# JOINT MONITORING PROGRAM IN THE CHUKCHI AND BEAUFORT SEAS, 2012

**Prepared By**
**LGL Alaska Research Associates, Inc.**
**JASCO Applied Sciences, Inc.**
**Greeneridge Sciences, Inc.**

**For**

**National Marine Fisheries Service**
**United States Fish and Wildlife Service**

**Final Report, September 2014**

**Shell Exploration & Production**

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03 September 2014

**Re: Joint Monitoring Program in the Chukchi and Beaufort Seas, 2012 Final Report**

Dear Mr. Guan,

Attached please find the final report entitled, Joint Monitoring Program in the Chukchi and Beaufort Seas, 2012. This report is submitted in compliance with the Incidental Harassment Authorizations issued by National Marine Fisheries Service to Shell Gulf of Mexico, Inc., Shell Offshore, Inc., and ION Geophysical.

Data incorporated within this report include results from monitoring efforts and joint industry studies programs conducted by industry operators in the Chukchi and Beaufort seas during 2012. Results from similar monitoring programs that began in 2006 are incorporated where relevant. Efforts have been made herein to document the full range of oil and gas industry operations and the comprehensive results from monitoring of these activities. The primary focus of these evaluations is related to potential impacts on marine mammal distribution and behavior.

Please address any comments or questions to a.macrander@shell.com, (907) 646-7123.

Thank you,

A. Michael Macrander
Lead Scientist

# JOINT MONITORING PROGRAM IN THE CHUKCHI AND BEAUFORT SEAS, 2012

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GREENERIDGE SCIENCES

**For**

**Shell Gulf of Mexico, Inc.**
**Shell Offshore, Inc.**
**ION Geophysical**
**and other Industry Contributors**

and

**National Marine Fisheries Service**
**United States Fish and Wildlife Service**

**LGL Final Report P1272-2**

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ~ | approximately |
| ADCP | acoustic Doppler current profiler |
| ADFG | Alaska Department of Fish and Game |
| AEWC | Alaska Eskimo Whaling Commission |
| AIS | Automatic Identification System |
| AMARs | Autonomous Multi-channel Acoustic Recorders |
| ASAMM | Aerial Survey for Arctic Marine Mammals |
| ASL | above sea level |
| AURALS | Autonomous Underwater Recorder for Acoustic Listening |
| AV | Alternating value |
| BCB | Bering−Chukchi−Beaufort |
| Bf | Beaufort Wind Force |
| BOEM | Bureau of Ocean Energy Management |
| BOP | blowout preventer |
| BOWFEST | bowhead whale feeding ecology |
| BPXA | BP Exploration (Alaska) Inc. |
| BSEE | Bureau of Safety and Environmental Enforcement |
| BWASP | bowhead whale aerial survey program |
| CAA | Conflict Avoidance Agreement |
| CAV | Complex alternating value |
| CF card | Compact Flash card |
| CSESP | Chukchi Sea Environmental Studies Program |
| cm | centimeter |
| cm/s | centimeters per second |
| COMIDA | Chukchi Sea Offshore Monitoring in Drilling Area |
| CPA | Closest (Observed) Point of Approach |
| CPAI | ConocoPhillips Alaska, Inc. |
| CSEL | cumulative sound exposure level |
| DASAR | Directional Autonomous Seafloor Acoustic Recorder |
| dB | decibel |
| df | degrees of freedom |
| DOD | Dc offset different range |
| DOS | Dc offset similar range |
| DP | dynamic positioning |
| DPS | Distinct Population Segments |
| DSLR | digital single lens reflex |
| ESA | (U.S.) Endangered Species Act |
| ESW | effective strip width |
| FFT | fast Fourier transform |
| FLIR | forward looking infrared |
| ft | feet |
| GB | giga bytes (1024 ^ 3) |
| GHGs | greenhouse gases |
| GPS | Global Positioning System |
| gt | gross tons |

| | |
|---|---|
| GXT | GX Technology |
| h | hour |
| HD | high-definition |
| hrs | hours |
| Hz | Hertz (cycles per second) |
| IHA | Incidental Harassment Authorization (under U.S. MMPA) |
| in | inch |
| $in^3$ | cubic inches |
| IWC | International Whaling Commission |
| JMP | Joint Monitoring Program |
| kB | kilobytes |
| kg | kilogram |
| kHz | kilohertz |
| km | kilometer |
| $km^2$ | square kilometers |
| km/h | kilometers per hour |
| kts | knots |
| lb | pound |
| LOA | Letter of Authorization |
| μPa | micro Pascal |
| m | meters |
| m/s | meters per second |
| $m^3/s$ | cubic meters per second |
| mi | statute mile |
| $mi^2$ | square statute mile |
| min | minutes |
| MLC | mud-line cellar |
| MMS | Minerals Management Service |
| MMPA | (U.S.) Marine Mammal Protection Act |
| mph | miles per hour |
| *n* | sample size |
| nmi | nautical miles |
| NMFS | (U.S.) National Marine Fisheries Service |
| NMML | National Marine Mammal Lab |
| NOAA | National Oceanic and Atmospheric Administration |
| NSB | North Slope Borough |
| NSIDC | National Snow and Ice Data Center |
| NVD | night vision devices |
| OBH | ocean bottom hydrophone |
| OBC | ocean bottom cable |
| OCS | Outer Continental Shelf |
| OCs | organochlorines |
| ODS | Oooguruk Drill Site |
| OSR | Offshore Spill Response |
| OST | Oil Storage Tanker |
| OSVs | Offshore Supply Vessels |

| | |
|---|---|
| PBN | Peard Bay stations |
| PCBs | polychlorinated biphenyls |
| Pioneer | Pioneer Natural Resources Alaska, Inc. |
| psi | pounds per square inch |
| PSO | Protected Species Observer |
| QA/QC | Quality Assurance/Quality Control |
| RAMMs | Random max mins |
| re | in reference to |
| RLs | received levels |
| rms | root-mean-square: an average, in the present context over the duration of a sound pulse |
| RSLs | received sound levels |
| s | seconds |
| s.d. | standard deviation |
| sec | second |
| SEL | Sound Exposure Level: a measure of energy content, in dB re 1 $\mu Pa^2 \cdot s$ |
| SIWAC | Shell Ice and Weather Advisory Center |
| Shell | Shell Offshore, Inc. |
| SID | Spy Island Drill site |
| SPL | Sound Pressure Level; the SPL for a seismic pulse is equivalent to its rms level |
| SSC | sound source characterization |
| SSV | sound source verification |
| TEK | traditional ecological knowledge |
| TK | traditional knowledge |
| UAS | unmanned aerial systems |
| USCG | United States Coast Guard |
| USGS | United States Geographical Survey |
| USFWS | United States Fish and Wildlife Service |
| V | volts |
| VOS | Variable offset similar range |
| vs. | versus |
| ZVSP | zero-offset vertical seismic profile |

