.000	0.628	1.000
Pinnipeds in Water						
1 observer	1.000	1.000	0.661 [a]	1.000	0.661	1.000
2 observers	1.000	1.000	0.720	1.000	0.720	1.000
3 observers	1.000	1.000	1.000	1.000	1.000	1.000
Other Vessels (speed 9.2 kts)						
Cetaceans (all observers)						
Bowhead						
feeding	0.165	1.000	0.902	1.000	0.149	1.000
migrating	0.147	1.000	0.902	1.000	0.133	1.000
Gray Whale						
feeding	0.391	1.000	0.902	1.000	0.353	1.000
migrating	0.504	1.000	0.902	1.000	0.455	1.000
Fin Whale						
feeding	0.379	1.000	0.902	1.000	0.342	1.000
Minke Whale						
feeding	0.389	1.000	0.840	1.000	0.327	1.000
Beluga Whale						
all behaviors	0.373	1.000	0.840	1.000	0.313	1.000
Killer Whale						
all behaviors	0.192	1.000	0.561	1.000	0.108	1.000
Harbor Porpoise						
all behaviors	0.480	1.000	0.768	1.000	0.369	1.000
Pinnipeds in Water						
1 observer	1.000	1.000	0.661	1.000	0.661	1.000
2 observers	1.000	1.000	0.720	1.000	0.720	1.000
3 observers	1.000	1.000	1.000	1.000	1.000	1.000

[a] The surveys were conducted during exceptionally good conditions with low sea states during the mid-season. $g_d(0)$ during the mid-season period was assumed to be 1.000.

- The above was repeated with the one-observer data which gave a $g_d(0)$ of 0.661 for one observer.

This was the only data set with adequate sighting and effort data and so these $g_d(0)$ values were used for pinnipeds for all areas and during all periods, except for the mid-season, offshore, open-water, vessel group B, one-observer estimates where $g_d(0)$ was assumed to be 1.00 because of the unusually calm sea states encountered during that survey period when one observer was used (see methods in the $f(0)$ section above).

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APPENDIX C

TABLE C.1. Visual sightings of marine mammals made from the *Torsvik* and *Gulf Provider* within the Chukchi Sea study area during all dedicated survey periods. A map of the Chukchi Sea lease sale area and the location of LGL designated transect lines is shown in Figure 4.1.

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Survey Number[b]	Survey Period[c]	LGL Transect Line[d]	Chukchi Sea Lease Sale Area[e]	Initial Sighting Distance (m)[f]	CPA Distance (m)[g]	Initial Move-ment[h]	Initial Behav.[i]	Bf[j]	Water Depth (m)[k]	Vessel Activ.[l]
Torsvik	1	Pacific walrus	N	1	196	17:29:45	69.203	-167.324	1	On Transect	1	Y	150	100	NO	LO	4	47	TR
Torsvik	2	Unidentified seal	N	1	196	18:31:13	69.338	-167.460	1	On Transect	1	Y	50	50	SP	LO	3	48	TR
Torsvik	3	Unidentified seal	N	1	196	19:28:25	69.460	-167.586	1	On Transect	1	Y	30	30	FL	SW	3	46	TR
Torsvik	4	Spotted seal	N	1	196	20:32:50	69.592	-167.735	1	On Transect	1	Y	80	80	PE	SW	3	46	TR
Torsvik	5	Unidentified seal	Y	1	197	1:14:42	69.930	-167.329	1	On Transect	2	Y	70	50	SP	LO	3	47	TR
Torsvik	6	Pacific walrus	Y	2	197	20:22:06	70.216	-166.133	1	Alt Transect		Y	1188	600	HO	RE	2	44	TR
Torsvik	7	Gray whale	Y	2	197	22:16:30	70.394	-166.586	1	Alt Transect		Y	466	150	SP	FD	2	43	TR
Gulf Provider	8	Gray whale	Y	30	240	5:46:32	71.110	-158.048	2	In Transit		N	500	500	SP	BL	3	32	TR
Gulf Provider	9	Bowhead whale	Y	5	240	6:11:34	71.072	-158.238	2	In Transit		N	300	300	SP	BL	3	32	TR
Gulf Provider	10	Beluga whale	N	30	240	6:11:34	71.072	-158.238	2	In Transit		N	20	20	SP	BL	3	32	TR
Gulf Provider	11	Unidentified seal	Y	1	240	6:17:30	71.058	-158.287	2	In Transit		N	20	5	SP	DI	3	32	TR
Gulf Provider	12	Spotted seal	N	3	240	16:30:15	70.402	-162.759	2	In Transit		N	187	187	ST	FE	1	20	TR
Gulf Provider	13	Pacific walrus	N	1	240	16:46:47	70.377	-162.857	2	In Transit		N	750	300	UN	LO	1	28	TR
Gulf Provider	14	Unidentified seal	Y	1	241	3:04:12	69.293	-166.995	2	In Transit		N	20	20	SP	LO	4	40	TR
Gulf Provider	15	Unidentified pinniped	Y	1	241	5:14:17	69.484	-167.455	2	On Transect	1	Y	100	100	FL	TH	4	45	TR
Gulf Provider	16	Unidentified whale	N	1	241	15:45:15	69.996	-167.455	2	On Transect	2	Y	30	30	ST	TH	4	45	TR
Gulf Provider	17	Spotted seal	Y	1	241	22:53:19	70.534	-166.276	2	Off Transect		Y	10	10	SA	TH	5	42	TR
Gulf Provider	18	Unidentified seal	Y	1	242	4:12:45	70.513	-164.434	2	On Transect	4	Y	292	292	MI	LO	3	42	TR
Gulf Provider	19	Unidentified seal	N	2	242	14:54:44	70.847	-164.172	2	Alt Transect		Y	30	30	SP	SW	2	42	TR
Gulf Provider	20	Unidentified seal	Y	1	242	15:13:41	70.843	-164.091	2	Alt Transect		Y	252	252	MI	SI	2	42	TR
Gulf Provider	21	Pacific walrus	Y	1	242	15:41:18	70.840	-163.873	2	Alt Transect		Y	346	346	SA	SW	2	45	TR
Gulf Provider	22	Unidentified seal	Y	1	242	16:48:10	70.787	-163.611	2	Alt Transect		Y	652	426	MI	SI	2	43	TR
Gulf Provider	23	Unidentified seal	Y	1	242	16:48:33	70.787	-163.611	2	Alt Transect		Y	15	15	SA	SW	2	43	TR
Gulf Provider	24	Unidentified seal	Y	1	242	17:09:05	70.786	-163.486	2	Alt Transect		Y	10	10	SA	SW	2	43	TR
Gulf Provider	25	Bearded seal	Y	1	242	17:09:08	70.777	-163.457	2	Alt Transect		Y	600	600	SA	SW	2	43	TR
Gulf Provider	26	Unidentified seal	Y	1	242	17:09:08	70.777	-163.457	2	Alt Transect		Y	100	100	SA	TH	2	43	TR
Gulf Provider	27	Unidentified seal	Y	1	242	17:56:59	70.790	-163.089	2	Alt Transect		Y	300	300	FL	TH	2	43	TR
Gulf Provider	28	Unidentified seal	Y	1	242	17:59:28	70.792	-163.058	2	Alt Transect		Y	129	129	SA	SI	2	43	TR
Gulf Provider	29	Unidentified seal	Y	2	242	18:12:47	70.805	-163.963	2	Alt Transect		Y	250	250	SA	SI	2	43	TR
Gulf Provider	30	Pacific walrus	Y	1	242	18:46:41	70.817	-163.732	2	Alt Transect		Y	400	400	SA	DI	2	43	TR
Gulf Provider	31	Unidentified seal	Y	1	242	18:52:53	70.829	-162.697	2	Alt Transect		Y	200	200	SA	SI	2	43	TR
Gulf Provider	32	Unidentified seal	Y	1	242	19:02:57	70.832	-162.633	2	Alt Transect		Y	500	500	NO	RE	2	43	TR
Gulf Provider	33	Unidentified seal	Y	1	242	19:10:12	70.812	-162.630	2	Alt Transect		Y	300	300	SA	SI	2	42	TR
Gulf Provider	34	Unidentified seal	Y	1	242	19:10:47	70.811	-162.630	2	Alt Transect		Y	200	200	SA	SI	2	42	TR
Gulf Provider	35	Unidentified seal	Y	1	242	19:12:49	70.805	-162.632	2	Alt Transect		Y	200	200	SA	SI	2	42	TR
Gulf Provider	36	Pacific walrus	Y	2	242	19:26:40	70.769	-162.622	2	Alt Transect		Y	600	600	SP	DI	2	41	TR
Gulf Provider	37	Unidentified seal	Y	1	242	19:29:56	70.764	-162.600	2	Alt Transect		Y	300	300	SP	DI	2	41	TR
Gulf Provider	38	Unidentified seal	Y	1	242	19:44:26	70.737	-162.504	2	Alt Transect		Y	300	300	SP	SW	2	40	TR
Gulf Provider	39	Unidentified seal	Y	1	242	20:24:08	70.634	-162.517	2	Alt Transect		Y	292	292	SA	SW	2	38	TR
Gulf Provider	40	Unidentified seal	Y	1	242	20:27:57	70.624	-162.506	2	Alt Transect		Y	179	179	SA	LO	2	38	TR
Gulf Provider	41	Pacific walrus	Y	1	242	20:33:05	70.612	-162.484	2	Alt Transect		Y	792	792	PE	BL	2	37	TR
Gulf Provider	42	Unidentified seal	Y	2	242	20:33:05	70.612	-162.484	2	Alt Transect		Y	292	292	MI	SI	2	37	TR
Gulf Provider	43	Unidentified seal	Y	1	242	20:42:17	70.586	-162.468	2	Alt Transect		N	129	129	PE	DI	2	37	TR
Gulf Provider	44	Unidentified seal	Y	1	242	20:43:05	70.584	-162.459	2	Alt Transect		N	222	222	SA	DI	2	37	TR
Gulf Provider	45	Unidentified seal	Y	1	242	20:49:10	70.575	-162.430	2	Alt Transect		N	222	222	SA	DI	2	36	TR

Table C.1 (continued)

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Survey Number[b]	Survey Period[c]	LGL Transect Line[d]	Chukchi Sea Lease Sale Area[e]	Initial Sighting Distance (m)[f]	CPA Distance (m)[g]	Initial Move-ment[h]	Initial Behav.[i]	Bf[j]	Water Depth (m)[k]	Vessel Activ.[l]
Gulf Provider	46	Unidentified seal	Y	1	242	20:51:07	70.572	-162.417	2	Alt Transect		N	292	292	SA	LO	2	35	TR
Gulf Provider	47	Unidentified seal	Y	1	242	20:56:57	70.563	-162.376	2	Alt Transect		N	554	554	SP	LO	2	35	TR
Gulf Provider	48	Unidentified seal	Y	1	242	21:06:33	70.549	-162.308	2	Alt Transect		N	252	252	SP	LO	2	34	TR
Gulf Provider	49	Unidentified seal	Y	1	242	21:14:30	70.543	-162.247	2	Alt Transect		N	179	179	SP	LO	2	33	TR
Gulf Provider	50	Unidentified seal	Y	1	242	21:25:52	70.561	-162.172	2	Alt Transect		N	100	100	SA	LO	2	35	TR
Gulf Provider	51	Unidentified seal	Y	1	242	22:12:46	70.595	-161.865	2	Alt Transect		N	252	252	SA	SW	2	36	TR
Gulf Provider	52	Bearded seal	Y	1	242	22:20:55	70.591	-161.809	2	Alt Transect		N	198	198	PE	SW	2	35	TR
Gulf Provider	53	Unidentified seal	Y	1	242	22:24:38	70.588	-161.783	2	Alt Transect		N	10	10	SP	SW	2	34	TR
Gulf Provider	54	Unidentified seal	Y	1	242	22:37:33	70.597	-161.681	2	Alt Transect		N	554	50	SP	SW	2	33	TR
Gulf Provider	55	Bearded seal	Y	1	242	22:43:36	70.598	-161.633	2	Alt Transect		N	30	30	MI	SI	2	33	TR
Gulf Provider	56	Bearded seal	Y	1	242	22:43:36	70.598	-161.633	2	Alt Transect		N	20	20	SA	SW	2	33	TR
Gulf Provider	57	Bearded seal	Y	1	242	22:43:36	70.598	-161.633	2	Alt Transect		N	150	150	SA	SW	2	33	TR
Gulf Provider	58	Unidentified seal	Y	1	242	22:43:36	70.598	-161.633	2	Alt Transect		N	300	300	SA	TH	2	33	TR
Gulf Provider	59	Bearded seal	Y	2	242	22:52:49	70.597	-161.558	2	Alt Transect		N	222	222	PE	FD	2	33	TR
Gulf Provider	60	Unidentified seal	Y	1	242	22:55:35	70.596	-161.534	2	Alt Transect		N	100	100	SP	SW	2	32	TR
Gulf Provider	61	Unidentified seal	Y	5	242	22:58:40	70.596	-161.510	2	Alt Transect		N	150	150	SA	SW	2	31	TR
Gulf Provider	62	Unidentified seal	Y	1	242	23:05:54	70.596	-161.445	2	Alt Transect		N	100	100	PE	SA	2	32	TR
Gulf Provider	63	Unidentified seal	Y	2	242	23:17:52	70.590	-161.343	2	Alt Transect		N	600	600	SA	SW	2	31	TR
Gulf Provider	64	Unidentified seal	Y	1	242	23:24:28	70.583	-161.293	2	Alt Transect		N	500	500	SP	SW	2	30	TR
Gulf Provider	65	Unidentified seal	Y	1	242	23:26:40	70.582	-161.275	2	Alt Transect		N	5	5	SP	SW	2	30	TR
Gulf Provider	66	Bearded seal	Y	1	242	23:28:42	70.580	-161.259	2	Alt Transect		N	600	600	MI	RE	2	30	TR
Gulf Provider	67	Spotted seal	Y	1	242	23:32:07	70.575	-161.207	2	Alt Transect		N	10	10	SA	SW	2	30	TR
Gulf Provider	68	Pacific walrus	Y	1	242	23:33:06	70.575	-161.207	2	Alt Transect		N	500	500	SA	SW	2	30	TR
Gulf Provider	69	Unidentified seal	Y	1	242	23:34:54	70.575	-161.207	2	Alt Transect		N	700	700	SP	SW	2	30	TR
Gulf Provider	70	Unidentified seal	Y	1	242	23:36:23	70.575	-161.196	2	Alt Transect		N	200	200	SP	SW	2	30	TR
Gulf Provider	71	Unidentified seal	Y	1	242	23:37:41	70.574	-161.188	2	Alt Transect		N	200	200	NO	SW	2	29	TR
Gulf Provider	72	Unidentified seal	Y	1	242	23:37:41	70.574	-161.188	2	Alt Transect		N	129	129			2	29	TR
Gulf Provider	73	Unidentified seal	Y	1	242	23:37:41	70.574	-161.188	2	Alt Transect		N	129	129			2	29	TR
Gulf Provider	74	Unidentified seal	Y	1	242	23:37:41	70.574	-161.188	2	Alt Transect		N	129	129			2	29	TR
Gulf Provider	75	Unidentified seal	Y	1	242	23:43:57	70.575	-161.134	2	Alt Transect		N	100	100	SP	SW	2	30	TR
Gulf Provider	76	Unidentified seal	Y	1	242	23:46:17	70.574	-161.114	2	Alt Transect		N	700	700	SP	SW	2	30	TR
Gulf Provider	77	Unidentified seal	Y	2	242	23:51:14	70.576	-161.073	2	Alt Transect		N	600	300	SP	SW	2	30	TR
Gulf Provider	78	Unidentified seal	Y	1	242	23:54:30	70.580	-161.045	2	Alt Transect		N	300	300	SP	SW	2	31	TR
Gulf Provider	79	Unidentified seal	Y	1	242	23:54:43	70.580	-161.045	2	Alt Transect		N	200	200	SA	DI	2	31	TR
Gulf Provider	80	Bearded seal	Y	1	242	23:57:56	70.586	-161.027	2	Alt Transect		N	600	600	NO	RE	2	32	TR
Gulf Provider	81	Unidentified seal	Y	2	242	23:59:16	70.590	-161.024	2	Alt Transect		N	500	30	SA	DI	2	32	TR
Gulf Provider	82	Unidentified seal	Y	2	243	0:00:51	70.594	-161.017	2	Alt Transect		N	500	500	SA	SW	2	32	TR
Gulf Provider	83	Unidentified seal	Y	1	243	0:03:37	70.601	-162.000	2	Alt Transect		N	200	200	SA	SW	2	32	TR
Gulf Provider	84	Unidentified seal	Y	2	243	0:04:10	70.602	-161.997	2	Alt Transect		N	400	400	SA	SW	2	32	TR
Gulf Provider	85	Bearded seal	Y	1	243	0:05:15	70.604	-161.998	2	Alt Transect		N	200	200	SA	SW	2	32	TR
Gulf Provider	86	Unidentified seal	Y	1	243	0:06:44	70.601	-161.979	2	Alt Transect		N	100	100	SA	SW	2	34	TR
Gulf Provider	87	Unidentified seal	Y	1	243	0:07:44	70.613	-161.979	2	Alt Transect		N	100	100	SA	SW	2	34	TR
Gulf Provider	88	Unidentified seal	Y	2	243	0:08:45	70.613	-161.980	2	Alt Transect		N	300	300	SA	SW	2	34	TR
Gulf Provider	89	Unidentified seal	Y	3	243	0:11:23	70.618	-160.963	2	Alt Transect		N	500	500	MI	SI	1	34	TR
Gulf Provider	90	Unidentified seal	Y	2	243	0:14:11	70.623	-160.946	2	Alt Transect		N	200	200	MI	SI	1	34	TR
Gulf Provider	91	Bearded seal	Y	1	243	0:19:58	70.633	-160.907	2	Alt Transect		N	100	100	SP	SW	1	34	TR
Gulf Provider	92	Unidentified seal	Y	1	243	0:30:07	70.633	-160.850	2	Alt Transect		N	10	10	FL	TH	1	32	TR
Gulf Provider	93	Unidentified seal	Y	1	243	0:35:21	70.619	-160.844	2	Alt Transect		N	200	200	SA	DI	1	32	TR
Gulf Provider	94	Unidentified seal	Y	3	243	0:35:42	70.618	-160.844	2	Alt Transect		N	300	300	NO	FE	1	32	TR
Gulf Provider	95	Spotted seal	Y	1	243	0:39:20	70.608	-160.849	2	Alt Transect		N	50	50	ST	SW	1	31	TR
Gulf Provider	96	Spotted seal	Y	1	243	0:40:40	70.605	-160.851	2	Alt Transect		N	30	30	SP	SW	1	32	TR

Table C.1 (continued)

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Survey Number[b]	Survey Period[c]	LGL Transect Line[d]	Chukchi Sea Lease Sale Area[e]	Initial Sighting Distance (m)[f]	CPA Distance (m)[g]	Initial Move-ment[h]	Initial Behav.[i]	Bf[j]	Water Depth (m)[k]	Vessel Activ.[l]
Gulf Provider	97	Spotted seal	Y	1	243	0:43:34	70.597	-160.850	2	Alt Transect		N	100	100	SA	LO	1	29	TR
Gulf Provider	98	Bearded seal	Y	1	243	0:48:17	70.585	-160.833	2	Alt Transect		N	600	600	SP	SW	1	26	TR
Gulf Provider	99	Spotted seal	Y	1	243	0:57:39	70.586	-160.762	2	Alt Transect		N	100	100	PE	SW	1	25	TR
Gulf Provider	100	Bearded seal	Y	1	243	1:11:03	70.577	-160.662	2	Alt Transect		N	20	20	FL	TH	1	23	TR
Gulf Provider	101	Spotted seal	Y	1	243	1:11:17	70.577	-160.661	2	Alt Transect		N	15	15	SA	SW	1	23	TR
Gulf Provider	102	Unidentified seal	Y	1	243	1:16:49	70.585	-160.619	2	Alt Transect		N	50	50	SA	DI	1	23	TR
Gulf Provider	103	Unidentified seal	Y	1	243	1:23:11	70.596	-160.577	2	Alt Transect		N	150	150	SA	SW	1	23	TR
Gulf Provider	104	Unidentified seal	Y	1	243	1:33:39	70.610	-160.501	2	Alt Transect		N	300	300	SA	SH	1	22	TR
Gulf Provider	105	Bearded seal	Y	1	243	1:39:35	70.618	-160.457	2	Alt Transect		N	400	400	PE	SW	1	21	TR
Gulf Provider	106	Spotted seal	Y	1	243	1:43:59	70.624	-160.424	2	Alt Transect		N	50	50	FL	TH	1	21	TR
Gulf Provider	107	Spotted seal	Y	1	243	1:48:11	70.632	-160.395	2	Alt Transect		N	25	25	SA	SW	1	21	TR
Gulf Provider	108	Bearded seal	Y	1	243	1:49:53	70.641	-160.351	2	Alt Transect		N	400	400	SP	SW	1	21	TR
Gulf Provider	109	Unidentified seal	Y	1	243	1:49:53	70.634	-160.386	2	Alt Transect		N	600	600	SP	SW	1	21	TR
Gulf Provider	110	Unidentified seal	Y	1	243	2:25:51	70.683	-160.167	2	Alt Transect		N	10	10	FL	TH	1	19	TR
Gulf Provider	111	Bearded seal	Y	1	243	2:53:46	70.737	-160.042	2	Alt Transect		N	500	500	SP	FD	1	20	TR
Gulf Provider	112	Unidentified seal	Y	1	243	3:05:59	70.751	-159.957	2	Alt Transect		N	700	700	MI	SI	1	19	TR
Gulf Provider	113	Bearded seal	Y	1	243	3:30:00	70.791	-159.809	2	Alt Transect		N	100	30	SA	FL	1	20	TR
Gulf Provider	114	Unidentified seal	Y	1	243	3:32:47	70.793	-159.778	2	Alt Transect		N	222	222	MI	SI	1	19	TR
Gulf Provider	115	Bearded seal	Y	1	243	3:38:40	70.798	-159.742	2	Alt Transect		N	129	5	FL	FD	1	18	TR
Gulf Provider	116	Spotted seal	Y	1	243	3:43:19	70.803	-159.714	2	Alt Transect		N	50	50	SA	DI	1	18	TR
Gulf Provider	117	Spotted seal	Y	1	243	3:43:19	70.803	-159.714	2	Alt Transect		N	70	70	SA	DI	1	18	TR
Torsvik	118	Ringed seal	Y	1	248	17:57:20	71.297	-156.844	3	Alt Transect		N	60	60	SP	TH	2	25	TR
Torsvik	119	Harbor porpoise	Y	3	248	18:01:35	71.291	-156.859	3	Alt Transect		N	200	100	SP	PO	2	25	TR
Torsvik	120	Ringed seal	Y	1	248	18:02:00	71.290	-156.861	3	Alt Transect		N	200	40	ST	SW	2	25	OT
Torsvik	121	Unidentified seal	Y	1	248	18:09:00	71.280	-156.886	3	Alt Transect		N	357	211	SA	LO	2	28	OT
Torsvik	122	Unidentified seal	Y	1	248	18:11:00	71.277	-156.893	3	Alt Transect		N	290	290	SA	SW	2	28	OT
Torsvik	123	Unidentified seal	Y	1	248	18:14:39	71.272	-156.907	3	Alt Transect		N	300	300	UN	DI	1	28	OT
Torsvik	124	Unidentified seal	Y	1	248	18:18:31	71.267	-156.922	3	Alt Transect		N	668	387	SP	LO	1	29	OT
Torsvik	125	Unidentified seal	Y	1	248	18:21:37	71.263	-156.935	3	Alt Transect		N	150	150	UN	DI	1	28	OT
Torsvik	126	Unidentified seal	Y	1	248	18:24:00	71.259	-156.944	3	Alt Transect		N	855	855	SA	DI	1	29	OT
Torsvik	127	Unidentified seal	Y	1	248	18:31:37	71.248	-156.971	3	Alt Transect		N	668	668	ST	SW	1	28	OT
Torsvik	128	Unidentified seal	Y	1	248	18:31:37	71.248	-156.971	3	Alt Transect		N	290	30	SA	MI	1	28	OT
Torsvik	129	Unidentified seal	Y	1	248	18:35:04	71.242	-156.981	3	Alt Transect		N	549	549	SP	DI	1	29	OT
Torsvik	130	Unidentified seal	Y	1	248	18:36:48	71.239	-156.987	3	Alt Transect		N	668	668	SP	DI	1	29	OT
Torsvik	131	Unidentified seal	Y	1	248	18:36:48	71.239	-156.987	3	Alt Transect		N	1188	1188	SP	SW	1	29	OT
Torsvik	132	Unidentified seal	Y	1	248	18:36:48	71.239	-156.987	3	Alt Transect		N	855	855	PE	FD	1	29	OT
Torsvik	133	Unidentified seal	Y	1	248	18:38:06	71.237	-156.991	3	Alt Transect		N	244	244	SA	SW	1	29	OT
Torsvik	134	Unidentified seal	Y	1	248	18:38:06	71.237	-156.991	3	Alt Transect		N	357	357	SA	SW	1	29	OT
Torsvik	135	Unidentified seal	Y	1	248	18:38:06	71.237	-156.991	3	Alt Transect		N	668	668	SP	SW	1	29	OT
Torsvik	136	Unidentified seal	Y	1	248	18:41:21	71.231	-157.000	3	Alt Transect		N	855	855	UN	LO	1	29	OT
Torsvik	137	Unidentified seal	Y	1	248	18:41:21	71.231	-157.000	3	Alt Transect		N	549	549	SA	SW	1	29	OT
Torsvik	138	Unidentified seal	Y	1	248	18:41:35	71.231	-157.001	3	Alt Transect		N	125	125	SA	SW	1	29	OT
Torsvik	139	Unidentified seal	Y	1	248	18:41:50	71.231	-157.002	3	Alt Transect		N	50	50	SA	SW	0	29	OT
Torsvik	140	Unidentified seal	Y	1	248	18:43:05	71.229	-157.006	3	Alt Transect		N	357	60	SA	SW	0	29	OT
Torsvik	141	Unidentified seal	Y	1	248	18:44:35	71.226	-157.011	3	Alt Transect		N	100	100	MI	SI	0	29	OT
Torsvik	142	Ringed seal	Y	1	248	18:46:49	71.222	-157.018	3	Alt Transect		N	20	20	PE	LO	0	1	OT
Torsvik	143	Unidentified seal	Y	1	248	18:48:20	71.220	-157.024	3	Alt Transect		N	357	357	SA	LO	0	1	OT
Torsvik	144	Unidentified seal	Y	1	248	18:49:35	71.218	-157.028	3	Alt Transect		N	668	668	SA	DI	0	1	OT
Torsvik	145	Unidentified whale	Y	2	248	18:50:52	71.216	-157.032	3	Alt Transect		N	1188	1188	SP	BL	0	1	OT
Torsvik	146	Unidentified seal	Y	1	248	18:52:34	71.212	-157.037	3	Alt Transect		N	244	244	SA	SW	0	1	OT
Torsvik	147	Gray whale	Y	2	248	18:56:34	71.205	-157.048	3	Alt Transect		N	1000	1000	SP	BL	0	1	OT