# EXECUTIVE SUMMARY

## *Chapter 1: Introduction and Report Objectives*

This report presents a comprehensive overview of offshore exploration activities conducted by the oil and gas industry in the Alaskan Chukchi and Beaufort seas during the 2012 Arctic open-water season and the potential influence of those activities on marine mammals. Two industry-funded exploration programs were conducted in offshore waters of the Alaskan Chukchi and Beaufort seas during 2012 under incidental harassment authorizations (IHAs) issued by the National Marine Fisheries Service (NMFS). Shell conducted an exploratory drilling program in the Chukchi and Beaufort seas during the open-water season, completing a single top hole in each sea. ION Geophysical (ION) conducted a 2D seismic survey in open-water and newly forming sea ice, primarily in the Beaufort Sea, but with some seismic activity in the Chukchi Sea. Other industry operators conducted nearshore and onshore exploration activities in 2012, however, the primary focus of this report pertains to oil and gas activities further offshore.

The Alaskan Arctic offshore oil and gas exploration period from 2006–2011 was characterized by 2D and 3D seismic programs, shallow hazards and site clearance surveys, and related geophysical and geotechnical activities. Shell's 2012 program marked the first offshore exploratory drilling since 1991 in the Chukchi Sea and 2003 in the Beaufort Sea. This report presents a preliminary, comprehensive analysis of 2012 drilling operations and associated marine mammal monitoring in addition to results from ION's 2012 seismic program. Results of the marine mammal monitoring and mitigation programs conducted by the oil and gas industry during offshore exploration activities in the Chukchi and Beaufort seas since 2006 are presented when relevant for comparisons with 2012 monitoring results.

Marine mammal monitoring and mitigation components were major parts of both Shell's and ION's offshore exploration programs in 2012. Monitoring and mitigation was accomplished by protected species observers (PSOs) onboard the drill rigs *Discoverer* and *Kulluk* (Shell) and the seismic source vessel *Geo Arctic* (ION), which operated airgun arrays. PSOs were also deployed aboard over a dozen support vessels associated with Shell's drilling program, including all ice-management, anchor-handler, and resupply vessels, as well as aboard ION's dedicated monitoring vessel, the icebreaker *Polar Prince*.

Shell also conducted aerial surveys in 2012 as part of its marine mammal monitoring program, which included high-definition digital video and still-frame cameras aboard each of two survey aircraft. Surveys were conducted over nearshore areas in the Chukchi Sea and the offshore Burger Prospect, in addition to the Sivulliq Prospect in the Beaufort Sea. The high-definition photographic and video-monitoring equipment were used concurrently with PSO observations on flights in the nearshore Chukchi Sea and for all surveys in the Beaufort Sea.

An acoustic monitoring program was implemented by Shell, ConocoPhillips, Alaska, Inc., and Statoil in 2012 and other industry participants in the Chukchi Sea, and by Shell in the Beaufort Sea during the open-water season. Programs in each sea contained a 2012–2013 overwinter component, including participation by ION in the Beaufort Sea. Sound source characterizations, or SSCs, were conducted using dedicated arrays near each drill site to capture the acoustic properties of vessels, drilling, and related support activities. A SSC was also conducted to measure and characterize vessel and seismic sounds produced during ION's seismic survey in 2012.

The report objectives as outlined in NMFS IHAs issued to offshore operators are to:

- deliver a comprehensive report describing vessel, aerial, and acoustic monitoring programs associated with offshore oil and gas exploration activities during 2012;

- describe the methods, results, conclusions, and limitations of each of the individual data sets; and,
- integrate monitoring studies into a broad-based assessment of all industry activities and their potential impacts on marine mammals and related subsistence activities in the Arctic Ocean during 2012.

A truly comprehensive synthesis of all available scientific data and traditional ecological knowledge would not be feasible within the timeline of this report. In preparing this report we worked under the following assumptions:

- emphasis on presentation of industry-sponsored monitoring and science related to effects of oil and gas exploration on marine mammals, with references to agency research;
- centralized focus on recent IHA-permitted activities in the Alaskan Arctic offshore;
- placement of new results in the context of current understanding;
- focus on potential direct (as opposed to indirect) effects, particularly those from underwater anthropogenic sounds, on marine mammals from recent IHA-authorized activities; this is not a comprehensive cumulative effects analysis;
- 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;
- this report is intended to document all current monitoring programs in the Alaskan Arctic and is not intended as a complete retrospective of previous work in the Chukchi and Beaufort seas; and,
- information presented from studies conducted by other companies, organizations, or agencies was usually available in reports issued by those entities; those reports should be consulted for more detailed information and interpretation.

The report structure has been modified significantly from the previous five comprehensive reports where vessel, aerial, and acoustics programs were addressed separately within each sea. In an effort to minimize redundancy and integrate results from different data streams, each species or species group has a dedicated results chapter. There are 10 report chapters plus appendices.

## *Chapter 2: Background and Context*

This chapter presents and discusses a wide variety of background information pertinent to understanding the potential effects of offshore oil and gas exploration on marine mammals inhabiting the Alaskan Arctic Outer Continental Shelf (OCS). Six subject areas are explored as they relate to the Alaskan Chukchi and Beaufort Seas: physical oceanography, sea ice, climate change, resident and migratory species of marine mammals, the acoustic environment, and a history of oil and gas exploration and their potential effects on marine mammals and subsistence hunting.