Table C.1 (continued)

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Survey Number[b]	Survey Period[c]	LGL Transect Line[d]	Chukchi Sea Lease Sale Area[e]	Initial Sighting Distance (m)[f]	CPA Distance (m)[g]	Initial Move-ment[h]	Initial Behav.[i]	Bf[j]	Water Depth (m)[k]	Vessel Activ.[l]
Torsvik	148	Unidentified seal	Y	1	248	18:58:00	71.202	-157.051	3	Alt Transect		N	290	290	SA	DI	0	1	OT
Torsvik	149	Unidentified seal	Y	1	248	18:59:22	71.200	-157.053	3	Alt Transect		N	668	466	SA	SW	0	1	OT
Torsvik	150	Unidentified seal	Y	1	248	19:03:15	71.192	-157.060	3	Alt Transect		N	200	200	SP	LO	0	16	OT
Torsvik	151	Unidentified seal	Y	1	248	19:05:46	71.187	-157.064	3	Alt Transect		N	357	357	NO	LO	0	15	OT
Torsvik	152	Unidentified seal	Y	1	248	19:07:00	71.185	-157.066	3	Alt Transect		N	855	855	NO	LO	0	15	OT
Torsvik	153	Unidentified seal	Y	1	248	19:09:32	71.180	-157.072	3	Alt Transect		N	668	668	NO	DI	0	15	OT
Torsvik	154	Unidentified seal	Y	2	248	19:09:32	71.180	-157.072	3	Alt Transect		N	357	357	PE	SW	0	15	OT
Torsvik	155	Unidentified seal	Y	1	248	19:09:35	71.180	-157.072	3	Alt Transect		N	357	357	SA	SW	0	15	OT
Torsvik	156	Unidentified seal	Y	2	248	19:10:43	71.178	-157.075	3	Alt Transect		N	668	668	NO	SI	0	15	OT
Torsvik	157	Unidentified seal	Y	1	248	19:12:21	71.175	-157.080	3	Alt Transect		N	466	466	SA	SW	0	12	OT
Torsvik	158	Unidentified seal	Y	1	248	19:14:00	71.172	-157.085	3	Alt Transect		N	668	668	SA	SW	0	12	TR
Torsvik	159	Unidentified seal	Y	1	248	19:16:00	71.169	-157.090	3	Alt Transect		N	1188	1188	NO	MI	0	12	TR
Torsvik	160	Unidentified seal	Y	1	248	19:16:27	71.168	-157.091	3	Alt Transect		N	357	244	SA	SW	0	12	TR
Torsvik	161	Unidentified seal	Y	1	248	19:19:35	71.163	-157.097	3	Alt Transect		N	357	357	NO	RE	0	12	TR
Torsvik	162	Unidentified seal	Y	1	248	19:23:03	71.158	-157.104	3	Alt Transect		N	549	549	SA	DI	0	10	TR
Torsvik	163	Unidentified seal	Y	1	248	19:26:01	71.154	-157.110	3	Alt Transect		N	466	185	NO	DI	0	10	TR
Torsvik	164	Unidentified seal	Y	1	248	19:27:05	71.152	-157.112	3	Alt Transect		N	668	668	NO	DI	0	10	TR
Torsvik	165	Unidentified seal	Y	1	248	19:29:40	71.148	-157.119	3	Alt Transect		N	668	668	NO	RE	0	10	TR
Torsvik	166	Unidentified seal	Y	1	248	19:31:20	71.145	-157.124	3	Alt Transect		N	855	855	SA	SW	0	9	TR
Torsvik	167	Unidentified seal	Y	2	248	19:31:50	71.144	-157.126	3	Alt Transect		N	855	855	NO	SI	0	9	TR
Torsvik	168	Unidentified seal	N	1	248	19:55:30	71.109	-157.199	3	Alt Transect		N	80	80	SP	SW	1	11	TR
Torsvik	169	Unidentified whale	N	1	248	20:00:00	71.101	-157.207	3	Alt Transect		N	1200	1200	SP	BL	1	10	TR
Torsvik	170	Unidentified whale	N	2	248	20:03:07	71.097	-157.217	3	Alt Transect		N	1200	1200	SP	BL	1	10	TR
Torsvik	171	Ringed seal	Y	3	248	20:24:00	71.068	-157.288	3	Alt Transect		N	357	80	NO	MI	1	13	TR
Torsvik	172	Ringed seal	Y	1	248	20:32:00	71.056	-157.319	3	Alt Transect		N	668	668	NO	RE	1	14	TR
Torsvik	173	Ringed seal	Y	2	248	20:38:40	71.047	-157.352	3	Alt Transect		N	668	200	NO	LO	1	14	TR
Torsvik	174	Ringed seal	Y	1	248	20:46:00	71.037	-157.388	3	Alt Transect		N	357	100	NO	TH	1	14	TR
Torsvik	175	Unidentified seal	Y	1	248	20:49:50	71.032	-157.407	3	Alt Transect		N	250	250	SA	SW	1	15	TR
Torsvik	176	Unidentified seal	Y	2	248	20:49:50	71.032	-157.407	3	Alt Transect		N	300	200	SA	DI	1	15	TR
Torsvik	177	Unidentified seal	Y	1	248	20:49:50	71.032	-157.407	3	Alt Transect		N	200	200	SA	DI	1	15	TR
Torsvik	178	Unidentified seal	Y	1	248	20:49:50	71.032	-157.407	3	Alt Transect		N	100	100	SA	SW	1	15	TR
Torsvik	179	Unidentified seal	Y	1	248	20:54:01	71.026	-157.427	3	Alt Transect		N	100	100	SP	SW	1	16	TR
Torsvik	180	Unidentified seal	Y	1	248	20:54:01	71.026	-157.427	3	Alt Transect		N	668	200	MI	LO	1	16	TR
Torsvik	181	Unidentified seal	Y	1	248	20:56:31	71.022	-157.439	3	Alt Transect		N	40	40	MI	DI	1	16	TR
Torsvik	182	Unidentified seal	Y	1	248	21:10:45	70.996	-157.491	3	Alt Transect		N	357	350	SP	FD	1	14	TR
Torsvik	183	Unidentified seal	Y	1	248	21:13:30	70.991	-157.501	3	Alt Transect		N	357	350	ST	LO	1	14	TR
Torsvik	184	Unidentified seal	Y	1	248	21:16:15	70.986	-157.512	3	Alt Transect		N	466	450	SA	MI	1	14	TR
Torsvik	185	Unidentified seal	Y	1	248	21:21:15	70.977	-157.530	3	Alt Transect		N	357	350	UN	TH	1	14	TR
Torsvik	186	Unidentified seal	Y	1	248	21:26:45	70.966	-157.546	3	Alt Transect		N	357	75	SA	LO	1	14	TR
Torsvik	187	Unidentified seal	Y	1	248	21:28:30	70.963	-157.548	3	Alt Transect		N	357	350	SP	SW	1	14	TR
Torsvik	188	Ringed seal	Y	1	248	21:31:00	70.958	-157.553	3	Alt Transect		N	75	60	SP	LO	1	11	TR
Torsvik	189	Unidentified seal	Y	1	248	21:57:12	70.928	-157.658	3	Alt Transect		N	855	855	SA	LO	2	9	TR
Torsvik	190	Unidentified seal	Y	1	248	22:15:45	70.913	-157.777	3	Alt Transect		N	357	357	UN	LO	1	14	TR
Torsvik	191	Unidentified seal	Y	1	248	22:17:54	70.911	-157.792	3	Alt Transect		N	244	244	SA	LO	1	14	TR
Torsvik	192	Unidentified seal	Y	1	248	22:18:40	70.911	-157.797	3	Alt Transect		N	100	100	UN	DI	1	14	TR
Torsvik	193	Unidentified seal	Y	1	248	22:32:00	70.901	-157.890	3	Alt Transect		N	357	357	UN	RA	1	14	TR
Torsvik	194	Ringed seal	Y	1	248	22:52:11	70.883	-158.031	3	Alt Transect		N	200	200	UN	LO	1	14	TR
Torsvik	195	Unidentified seal	Y	1	248	23:05:20	70.863	-158.110	3	Alt Transect		N	357	357	NO	LO	1	11	TR
Torsvik	196	Unidentified seal	Y	1	248	23:20:30	70.852	-158.217	3	Alt Transect		N	855	855	NO	SI	1	9	TR
Torsvik	197	Unidentified seal	Y	1	248	23:55:50	70.867	-158.476	3	Alt Transect		N	20	20	SA	SW	1	9	TR
Torsvik	198	Minke whale	Y	1	249	0:01:50	70.878	-158.508	3	Alt Transect		N	855	466	SP	DI	1	9	TR

Table C.1 (continued)

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Survey Number[b]	Survey Period[c]	LGL Transect Line[d]	Chukchi Sea Lease Sale Area[e]	Initial Sighting Distance (m)[f]	CPA Distance (m)[g]	Initial Move-ment[h]	Initial Behav.[i]	Bf[j]	Water Depth (m)[k]	Vessel Activ.[l]
Torsvik	199	Unidentified seal	Y	1	249	0:16:50	70.904	-158.593	3	Alt Transect		N	400	40	PE	DI	0	9	TR
Torsvik	200	Bearded seal	Y	1	249	0:20:20	70.910	-158.612	3	Alt Transect		N	466	400	SP	LO	0	9	TR
Torsvik	201	Ringed seal	Y	1	249	0:33:51	70.929	-158.647	3	Alt Transect		N	75	75	SA	LO	0	10	TR
Torsvik	202	Ringed seal	Y	1	249	0:39:48	70.929	-158.672	3	Alt Transect		N	668	668	SP	LO	0	8	TR
Torsvik	203	Bearded seal	N	1	249	0:52:10	70.930	-158.709	3	Alt Transect		N	75	75	SA	LO	0	6	TR
Torsvik	204	Ringed seal	Y	1	249	1:07:30	70.935	-158.687	3	Alt Transect		N	100	75	SA	LO	0	10	TR
Torsvik	205	Bearded seal	Y	1	249	1:10:30	70.938	-158.688	3	Alt Transect		N	600	125	SP	SW	0	11	TR
Torsvik	206	Unidentified seal	Y	1	249	1:15:45	70.941	-158.699	3	Alt Transect		N	120	100	SP	LO	0	11	TR
Torsvik	207	Unidentified seal	Y	1	249	1:28:00	70.947	-158.736	3	Alt Transect		N	244	244	ST	SW	1	11	TR
Torsvik	208	Unidentified seal	Y	2	249	1:34:30	70.948	-158.759	3	Alt Transect		N	466	466	SP	LO	1	11	TR
Torsvik	209	Unidentified seal	Y	1	249	1:36:00	70.947	-158.767	3	Alt Transect		N	357	357	SP	LO	1	11	TR
Torsvik	210	Unidentified seal	Y	1	249	1:36:00	70.947	-158.767	3	Alt Transect		N	60	60	SP	DI	1	11	TR
Torsvik	211	Unidentified seal	Y	2	249	1:47:20	70.948	-158.807	3	Alt Transect		N	669	669	SA	LO	0	12	TR
Torsvik	212	Unidentified seal	Y	1	249	1:47:40	70.948	-158.808	3	Alt Transect		N	357	357	SP	SW	0	12	TR
Torsvik	213	Unidentified seal	Y	1	249	1:57:20	70.950	-158.844	3	Alt Transect		N	466	250	SP	LO	0	12	TR
Torsvik	214	Bearded seal	Y	1	249	2:04:42	70.940	-158.875	3	Alt Transect		N	466	466	MI	LO	0	13	TR
Torsvik	215	Unidentified seal	Y	1	249	2:07:30	70.936	-158.885	3	Alt Transect		N	668	668	NO	RE	0	12	TR
Torsvik	216	Bearded seal	Y	1	249	2:09:38	70.932	-158.893	3	Alt Transect		N	20	20	SA	LO	0	13	TR
Torsvik	217	Unidentified seal	Y	1	249	2:11:55	70.929	-158.901	3	Alt Transect		N	1053	588	NO	RE	0	12	TR
Torsvik	218	Unidentified seal	Y	1	249	2:16:28	70.922	-158.917	3	Alt Transect		N	549	549	SP	SW	0	11	TR
Torsvik	219	Unidentified seal	Y	1	249	2:16:28	70.922	-158.917	3	Alt Transect		N	466	466	SA	SW	0	11	TR
Torsvik	220	Bearded seal	Y	1	249	2:19:50	70.917	-158.930	3	Alt Transect		N	668	290	ST	SW	0	10	TR
Torsvik	221	Unidentified seal	Y	1	249	2:21:15	70.915	-158.935	3	Alt Transect		N	357	30	SA	LO	0	10	TR
Torsvik	222	Unidentified seal	Y	1	249	2:26:10	70.909	-158.957	3	Alt Transect		N	290	290	SA	SW	0	9	TR
Torsvik	223	Unidentified seal	Y	1	249	2:30:49	70.911	-158.982	3	Alt Transect		N	244	244	SA	DI	0	9	TR
Torsvik	224	Gray whale	Y	1	249	2:32:50	70.914	-158.987	3	Alt Transect		N	1966	1966	NO	BL	0	9	TR
Torsvik	225	Ringed seal	Y	5	249	2:39:37	70.928	-159.002	3	Alt Transect		N	290	290	PE	MI	0	20	TR
Torsvik	226	Unidentified seal	Y	1	249	2:46:40	70.941	-159.029	3	Alt Transect		N	290	290	SP	LO	0	23	TR
Torsvik	227	Unidentified seal	Y	1	249	2:48:00	70.943	-159.036	3	Alt Transect		N	466	466	SP	PO	0	25	TR
Torsvik	228	Unidentified seal	Y	1	249	2:48:10	70.943	-159.037	3	Alt Transect		N	466	466	SP	SW	0	25	TR
Torsvik	229	Unidentified seal	Y	1	249	2:50:20	70.946	-159.049	3	Alt Transect		N	357	357	SP	LO	2	26	TR
Torsvik	230	Gray whale	Y	2	249	3:07:23	70.954	-159.154	3	Alt Transect		N	2979	2979	SP	BL	2	31	OT
Torsvik	231	Unidentified seal	Y	1	249	3:09:54	70.954	-159.171	3	Alt Transect		N	244	244	NO	LO	2	32	OT
Torsvik	232	Unidentified seal	Y	1	249	3:17:10	70.953	-159.218	3	Alt Transect		N	290	290	NO	LO	2	34	OT
Torsvik	233	Unidentified seal	Y	1	249	3:22:12	70.948	-159.248	3	Alt Transect		N	357	357	SA	PO	2	34	OT
Torsvik	234	Unidentified seal	Y	2	249	3:22:40	70.948	-159.251	3	Alt Transect		N	185	185	NO	SI	2	34	OT
Torsvik	235	Unidentified seal	N	1	249	3:28:33	70.940	-159.285	3	Alt Transect		N	244	244	UN	SW	2	34	OT
Torsvik	236	Unidentified seal	N	1	249	3:29:25	70.939	-159.290	3	Alt Transect		N	244	60	SP	SW	2	34	OT
Torsvik	237	Unidentified seal	Y	1	249	3:36:16	70.934	-159.330	3	Alt Transect		N	549	549	SP	SW	2	35	OT
Torsvik	238	Unidentified seal	N	1	249	3:40:40	70.933	-159.345	3	Alt Transect		N	466	466	ST	SW	2	35	OT
Torsvik	239	Unidentified seal	N	1	249	3:41:07	70.933	-159.346	3	Alt Transect		N	244	165	ST	SW	2	35	OT
Torsvik	240	Unidentified seal	N	1	249	3:43:50	70.933	-159.355	3	Alt Transect		N	466	466	NO	LO	2	35	OT
Torsvik	241	Unidentified seal	Y	1	249	4:13:10	70.921	-159.519	3	Alt Transect		N	211	211	NO	LO	1	1	OT
Torsvik	242	Unidentified seal	Y	1	249	4:25:00	70.903	-159.584	3	Alt Transect		N	290	200	SP	SW	1	42	OT
Torsvik	243	Bearded seal	Y	1	249	4:30:00	70.895	-159.611	3	Alt Transect		N	357	357	SA	FD	1	40	OT
Torsvik	244	Ringed seal	Y	1	249	4:32:00	70.892	-159.619	3	Alt Transect		N	466	466	SP	SW	1	40	OT
Torsvik	245	Ringed seal	Y	1	249	4:34:00	70.891	-159.622	3	Alt Transect		N	244	200	SP	SA	1	40	OT
Torsvik	246	Ringed seal	Y	1	249	4:38:00	70.887	-159.632	3	Alt Transect		N	357	300	SA	FD	1	38	OT
Torsvik	247	Ringed seal	Y	1	249	4:42:00	70.879	-159.652	3	Alt Transect		N	466	466	SP	DI	1	38	OT
Torsvik	248	Ringed seal	Y	1	249	4:45:00	70.874	-159.667	3	Alt Transect		N	357	300	NO	RA	1	36	OT
Torsvik	249	Ringed seal	Y	2	249	4:47:00	70.870	-159.677	3	Alt Transect		N	466	466	UN	LO	1	36	OT

Table C.1 (continued)

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Survey Number[b]	Survey Period[c]	LGL Transect Line[d]	Chukchi Sea Lease Sale Area[e]	Initial Sighting Distance (m)[f]	CPA Distance (m)[g]	Initial Move-ment[h]	Initial Behav.[i]	Bf[j]	Water Depth (m)[k]	Vessel Activ.[l]
Torsvik	250	Ringed seal	Y	1	249	4:55:14	70.856	-159.720	3	Alt Transect		N	466	265	SA	SW	1	34	OT
Torsvik	251	Bearded seal	Y	1	249	5:04:15	70.862	-159.762	3	Alt Transect		N	290	250	SP	LO	0	40	OT
Torsvik	252	Ringed seal	Y	1	249	5:10:00	70.866	-159.777	3	Alt Transect		N	244	215	ST	RE	0	42	OT
Torsvik	253	Unidentified seal	Y	1	249	5:10:00	70.866	-159.777	3	Alt Transect		N	357	350	SA	SW	0	42	OT
Torsvik	254	Unidentified seal	Y	1	249	5:15:15	70.870	-159.807	3	Alt Transect		N	357	350	SP	LO	0	44	OT
Torsvik	255	Unidentified seal	Y	1	249	5:20:45	70.875	-159.845	3	Alt Transect		N	290	290	SA	SW	0	48	OT
Torsvik	256	Unidentified seal	Y	1	249	5:23:45	70.874	-159.865	3	Alt Transect		N	668	668	ST	LO	0	48	OT
Torsvik	257	Unidentified seal	Y	1	249	5:31:30	70.860	-159.896	3	Alt Transect		N	290	290	UN	SW	1	47	OT
Torsvik	258	Bearded seal	Y	1	249	5:34:30	70.857	-159.898	3	Alt Transect		N	466	466	SP	LO	1	46	OT
Torsvik	259	Unidentified seal	Y	1	249	5:35:45	70.856	-159.899	3	Alt Transect		N	357	357	ST	LO	1	46	OT
Torsvik	260	Unidentified seal	Y	1	249	5:46:42	70.830	-159.902	3	Alt Transect		N	668	40	ST	SW	1	37	OT
Torsvik	261	Unidentified seal	Y	2	249	5:55:31	70.832	-159.958	3	Alt Transect		N	549	549	ST	SW	1	42	OT
Torsvik	262	Unidentified seal	Y	1	249	6:03:03	70.838	-159.994	3	Alt Transect		N	50	50	NO	LO	2	47	OT
Torsvik	263	Ringed seal	Y	1	249	16:33:00	70.835	-160.284	3	Alt Transect		N	40	40	NO	LO	3	49	TR
Torsvik	264	Bearded seal	Y	1	249	16:54:11	70.819	-160.402	3	Alt Transect		N	80	40	SP	SW	3	49	OT
Torsvik	265	Unidentified seal	Y	1	249	18:01:00	70.876	-160.753	3	Alt Transect		Y	80	40	SA	RA	3	51	OT
Torsvik	266	Bearded seal	Y	1	249	18:13:30	70.888	-160.807	3	Alt Transect		Y	244	244	SP	LO	3	49	OT
Torsvik	267	Bearded seal	Y	1	249	18:40:25	70.926	-160.925	3	Alt Transect		Y	290	29	PE	LO	3	48	OT
Torsvik	268	Bearded seal	Y	1	249	19:05:58	70.957	-161.042	3	Alt Transect		Y	70	40	PE	LO	3	45	OT
Torsvik	269	Unidentified seal	N	1	249	19:22:40	70.956	-161.136	3	Alt Transect		Y	20	20	SA	TH	3	44	OT
Torsvik	270	Ringed seal	N	1	249	19:33:05	70.956	-161.189	3	Alt Transect		Y	40	30	NO	LO	3	43	OT
Torsvik	271	Bearded seal	N	1	249	19:50:30	70.957	-161.279	3	Alt Transect		Y	100	20	ST	SW	3	44	OT
Torsvik	272	Bearded seal	N	1	249	19:57:00	70.957	-161.319	3	Alt Transect		Y	200	200	MI	LO	4	44	OT
Torsvik	273	Bearded seal	N	1	249	19:59:15	70.957	-161.333	3	Alt Transect		Y	30	30	SA	LO	4	43	OT
Torsvik	274	Ringed seal	N	1	249	19:59:15	70.957	-161.333	3	Alt Transect		Y	40	40	SP	SW	4	44	OT
Torsvik	275	Ringed seal	N	1	249	20:14:45	70.959	-161.399	3	Alt Transect		Y	80	60	NO	RA	4	45	OT
Torsvik	276	Unidentified seal	N	1	250	0:42:03	71.235	-162.069	3	Alt Transect		Y	60	40	SA	TH	2	45	OT
Torsvik	277	Ringed seal	N	1	250	0:59:08	71.255	-162.171	3	Alt Transect		Y	100	60	UN	RE	2	45	OT
Torsvik	278	Unidentified seal	Y	1	250	3:31:20	71.107	-162.484	3	On Transect	7	Y	80	80	UN	TH	1	44	OT
Torsvik	279	Ringed seal	Y	1	250	3:36:15	71.100	-162.483	3	On Transect	7	Y	466	450	ST	LO	1	44	OT
Torsvik	280	Unidentified seal	Y	1	250	3:41:30	71.087	-162.482	3	On Transect	7	Y	290	244	SP	SW	1	44	OT
Torsvik	281	Ringed seal	Y	1	250	3:48:50	71.067	-162.483	3	On Transect	7	Y	466	466	NO	LO	1	46	OT
Torsvik	282	Ringed seal	Y	2	250	3:53:00	71.056	-162.484	3	On Transect	7	Y	404	290	SA	LO	2	45	OT
Torsvik	283	Ringed seal	Y	1	250	3:59:45	71.038	-162.484	3	On Transect	7	Y	265	265	ST	LO	2	45	OT
Torsvik	284	Bearded seal	Y	1	250	4:19:00	70.994	-162.485	3	On Transect	7	Y	668	466	SP	SW	2	43	OT
Torsvik	285	Ringed seal	Y	1	250	4:25:20	70.977	-162.485	3	On Transect	7	Y	855	668	SP	LO	2	44	OT
Torsvik	286	Ringed seal	Y	1	250	4:31:30	70.963	-162.485	3	On Transect	7	Y	40	30	ST	LO	2	45	OT
Torsvik	287	Unidentified seal	Y	1	250	4:52:20	70.913	-162.487	3	On Transect	7	Y	20	20	NO	TH	2	45	OT
Torsvik	288	Ringed seal	Y	1	250	16:32:10	70.997	-163.042	3	On Transect	6	Y	40	40	NO	LO	4	44	OT
Torsvik	289	Unidentified seal	N	1	251	18:02:50	71.156	-164.728	3	On Transect	5	Y	35	35	ST	TH	7	42	OT
Torsvik	290	Unidentified seal	N	1	251	21:00:00	70.798	-164.397	3	Off Transect		Y	35	35	ST	LO	7	44	OT
Torsvik	291	Unidentified seal	N	1	251	22:03:30	70.675	-164.238	3	Off Transect		Y	45	45	SA	LO	6	46	OT
Torsvik	292	Ringed seal	N	1	251	22:30:01	70.611	-164.273	3	Off Transect		Y	30	30	NO	LO	6	44	OT
Torsvik	293	Ringed seal	N	2	251	22:45:38	70.582	-164.298	3	Off Transect		Y	40	20	NO	LO	6	44	OT
Torsvik	294	Ringed seal	Y	1	251	23:54:40	70.436	-164.307	3	On Transect	4	Y	30	20	NO	LO	5	41	OT
Torsvik	295	Unidentified seal	Y	1	252	0:01:50	70.443	-164.357	3	On Transect	4	Y	30	30	NO	TH	5	42	OT
Torsvik	296	Unidentified seal	Y	1	252	0:48:10	70.480	-164.690	3	On Transect	4	Y	5	5	NO	UN	5	42	OT
Torsvik	297	Ringed seal	N	1	252	1:02:32	70.491	-164.799	3	On Transect	4	Y	40	40	SP	SW	5	43	OT
Torsvik	298	Unidentified seal	Y	1	252	20:56:23	69.887	-165.916	3	On Transect	2	Y	50	50	NO	LO	4	1	OT
Torsvik	299	Unidentified seal	Y	1	253	2:37:08	69.897	-168.047	3	On Transect	1	Y	30	30	SA	FD	4	46	OT
Torsvik	300	Unidentified seal	Y	1	253	3:27:09	69.772	-167.926	3	On Transect	1	Y	10	10	NO	DI	4	46	OT

Table C.1 (continued)