### *Physical Oceanography*

Oceanography of the Chukchi Sea is driven largely by the region's topographic features – Hope Valley, Herald Shoal, Herald Valley, the Central Channel, Hanna Shoal, Barrow Canyon, and the Chukchi Continental Shelf. Sea level in the Pacific Ocean is higher than in the Chukchi Sea, and so water

flows "downhill" through the Bering Strait via three main mechanisms: 1) Anadyr Water and Bering Sea Water flow into Hope Valley, 2) Alaska Coastal Current flows along the coasts of northern British Columbia and southeast Alaska and mixes with freshwater outflows once it reaches the Chukchi Shelf, and 3) Pacific water splits eastward toward Barrow Canyon and northward to the west shelf of Hanna Shoal. The warmer water from these three channel areas speeds melting, and so three north-south oriented "meltback embayments" develop within the ice that persists over the shelf. During summer, four distinct water masses form seasonally or occasionally intrude on the Chukchi Shelf: the Siberian Coastal Current, shelf waters near Hanna Shoal, continental slope water, and polynyas. Overall, waters in the Chukchi Sea are strongly stratified, weakly circulated, and are not quickly replaced, particularly over the shelf. When water from the Chukchi Sea is eventually flushed in to the Arctic Ocean, the stratification of fresh summer waters over saline winter waters further reinforces the strong Arctic halocline.

The physical oceanography of the Alaskan Beaufort Sea differs from the Chukchi in that the Beaufort shelf is much smaller, there is relatively little influence from the Pacific Ocean, and ice is far more prevalent. Ice can be present year round over the shelf, although there have been some ice-free summers in recent years. Ridges of offshore ice form boundaries that inhibit exchange between nearshore and offshore waters for much of the year. Exchanges across the four oceanic boundaries (the eastern, western, offshore and coastal boundaries) are modulated by the winds, topography, and the annual cycle of freezing and thawing.

### *Sea Ice in the Arctic*

Sea ice is perhaps the single most important factor that sets the Arctic apart from lower latitude environments. Ice plays an integral role in food webs and subsistence activities, directly and indirectly influencing the distribution, abundance, and behaviors of phytoplankton, zooplankton, fish, marine mammals, and humans. Many species of marine mammals depend on sea ice directly as a platform on which to haul out, rest, sleep, and bear their young. For many species of cetaceans, their distribution and movement is dictated by the availability of open water, and it is expected that distributions of these animals will change in response to an increasing number of lower ice years.

Since the collection of satellite data of polar ice began in 1979, the density and extent of sea ice have been decreasing, with 2012 having the lowest sea-ice minimum on record. The six lowest Arctic sea-ice minima on record occurred in the six-year period between 2007 and 2012. During the scope of this report, from 2006–2012, ice cover in the Chukchi Sea was highest in 2006, lowest in 2007, and has been variable from year to year. In the Beaufort Sea, ice cover was less variable from year to year. Ice cover remained later in the open-water seasons of 2006, 2009, and 2010 than in 2007, 2008, 2011, and 2012.

### *Climate Change*

Data from various sources suggest that the temperatures in the Arctic during the last 100 years are the warmest observed throughout the last 400 years. The overall picture from a synthesis of currently available models suggests that average temperatures in the Arctic marine environment may increase several degrees Celsius by 2050. The decreases in sea ice persistence and density give an indication of how significant change in sea ice is in the Arctic environment. Factors of significance to marine mammals in the Beaufort and Chukchi seas include potential changes in the distribution, concentration and availability of marine mammal prey species, potential competition from range expansion by species not currently using the area, and increased risks to marine mammals via vessel collisions, disturbance from noise, and exposure to contaminants from increased human use of areas during an expanded open-water season. These changes would, in turn, potentially affect the availability of marine mammals to communities who rely upon them for subsistence hunting.

### *Marine Mammals of the Chukchi and Beaufort Seas*

This section discusses the distribution (both worldwide and within the study area), population size, migration, prey, predation, and life history of the marine mammal species most commonly encountered in the Chukchi and Beaufort seas, and also details subsistence use for each of the relevant species. These include: bowhead whale, gray whale, beluga whale, harbor porpoise, ringed seal, spotted seal, bearded seal, ribbon seal, Pacific walrus, and polar bear. The section also briefly describes species that are extralimital or infrequently sighted in the Chukchi and Beaufort seas, such as killer whale, minke whale, narwhal, fin whale, and humpback whale.

### *Acoustic Environment of the Alaskan Chukchi and Beaufort Seas*

The Chukchi Sea continental shelf is characterized by a very uniform, relatively shallow depth that tends to support long-range propagation of sounds at the dominant frequencies of sounds emitted by anthropogenic sources. In contrast, the Beaufort Sea has a narrow continental shelf that drops off to the north into a deep basin, the Beaufort Plateau, which allows long-range propagation of high amplitude sounds such as airgun pulses. Ice in the Chukchi and Beaufort seas plays several roles in reducing the level of ambient noise: 1) preventing wind from agitating the water's surface, 2) impeding vessel traffic, and 3) scattering of sound waves and thereby reducing sound propagation distances.

Anthropogenic sources of sound include smaller vessels such as whaling skiffs, larger vessels for pulling barges to deliver supplies to communities or industry work sites, icebreakers, and vessels for tourism and scientific research. Sources of noise associated with oil and gas activities include vessels, drilling equipment, seismic arrays, and other geophysical research instrumentation.

Marine mammals periodically contribute considerably to ambient sound in the Beaufort and Chukchi seas. Beluga whale vocalizations are frequently recorded in the Chukchi Sea during their spring migration. Recorders placed in both the Beaufort and Chukchi seas detect bowhead whale calls during the animals' spring and fall migrations. Walrus sounds are detected most frequently between Hanna Shoal and Wainwright as well as near to Point Lay. Seals are detected all months of the year, but calls from male bearded seals increase markedly during the May breeding season, noticeably increasing background ambient noise levels.

### *Recent Offshore Oil and Gas Industry Activities, Other Vessel Activities, and Potential Effects on Marine Mammals and Subsistence*

Marine seismic programs in support of offshore drilling operations have operated since the late 1960's in the Beaufort Sea and as early as 1970 in the Chukchi Sea. Offshore seismic activity in previous decades was much higher compared to the last 10 years. Exploratory drilling in offshore areas of the US Beaufort Sea began in 1981 and around the mid-1980s in the Chukchi Sea.