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Survey Number[b]	Survey Period[c]	LGL Transect Line[d]	Chukchi Sea Lease Sale Area[e]	Initial Sighting Distance (m)[f]	CPA Distance (m)[g]	Initial Move-ment[h]	Initial Behav.[i]	Bf[j]	Water Depth (m)[k]	Vessel Activ.[l]
Torsvik	301	Unidentified seal	Y	1	253	4:48:30	69.586	-167.735	3	On Transect	1	Y	30	20	NO	TH	4	45	OT
Torsvik	302	Spotted seal	Y	1	253	5:26:45	69.499	-167.629	3	On Transect	1	Y	185	185	NO	LO	4	46	OT
Torsvik	303	Unidentified seal	Y	2	253	17:46:20	69.290	-167.859	3	Off Transect		Y	357	357	ST	LO	5	49	TR
Gulf Provider	304	Bearded seal	Y	1	273	18:36:10	71.354	-157.042	4	In Transit		N	100	100	SA	SW	1	61	TR
Gulf Provider	305	Bearded seal	Y	1	273	19:17:25	71.429	-157.258	4	In Transit		N	500	500	SA	SW	1	129	TR
Gulf Provider	306	Unidentified seal	Y	1	273	19:51:00	71.488	-157.538	4	In Transit		Y	50	50	SA	SW	1	93	TR
Gulf Provider	307	Bearded seal	Y	1	273	20:44:55	71.576	-157.993	4	In Transit		Y	500	300	SP	SW	2	62	TR
Gulf Provider	308	Unidentified seal	Y	1	273	21:13:22	71.626	-158.215	4	In Transit		Y	150	150	SA	TH	2	57	TR
Gulf Provider	309	Unidentified seal	Y	1	273	21:17:45	71.633	-158.239	4	In Transit		Y	554	554	SA	TH	2	56	TR
Gulf Provider	310	Unidentified seal	Y	2	273	21:23:44	71.643	-158.275	4	In Transit		Y	150	150	SA	TH	2	56	TR
Gulf Provider	311	Spotted seal	Y	2	273	22:11:49	71.735	-158.632	4	In Transit		Y	150	100	PE	SW	2	53	TR
Gulf Provider	312	Spotted seal	Y	1	273	23:42:37	71.907	-159.337	4	On Transect	10	Y	292	292	SA	SW	2	46	TR
Gulf Provider	313	Unidentified seal	Y	1	273	23:54:18	71.931	-159.429	4	On Transect	10	Y	200	200	SA	TH	2	43	TR
Gulf Provider	314	Unidentified seal	Y	2	274	0:18:55	71.945	-159.609	4	On Transect	10	Y	300	300	SP	SW	2	41	TR
Gulf Provider	315	Spotted seal	N	1	274	0:37:43	72.012	-159.749	4	On Transect	10	Y	500	500	SP	SW	2	37	TR
Gulf Provider	316	Unidentified seal	Y	1	274	0:43:47	72.022	-159.793	4	On Transect	10	Y	25	25	SP	SW	2	37	TR
Gulf Provider	317	Spotted seal	Y	1	274	0:49:37	72.035	-159.843	4	On Transect	10	Y	700	700	SA	SW	2	36	TR
Gulf Provider	318	Unidentified seal	N	1	274	4:49:45	72.030	-160.673	4	On Transect	9	Y	500	500	SP	SW	2	35	TR
Gulf Provider	319	Spotted seal	Y	1	274	18:51:10	71.530	-160.246	4	Off Transect		Y	75	75	SA	SW	4	46	TR
Gulf Provider	320	Bearded seal	Y	1	274	19:00:00	71.529	-160.316	4	Off Transect		Y	300	300	SA	SW	4	46	TR
Gulf Provider	321	Pacific walrus	Y	1	274	20:34:45	71.509	-160.755	4	Off Transect		Y	150	150	SP	SW	3	45	TR
Gulf Provider	322	Pacific walrus	Y	3	274	21:25:10	71.514	-160.941	4	On Transect	8	Y	350	350	SA	SW	3	45	TR
Gulf Provider	323	Pacific walrus	Y	1	274	21:53:01	71.553	-161.123	4	On Transect	8	Y	200	200	SA	SW	3	46	TR
Gulf Provider	324	Unidentified seal	Y	1	275	2:04:57	71.678	-161.800	4	Alt Transect		Y	150	50	ST	SW	3	43	TR
Gulf Provider	325	Spotted seal	Y	1	275	3:09:57	71.564	-161.556	4	Alt Transect		Y	100	50	ST	SW	3	44	TR
Gulf Provider	326	Spotted seal	Y	1	275	3:43:43	71.499	-161.494	4	Alt Transect		Y	100	100	SP	SW	3	45	TR
Gulf Provider	327	Bearded seal	Y	1	275	4:00:00	71.466	-161.409	4	Alt Transect		Y	200	200	FL	TH	3	43	TR
Gulf Provider	328	Spotted seal	Y	1	275	4:08:17	71.453	-161.353	4	Alt Transect		Y	50	50	SA	SW	3	44	TR
Gulf Provider	329	Pacific walrus	Y	2	275	4:17:11	71.434	-161.264	4	Alt Transect		Y	250	250	SP	SW	3	45	TR
Gulf Provider	330	Pacific walrus	Y	2	275	4:18:35	71.433	-161.260	4	Alt Transect		Y	200	100	SA	SW	3	44	TR
Gulf Provider	331	Pacific walrus	N	1	275	4:25:30	71.432	-161.245	4	Alt Transect		Y	150	150	SP	SW	3	45	TR
Gulf Provider	332	Pacific walrus	N	2	275	4:36:42	71.427	-161.156	4	Alt Transect		Y	250	100	MI	SW	3	45	TR
Gulf Provider	333	Pacific walrus	N	3	275	4:51:32	71.411	-161.072	4	Alt Transect		Y	150	100	SA	SW	3	44	TR
Gulf Provider	334	Unidentified seal	Y	1	275	20:16:00	71.284	-158.414	4	Alt Transect		Y	500	188	SP	SW	2	113	TR
Gulf Provider	335	Unidentified seal	Y	1	275	20:17:45	71.282	-158.387	4	Alt Transect		Y	300	300	SA	FD	2	115	TR
Gulf Provider	336	Unidentified seal	Y	1	275	20:26:06	71.273	-158.334	4	Alt Transect		Y	150	150	SA	SW	2	114	TR
Gulf Provider	337	Unidentified seal	Y	1	275	20:35:03	71.255	-158.265	4	Alt Transect		Y	600	600	SA	SW	2	102	TR
Gulf Provider	338	Unidentified seal	Y	1	275	21:17:34	71.166	-158.142	4	Alt Transect		N	20	20	SA	SW	2	42	TR
Gulf Provider	339	Unidentified seal	Y	1	275	21:18:52	71.151	-158.176	4	Alt Transect		N	600	600	SA	SW	2	41	TR
Gulf Provider	340	Unidentified pinniped	Y	1	275	21:28:00	71.139	-158.201	4	Alt Transect		N	800	800	SA	SW	2	39	TR
Gulf Provider	341	Unidentified pinniped	Y	1	275	21:37:05	71.119	-158.238	4	Alt Transect		N	500	500	SA	SW	2	38	TR
Gulf Provider	342	Unidentified seal	Y	2	275	21:40:35	71.112	-158.243	4	Alt Transect		N	250	250	SA	SW	2	38	TR
Gulf Provider	343	Gray whale	Y	1	275	21:45:09	71.102	-158.263	4	Alt Transect		N	200	200	SP	FD	2	36	TR
Gulf Provider	344	Spotted seal	N	1	275	21:52:47	71.088	-158.298	4	Alt Transect		N	100	100	PE	FD	2	34	TR
Gulf Provider	345	Unidentified seal	Y	1	275	22:13:05	71.048	-158.518	4	Alt Transect		N	300	300	SP	SW	2	22	TR
Gulf Provider	346	Spotted seal	Y	1	275	22:43:00	71.014	-158.610	4	Alt Transect		N	50	10	SP	SW	2	19	TR
Gulf Provider	347	Spotted seal	N	1	275	23:12:07	70.984	-158.816	4	Alt Transect		N	10	10	SP	FD	2	24	TR
Gulf Provider	348	Unidentified seal	Y	1	276	0:29:20	70.960	-159.216	4	Alt Transect		N	300	250	SP	SW	2	45	TR
Gulf Provider	349	Unidentified pinniped	Y	1	276	0:32:00	70.958	-159.212	4	Alt Transect		N	50	50	SA	TH	2	33	TR
Gulf Provider	350	Unidentified seal	Y	2	276	0:37:57	70.947	-159.200	4	Alt Transect		N	150	30	ST	SW	2	32	TR
Gulf Provider	351	Unidentified seal	Y	1	276	0:53:30	70.933	-159.303	4	Alt Transect		N	250	250	SA	DI	2	31	TR

Table C.1 (continued)

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Survey Number[b]	Survey Period[c]	LGL Transect Line[d]	Chukchi Sea Lease Sale Area[e]	Initial Sighting Distance (m)[f]	CPA Distance (m)[g]	Initial Move-ment[h]	Initial Behav.[i]	Bf[j]	Water Depth (m)[k]	Vessel Activ.[l]
Gulf Provider	352	Unidentified seal	Y	1	276	0:54:27	70.933	-159.305	4	Alt Transect		N	200	175	FL	SW	2	31	TR
Gulf Provider	353	Spotted seal	Y	1	276	1:22:30	70.938	-159.496	4	Alt Transect		N	75	75	FL	TH	2	43	TR
Gulf Provider	354	Spotted seal	Y	1	276	2:24:06	70.896	-159.904	4	Alt Transect		N	50	50	SA	FD	2	50	TR
Gulf Provider	355	Spotted seal	Y	2	276	2:50:00	70.831	-160.018	4	Alt Transect		N	100	100	SA	SW	1	45	TR
Gulf Provider	356	Pacific walrus	Y	1	276	3:09:19	70.810	-160.089	4	Alt Transect		N	1000	1000	SA	SW	1	41	TR
Gulf Provider	357	Unidentified seal	Y	2	276	3:09:19	70.810	-160.089	4	Alt Transect		N	300	300	ST	SW	1	41	TR
Gulf Provider	358	Unidentified seal	Y	1	276	3:09:19	70.810	-160.089	4	Alt Transect		N	400	200	SP	SW	1	41	TR
Gulf Provider	359	Pacific walrus	Y	2	276	3:17:20	70.798	-160.132	4	Alt Transect		N	600	600	SA	SW	1	41	TR
Gulf Provider	360	Unidentified seal	Y	2	276	3:19:15	70.792	-160.152	4	Alt Transect		N	600	600	SA	SW	1	40	TR
Gulf Provider	361	Unidentified seal	Y	2	276	3:39:45	70.755	-160.258	4	Alt Transect		N	400	200	ST	SW	1	34	TR
Gulf Provider	362	Bearded seal	Y	1	276	3:44:50	70.744	-160.281	4	Alt Transect		N	1000	1000	SA	SW	1	33	TR
Gulf Provider	363	Unidentified seal	Y	1	276	3:44:50	70.744	-160.281	4	Alt Transect		N	300	300	ST	SW	1	33	TR
Gulf Provider	364	Unidentified seal	Y	1	276	3:52:10	70.727	-160.311	4	Alt Transect		N	382	382	SP	SW	1	32	TR
Gulf Provider	365	Unidentified seal	Y	1	276	3:57:50	70.714	-160.324	4	Alt Transect		N	300	300	SP	SW	1	30	TR
Torsvik	366	Bearded seal	Y	1	291	20:45:15	72.101	-160.385	5	On Transect	10	Y	50	50	SP	SW	4	40	OT
Torsvik	367	Spotted seal	Y	1	291	20:49:15	72.108	-160.415	5	On Transect	10	Y	30	30	SP	SW	4	41	OT
Torsvik	368	Bearded seal	Y	1	291	20:59:00	72.125	-160.485	5	On Transect	10	Y	40	40	UN	LO	4	39	OT
Torsvik	369	Unidentified seal	Y	1	291	21:03:52	72.131	-160.507	5	On Transect	10	Y	244	244	NO	LO	4	39	OT
Torsvik	370	Bowhead whale	Y	1	291	21:18:20	72.156	-160.597	5	On Transect	10	Y	400	250	SA	BL	4	39	OT
Torsvik	371	Ringed seal	Y	1	291	21:28:16	72.172	-160.663	5	On Transect	10	Y	75	50	ST	SW	4	37	OT
Torsvik	372	Pacific walrus	Y	1	291	22:03:47	72.222	-160.867	5	On Transect	10	Y	100	100	SA	SW	4	44	OT
Torsvik	373	Bearded seal	Y	1	291	23:25:00	72.108	-160.829	5	On Transect	9	Y	244	100	PE	SW	4	45	OT
Torsvik	374	Bearded seal	N	1	292	2:30:10	71.693	-160.488	5	On Transect	9	Y	20	20	NO	FD	4	48	OT
Torsvik	375	Unidentified seal	Y	1	292	19:13:10	71.504	-161.111	5	On Transect	8	Y	100	100	UN	LO	5	46	OT
Torsvik	376	Unidentified seal	Y	1	292	21:01:46	71.643	-161.883	5	On Transect	8	Y	30	30	UN	LO	5	43	OT
Torsvik	377	Unidentified seal	Y	1	292	21:06:07	71.647	-161.901	5	On Transect	8	Y	60	60	UN	LO	5	42	OT
Torsvik	378	Unidentified seal	Y	1	292	23:16:39	71.646	-162.491	5	On Transect	7	Y	100	100	NO	DI	5	41	OT
Torsvik	379	Unidentified seal	Y	1	292	23:22:12	71.632	-162.489	5	On Transect	7	Y	100	50	ST	DI	5	41	OT
Torsvik	380	Unidentified seal	Y	1	292	23:31:00	71.610	-162.485	5	On Transect	7	Y	100	50	SP	SW	5	41	OT
Torsvik	381	Ringed seal	N	1	293	0:30:25	71.471	-162.477	5	On Transect	7	Y	10	10	SP	SW	7	43	OT
Torsvik	382	Unidentified seal	N	1	293	0:37:20	71.459	-162.477	5	On Transect	7	Y	60	50	ST	SW	7	42	OT
Torsvik	383	Ringed seal	N	1	293	0:57:14	71.407	-162.484	5	On Transect	7	Y	20	15	ST	SW	7	43	OT
Torsvik	384	Ringed seal	N	1	293	2:35:43	71.179	-162.487	5	On Transect	7	Y	50	40	NO	LO	7	43	OT
Torsvik	385	Unidentified seal	N	1	293	19:53:15	71.094	-163.713	5	On Transect	6	Y	100	100	NO	LO	5	42	OT
Torsvik	386	Ringed seal	N	1	293	20:04:30	71.103	-163.785	5	On Transect	6	Y	50	30	ST	TH	5	42	OT
Torsvik	387	Unidentified seal	N	1	293	21:59:23	71.219	-164.580	5	On Transect	6	Y	20	20	NO	TH	5	42	OT
Torsvik	388	Unidentified seal	Y	1	294	2:23:31	70.714	-164.418	5	On Transect	5	Y	290	150	ST	LO	4	46	OT
Torsvik	389	Harbor porpoise	N	3	294	2:45:20	70.662	-164.379	5	On Transect	5	Y	200	150	SA	TR	4	45	OT
Torsvik	390	Unidentified seal	Y	1	294	3:00:34	70.623	-164.351	5	On Transect	5	Y	244	100	ST	LO	4	44	OT
Torsvik	391	Unidentified seal	Y	1	294	18:13:00	70.502	-164.910	5	On Transect	4	Y	40	30	SP	SW	2	43	OT
Torsvik	392	Unidentified seal	Y	1	294	18:32:09	70.517	-165.051	5	On Transect	4	Y	60	60	NO	DI	2	42	OT
Torsvik	393	Unidentified seal	Y	1	294	19:03:20	70.542	-165.267	5	On Transect	4	Y	70	70	SP	DI	2	42	OT
Torsvik	394	Unidentified seal	Y	1	294	19:14:38	70.551	-165.343	5	On Transect	4	Y	466	357	NO	RE	2	42	OT
Torsvik	395	Ringed seal	Y	1	294	19:18:04	70.554	-165.370	5	On Transect	4	Y	466	125	ST	LO	2	42	OT
Torsvik	396	Ringed seal	Y	1	294	19:29:45	70.565	-165.460	5	On Transect	4	Y	150	100	ST	SW	2	42	OT
Torsvik	397	Ringed seal	Y	1	294	19:48:00	70.576	-165.579	5	On Transect	4	Y	40	20	SP	LO	2	42	OT
Torsvik	398	Unidentified seal	Y	1	294	19:48:34	70.576	-165.584	5	On Transect	4	Y	668	466	SP	SW	2	42	OT
Torsvik	399	Unidentified seal	Y	1	294	20:28:00	70.606	-165.863	5	On Transect	4	Y	150	100	NO	LO	2	43	OT
Torsvik	400	Ringed seal	Y	1	294	20:33:45	70.610	-165.896	5	On Transect	4	Y	357	357	SP	LO	2	43	OT
Torsvik	401	Ringed seal	Y	1	294	20:39:15	70.614	-165.930	5	On Transect	4	Y	40	25	ST	LO	2	43	OT
Torsvik	402	Bearded seal	Y	1	294	20:45:30	70.619	-165.978	5	On Transect	4	Y	357	357	SA	SW	2	42	OT

Table C.1 (continued)

Vessel	Sighting ID	Species	Useable (Y) or Non-useable (N)[a]	Group Size	Day in 2006	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Survey Number[b]	Survey Period[c]	LGL Transect Line[d]	Chukchi Sea Lease Sale Area[e]	Initial Sighting Distance (m)[f]	CPA Distance (m)[g]	Initial Move-ment[h]	Initial Behav.[i]	Bf[j]	Water Depth (m)[k]	Vessel Activ.[l]
Torsvik	403	Ringed seal	Y	1	294	20:55:45	70.627	-166.057	5	On Transect	4	Y	125	125	NO	LO	2	40	OT
Torsvik	404	Ringed seal	Y	1	294	21:02:52	70.632	-166.100	5	On Transect	4	Y	20	10	NO	LO	2	40	OT
Torsvik	405	Unidentified seal	Y	1	294	21:16:42	70.642	-166.193	5	On Transect	4	Y	357	357	NO	LO	2	40	OT
Torsvik	406	Bearded seal	Y	1	294	21:30:31	70.653	-166.297	5	On Transect	4	Y	750	750	SP	SW	2	41	OT
Torsvik	407	Bearded seal	Y	1	294	23:00:40	70.564	-166.412	5	On Transect	3	Y	50	30	SP	LO	3	42	OT
Torsvik	408	Ringed seal	Y	1	294	23:10:12	70.547	-166.395	5	On Transect	3	Y	50	30	SP	SW	3	43	OT
Torsvik	409	Unidentified pinniped	N	1	294	23:30:00	70.500	-166.345	5	On Transect	3	Y	100	30	DE		3	44	OT
Torsvik	410	Ringed seal	Y	1	295	0:20:00	70.393	-166.242	5	On Transect		Y	150	125	NO	RE	2	44	OT
Torsvik	411	Ringed seal	Y	1	295	0:24:50	70.381	-166.230	5	On Transect		Y	350	150	ST	SW	2	44	OT
Torsvik	412	Ringed seal	Y	1	295	0:27:58	70.373	-166.223	5	On Transect		Y	10	10	SA	SW	2	44	OT
Torsvik	413	Ringed seal	Y	1	295	0:27:58	70.373	-166.223	5	On Transect		Y	150	125	UN	RE	2	44	OT
Torsvik	414	Ringed seal	Y	1	295	0:29:53	70.369	-166.218	5	On Transect		Y	60	30	ST	TH	2	44	OT
Torsvik	415	Bearded seal	Y	1	295	0:39:28	70.352	-166.201	5	On Transect		Y	60	60	SP	SW	2	44	OT
Torsvik	416	Ringed seal	Y	1	295	0:39:28	70.352	-166.201	5	On Transect		Y	150	100	NO	LO	2	44	OT
Torsvik	417	Ringed seal	Y	1	295	0:43:02	70.343	-166.193	5	On Transect		Y	150	150	NO	LO	2	44	OT
Torsvik	418	Ringed seal	Y	2	295	0:43:46	70.342	-166.191	5	On Transect		Y	125	100	NO	LO	2	44	OT
Torsvik	419	Unidentified seal	Y	1	295	1:01:00	70.302	-166.151	5	On Transect		Y	160	160	PE	LO	2	44	OT
Torsvik	420	Ringed seal	Y	1	295	1:36:45	70.222	-166.066	5	On Transect		Y	185	80	NO	LO	2	44	OT
Torsvik	421	Bearded seal	Y	1	295	1:51:47	70.186	-166.031	5	On Transect		Y	244	150	SA	SW	2	44	OT
Torsvik	422	Harbor porpoise	Y	2	295	2:01:00	70.165	-166.010	5	On Transect		Y	150	150	SA	SW	2	44	OT
Torsvik	423	Unidentified seal	Y	1	295	2:41:14	70.072	-165.928	5	On Transect		Y	200	200	SA	SW	2	43	OT
Torsvik	424	Ringed seal	Y	1	295	19:40:20	69.932	-167.302	5	On Transect	2	Y	357	357	NO	LO	4	46	OT
Torsvik	425	Spotted seal	Y	1	295	21:05:50	69.953	-167.891	5	On Transect	2	Y	60	40	PE	SW	5	47	OT
Torsvik	426	Ringed seal	Y	1	295	21:13:42	69.955	-167.952	5	On Transect	2	Y	100	10	SA	SW	5	47	OT
Torsvik	427	Ringed seal	Y	1	295	21:25:30	69.956	-168.043	5	On Transect	2	Y	50	50	NO	RE	5	47	OT
Torsvik	428	Unidentified seal	Y	1	295	21:33:07	69.957	-168.092	5	On Transect	2	Y	244	185	ST	LO	5	46	OT
Torsvik	429	Unidentified seal	Y	1	295	21:57:05	69.905	-168.054	5	On Transect	1	Y	60	60	NO	LO	5	47	OT
Torsvik	430	Unidentified seal	Y	1	295	22:32:16	69.828	-167.981	5	On Transect	1	Y	50	50	SA	SW	5	47	OT
Torsvik	431	Unidentified seal	Y	1	295	23:46:00	69.677	-167.816	5	On Transect	1	Y	20	20	NO	TH	5	46	OT
Torsvik	432	Pacific walrus	N	1	296	2:12:44	69.350	-167.468	5	On Transect	1	Y	150	150	ST	SW	6	48	OT

[a] Useable or non-useable sightings: Y= useable sightings made during useable daylight periods of visual observation, as defined in *List of Acronyms and Abbreviations,* N= non-useable sightings.

[b] Survey number: 1=; 2= 3= 4= 5= , as defined in Table 4.X.

[c] Survey period: In transit= ; On transect= ; Off transect= ; Alternate transect= , as defined in *Methods.*

[d] LGL Tranect Line: Desginated pre-planned transect lines, as defined in Figure 4.1.

[e] Chukchi Sea Lease Sale Area: Y= ; N= , as defined in Figure 4.1.

[f] Initial sighting distance from observer.

[g] Closest observed point of approach to the observer.

[h] Initial movement of the animal(s) relative to the vessel: MI=milling, FL=Flee, PE=swimming perpendicular to ship or across bow, SA=swimming away, SP=swimming parallel, ST=swimming toward, NO=no movement, UN=unknown.

[i] Initial behavior observed: BR=breach, FL=fluke, DI=dive, FD=forward dive, SW=swim, TR=travel, ST=surface-active travel, LG=log, RE=rest, LO=look, SI=sink, TH=thrash, FE/FG=feed, MI=mill, SA=surface-active, UN=unknown.

[j] Beaufort Wind Force Scale.

[k] Water depth, or, if unknown, water depth range.

[l] Activity of the vessel at the time of the sighting: TR=travelling within the study area, OT=other.

APPENDIX D: EASTERN CHUKCHI SEA WHALE SIGHTINGS, 2006

Appendix D consists of

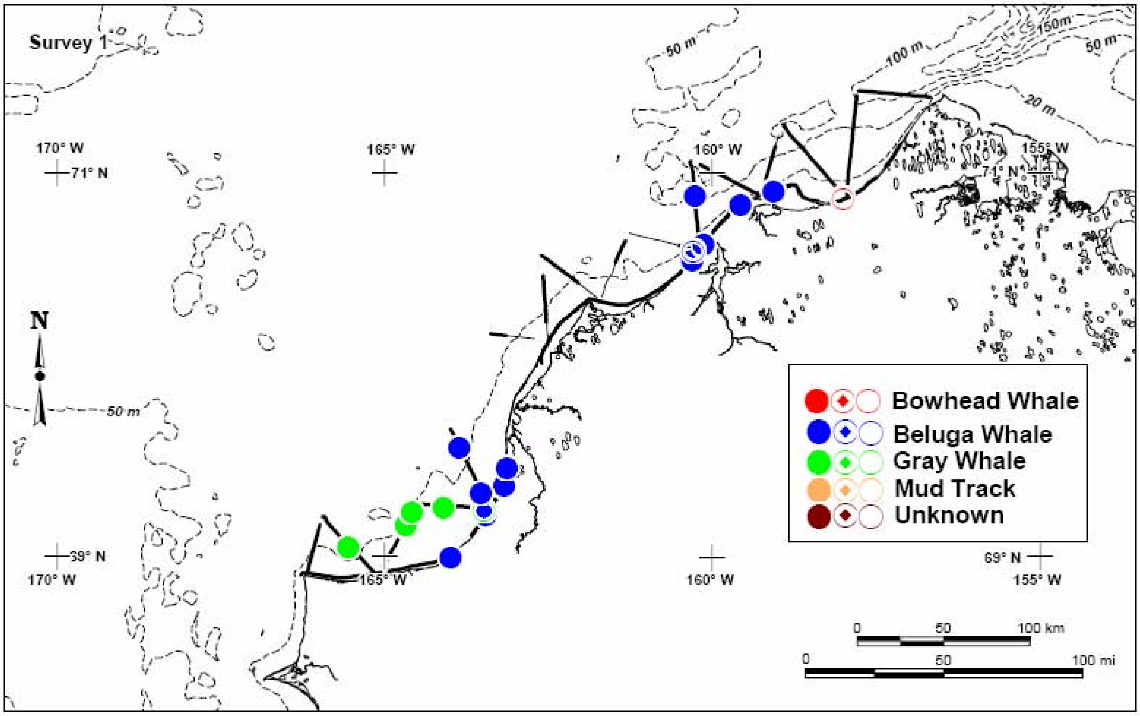
1. Figures D.1 – D.13, maps of survey coverage (survey periods were between one and three days in length) and whale sightings for 2006 in the eastern Chukchi Sea, and
2. Table D.1 – D.2, summarizing 2006 whale sightings in the eastern Chukchi Sea for the coastline and sawtooth surveys.

Figures D.1 – D.13 show for each survey,

1. ***Aerial survey coverage (survey lines).*** Sightability along survey lines is depicted as shown in the legend below.

2. ***Whale sightings.*** The symbols used on the maps are color coded to identify the species as explained in the legends. Mud tracks are indications that whales (probably gray whales) are likely feeding in the area. They are plumes of mud created by whales feeding in the benthic substrate and indicate that a whale is likely present under the water but not visible. Each sighting symbol on these maps represents a sighting of one or more individual whales. Sightings along formal transects (regardless of distance from trackline) are shown as filled (“useable” sightings) or ‘dotted’ (“non-useable” sightings) symbols. Incidental sightings, include sightings during “Connect” legs between transects and during non-systematic “Search” legs, are shown as open symbols, and are not considered during analyses.