In 2012, Shell conducted exploratory drilling activities in the Chukchi and Beaufort seas. ION Geophysical conducted a deep seismic survey mainly in the Beaufort Sea, and BP performed a 3D ocean-bottom cable (OBC) survey in Simpson Lagoon, Beaufort Sea. In addition to work in Alaskan waters, seismic acquisition also occurred in the Canadian Beaufort Sea. Numerous other vessel activities occurred in the Chukchi and Beaufort seas in support of onshore oil and gas exploration and production.

Other vessel activities occurring in the region in 2012 included general commerce, research (including seismic programs conducted by the United States Geographical Survey [USGS]), the United States Coast Guard (USCG), recreation and tourism, and Alaska Native subsistence activities. Automatic Identification System (AIS) data were used to capture the tracklines of vessels equipped with AIS in the Chukchi and Beaufort seas. Summaries of the number of vessels, vessel activities, and trackline totals are presented in this section.

The predominant concern associated with offshore oil and gas exploration activities is the potential for underwater sound to affect marine mammals. Potential effects may include masking, disturbance reactions, or hearing impairment. To date there have been no population-level effects to any species of marine mammal associated with oil and gas exploration activities, and there has never been a marine mammal mortality event associated with these activities. Concerns have also been raised over the potential for collisions between vessels and marine mammals, separation of groups, or habitat alteration.

Subsistence remains the basis for Alaska Native culture and community. Possible short-term effects that oil and gas exploration could have on traditional subsistence patterns include displacing, reducing, or contaminating subsistence species. Since 2006, industry has worked to design projects both temporally and spatially with regard to regional subsistence hunting to minimize these potential impacts.

## *Chapter 3: Description of Offshore Industry Activities and Monitoring in 2012*

Shell conducted an exploratory drilling program in the Chukchi and Beaufort seas during the open-water season, completing a single top hole in each sea. ION conducted a 2D seismic survey mainly in the Beaufort Sea but with some seismic activity in the Chukchi Sea. Other industry operators conducted exploration activities in 2012, including BP's ocean bottom cable seismic program in Simpson Lagoon and other near shore industry activities conducted by ENI, Pioneer, and Exxon Mobile. Marine mammal monitoring and mitigation components were major parts of Shell and ION programs.

The drill rigs M/V *Noble Discoverer* (*Discoverer*) and the *Kulluk* each completed a single, shallow top hole in the Chukchi and Beaufort seas, respectively. Vessels associated with the exploratory drilling program were present in the Chukchi Sea from 23 July to 14 November, and the Beaufort Sea from 15 August to 10 November. Anchor handling, ice management, and support vessels were active on and near the drill site during exploratory drilling activities. The different phases of anchor handling include anchor setting, anchor hook-up, disconnection, and anchor retrieval. In general, ice management activities included physical pushing or breaking of drift ice to allow the drillship ample time to move off prospect to prevent ice-floe collision with the drillship. Ice management activities were limited to 10 km (6 mi) north-northeast of the Burger-A drill site in the Chukchi Sea and no ice management activities occurred in the Beaufort Sea during Shell's drilling program.

The 2D geophysical survey (seismic reflection/refraction) by ION Geophysical occurred primarily in the Alaskan Beaufort Sea from 20 October to 15 November, 2012. The seismic survey vessel (M/V *Geo Arctic*) used a 26-airgun configuration (with a total discharge volume of 4380 $in^3$) for seismic data acquisition and a single 70 $in^3$ airgun for mitigation purposes. The M/V *Geo Arctic* was escorted by the medium class (100A) icebreaker M/V *Polar Prince* during some survey operations in open-water and during most survey operations in heavily ice-covered waters.

Numerous other industry and human activities occurred in the Alaskan Arctic OCS during 2012. These other activities included BP's ocean bottom cable (OBC) seismic program in Simpson Lagoon, a nearshore area in the Alaskan Beaufort Sea, oil production operations by Eni, Pioneer, and BP in nearshore waters of the Beaufort Sea, vessel activities associated with onshore oil and gas exploration and production, seismic acquisition in the Canadian Beaufort Sea, intra and interstate commerce, research, the United States Coast Guard (USCG), recreation and tourism, and Alaska Native subsistence activities.

A three-tiered marine mammal mitigation and monitoring program was implemented in 2012. The program consisted of 1) dedicated protected species observers (PSOs) onboard most vessels, 2) aerial surveys using high-definition camera systems and PSOs, and 3) wide-area arrays of acoustic recorders deployed on the seabed and from vessels in both the Chukchi and Beaufort seas. The three-tiered design

is intended to inform responsible operational practices by minimizing potential impacts to marine mammals and local subsistence users.

The main purposes of PSOs aboard the vessels were to conduct visual watches for marine mammals to serve as the basis for implementation of mitigation measures, to document numbers of marine mammals present, record any reactions of marine mammals to exploration related activities, and identify whether there were any possible effects on the accessibility of marine mammals to subsistence hunters in Alaska. Mitigation measures were designed to minimize encounters between vessels and marine mammals and maximize the distance between operations and animals, including the implementation of sound threshold safety radii.

The aerial-survey component was designed to provide systematic assessment of the distribution of marine mammals in areas within and adjacent to offshore exploration activities. The 2012 Shell aerial survey program was conducted in the Chukchi Sea over the nearshore areas between Barrow and Pt. Hope as well as offshore over the Burger prospect area. In the Beaufort Sea, surveys were conducted over the Sivulliq prospect area to address concerns regarding a potential deflection of bowhead whales around exploratory drilling operations. High definition digital still and video cameras were installed aboard each survey aircraft for use during all flights in 2012 in conjunction human observers on all flights except those over the Burger prospect area.

An acoustic monitoring program in support of offshore exploration activities was first implemented in the Alaskan Chukchi and Beaufort seas in 2006. The acoustic monitoring programs were designed to serve three primary functions: 1) record and characterize industry sound levels and sound propagation as well as ambient sound levels, 2) observe call distributions of marine mammals (including bowhead, beluga, gray, fin, humpback, and killer whales, as well as walruses and seals) over a large area, and 3) investigate the possible effects of anthropogenic sounds on measureable aspects of bowhead whale behavior, such as call detection rates and locations in the Beaufort Sea.

## *Chapter 4: Acoustic Monitoring of Oil and Gas Industry Noise Sources*

Chapter 4 of this report focuses on the monitoring and reporting of underwater sound levels associated with offshore oil and gas exploration activities in the Chukchi and Beaufort seas. The chapter begins with a high-level review of the acoustic monitoring studies that have been conducted by various operators in the Chukchi and Beaufort Seas from 2006 to 2012. This section summarizes reported distances to important sound level thresholds from noise sources including seismic airgun arrays and vessels. This is followed by an overview of the acoustic monitoring that was completed for three different companies in 2012, with particular focus on measurements of sound levels from Shell's drilling operations. Results of a sound source characterization (SSC) study are summarized to provide distances to important sound level thresholds for specific activities and for each individual vessel involved in the drilling operations. A more comprehensive examination of the total noise footprint of the fleet of assets from the drilling operations is provided through maps, called soundscapes, showing median sound levels recorded over an array of sound recorders during the major phases of the operations.

The drilling SSC measurements were conducted to satisfy Shell's 2012 IHAs which stipulated a requirement to measure underwater sound levels for all vessels and equipment involved with the drilling program at each prospect. The measurements were to be analyzed to determine the distances corresponding to sound levels between 190 and 120 dB re 1 μPa (rms). Source sound levels for all vessels and equipment were also to be provided. Sounds from different phases of the drilling operations were characterized by activity. The activities considered included anchor handling, ice management, pilot

hole drilling, and excavation of the mud-line cellar. Sound levels generated during anchor handling and ice management were found to be greater than those measured during the other phases of the drilling operations, resulting from the noise from the powerful thrusters of the anchor handling and the ice management vessels. Excavation of the mud-line cellar generated the next highest levels, with sounds from drilling of the pilot holes being the lower measured sound levels.

The soundscape analysis was completed to provide a more complete understanding of the noise distribution beyond the immediate project area by incorporating measured sound levels from arrays of recorders distributed in the Chukchi and Beaufort seas. This analysis considered median sound levels measured over longer timescales to more realistically account for the sound level fluctuations with variation of the intensity of the activities. This is more meaningful for impact assessment applications.

## *Chapter 5: Marine Mammal Sightings by Analysts of Digital Imagery vs. Aerial Surveyors*

Shell conducted aerial surveys for marine mammals in the Alaskan Chukchi and Beaufort seas during 2012 in support of its exploratory drilling program. From 14 August through 3 November, surveys were flown in two Twin Otter aircrafts that were specially modified for survey work. Surveys were conducted at altitudes of 305 to 457 m (1000 to 1500 ft) above sea level (ASL) and a groundspeed of 222 km/h (138 mph or 120 kts). Altitude varied due to area restrictions in the Ledyard Bay Critical Habitat Unit in the Chukchi Sea and in a bowhead whale subsistence hunting area in the Beaufort Sea from Kaktovik to north of Deadhorse. The preferred altitude outside the critical habitat area was 305 m ASL (1001 ft), but some surveys were conducted at 457 m (1499 ft) during periods when there was concern about potential aircraft disturbance to subsistence hunting activities near specific villages.

Sightings of marine mammals made by protected species observers (PSOs) on manned aircraft were compared to sightings obtained from later review of high-definition (HD) video and digital single lens reflex (DSLR) camera imagery covering the same swaths and collected concurrent with the PSO observations. If the data were comparable, future similar surveys could be conducted with unmanned aerial systems (UAS) or manned aircraft without PSOs. Two reviews were conducted on the DSLR images: one used image enhancement and scanned the images at full resolution of the cameras (detailed review) and the other flashed images at $1/9^{th}$ resolution on monitors for 3 to 4 seconds using a slide show format to simulate the view a PSO would have out an airplane window. Image reviewers saw fewer animals in HD video than did PSOs but samples sizes were small. During detailed review of DSLR imagery, reviewers saw similar numbers of cetaceans and polar bears and slightly more pinnipeds as compared to PSOs. PSOs saw more animals than the quick review found, but changes to the quick review process are suggested that will increase detection rates. Additional data are required to confirm the results presented here and to determine whether photographic versus PSO detections are similar across varying survey conditions.

A major impetus for this study was the desire to reduce the risk to people conducting marine mammal and bird surveys in offshore waters where accidents have led to loss of human life. The sensor packages tested here were selected because they were small enough to install in UAS and were not the highest quality sensors available. Despite the size and weight limitations for sensors that can be used in small to medium UAS, this study suggests that some of these sensors have potential to be used in UAS to replace manned aerial surveys without risk to human life.

## *Chapter 6: Bowhead Whale Monitoring*

In order to investigate bowhead whale distribution and behavior, numerous data sets have been collected around offshore industry activities since 2006. The goals of this chapter are to provide a synthesis of available information, and to document the extent of any changes in bowhead whale distribution and behavior in response to offshore industry activities. A unified presentation of the three data sets (aerial, acoustic, and vessel) collected as part of the 2012 monitoring program around Shell's drilling program and ION's geophysical survey in the Alaskan Beaufort and Chukchi Seas is also discussed. Additionally, independent sources of information are taken into account (e.g., federal agency aerial surveys, satellite tagging, reports on subsistence hunts, and documented traditional knowledge).

Large-scale patterns of bowhead distribution in the Alaskan Chukchi Sea were investigated using acoustic detections, as well as boat-based sightings and aerial survey data. The observed large-scale patterns are consistent across data sets, and indicate that bowhead whale distribution during the early fall migration period in recent years has been concentrated north of 71°N. Between years, the data sets suggest an increase in relative abundance in the central part of the Lease Sale Area in August 2011 and 2012 compared to 2009 and 2010. During the late summer and early fall, acoustic data indicate that the Burger prospect area has been near the center of the distribution of vocalizing bowhead whales, whereas the Klondike area has been on the southern edge.