D.1A



D.1B

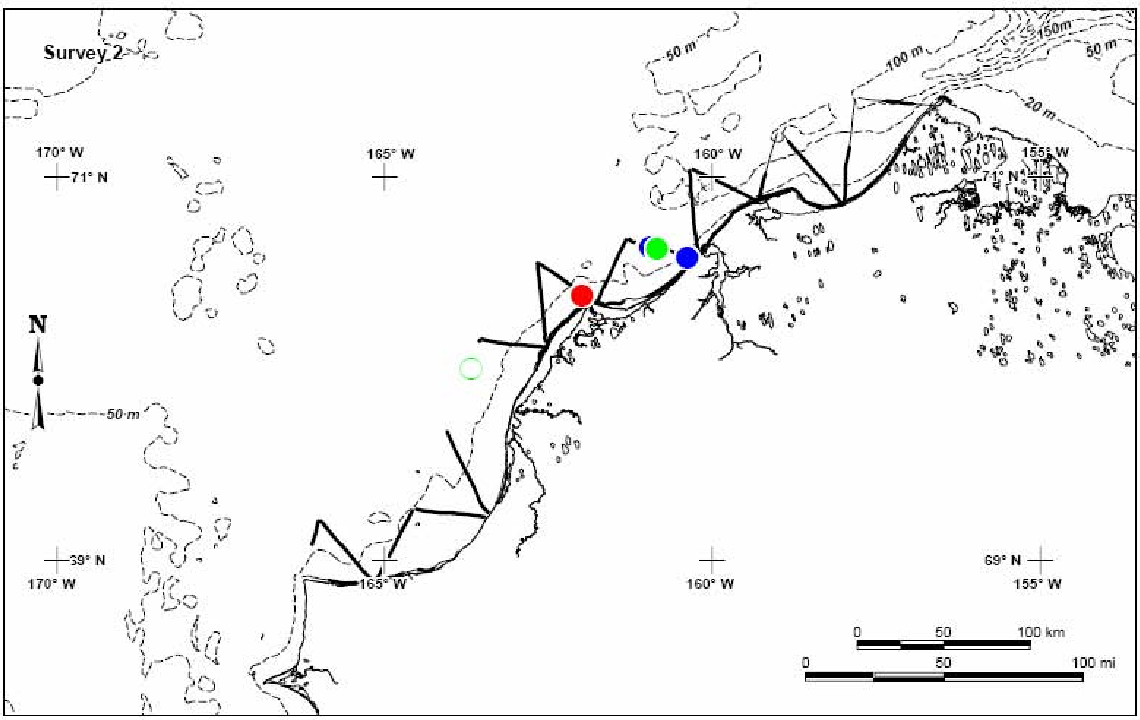
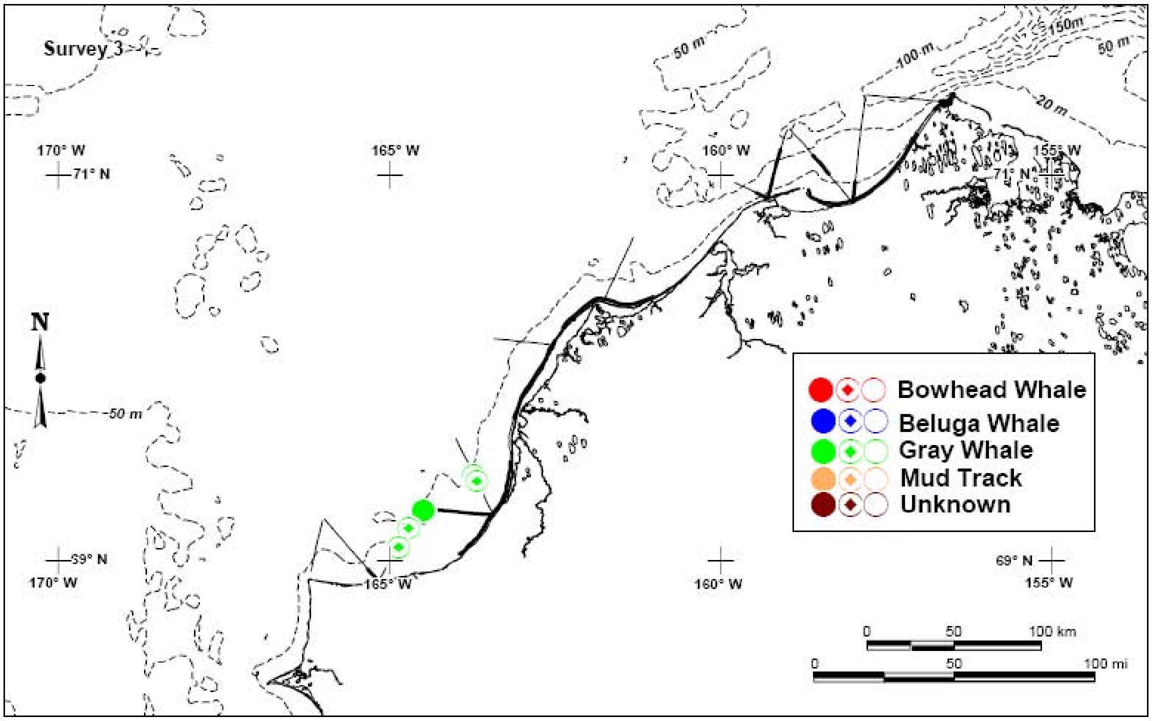


FIGURE D.1A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 1 (9-10 July; D.1A) and 2 (15 July; D.1B). Solid symbols denote “useable”sightings, open symbols containing a dot denote “non-useable” sightings, and open symbols denote incidental sightings, including search and connect legs.

D.2A



D.2B

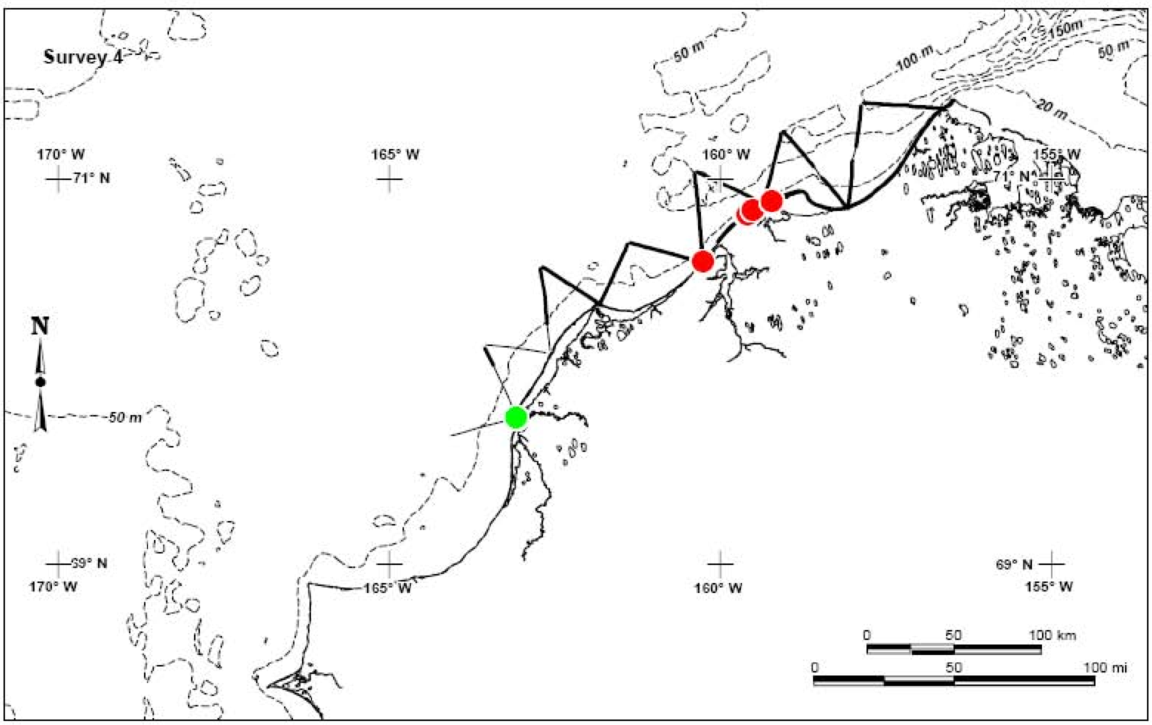
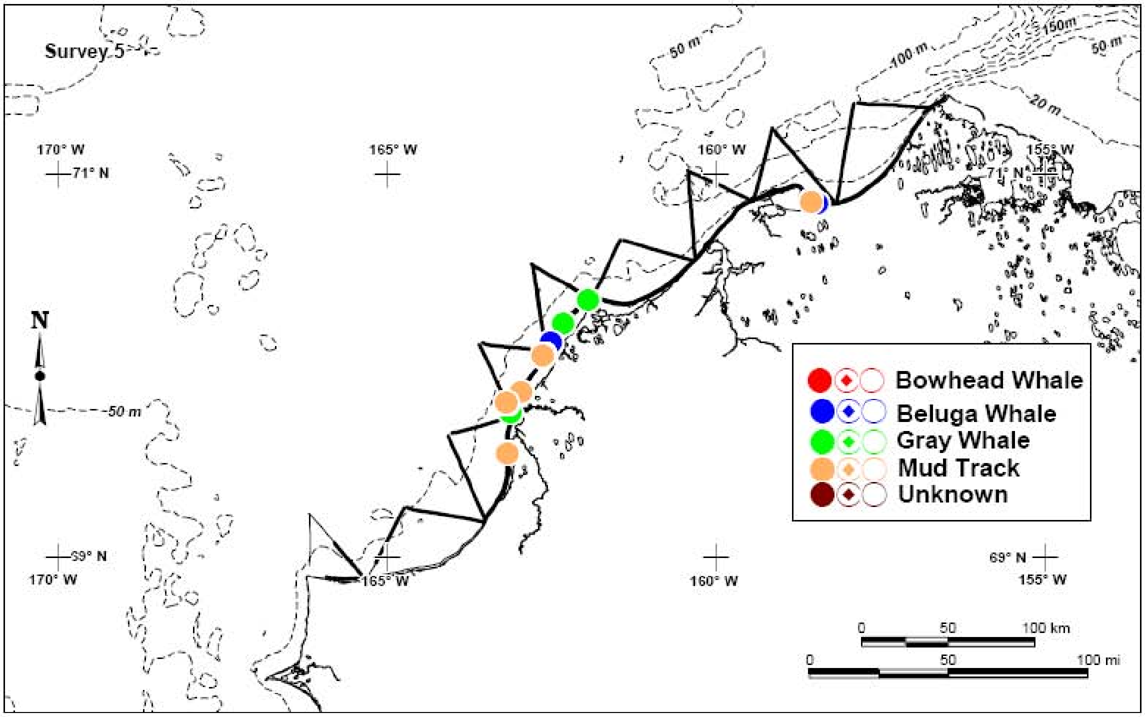


FIGURE D.2A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 3 (18 July; D.2A) and 4 (20 July; D.2B). See Figure D.1 for notes on symbols.

D.3A



D.3B

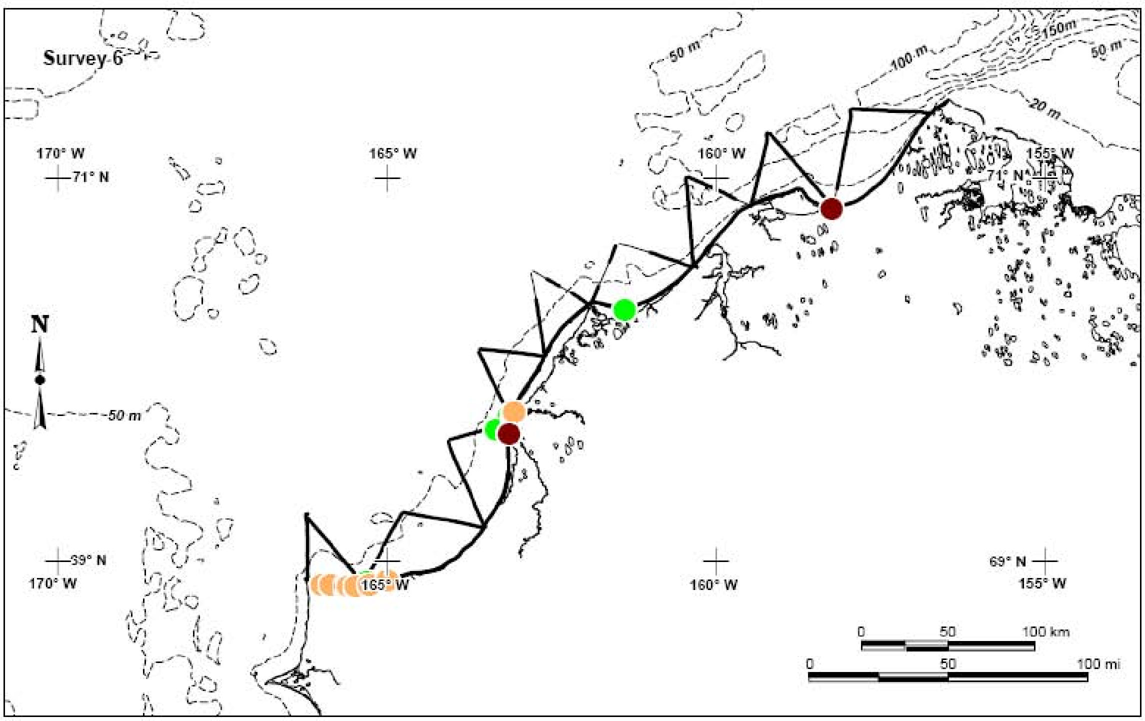
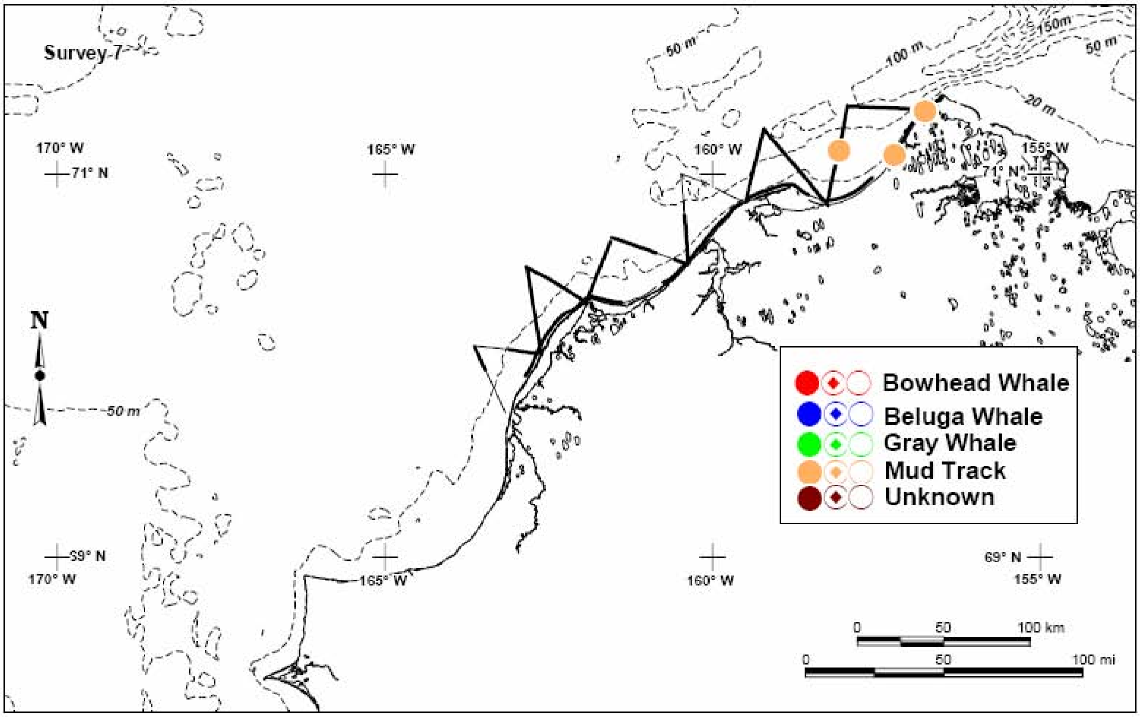


FIGURE D.3A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 5 (23-24 July; D.3A) and 6 (25 July; D.3B). See Figure D.1 for notes on symbols.

D.4A



D.4B

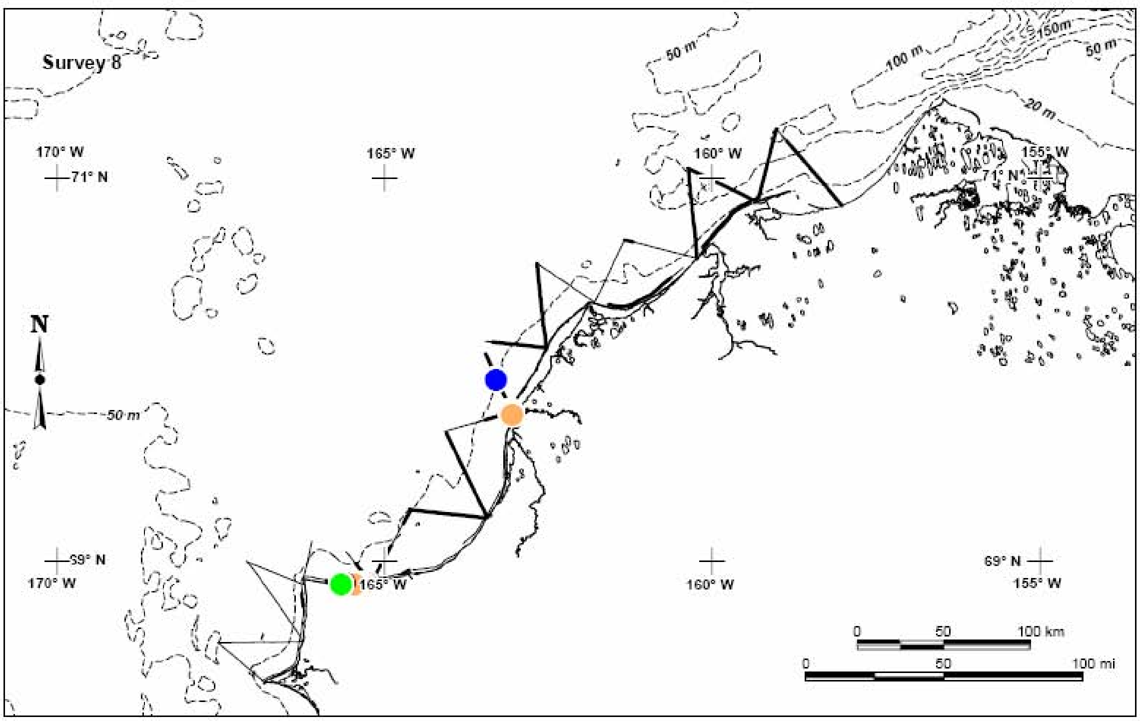
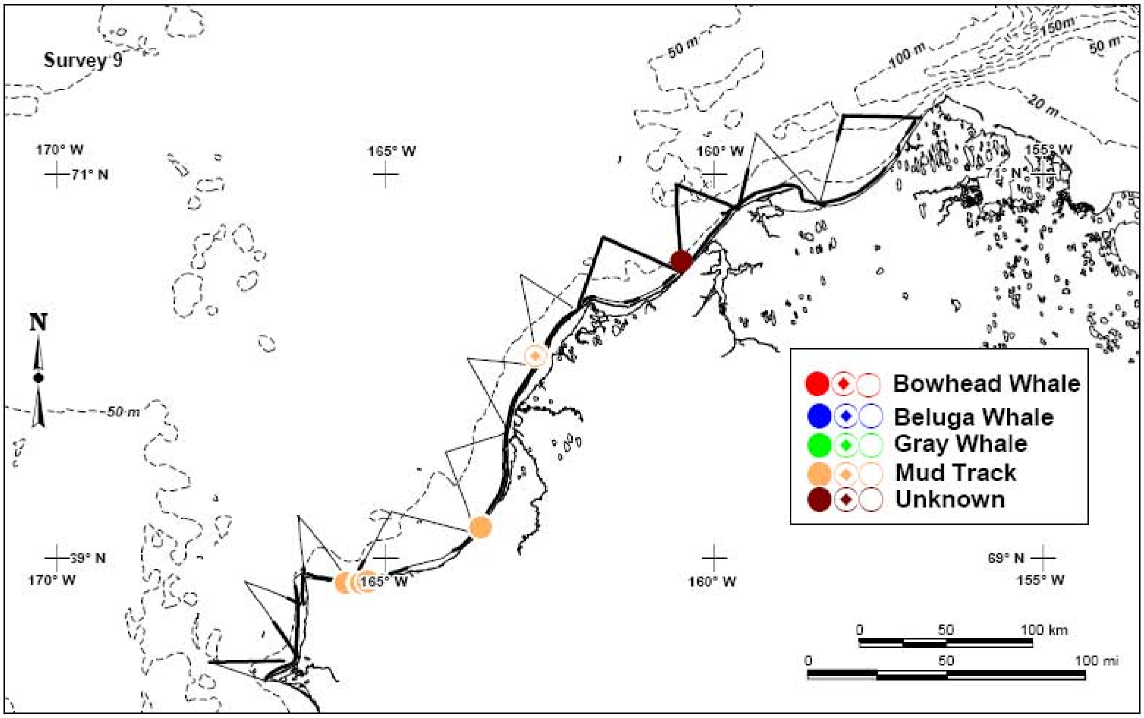


FIGURE D.4A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 7 (23 August; D.4A) and 8 (28-30 August; D.4B). See Figure D.1 for notes on symbols.

D.5A



D.5B

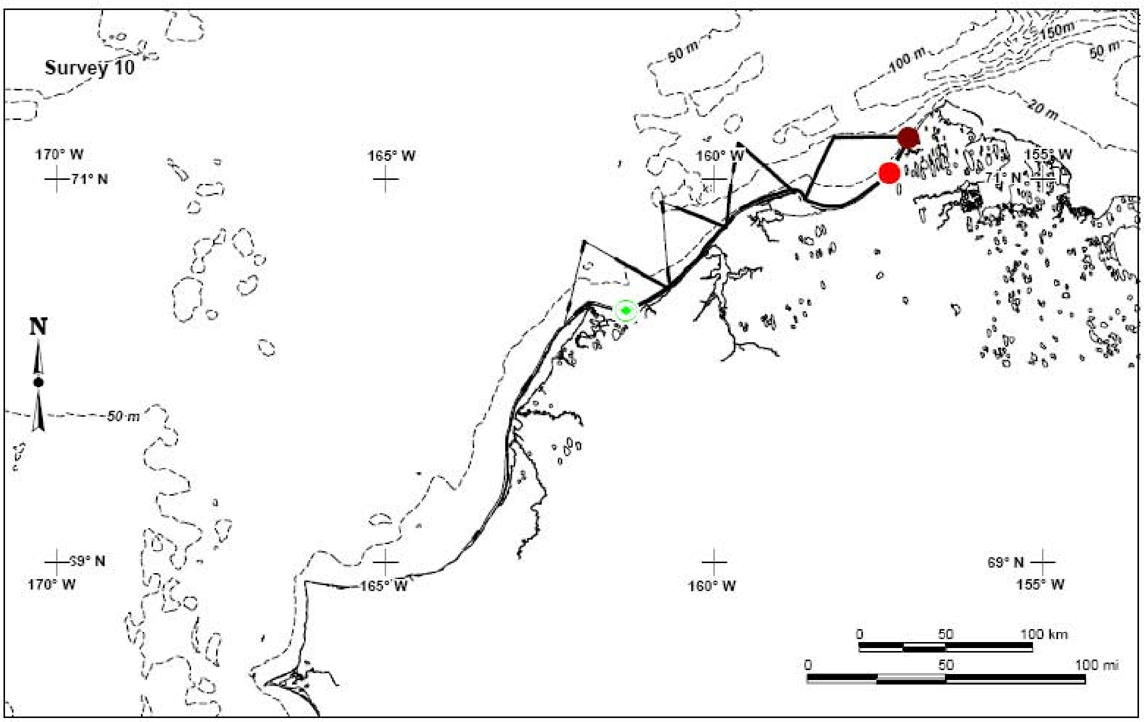
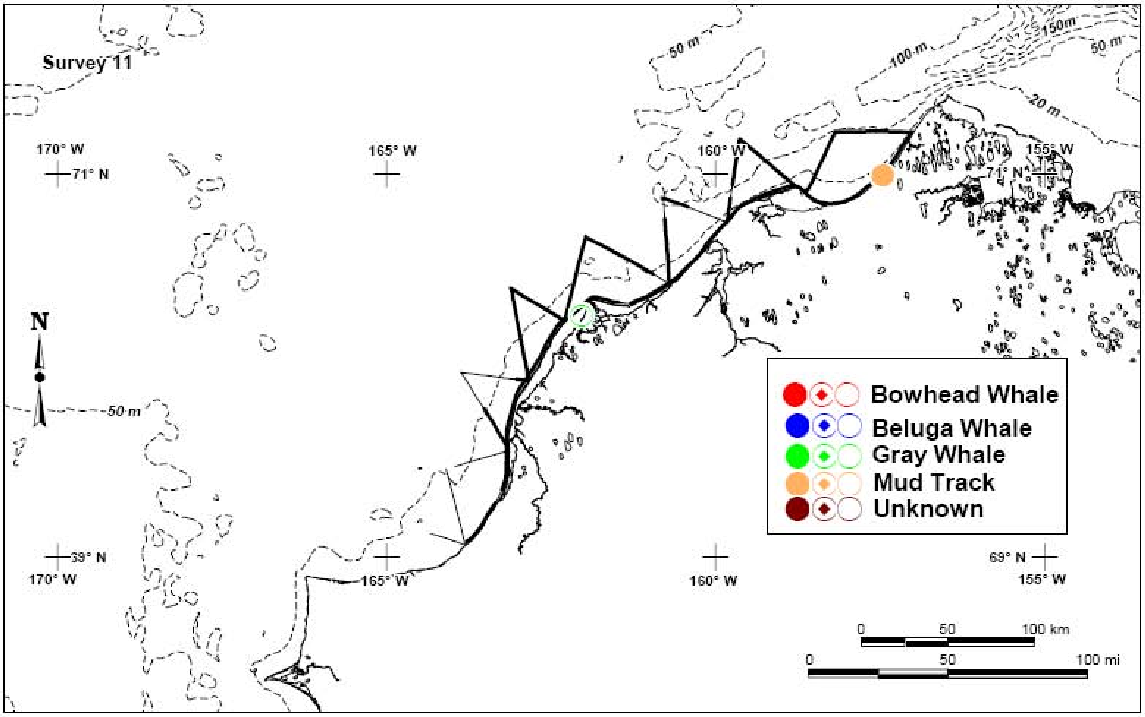


FIGURE D.5A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 9 (31 August – 1 September; D.5A) and 10 (3 September; D.5B). See Figure D.1 for notes on symbols.

D.6A



D.6B

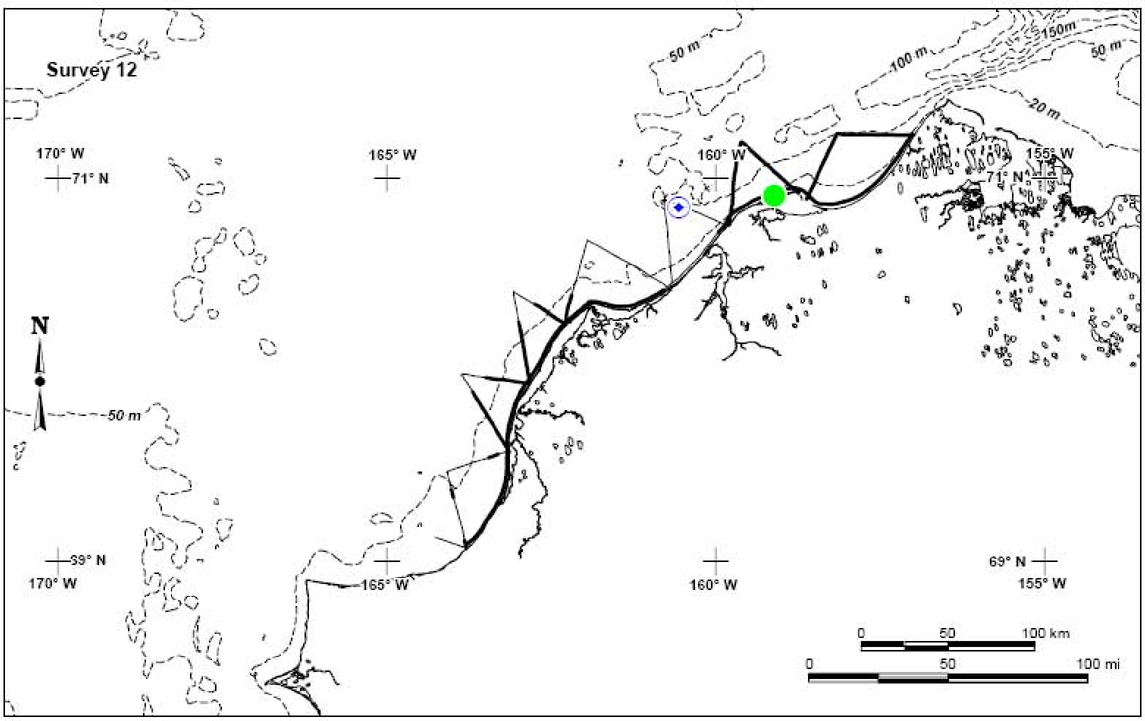
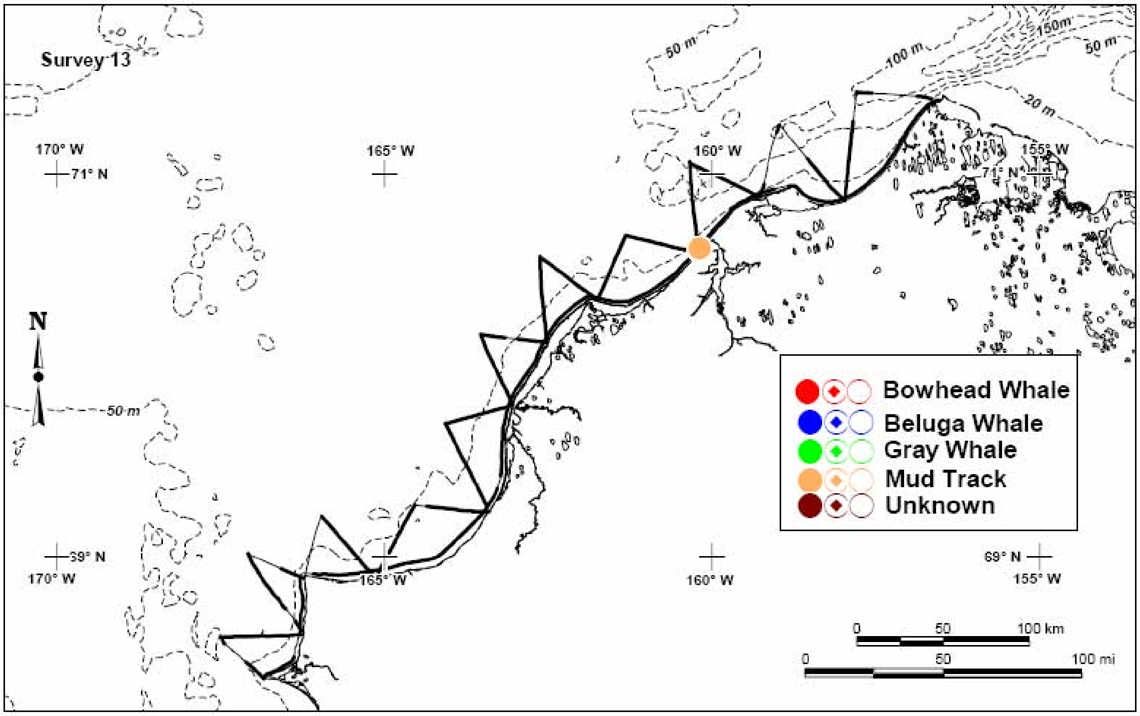


FIGURE D.6A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 11 (5-6 September; D.6A) and 12 (11-12 September; D.6B). See Figure D.1 for notes on symbols.

D.7A



D.7B

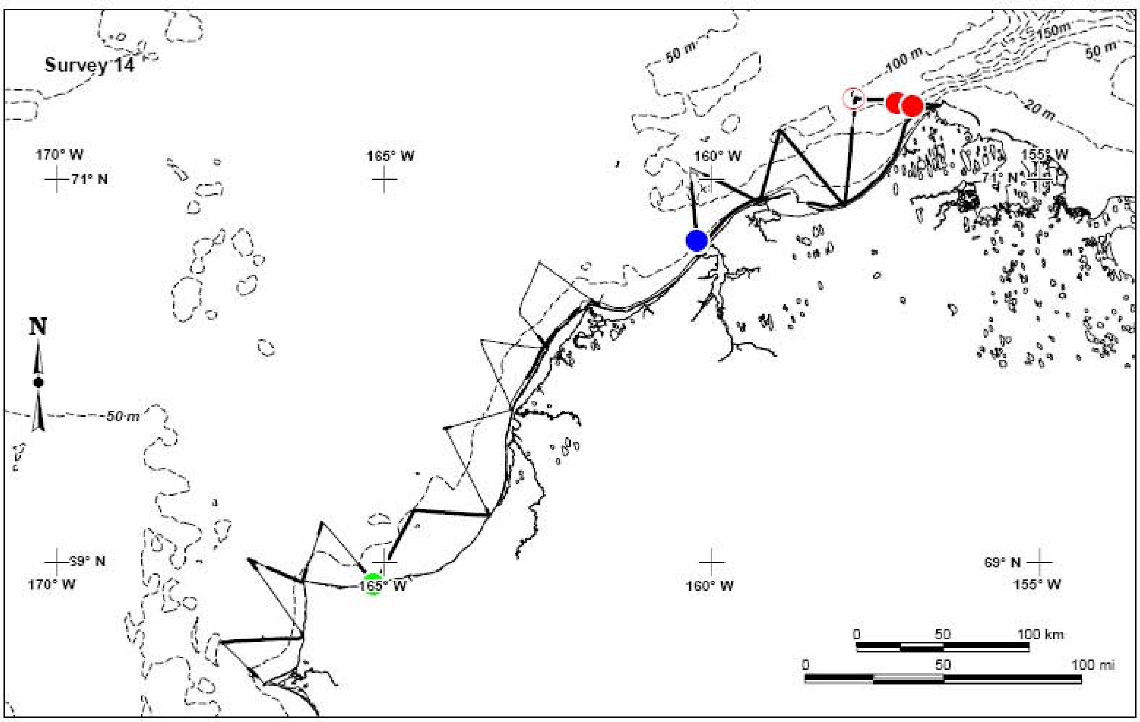
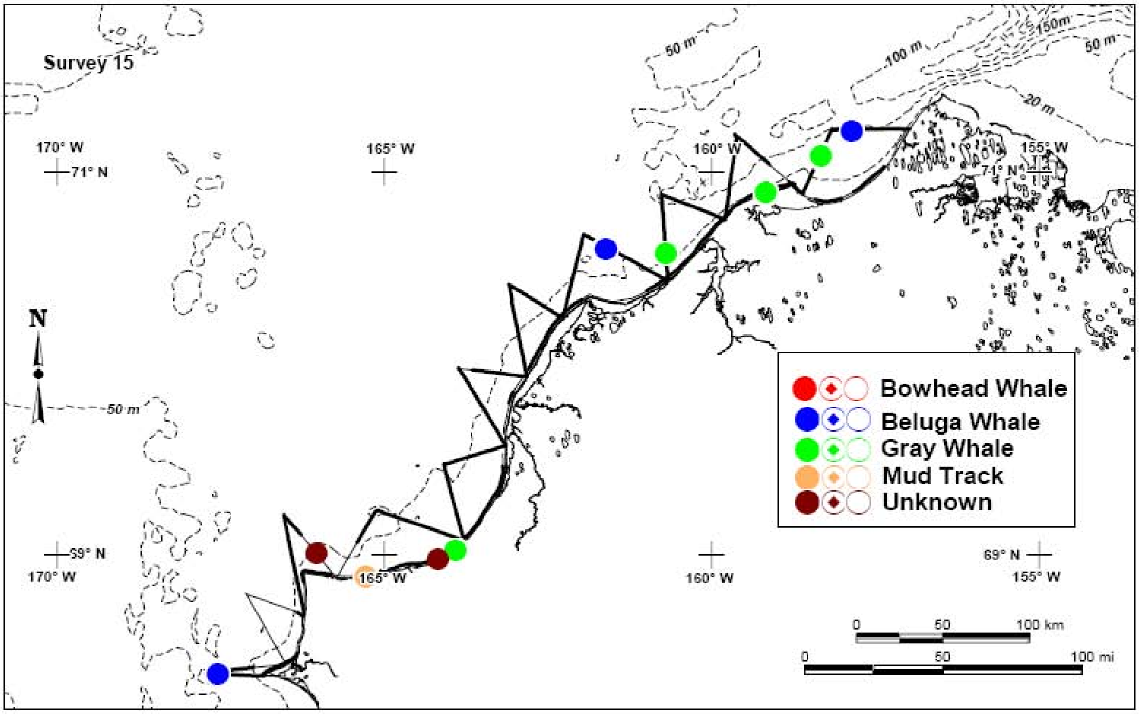


FIGURE D.7A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 13 (14-15 September; D.7A) and 14 (21-23 September; D.7B). See Figure D.1 for notes on symbols.

D.8A



D.8B

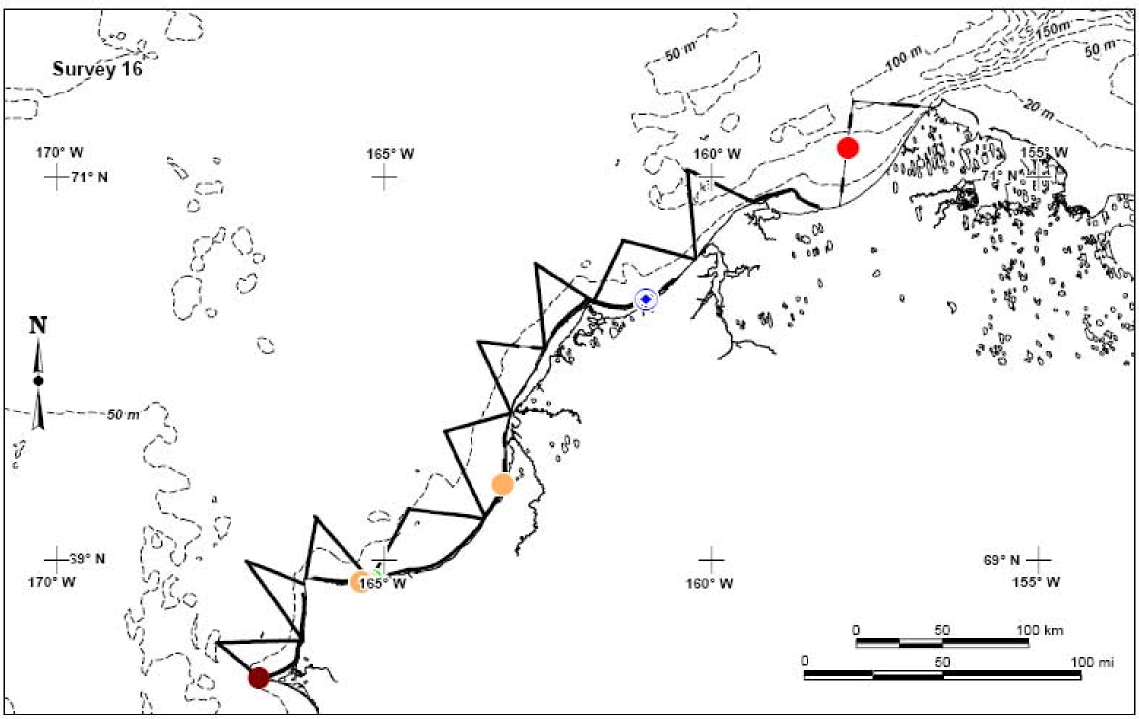
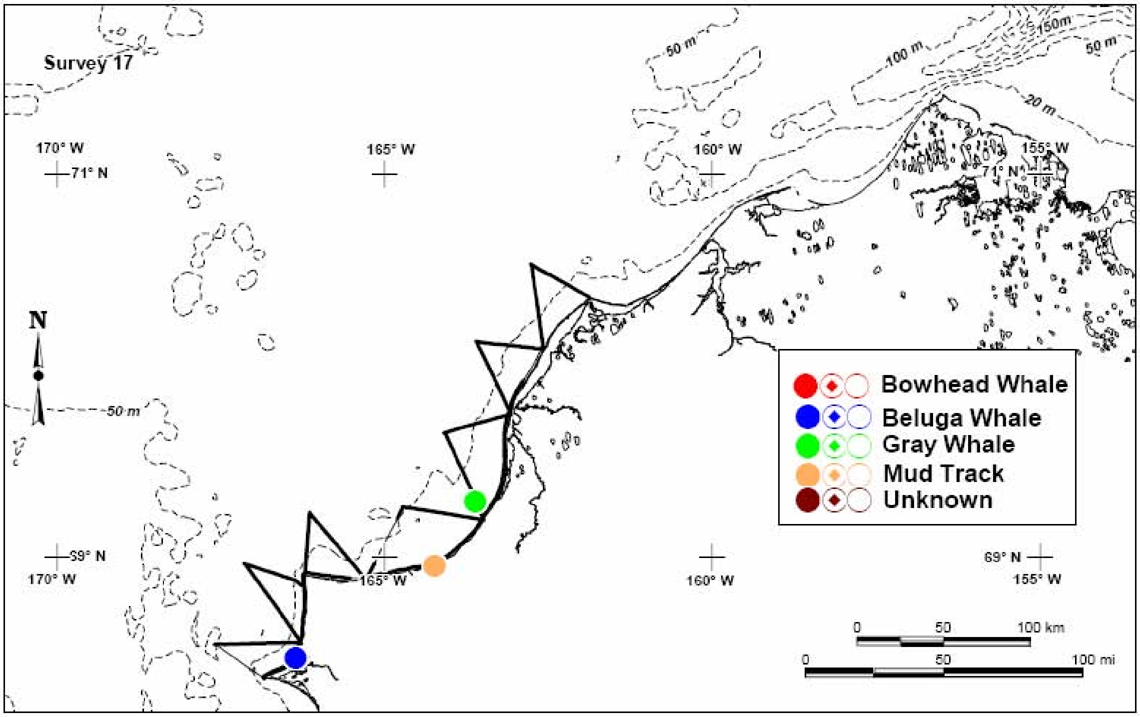


FIGURE D.8A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 15 (24-25 September; D.8A) and 16 (30 September – 2 October; D.8B). See Figure D.1 for notes on symbols.

D.9A



D.9B

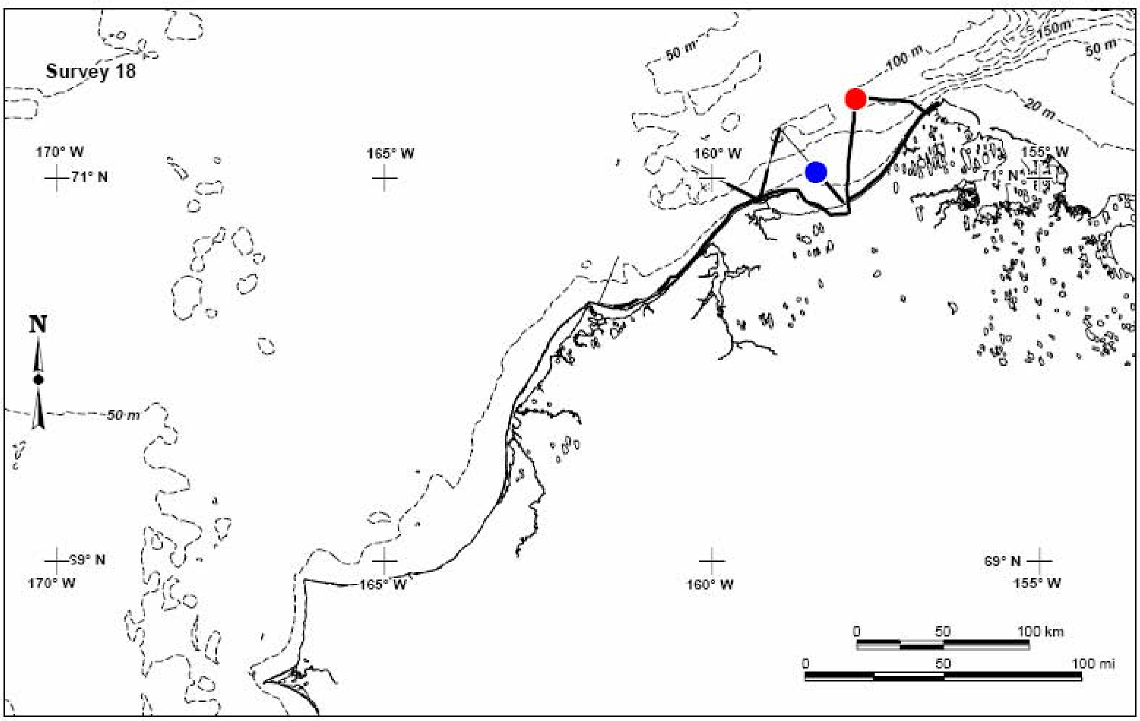
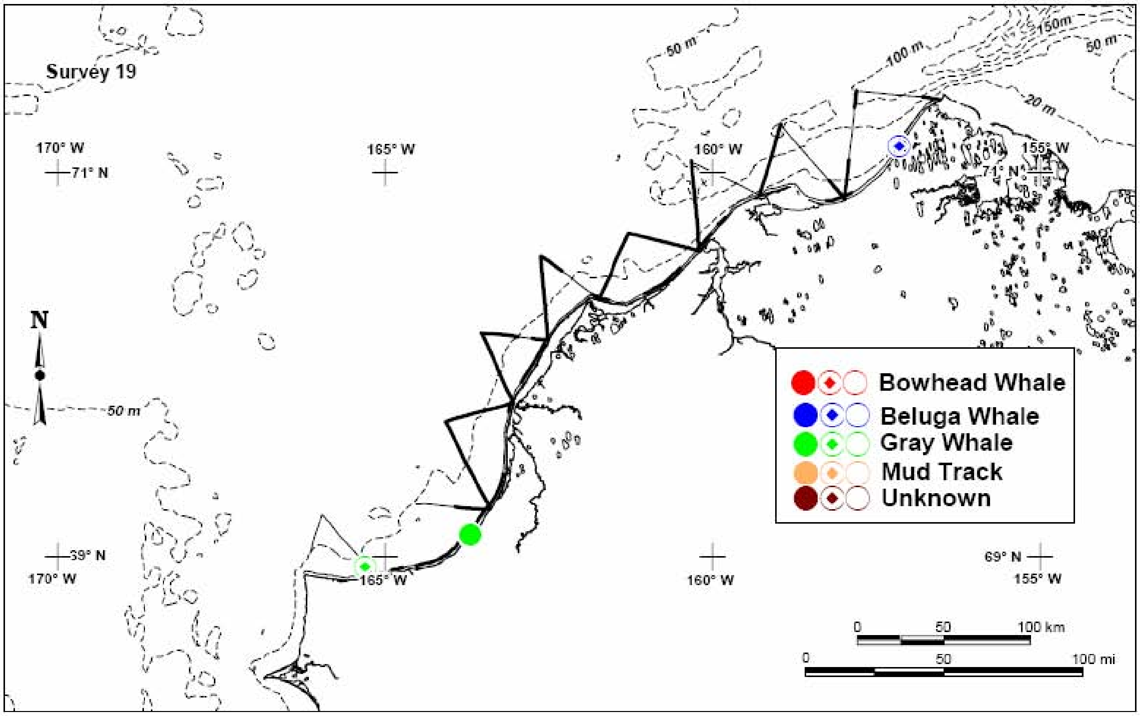


FIGURE D.9A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 17 (6 October; D.9A) and 18 (11 October; D.9B). See Figure D.1 for notes on symbols.

D.10A



D.10B

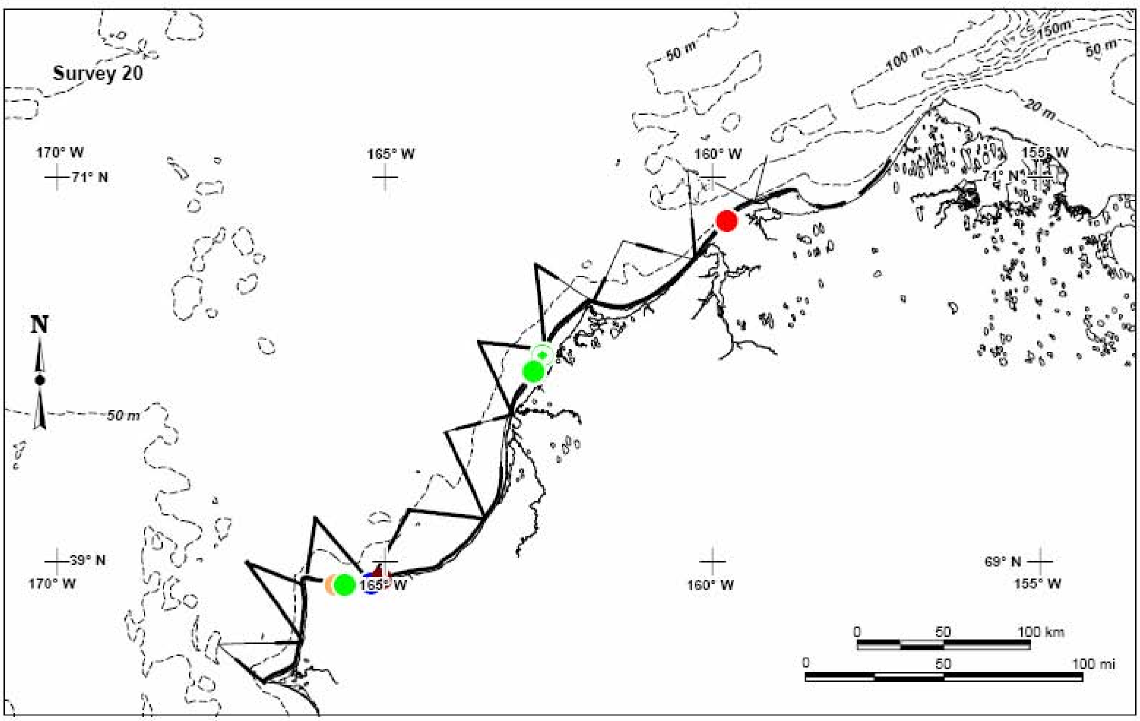
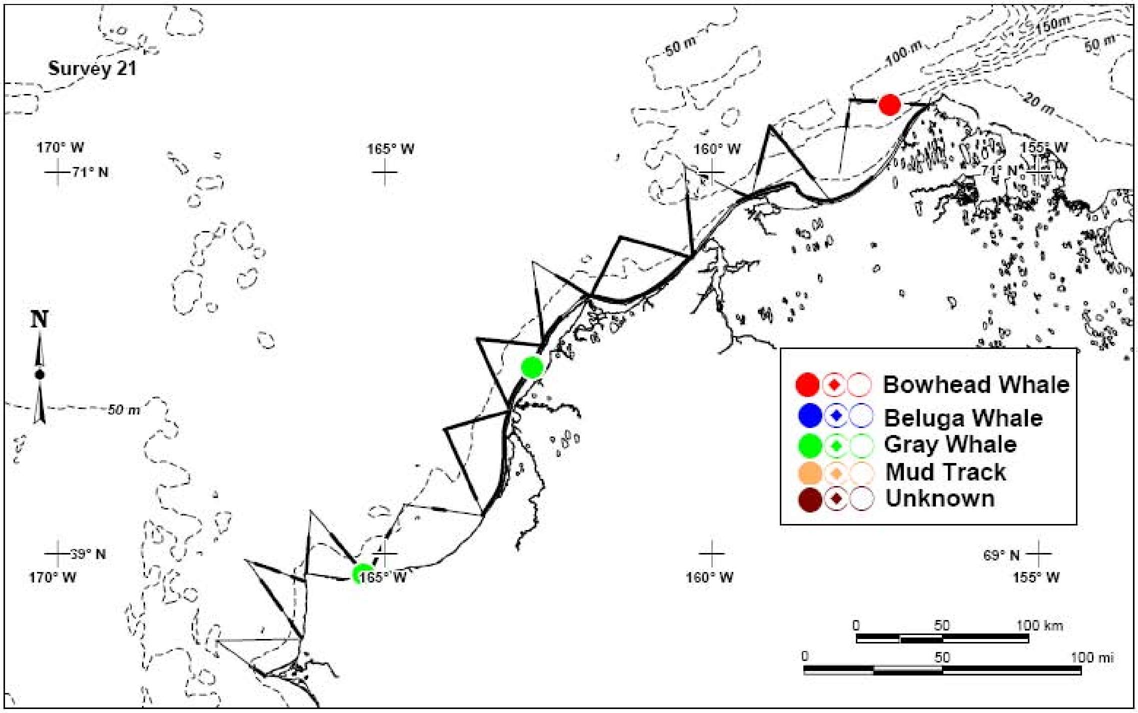


FIGURE D.10A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 19 (14-15 October; D.10A) and 20 (18-20 October; D.10B). See Figure D.1 for notes on symbols.