Large-scale patterns of bowhead whale distribution in the Alaskan Beaufort Sea have been examined using data collected from acoustic arrays of DASARs (Directional Autonomous Seafloor Acoustic Recorders) deployed during the fall migration every year since 2007. The data show that the fall migration corridor of bowhead whales is mostly within the general bounds of the acoustic arrays. Based on a broad-scale qualitative assessment of these data, it does not appear that the various anthropogenic activities taking place near the DASAR arrays have resulted in large displacements (tens of km) of calling whales.

Shell performed seismic exploration in the Beaufort Sea during three (2007, 2008, and 2010) of the six years of acoustic monitoring (2007–2012) and ION operated in late 2012, after the DASAR arrays were retrieved. In addition, a number of other operators used airguns at known distances of up to ~1400 km (870 mi) from the DASAR arrays. Many of these airgun pulses were recorded by the DASARs. Airgun pulses at DASAR 5G, at the northern end of the easternmost site, were subsequently analyzed, showing that the lowest number of received airgun pulses was in 2011 and the highest in 2012. In addition, in every year except 2011, received levels of sound from airgun pulses were mostly in the range 100–120 dB re 1 $\mu Pa^2$-s (sound exposure level).

The hundreds of thousands of localized whale calls collected by the DASAR arrays since 2007 have allowed evaluation of the effects of airgun pulses on calling behavior. Analyses based on DASAR data collected in 2007 have shown that bowhead calling rates drop significantly when airgun operations are near the whales (median distance to airgun array = 41–45 km [25–28 mi]). A different analysis using four years of data (2007–2010) has shown that calling rates start to decrease when the received cumulative sound exposure level (CSEL) at the whale exceeds ~127 dB re 1 $\mu Pa^2$-s (as calculated over 10 minutes). At received CSELs close to 160 dB, the animals are nearly silent. Interestingly, before this drop in calling rates occurs there is a substantial increase in calling activity. That is, as soon as airgun pulses become detectable, bowhead whales start calling more often, until the calling rate is about double that seen when no airgun pulses are present.

During 2007–2012, 2010 was the only year during which there existed persistently high concentrations of ice in the coastal Alaskan Beaufort Sea. The distribution of 2010 acoustic and aerial

detections was consistent with previous observations of heavy nearshore ice cover (70–100%) resulting in the migration route being farther offshore. The bulk of the geophysical survey activity in the Alaskan Beaufort that year occurred late in the season, after storms had dissipated the ice. The aerial survey data that were collected during this open-water period of geophysical surveys indicated that the distribution of bowhead whales shifted closer to the shallow-hazard survey area (nearshore) than it had been earlier in the season when there were high concentrations of sea ice, but little to no geophysical survey activity. The extent of sea ice therefore seemed to have a greater effect on bowhead distribution around Harrison Bay during 2010 than did Shell's shallow-hazard survey (performed using a relatively small 40 $in^3$ airgun array).

Based on a detailed analysis of aerial sightings in the Alaskan Beaufort Sea, feeding bowhead whales appeared to tolerate seismic sounds around Shell's 2007–2008 geophysical surveys until levels approached an estimated value of ~150 dB re 1 μPa (rms SPL). Further, given observations from the active geophysical survey vessels, some feeding whales appeared to have tolerated even higher levels. On the other hand, sighting rates of whales that were traveling in the geophysical survey area declined as sound exposure to airgun pulses increased. This suggests there was localized avoidance of airgun pulse sounds by traveling whales. Nevertheless, regardless of bowhead whale activity state, no evidence was found for offshore deflection around the 120 dB (rms SPL) radius of estimated received levels.

Based on call counts from the DASAR arrays in 2012, it appears the peak of the 2012 fall migration through the Alaskan Beaufort Sea study area was right before 20 September. The aerial survey data indicate that the distribution of bowhead whales in the study area shifted nearshore as the fall migration progressed. The evidence for the hypothesis that there was a nearshore displacement around Shell's drilling activities in the Beaufort Sea study is inconclusive. Both industry-sponsored and federally funded aerial surveys detected an apparent pulse of migrating whales unusually late in the year on 21–22 October; however, no bowheads were observed from ION's seismic survey vessels which operated in the Beaufort Sea until 11 November.

In the Alaskan Chukchi Sea, most of the bowhead whale acoustic and visual detections during 2012 occurred between late September and mid-October, at which point the acoustic recorders were retrieved. During September, acoustic detections were characterized by relatively high call counts off the coast of Wainwright. In general, observations across data sets indicated that the bulk of bowhead whale distribution during September–mid-October was north of 71° N. Observations from Shell and ION vessels in early to mid-November indicated that a number of bowheads were still present in the northern Chukchi Sea as the sea ice edge advanced rapidly southward.

The most recent abundance estimate indicates that this population of bowhead whales has been experiencing an annual increase rate of 3.7% since at least the late 1970s, with no signs of slowing in recent years. Furthermore, total abundance has increased by about 50% in the last ten years, and has roughly doubled since the early 1990s. Since the late 1970s and the initiation of surveys for abundance, the estimates of population size do not indicate that either anthropogenic (e.g., offshore oil and gas activities, subsistence whaling catch quotas, etc.) or natural factors (e.g., prey availability) have resulted in any negative influence on trend in abundance.

## *Chapter 7: Beluga, Gray Whale, and Other Cetacean Monitoring*

Beluga whales are commonly sighted species in the Chukchi Sea during aerial surveys, however there are relatively few belugas sighted by vessel-based observers. Distribution varies substantially by season with sighting rates higher during July and October to November than during September during

surveys conducted from 2006–2012. These results were similar to previous research efforts as well as other current independent studies. Group sizes were largest in July and much smaller in October and November, possibly indicating a more spatially dispersed fall migration.

Beluga whales are common in the Alaskan Beaufort Sea during summer periods; however few belugas were recorded by vessel-observers and during aerial surveys. Belugas generally occur at or near the shelf break in the Beaufort Sea farther offshore than operations. However, in 2012 the majority of belugas sighted during industry aerial surveys were on the shelf, possibly due to lingering sea ice in the vicinity. In 2012, beluga sightings were recorded from aerial surveys during anchor handling activities and during drilling, however, the distant location of the sighting resulted in the same median SPL as during periods with no industrial activity. Thus, during periods of drilling activity in the Beaufort Sea, beluga whales along the shelf break were probably exposed to industrial sound levels similar to typical ambient sound levels in the Beaufort Sea. A group of 125 beluga whales was observed by ION PSOs in the Canadian Beaufort Sea; however, airguns were not operational at the time of the sighting.

Gray whales were by far the most frequently sighted and most numerous cetacean species recorded during industry monitoring studies in the Chukchi Sea from 2006–2012. Gray whales in the Chukchi Sea were seen most often in coastal or shoal habitats in the northern part of the survey area from about Wainwright to Barrow, where feeding activity was frequently observed. In all years, gray whale numbers increased from July to August then declined in September with few observations after mid-September. Acoustic detections of gray whale vocalizations occurred from mid-August to mid-October. Generally, sound generating exploration activities occur farther offshore than the majority of gray whales, and sounds from exploration activities reach background levels before reaching these areas of higher gray whale concentration.

Harbor porpoises are difficult to detect from vessels and during aerial surveys, however they are detected consistently by vessel-based observers in the Chukchi Sea and occasionally in the Beaufort Sea. The location of these sightings indicates that harbor porpoises are more common in the Chukchi Sea than the Beaufort Sea; but they may have a larger range in the Beaufort Sea and be more numerous than previously thought.

PSOs onboard industry vessels in the Chukchi Sea have recorded killer whales consistently since 2006. The first killer whale sighting from industry aerial surveys in the Chukchi Sea was in 2012. Transient killer whales were acoustically detected predominantly off Cape Lisburne and Point Lay in all years with a few detections off Wainwright.

Sightings and acoustic detections of some species which are considered to be uncommon in the Chukchi Sea appear to be increasing, suggesting the initial stages of possible range expansion of these populations. Minke whales were detected acoustically in the Chukchi Sea first in 2011 and again in 2012, and the first sighting of a minke whale during an industry aerial survey was in 2012. Minke whales have been sighted by vessel-based observers in the Chukchi Sea consistently since 2006 and rarely since 2007 in the Beaufort Sea. Humpback and fin whales, which are both considered to be rare in the Chukchi Sea, were recorded during the 2006–2010 industry monitoring programs and again in 2012. Acoustic detections of fin whales were also recorded in 2012.

## *Chapter 8: Ice Seal Monitoring*

Bearded, ringed, spotted, and ribbon seals are known as ice seals due to their dependence on sea ice during at least some stage of their life histories. They are widely distributed across both the Chukchi and Beaufort seas. All of these species are common in the study area, at least seasonally, with the exception

of ribbon seals. Seals were commonly seen during all industry operations in both study areas during all years. From 2006 through 2012, a total of 8252 sightings of 11,176 individuals and 7125 sightings of 11,625 individuals were recorded by observers aboard vessels and aerial surveys operating in the Chukchi and Beaufort seas, respectively.

Monitoring data from vessel and aerial platforms during industry operations indicated that seals are closely associated with ice even during the open-water season. There were numerous seal sightings across ice presence classifications, in all years, but in years when ice was persistent in the study areas there was a general trend of higher sighting rates in areas with greater ice persistence.

Of the 163 sightings of seals recorded by observers on the *Kulluk* in 2012, 94 were of uniquely-identified animals based on marks on pelage such as color patterns and scars. Two large groups of ringed seals were sighted on multiple occasions and were thought to be of the same groups of individuals. Individuals were sighted on separate occasions between two and eleven times. Some individual seals were seen daily for weeks at a time while the *Kulluk* was moored at the drill site in the Beaufort Sea.

Data collected onboard the drill rigs in both the Chukchi and Beaufort seas in 2012 suggest that seals tolerate some drilling noise, which is supported by previous research. There was little difference between active drilling periods and non-drilling periods in the closest point of approach of seals or the length of time that they remained around the rigs. While in proximity to the drill rigs, the majority of seals displayed no discernible reaction to the rig. The most frequently observed reaction was an animal "looking" at the vessel. Seals showed no overt reactions or behavioral changes associated with the exploration activities regardless of the specific activities that were occurring.

During the transit from the Beaufort Sea portion of the study area to the Chukchi Sea, ION PSOs aboard the *Geo Arctic* and *Polar Prince* observed 92 seal sightings of 125 individual seals during a 5.5 hr period on 11 November 2012. These seal sightings accounted for approximately 88% of the total seal sightings observed during ION's 2012 operations in the Beaufort Sea. However, this observation period accounted for only a small percentage (~2%) of the total time the *Geo Arctic* and *Polar Prince* spent in the Beaufort Sea during the 2012 season. Airguns were not operational at the time of these sightings. This isolated sighting event in 2012 suggested a heterogeneous distribution of seals in the Beaufort Sea in late fall as ice was forming.

Acoustic data support the vessel and aerial survey data regarding the distribution of seals in the Chukchi Sea. Most bearded seals in the northeastern Chukchi Sea were concentrated to the north of the study area, with an increase in calling rates from September to June. Acoustic data suggest that the area is used fairly extensively by bearded seals during the winter. Ringed seal calls were detected in both winter and summer and ribbon seal calls were detected in summer. No spotted seal calls were detected, although there is a general lack of knowledge about their calls.

## *Chapter 9: Pacific Walrus Monitoring*

The combined use of aerial and vessel-based visual observation platforms, extensive arrays of acoustic recorders, satellite tagging, and detailed monitoring of ice conditions in the Chukchi Sea has provided insights into Pacific walrus ecology and their adaptation to changing sea ice patterns in the Arctic. Although walruses use many areas throughout the Chukchi Sea, including along the Russian coast, large numbers of animals typically congregate in the area around Hanna Shoal to the north and east of several oil and gas prospects during the open-water season.

Walrus typically overwinter in the Bering Sea and move northward with the receding pack ice edge during spring. The movements of walruses into the Chukchi Sea in the spring have been monitored since

2009 with acoustic recorders. These data indicate that walrus typically arrive in the Chukchi Sea from mid-May to mid-June. As walrus move north into their Chukchi Sea summering grounds they remain closely associated with sea ice. Industry-sponsored acoustic recorders in the Chukchi Sea detected high numbers of walrus calls in the Hanna Shoal area from 2009–2012, coinciding with results from USGS tagging studies.