D.11A



D.11B

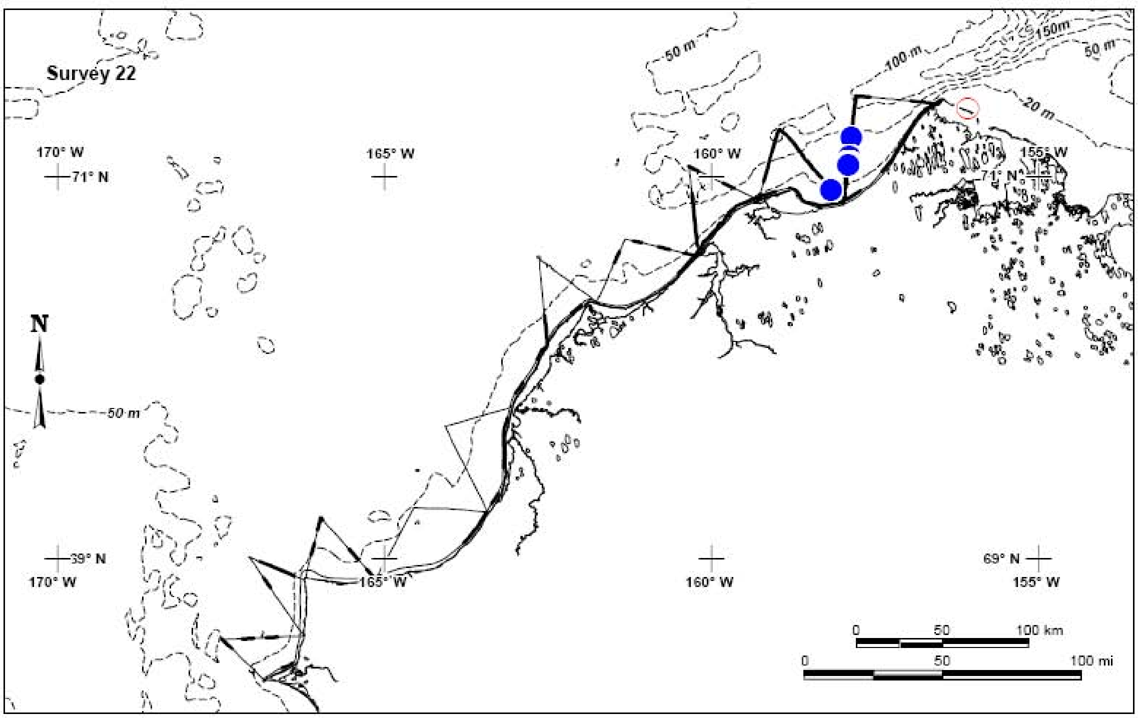
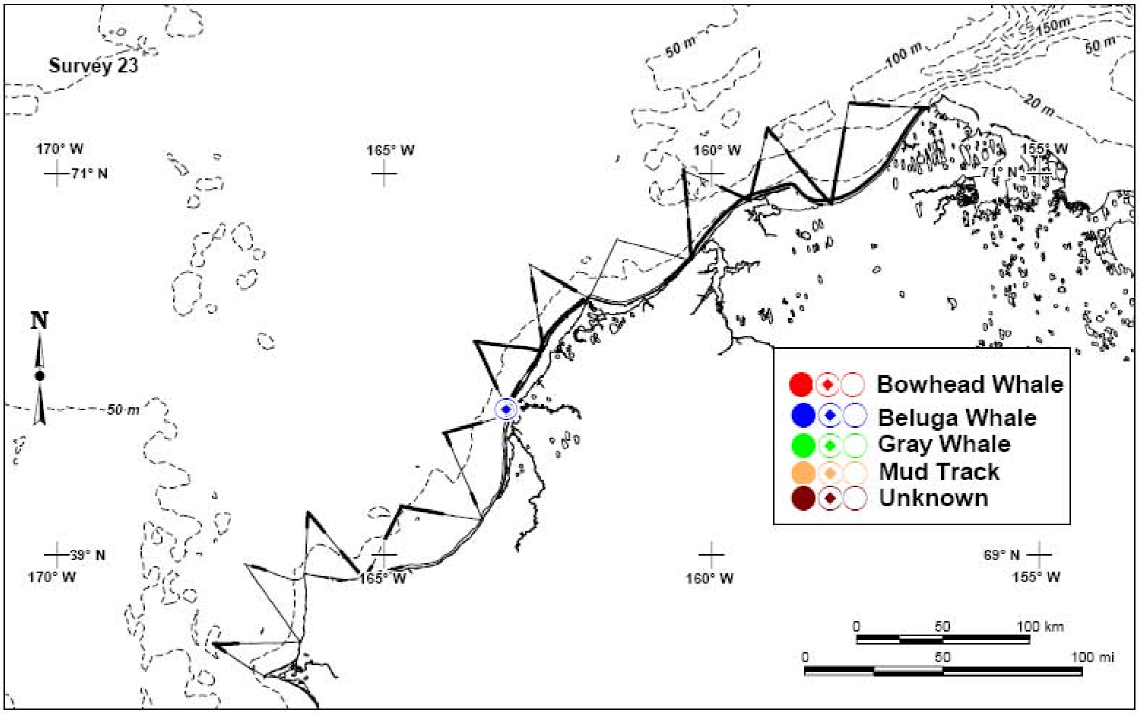


FIGURE D.11A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 21 (21-23 October; D.11A) and 22 (25-26 October; D.11B). See Figure D.1 for notes on symbols.

D.12A



D.12B

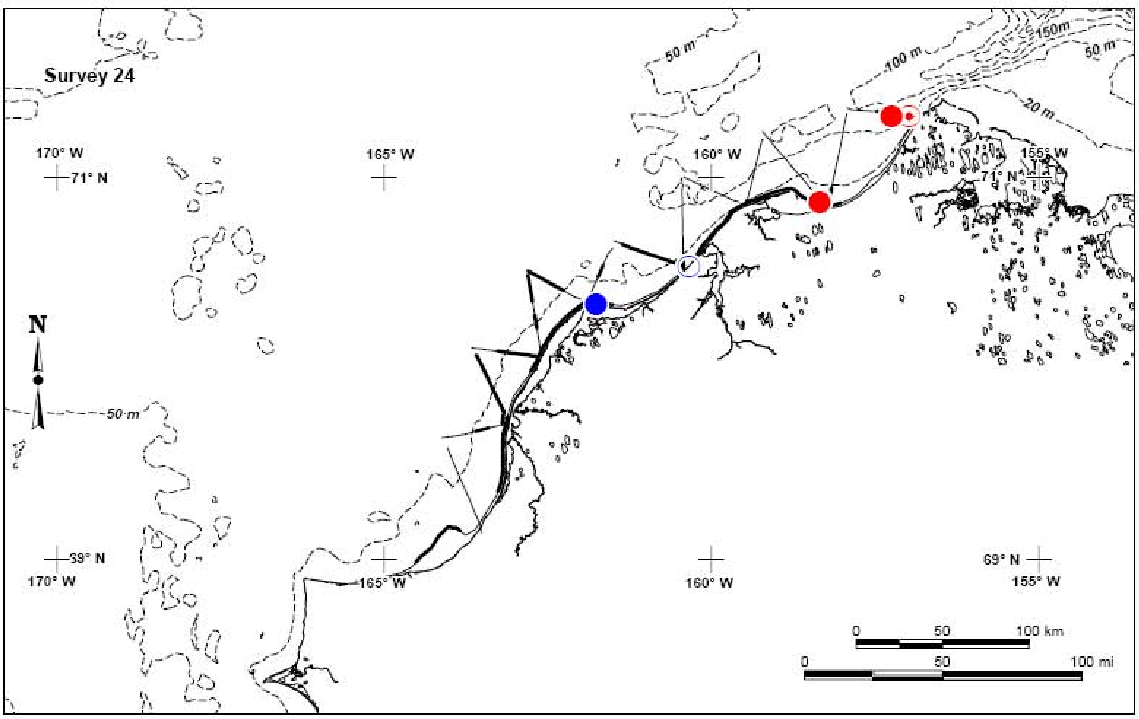


FIGURE D.12A and B. Locations of whale sightings in the eastern Chukchi Sea during aerial surveys 23 (29-31 October; D.12A) and 24 (7-9 November; D.12B). See Figure D.1 for notes on symbols.

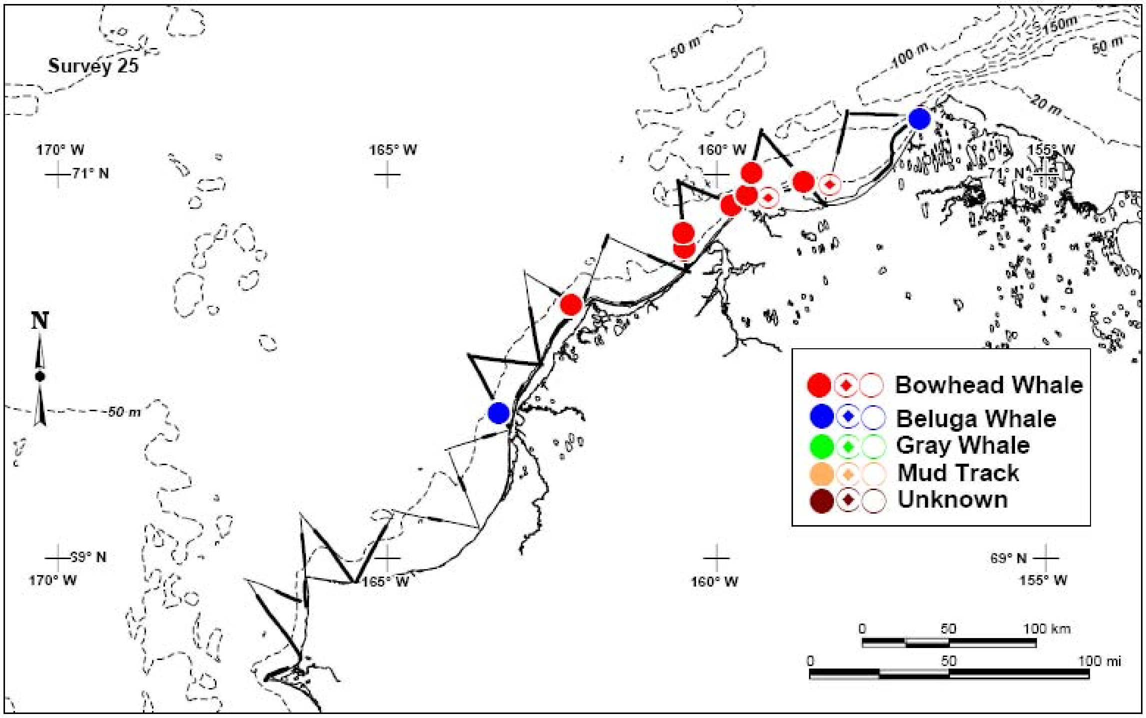


FIGURE D.13. Locations of whale sightings in the eastern Chukchi Sea during aerial survey 25 (11-12 November). See Figure D.1 for notes on symbols.

TABLE D.1. Summary of **coastline** aerial survey effort and whale sightings in the Alaskan Chukchi Sea, 9 July to 12 November 2006. "All sightings" include useable, non-useable and incidental sightings.

		All Sightings							Useable Sighting Conditions						
			Beluga		Bowhead		Gray			Beluga		Bowhead		Gray	
Date in 2006	Survey No.	Total km	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals	Transect km	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals
9 Jul	1	419	8	320					378	8	320				
10 Jul	1	0	-	-	-	-	-	-	0	-	-	-	-	-	-
15 Jul	2	442							346						
18 Jul	3	363							292						
20 Jul	4	172			4	4			172			4	4		
23 Jul	5	458							371						
24 Jul	5	302	3	8			3	3	302	3	8			3	3
25 Jul	6	526					1	1	522					1	1
23 Aug	7	293					1	1	264					1	1
28 Aug	8	50							46						
29 Aug	8	237					2	2	94					2	2
30 Aug	8	0	-	-	-	-	-	-	0	-	-	-	-	-	-
31 Aug	9	588					1	1	534					1	1
1 Sep	9	0	-	-	-	-	-	-	0	-	-	-	-	-	-
3 Sep	10	398			1	1	1	1	300			1	1		
5 Sep	11	145					1	1	141						
6 Sep	11	252							249						
11 Sep	12	117							71						
12 Sep	12	279					1	1	279					1	1
14 Sep	13	592							570						
15 Sep	13	0	-	-	-	-	-	-	0	-	-	-	-	-	-
21 Sep	14	346							252						
23 Sep	14	0	-	-	-	-	-	-	0	-	-	-	-	-	-
24 Sep	15	182					2	2	154					2	2
25 Sep	15	377					1	1	283					1	1
30 Sep	16	171	1	1					125						
1 Oct	16	0	-	-	-	-	-	-	0	-	-	-	-	-	-
2 Oct	16	222					1	1	218					1	1
6 Oct	17	300	1	1					277	1	1				
11 Oct	18	251							230						
14 Oct	19	533	1	3			1	2	287					1	2
15 Oct	19	0	-	-	-	-	-	-	0	-	-	-	-	-	-
18 Oct	20	462			1	1	3	3	435			1	1	2	2
20 Oct	20	82							66						
21 Oct	21	334					1	1	288					1	1
23 Oct	21	65							65						
25 Oct	22	310			1	26			227						
26 Oct	22	310							128						
29 Oct	23	244							201						
30 Oct	23	39							39						
31 Oct	23	192							47						
7 Nov	24	471	2	3					338	1	1				
9 Nov	24	0	-	-	-	-	-	-	0	-	-	-	-	-	-
11 Nov	25	277			3	4			144			1	1		
12 Nov	25	82	1	2					50	1	2				
Total		10887	17	338	10	36	20	21	8781	14	332	7	7	17	18

TABLE D.2. Summary of **sawtooth** aerial survey effort and whale sightings in the Alaskan Chukchi Sea, 9 July to 12 November 2006. “All sightings” include useable, non-useable and incidental sightings.

		All Sightings							Useable Sighting Conditions						
			Beluga		Bowhead		Gray			Beluga		Bowhead		Gray	
Date in 2006	Survey No.	Total km	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals	Transect km	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals
9 Jul	1	0	-	-	-	-	-	-	0	-	-	-	-	-	-
10 Jul	1	649	5	13	1	1	5	7	552	4	10			4	6
15 Jul	2	687	3	8	1	1	2	2	611	3	8	1	1	1	1
18 Jul	3	517					5	8	236					1	2
20 Jul	4	578			1	1	1	1	476			1	1	1	1
23 Jul	5	393					1	1	330					1	1
24 Jul	5	457					1	3	457					1	3
25 Jul	6	823					3	4	760					3	4
23 Aug	7	551					1	3	448					1	3
28 Aug	8	292	1	1					254	1	1				
29 Aug	8	254							54						
30 Aug	8	315							198						
31 Aug	9	826							503						
1 Sep	9	193							95						
3 Sep	10	362							302						
5 Sep	11	648							509						
6 Sep	11	0	-	-	-	-	-	-	0	-	-	-	-	-	-
11 Sep	12	195	1	2					54						
12 Sep	12	462							351						
14 Sep	13	808							740						
15 Sep	13	210							121						
21 Sep	14	494	1	1	3	3			339	1	1	2	2		
23 Sep	14	457					1	2	326					1	2
24 Sep	15	1038	4	4			2	2	894	4	4			2	2
25 Sep	15	0	-	-	-	-	-	-	0	-	-	-	-	-	-
30 Sep	16	364							364						
1 Oct	16	105			1	1			38			1	1		
2 Oct	16	443							439						
6 Oct	17	643					1	1	596					1	1
11 Oct	18	288	1	1	1	1			217	1	1	1	1		
14 Oct	19	216					1	1	124						
15 Oct	19	564							474						
18 Oct	20	456	1	5					408	1	5				
20 Oct	20	382							250						
21 Oct	21	462					1	1	299					1	1
23 Oct	21	536			1	1			451			1	1		
25 Oct	22	550	5	5					349	5	5				
26 Oct	22	460							180						
29 Oct	23	377							248						
30 Oct	23	550	1	1					308						
31 Oct	23	89							65						
7 Nov	24	273			3	6			69			2	2		
9 Nov	24	328							198						
11 Nov	25	383							242						
12 Nov	25	559	1	5	11	17			458	1	5	10	16		
Total		19232	24	46	23	32	25	36	14385	21	40	19	25	18	27

APPENDIX E: EASTERN CHUKCHI SEA SEAL SIGHTINGS, 2006

Appendix E consists of

1. Figures E.1 – E.4, distribution maps of seal species (ringed seal, bearded seal, spotted seal, and unidentified seals) for 2006 in the eastern Chukchi Sea divided into three seasons: early (before 29 Aug.), mid (29 Aug. to 8 Oct.) and late (after 8 Oct.), and
2. Table E.1 –E.2, 2006 seal sighting rates in the eastern Chukchi Sea for the coastline and sawtooth surveys. Sighting rates were divided into three seasons: early (before 29 Aug.), mid (29 Aug. to 8 Oct.) and late (after 8 Oct.).

During the 2006 aerial surveys of the eastern Chukchi Sea, seal sightings were recorded as incidental sightings while focusing on the primary species of issue cetaceans. The study design was developed to collect data on cetaceans, and was therefore not qualified for the collection of seals. Seal studies are generally flown at lower altitudes to collect consistent and reliable data. Therefore the data shown in this appendix should be interpreted with caution.

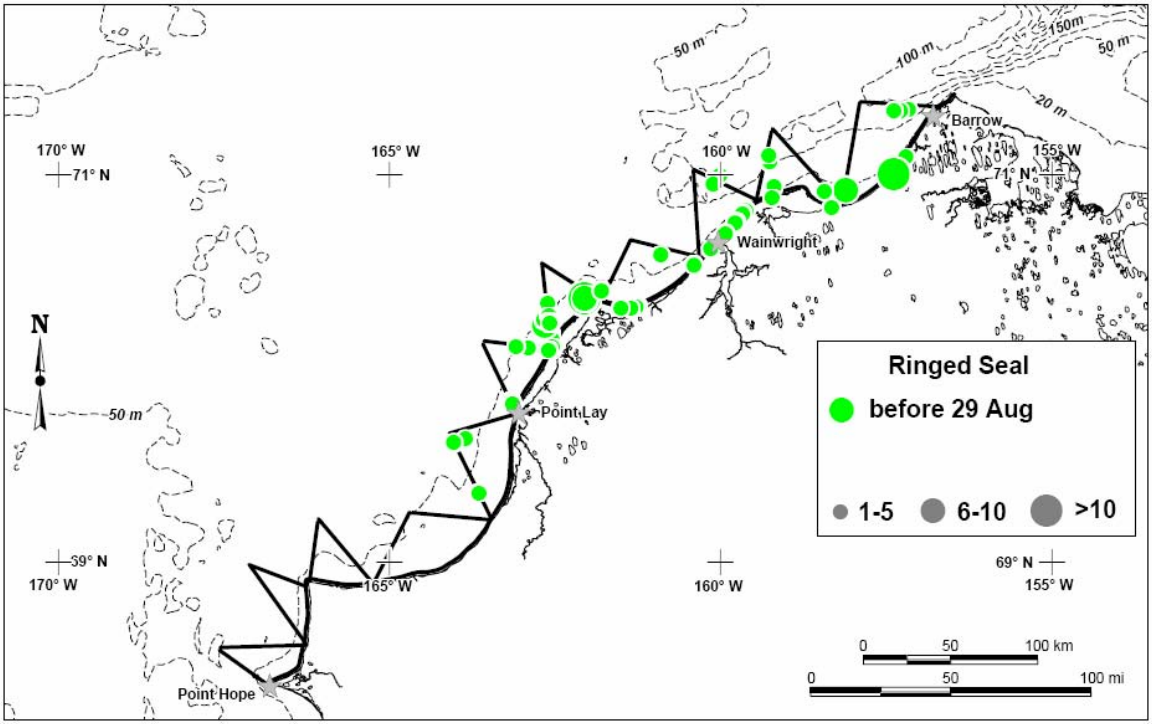
Aerial surveys for marine mammals in the eastern Chukchi Sea were conducted twice per week from 9 Jul. to 12 Nov. 2006 using a standard survey route, weather permitting. No surveys were flown from 26 Jul. to 22 Aug. due to logistical restraints related to aircraft availability. A total of 25 surveys were flown during the study period. Refer to Chapter 5 for a description of the methods.

Distribution.—Ringed seals were uniformly distributed throughout the study area (Figure E.1A,B), although in the early season (before 29 Aug.) they were concentrated in the northern two-thirds of the study area (Figure E.1A). Ringed seals were most often located in areas with ice floes. Bearded seals were uniformly distributed throughout the study area (Figure E.2A,B), although in the early season (before 29 Aug.) like the ringed seals they were concentrated in the northern two-thirds of the study area (Figure E.2A). Spotted seals were uniformly distributed in the study area (Figure E.3), and like ringed seals they were most often located in area with ice floes. Unidentified seal sightings during the aerial surveys in summer and autumn 2006 are shown in Figure E.4A,B,C. Unidentified seals made up 53% of the seal sightings in the study area, although most of the unidentified seals were likely ringed or spotted seals.

Coastline Survey Sighting Rates.—We examined the seasonal sighting rates for each seal species, using useable data, during 2006 (Table E.1). Ringed seals had their lowest sightings rates during the late season (0.00 ringed seals per 100 km of survey) and their highest sighting rate during the early season (1.08 ringed seals per 100 km of survey) (Table E.1). Ringed seals were generally seen in small groups, with the largest group seen on 25 Jul. (20 individuals). Spotted seals had their lowest sightings rates during the late season (0.00 spotted seals per 100 km of survey) and their highest sighting rate during the early season (2.62 spotted seals per 100 km of survey) (Table E.1). Spotted seals were generally seen in small groups, with the largest group seen on 20 Jul. (25 individuals). Bearded seals had their lowest sightings rates during the late season (0.00 bearded seals per 100 km of survey) and their highest sighting rate during the early season (0.80 bearded seals per 100 km of survey) (Table E.1). Bearded seals were generally seen as single animals, but pairs were seen sporadically. Unidentified seals had their lowest sightings rates during the early season (0.71 seals per 100 km of survey) and their highest sighting rate during the late season (1.59 seals per 100 km of survey) (Table E.1). Unidentified seals were generally seen as single animals, but larger groups (10 and 15 individuals) were seen on two occasions.

Sawtooth Survey Sighting Rates.—We examined the seasonal sighting rates for each seal species, using useable data, during 2006 (Table E.2). Ringed seals had their lowest sightings rates during the late season (0.10 ringed seals per 100 km of survey) and their highest sighting rate during the mid season (3.43 ringed seals per 100 km of survey) (Table E.2). Ringed seals were generally seen in small groups, with the largest group seen on 24 Jul. (7 individuals). Spotted seals had their lowest sightings rates during the late season (0.00 spotted seals per 100 km of survey) and their highest sighting rate during the early season (2.36 spotted seals per 100 km of survey) (Table E.2). Spotted seals were generally seen in small groups, with the largest group seen on 20 Jul. (45 individuals). Bearded seals had their lowest sightings rates during the late season (0.25 bearded seals per 100 km of survey) and their highest sighting rate during the mid season (1.40 bearded seals per 100 km of survey) (Table E.2). Bearded seals were generally seen as single animals, but pairs were seen sporadically. Unidentified seals had their lowest sightings rates during the early season (2.18 seals per 100 km of survey) and their highest sighting rate during the late season (4.58 seals per 100 km of survey) (Table E.2). Unidentified seals were seen as single animals and small groups, but a large group was seen on 25 Jul. (80 individuals).

E.1A



E.1B

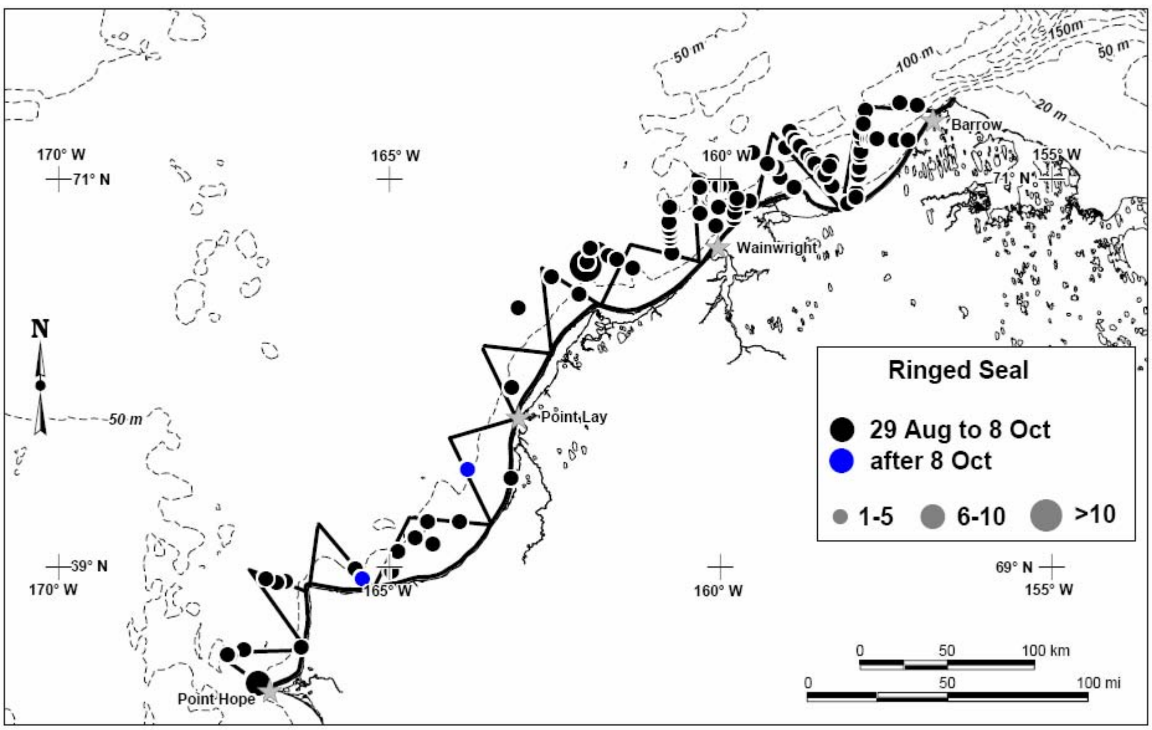
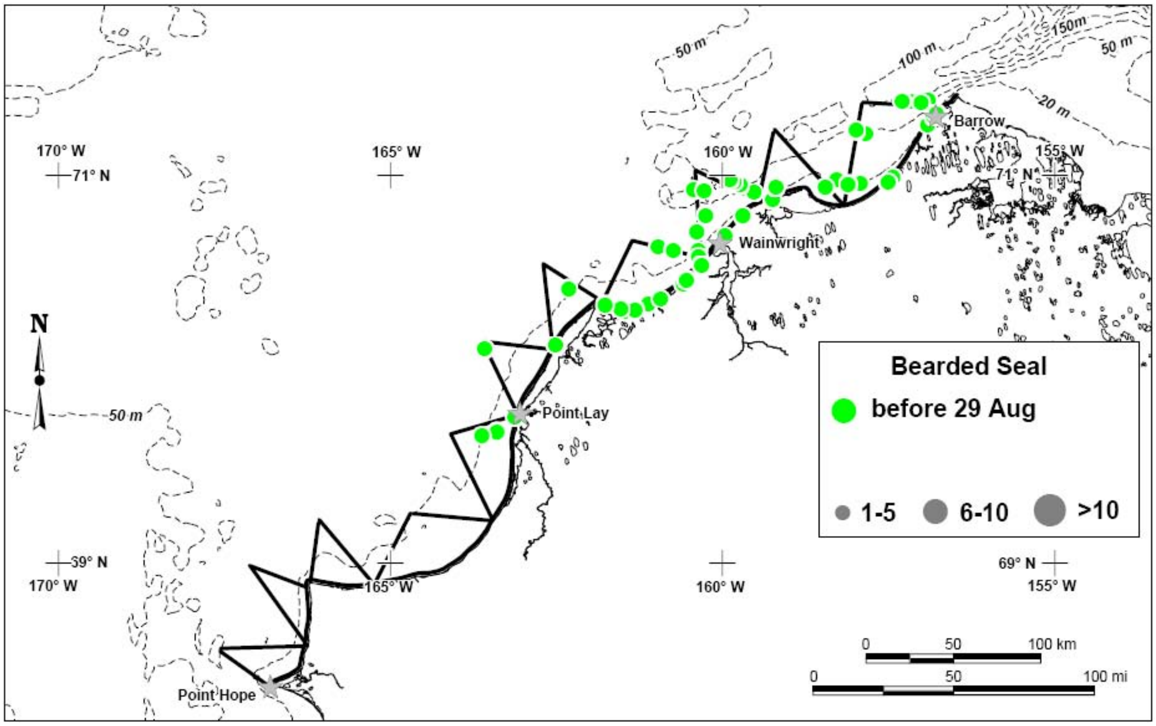


FIGURE E.1A and B. Locations of ringed seal sightings during aerial surveys in the eastern Chukchi Sea during the early season (before 29 Aug.; E.1A) and the mid and late season (29 Aug. to 8 Oct. and after 8 Oct.; E.1B). All ringed seal sightings (useable, non-useable and incidental) are shown on the map as a solid symbol.

E.2A



E.2B

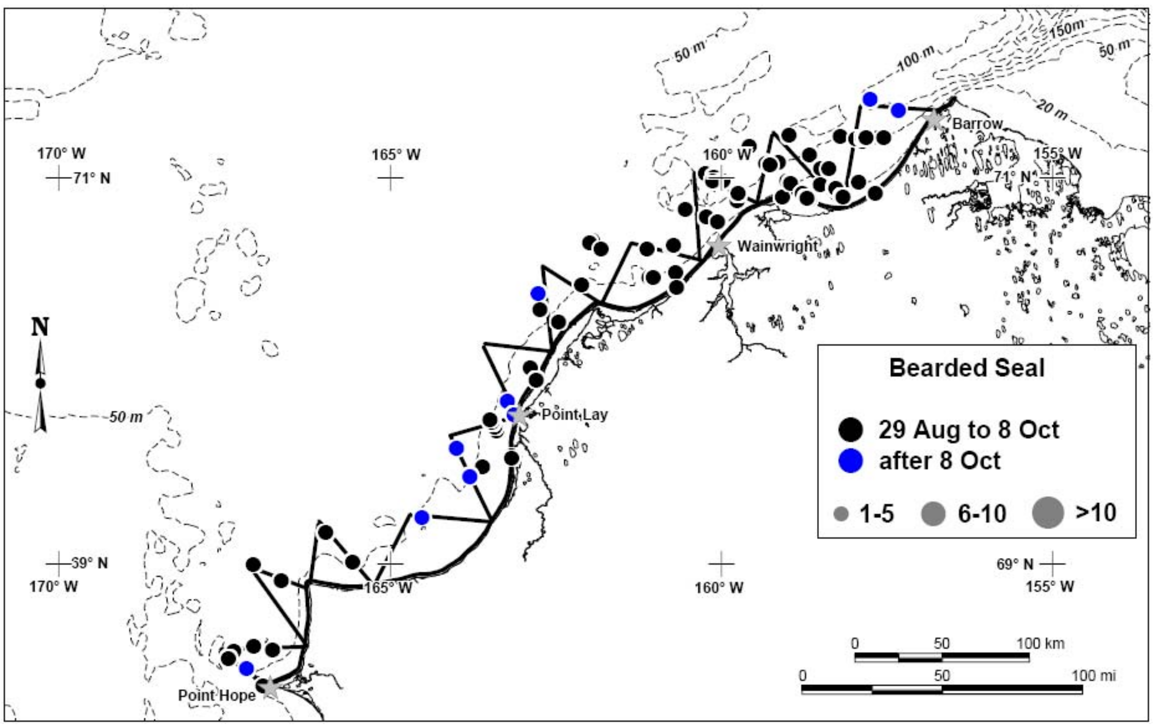


FIGURE E.2A and B. Locations of bearded seal sightings during aerial surveys in the eastern Chukchi Sea during the early season (before 29 Aug.; E.2A) and the mid and late season (29 Aug. to 8 Oct. and after 8 Oct.; E.2B). All bearded seal sightings (useable, non-useable and incidental) are shown on the map as a solid symbol.

E.3

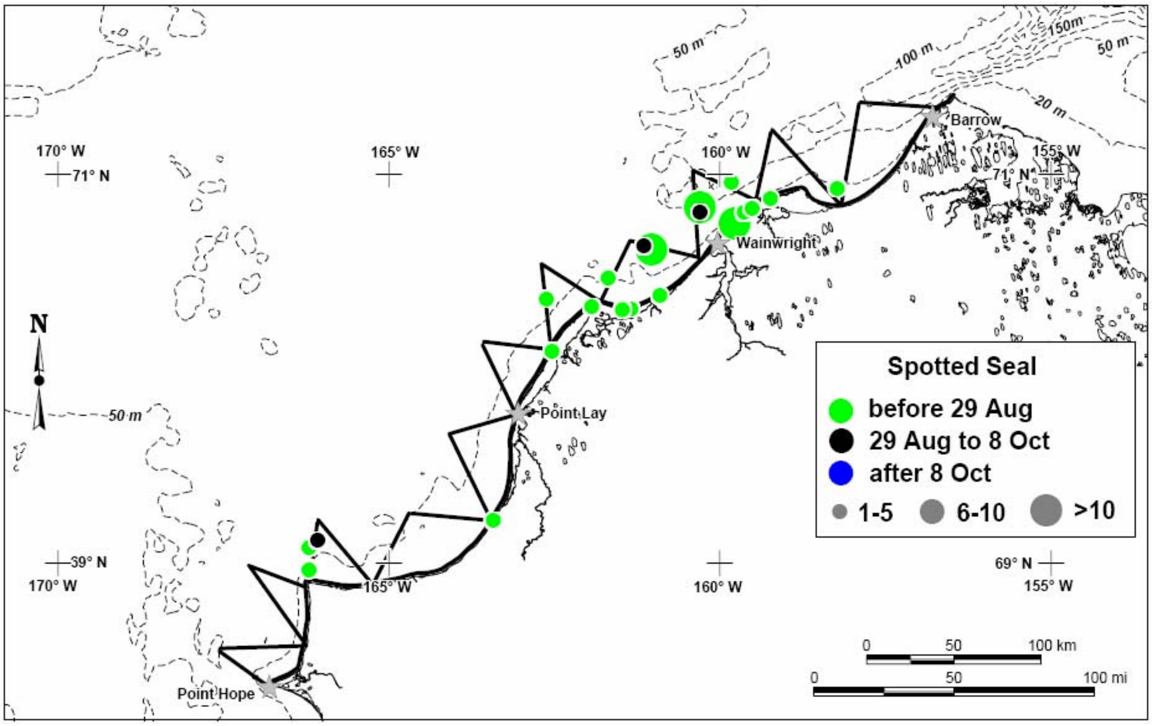
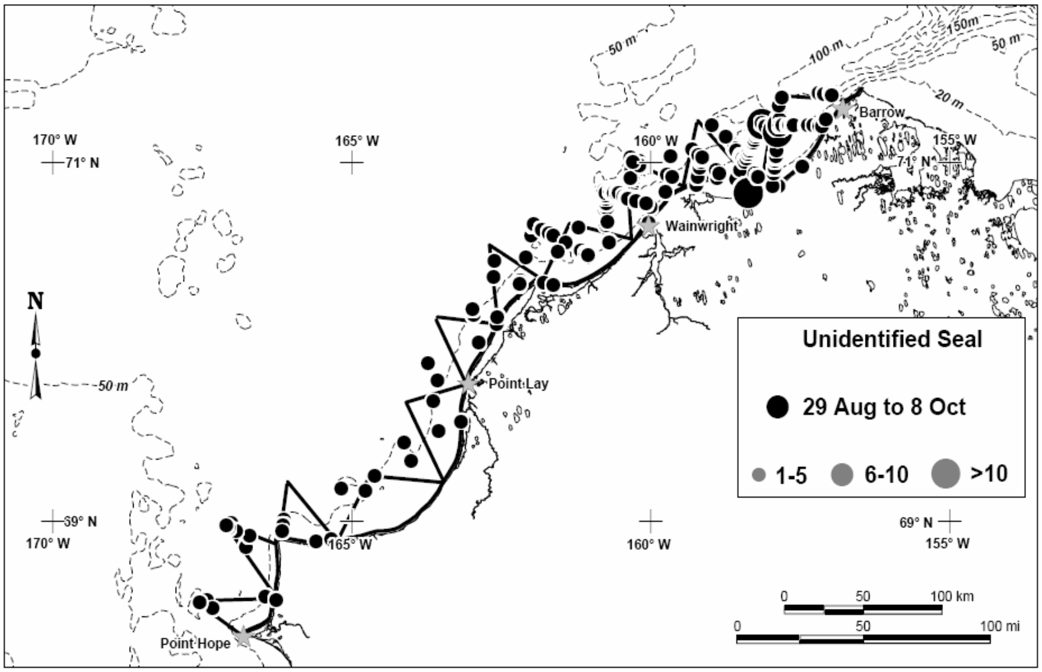


FIGURE E.3. Locations of spotted seal sightings during aerial surveys in the eastern Chukchi Sea during the early, mid and late seasons (before 29 Aug., 29 Aug. to 8 Oct. and after 8 Oct). All spotted seal sightings (useable, non-useable and incidental) are shown on the map as a solid symbol.

E.4A



E.4B

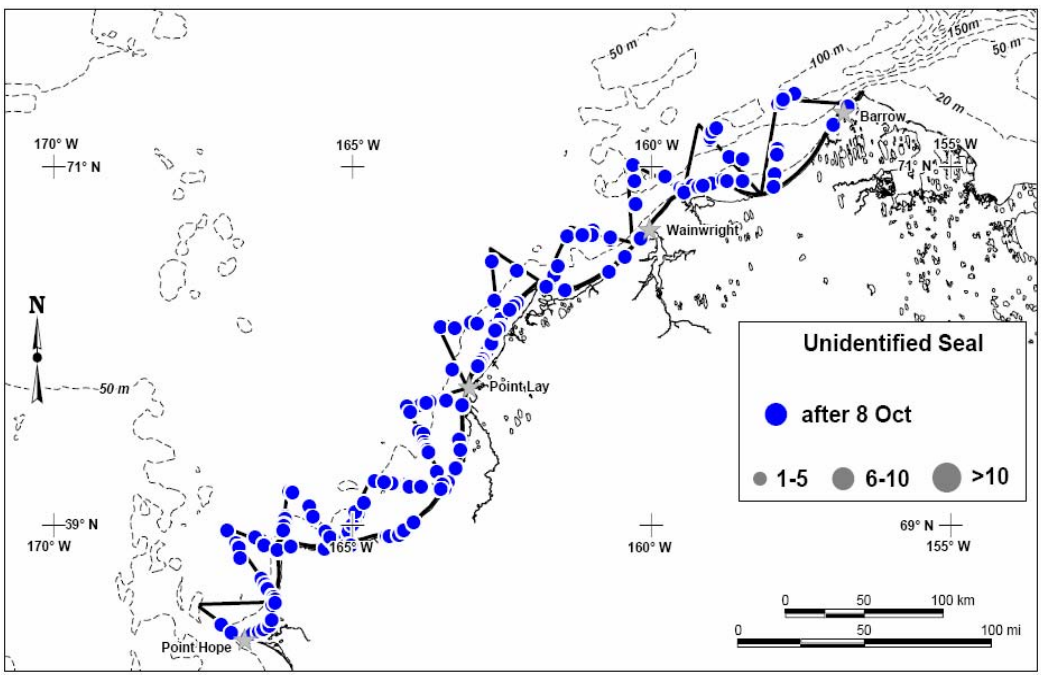


FIGURE E.4A,B and C. Locations of unidentified seal sightings during aerial surveys in the eastern Chukchi Sea during the early season (before 29 Aug.; E.4A), the mid season (29 Aug. to 8 Oct.; E.4B) and late season (after 8 Oct.; E.4C). All unidentified seal sightings (useable, non-useable and incidental) are shown on the map as a solid symbol.

TABLE E.1. Seal sightings and sighting rates during coastline aerial surveys, 2006, divided into early, mid, and late seasons (non-useable data excluded).

			Ringed Seal				Spotted Seal				Bearded Seal				Unknown Seal			
Date in 2006	Survey No.	Transect km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km
Early Season																		
9-10 Jul	1	350	2	2	0.57	0.57	0	0	0.00	0.00	3	5	0.86	1.43	0	0	0.00	0.00
15-Jul	2	340	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
18-Jul	3	194	0	0	0.00	0.00	1	1	0.52	0.52	3	3	1.55	1.55	1	1	0.52	0.52
20-Jul	4	172	0	0	0.00	0.00	3	28	1.74	16.28	1	2	0.58	1.16	0	0	0.00	0.00
23-24 Jul	5	551	7	15	1.27	2.72	1	5	0.18	0.91	7	7	1.27	1.27	0	0	0.00	0.00
25-Jul	6	470	1	20	0.21	4.25	3	3	0.64	0.64	1	1	0.21	0.21	10	21	2.13	4.47
No Surveys	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Aug	7	260	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
Mean					**0.29**	**1.08**			**0.44**	**2.62**			**0.64**	**0.80**			**0.38**	**0.71**
Mid Season																		
28-30 Aug	8	59	4	6	6.81	10.22	1	1	1.70	1.70	0	0	0.00	0.00	0	0	0.00	0.00
31 Aug-1 Sept	9	195	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
3-Sep	10	169	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
5-6 Sept	11	342	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	4	20	1.17	5.85
11-12 Sept	12	251	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
14-15 Sept	13	559	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.18	0.18	3	3	0.54	0.54
21-23 Sept	14	120	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.83	0.83
24-25 Sept	15	118	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.85	0.85	1	1	0.85	0.85
30 Sept-2 Oct	16	287	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.35	0.35
6-Oct	17	217	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
Mean					**0.68**	**1.02**			**0.17**	**0.17**			**0.10**	**0.10**			**0.37**	**0.84**
Late Season																		
11-Oct	18	42	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
14-15 Oct	19	104	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.96	0.96
18-20 Oct	20	374	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	33	37	8.83	9.90
21-23 Oct	21	232	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	2	2	0.86	0.86
25-26 Oct	22	205	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	2	2	0.97	0.97
29-31 Oct	23	140	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
7-9 Nov	24	229	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
11-12 Nov	25	99	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
Mean					**0.00**	**0.00**			**0.00**	**0.00**			**0.00**	**0.00**			**1.45**	**1.59**

TABLE E.2. Seal sightings and sighting rates during sawtooth aerial surveys, 2006, divided into early, mid, and late seasons (non-useable data excluded).

			Ringed Seal				Spotted Seal				Bearded Seal				Unknown Seal			
Date in 2006	Survey No.	Transect km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km	Sight-ings	Indivi-duals	Sight. /100 km	Indiv. /100 km
Early Season																		
9-10 Jul	1	538	3	3	0.56	0.56	2	2	0.37	0.37	11	12	2.04	2.23	2	2	0.37	0.37
15-Jul	2	492	0	0	0.00	0.00	2	24	0.41	4.88	4	5	0.81	1.02	1	1	0.20	0.20
18-Jul	3	138	0	0	0.00	0.00	0	0	0.00	0.00	3	3	2.17	2.17	1	3	0.72	2.17
20-Jul	4	419	0	0	0.00	0.00	1	45	0.24	10.73	0	0	0.00	0.00	0	0	0.00	0.00
23-24 Jul	5	644	8	24	1.24	3.72	1	1	0.16	0.16	3	3	0.47	0.47	2	2	0.31	0.31
25-Jul	6	745	7	7	0.94	0.94	3	3	0.40	0.40	7	8	0.94	1.07	9	91	1.21	12.22
No Surveys	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Aug	7	391	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
Mean					**0.39**	**0.75**			**0.22**	**2.36**			**0.92**	**0.99**			**0.40**	**2.18**
Mid Season																		
28-30 Aug	8	438	26	40	5.93	9.13	3	8	0.68	1.83	2	2	0.46	0.46	0	0	0.00	0.00
31 Aug-1 Sept	9	227	1	1	0.44	0.44	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
3-Sep	10	217	0	0	0.00	0.00	0	0	0.00	0.00	2	3	0.92	1.38	2	2	0.92	0.92
5-6 Sept	11	423	13	18	3.07	4.25	0	0	0.00	0.00	5	5	1.18	1.18	19	25	4.49	5.91
11-12 Sept	12	200	9	15	4.49	7.49	0	0	0.00	0.00	4	4	2.00	2.00	7	8	3.49	3.99
14-15 Sept	13	772	12	19	1.55	2.46	0	0	0.00	0.00	4	5	0.52	0.65	30	63	3.88	8.16
21-23 Sept	14	272	20	21	7.36	7.73	0	0	0.00	0.00	5	6	1.84	2.21	16	19	5.89	6.99
24-25 Sept	15	505	7	7	1.39	1.39	0	0	0.00	0.00	23	26	4.55	5.15	49	55	9.70	10.88
30 Sept-2 Oct	16	806	10	11	1.24	1.36	2	2	0.25	0.25	8	8	0.99	0.99	16	19	1.99	2.36
6-Oct	17	329	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	2	2	0.61	0.61
Mean					**2.55**	**3.43**			**0.09**	**0.21**			**1.25**	**1.40**			**3.10**	**3.98**
Late Season																		
11-Oct	18	14	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
14-15 Oct	19	200	1	1	0.50	0.50	0	0	0.00	0.00	0	0	0.00	0.00	8	10	3.99	4.99
18-20 Oct	20	376	1	1	0.27	0.27	0	0	0.00	0.00	3	3	0.80	0.80	76	99	20.24	26.36
21-23 Oct	21	267	0	0	0.00	0.00	0	0	0.00	0.00	2	2	0.75	0.75	6	7	2.25	2.62
25-26 Oct	22	180	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	4	4	2.23	2.23
29-31 Oct	23	87	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
7-9 Nov	24	227	0	0	0.00	0.00	0	0	0.00	0.00	1	1	0.44	0.44	1	1	0.44	0.44
11-12 Nov	25	445	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00
Mean					**0.10**	**0.10**			**0.00**	**0.00**			**0.25**	**0.25**			**3.64**	**4.58**

APPENDIX F: CENTRAL ALASKAN BEAUFORT SEA WHALE SIGHTINGS, 2006

Appendix F consists of

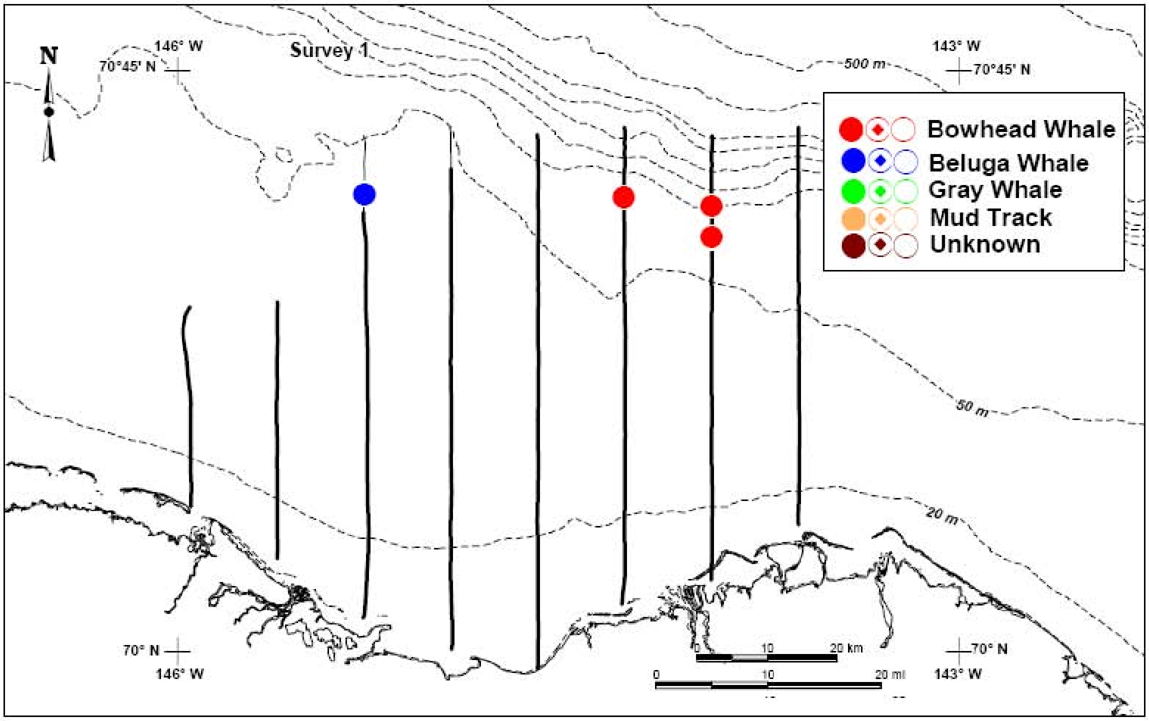
1. Figures F.1 – F.5, daily maps of aerial survey coverage and whale sightings for 2006 in the central Alaskan Beaufort Sea, and
2. Table F.1, summarizing whale sightings in the central Alaskan Beaufort Sea in 2006.

Figures F.1 – F.5 show for the following data for each day of aerial surveys during August-September 2006,

1. ***Aerial survey coverage (survey lines)***. Sightability along survey lines is depicted as shown in the legend below.

2. ***Whale sightings***. The symbols used on the maps are color coded to identify the species as explained in the legends. Mud tracks are indications that whales (most likely gray whales) are in the area. They are plumes of mud brought up by feeding whales, indicating a whale present under the water not visible, or a whale was present in area not long before we flew over. Each sighting symbol on these maps represents a sighting of one or more individual whales. Sightings along formal transects (regardless of distance from trackline) are shown as filled (useable sightings) or 'dotted' (non-useable sightings) symbols. Incidental sightings, include sightings during "Connect" legs between transects and during non-systematic "Search" legs, are shown as open symbols, and are not considered during analyses.

F.1A



F.1B

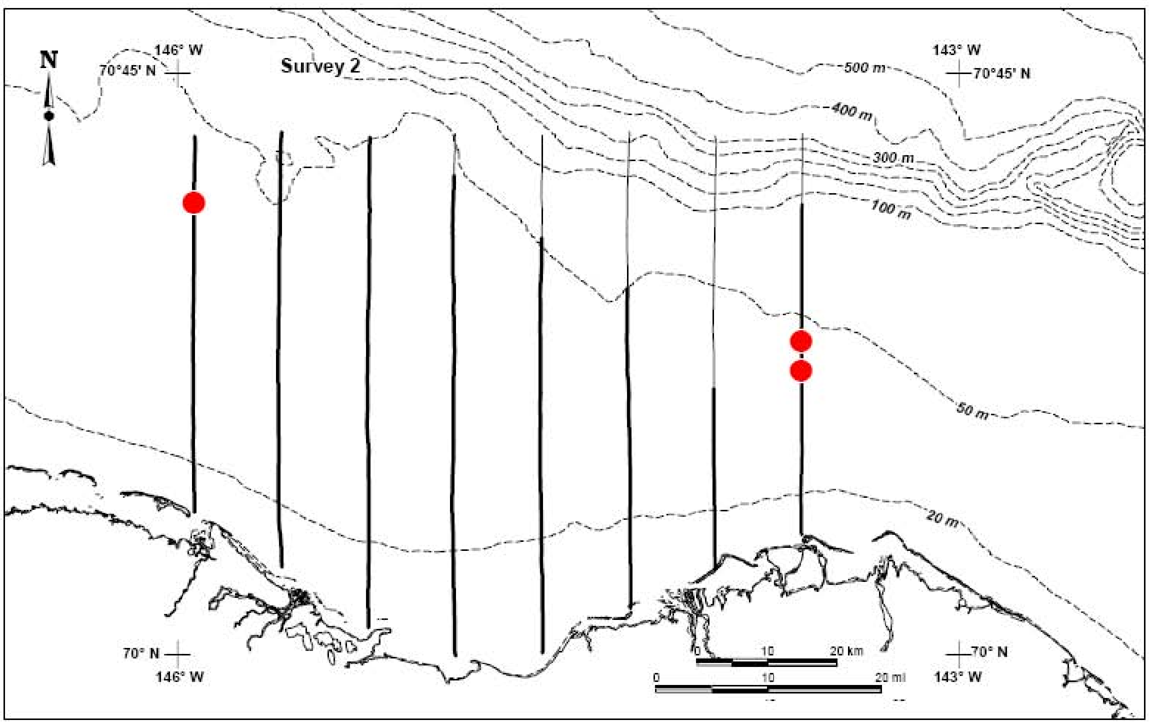
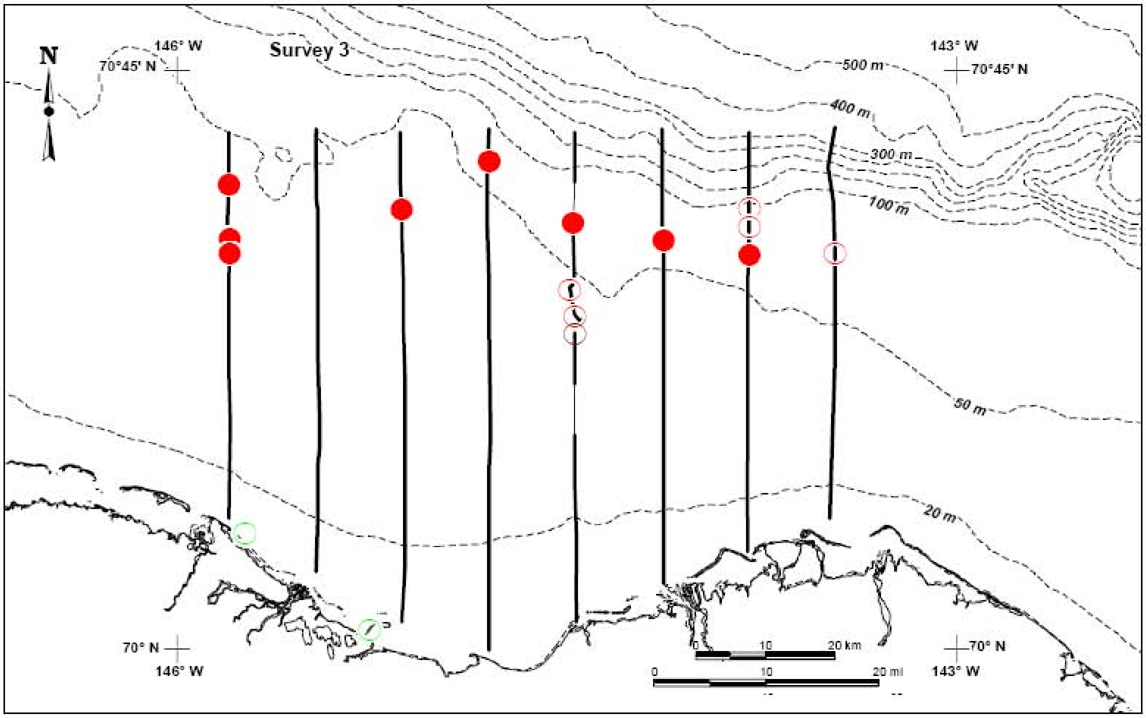


FIGURE F.1A and B. Locations of whale sightings in the central Alaskan Beaufort Sea during aerial surveys 1 (26 August; F.1A) and 2 (3 September; F.1B). Solid symbols denote "useable" sightings, open symbols containing a dot denote "non-useable" sightings, and open symbols denote incidental sightings during search and connect legs.

F.2A



F.2B

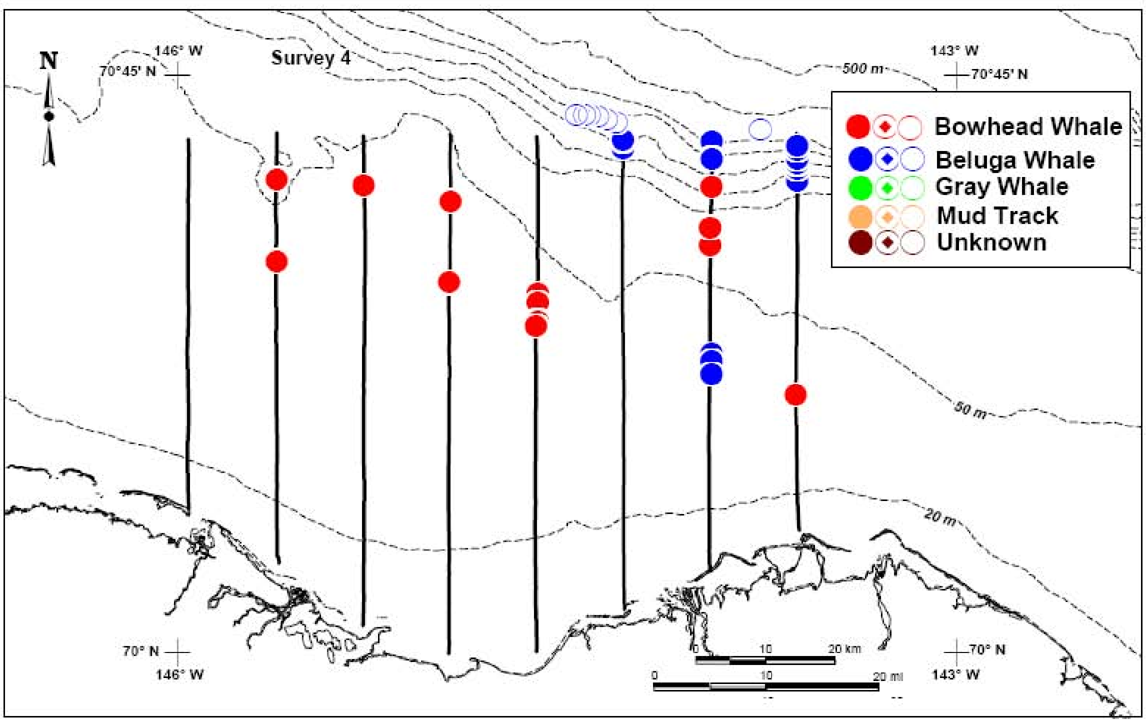
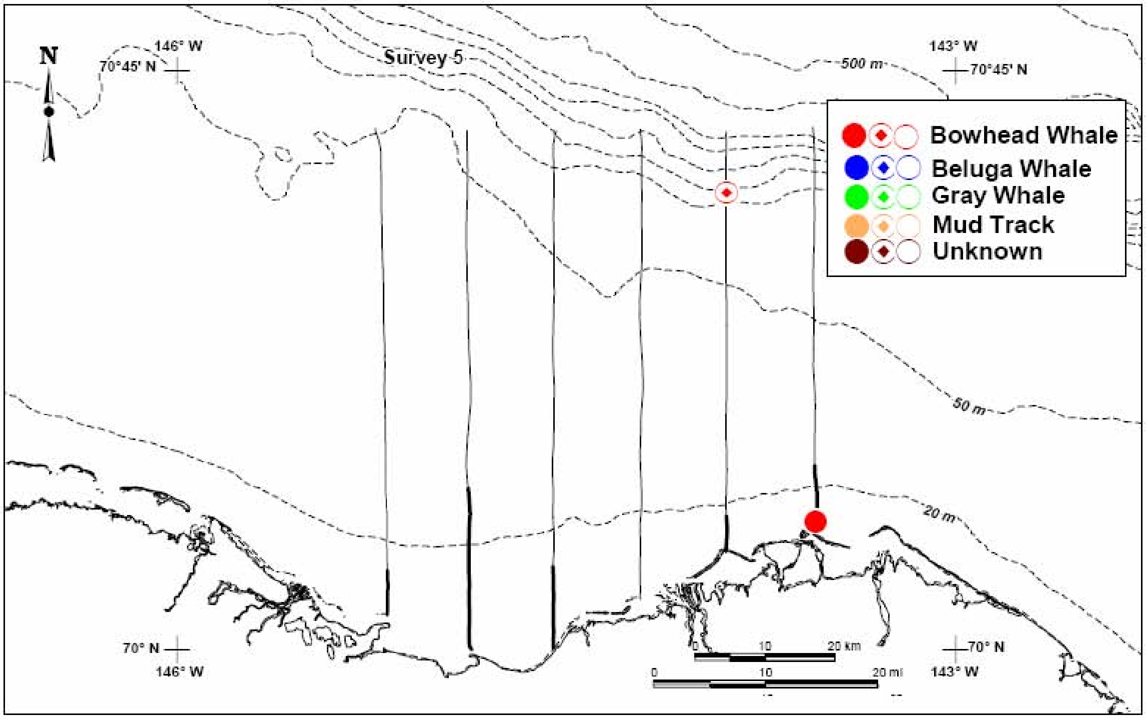


FIGURE F.2A and B. Locations of whale sightings in the central Alaskan Beaufort Sea during aerial surveys 3 (4 September; F.2A) and 4 (6 September; F.2B). See Figure F.1A,B for notes on symbols.

F.3A



F.3B

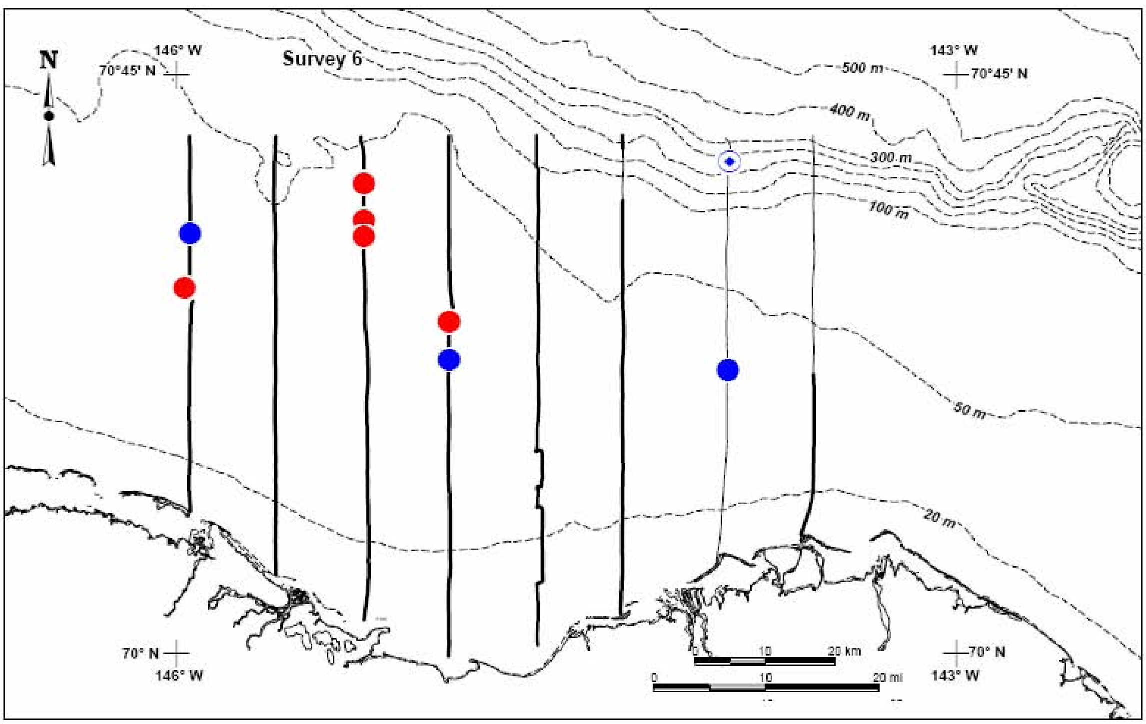
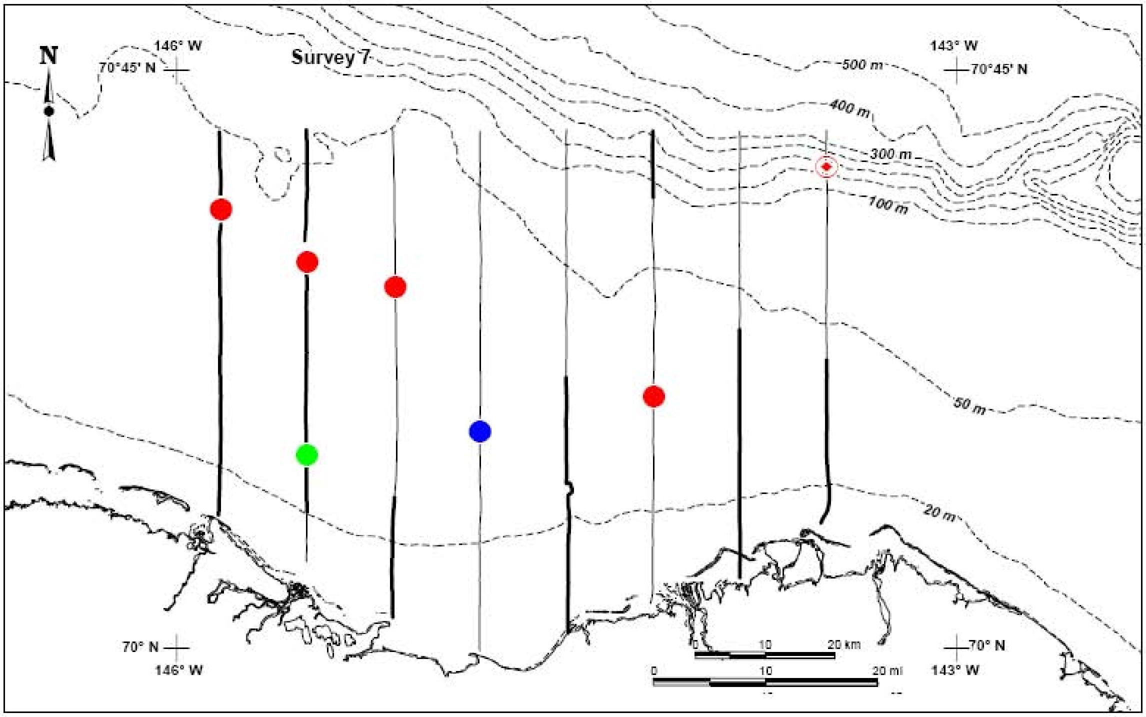


FIGURE F.3A and B. Locations of whale sightings in the central Alaskan Beaufort Sea during aerial surveys 5 (12 September; F.3A) and 6 (13 September; F.3B). See Figure F.1A,B for notes on symbols.

F.4A



F.4B

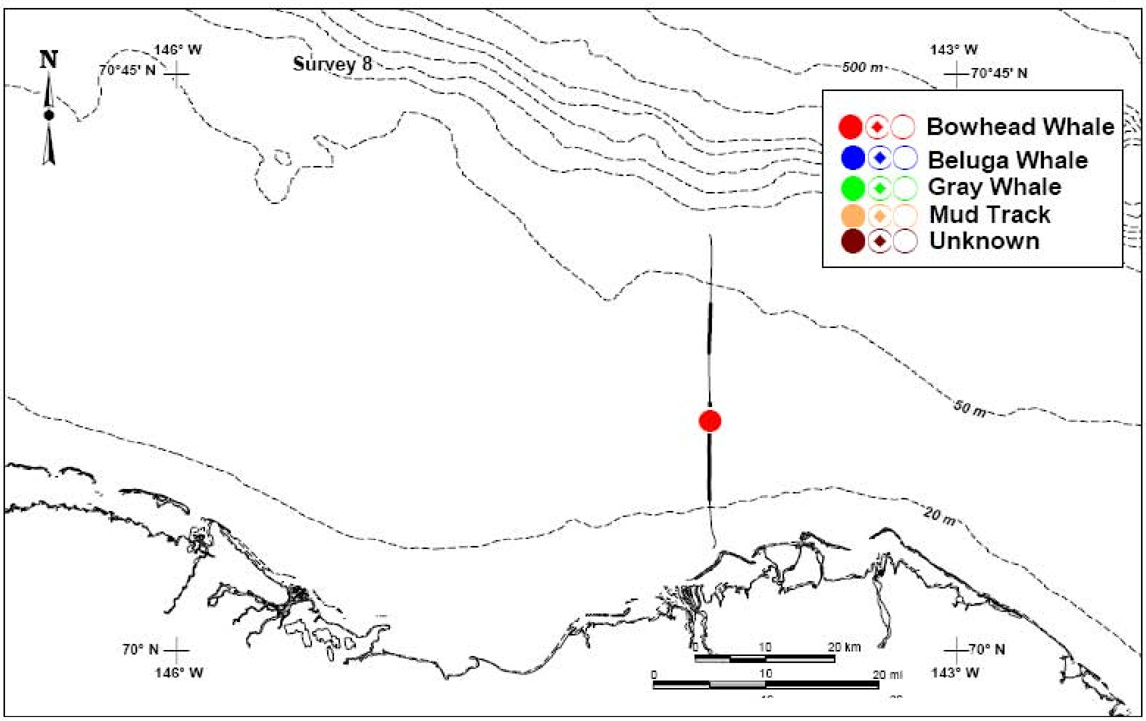


FIGURE F.4A and B. Locations of whale sightings in the central Alaskan Beaufort Sea during aerial surveys 7 (14 September; F.4A) and 8 (23 September; F.4B). See Figure F.1A,B for notes on symbols.

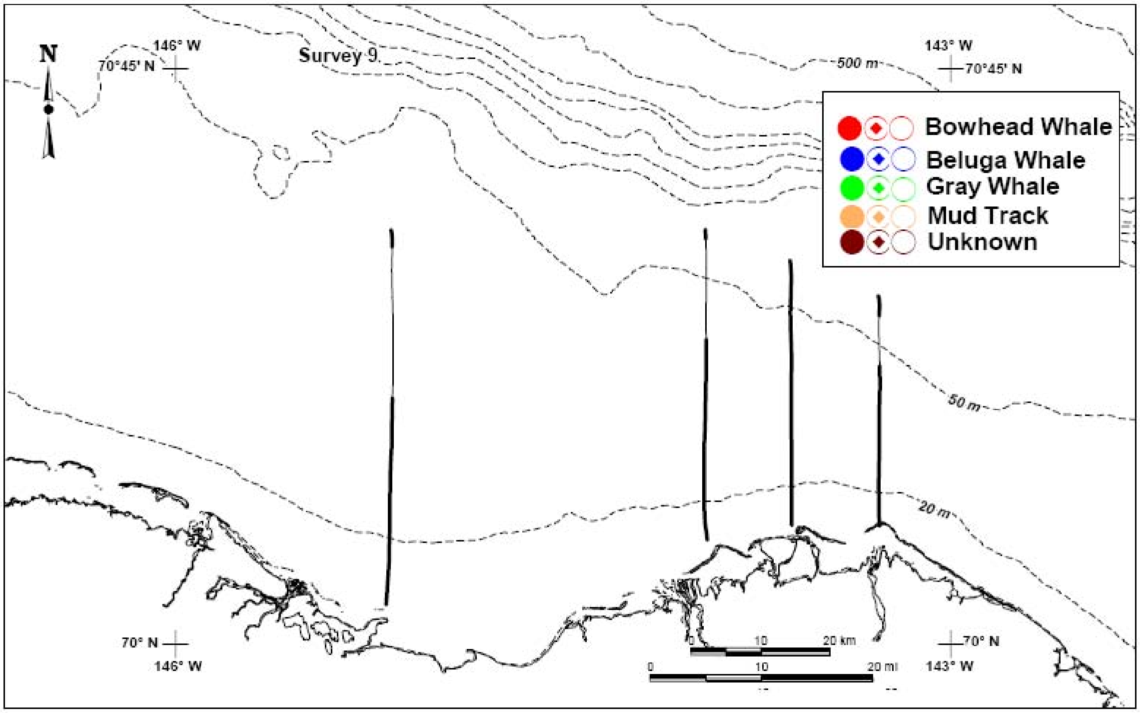


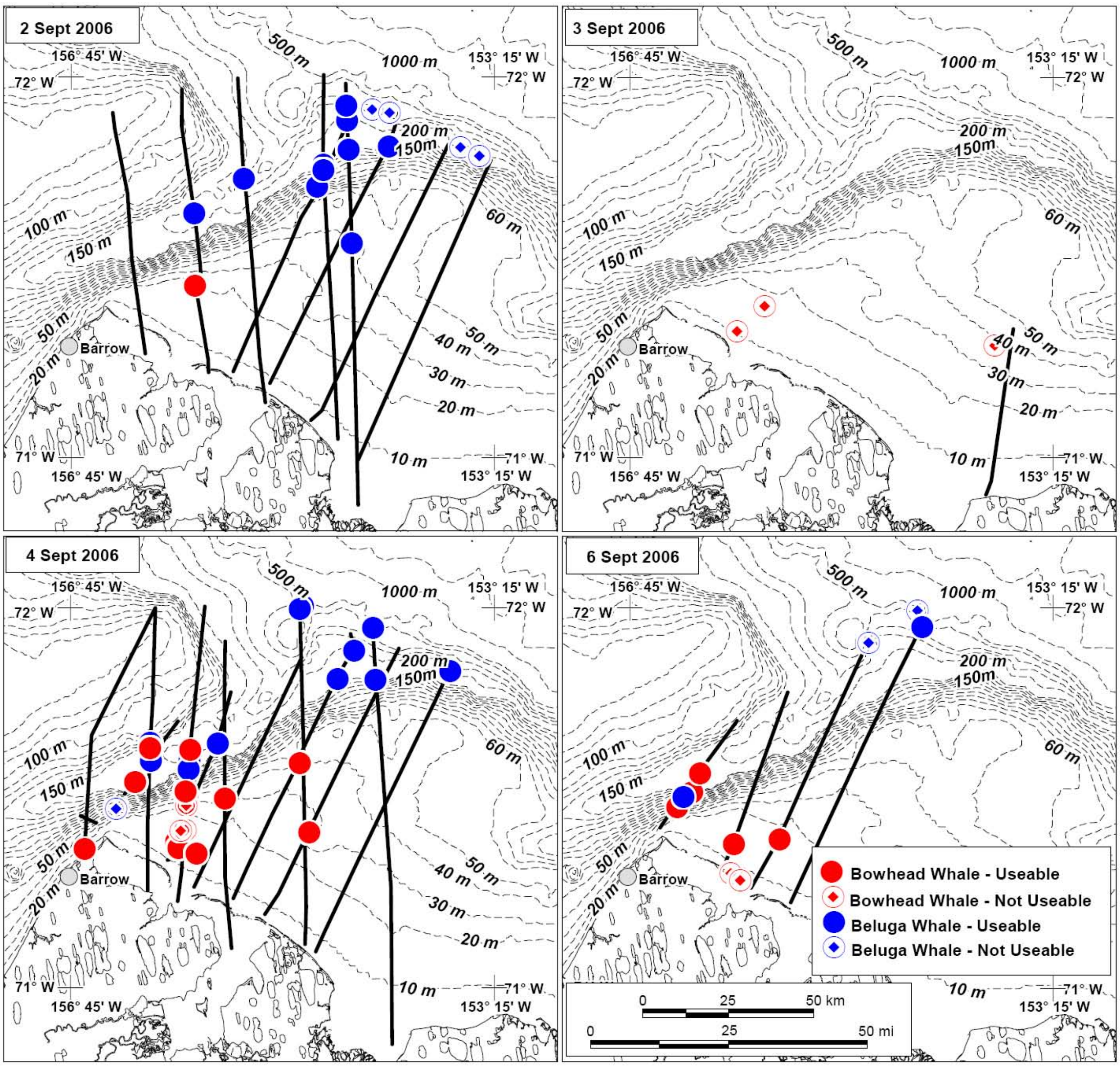
FIGURE F.5. Locations of whale sightings in the central Alaskan Beaufort Sea during aerial survey 9 (24 September). See Figure F.1A,B for notes on symbols.

TABLE F.1. Summary of aerial survey effort and whale sightings in the central Alaskan Beaufort Sea, 26 August to 24 September 2006. "All sightings" include useable, non-useable, and incidental sightings.

		All Sightings							Useable Sighting Conditions						
			Bowhead		Beluga		Gray			Bowhead		Beluga		Gray	
Date in 2006	Survey No.	Total km	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals	Transect km	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals	Sight-ings	Indivi-duals
26 Aug	1	477	3	3	1	1	0	0	468	3	3	1	1	0	0
3 Sep	2	525	3	3	0	0	0	0	471	3	3	0	0	0	0
4 Sep	3	520	13	20	0	0	2	2	513	8	12	0	0	0	0
6 Sep	4	525	14	22	23	56	0	0	525	14	22	16	46	0	0
12 Sep	5	407	2	2	0	0	0	0	95	1	1	0	0	0	0
13 Sep	6	525	5	8	4	11	0	0	464	5	8	3	10	0	0
14 Sep	7	524	5	7	1	2	1	1	346	4	6	1	2	1	1
23 Sep	8	45	1	1	0	0	0	0	29	1	1	0	0	0	0
24 Sep	9	171	0	0	0	0	0	0	139	0	0	0	0	0	0
Total		3720	46	66	29	70	3	3	3049	39	56	21	59	1	1

APPENDIX G: STUDY OF NORTHERN ALASKA COASTAL SYSTEM

Aerial surveys for marine mammals were conducted east of Barrow as part of the Study of Northern Alaska Coastal System (SNACS) “Environmental Variability, Bowhead Whale Distributions and Inupiat Subsistence Whaling” study funded by the National Science Foundation and lead by Dr. Carin Ashjian of Woods Hole Oceanographic Institute. The study team included researchers from several universities, the National Marine Mammal Laboratory (NMML) and the North Slope Borough. Aerial surveys were conducted in collaboration with C. Monnett (MMS). The following maps were produced from raw sightings and effort data provided by the SNACS study team for inclusion in the Comprehensive Report. They do not represent analyses, opinions or findings of the SNACS survey team and should *not be cited* without permission of the primary researchers.



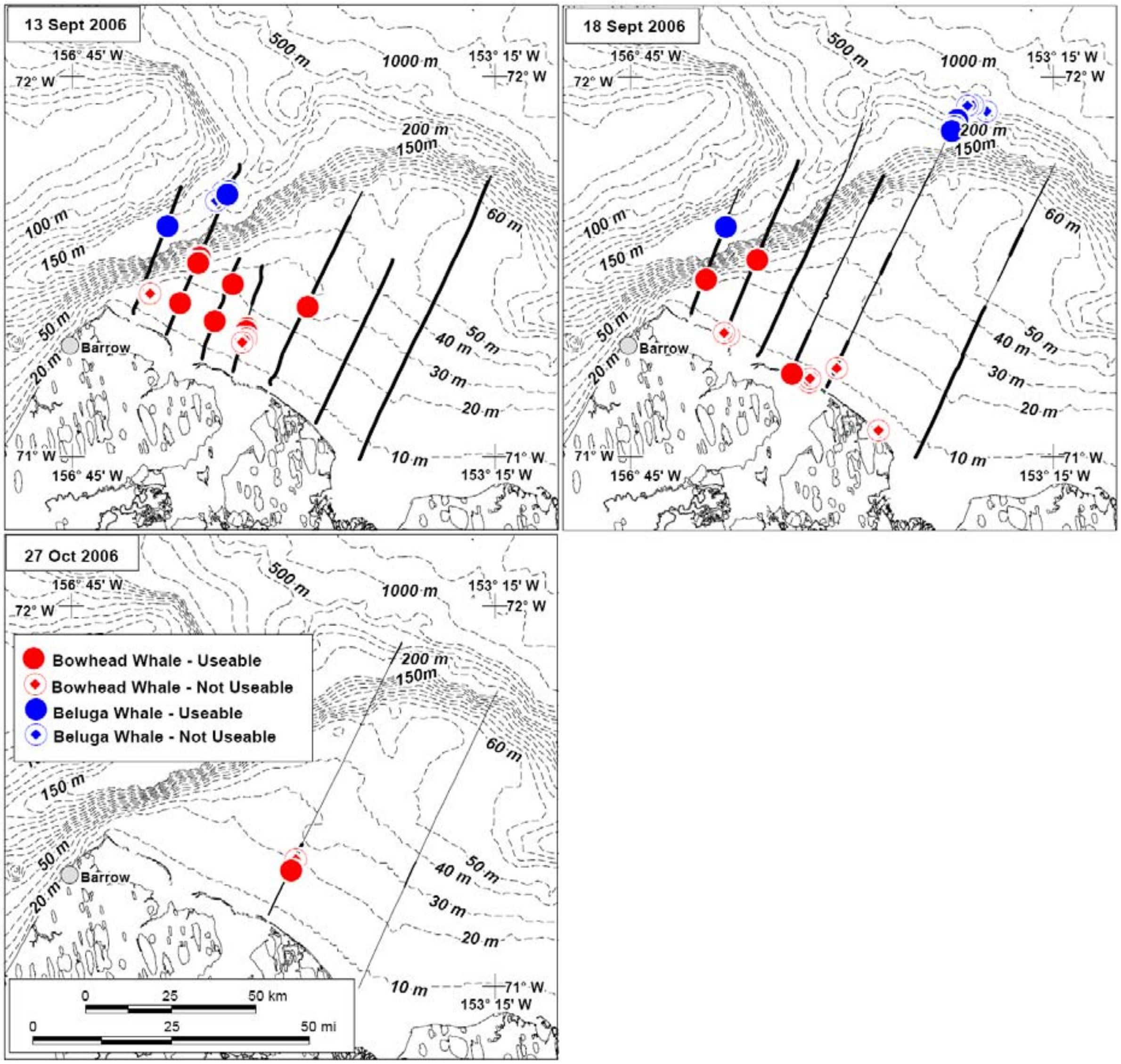


FIGURE G.1. Survey tracks flown east of Point Barrow and whale sightings recorded during September and October 2006. Dark lines represent individual transects and thick portions of the transect lines indicate the periods during which useable data were collected (i.e., the sightability conditions were good).