The distribution of walruses during the summer season varied yearly depending on the presence or absence of sea ice. In years with greater ice persistence (2006, 2008 and 2012) walrus remained offshore using the ice as resting platforms well into September. In low ice years (2007, 2009, 2010 and 2011) many walruses used terrestrial haulouts along the Alaskan Chukchi Sea coast once sea ice retreated off the continental shelf and no longer provided a platform from which to feed. In 2012, walrus vessel-based sighting rates were significantly greater in areas with >10% ice compared to areas with <10% ice or open water.

Data collected by protected species observers (PSOs) aboard the drill ship *Discoverer* and associated support vessels, along with aerial photographic survey data collected over the drill site, were used to investigate potential impacts to walrus distribution and behavior from offshore exploration activities in the Alaskan Chukchi Sea during 2012. Sighting rates of walruses in water from aerial photographic data were significantly higher during the anchor-handling period than during drilling or general vessel activities, and sighting rates during general vessel activities were significantly higher than during drilling. These data alone suggest that walrus may have been avoiding the drilling activities occurring at the Burger prospect, however, most drilling activity occurred late in the open-water season when the ice had retreated out of the survey area, and most walruses had already left the area. Further, the large number of sightings during anchor handling, which is one of the noisiest activities, suggest that sighting rates were more dependent on the time of year and ice presence than they were on the activity occurring at and adjacent to the drill site.

Mean distance of walrus detections from the drill site during drilling activities was similar to the distance of sightings during anchor handling and general vessel activities. The vast majority of walrus sightings in 2012 were associated with ice until it receded completely from the Chukchi Sea in mid-September, thus the distances of walruses from the drill site during the aerial surveys likely were more related to the distribution of ice around the drill site than they were to avoidance of the drill site by walruses.

Mean CPA (closest point of approach) for walruses on ice observed from vessels was significantly greater than the mean CPA for walruses observed in water in 2012. The different CPA distances between walruses on ice and in water is largely due to the different regulatory requirements (vessels were instructed to maintain a distance of 805 m [0.5 mi] from walruses on ice) and the sightability by PSOs (walruses were more easily detected on ice than in water). The majority of Pacific walruses exposed to different vessel activities exhibited no reaction to vessels (58% of sightings). ‘Look’ was the most commonly observed reaction for walruses exposed to anchor handling, drilling activities, and ice management (54%, 43%, and 67%, respectively) with fewer observations of ‘change direction,’ ‘increase speed,’ and ‘splash.’

On 13 September 2012, the *Fennica* (Shell's primary ice-management vessel in the Chukchi Sea) was given permission to sail into some loosely-packed ice that posed a risk to the safety of the drilling operation at Burger. This situation provided an opportunity to investigate the efficacy of the marine exclusion zone for walruses of 805 m (0.5 mi). Data from this cautious approach of walruses on ice indicated a significant difference in the CPA between walruses on ice that did not enter water (mean CPA = 962 m or 0.6 mi) when compared to walruses that did enter the water (mean CPA = 525 m or 0.3 mi).

These results provide empirical support for the marine exclusion zone of 805 m (0.5 mi) given that animals more likely to enter the water when the vessel approached within 805 m (0.5 mi). This result was based on relatively few data from an isolated time period and therefore should be interpreted with caution.

When walrus sightings from both vessel and aerial platforms were plotted over the median sound pressure levels during different activities in 2012, most maps showed a clumping pattern of walrus in areas with sea ice regardless of the median sound pressure levels. These data suggest that walrus presence in an area was more related to ice than to avoidance of the exploration activities. On the one day when there were multiple walrus sightings in aerial imagery and no ice present, the sightings were scattered throughout the survey area, again implying no large-scale avoidance of exploration activities by walruses. The only sightings of walruses during ION's 2012 exploration program was after the cessation of survey activities as vessels transited offshore of Point Hope en route to Dutch Harbor.

## *Chapter 10: Polar Bear Monitoring*

Polar bear sightings during the 2012 Joint Monitoring Program originated primarily from vessel-based observers but were also sighted opportunistically during aerial surveys. Differences in spatial and temporal sea ice extent among years and proximity of operations to ice (e.g., the 2012 season) likely resulted in the observable differences in the distribution and behavior of polar bears.

Aerial surveys were conducted in 2006–2008, 2010 and 2012 in the Chukchi and Beaufort seas. The aerial surveys were not designed for the purposes of detecting polar bears; as a result sightings are mostly opportunistic and sighting rates are highly variable among years. A total of 26 polar bear sightings involving 32 individuals were recorded in the Chukchi Sea in 2012. These numbers included three sightings of three individuals occurred on 28 September on the coast north of Wainwright. In the Beaufort Sea, a total of 70 polar bear sightings involving 142 individuals were recorded, 46 of these sightings were located on the barrier islands and sighted off-transect during aircraft transit to and from the survey area or during aircraft turns at the end of a survey line.

From 2006–2012 there were a total of 72 polar bear sightings involving 88 individuals from only three years in the Chukchi Sea. Ten of the polar bear sightings were recorded in 2006 and 2008 while 62 sightings were recorded in 2012; this increase is likely due to an increase in the overall number of vessels operating in the study area, an increase in ice capable operations, and persistent sea ice near planned operations, as polar bears in previous years were observed in roughly equal parts ice, land, and water, but in 2012 ~75% were observed on ice and ~25% were observed in the water.

From 2006 to 2012 there were 94 polar bear sightings (276 individuals) from vessels in the Beaufort Sea. Most bears (71%) were sighted on land (on Cross Island or other barrier islands), 17% were sighted in mostly shallow water (all but ten in <50 m [164 ft]) and 11% were sighted on ice. The average group size per sighting was three bears with larger group sightings associated with Cross Island or other barrier islands; this is likely due to ample forage provided by carcasses left on the islands by hunters.

Bears on ice in both the Chukchi and Beaufort seas were often initially sighted at much greater distances than were those seen in the water, and subsequently avoided by vessels as a mitigation measure. Bears were visible from a stationary vessel about ~1 h regardless of whether they were in water or on ice; however bears visible from a moving vessel were only visible <10 min on water and ~20 minutes on ice. "No movement" was the most common movement pattern of bears with respect to the vessel and also included "neutral", "move away", and "move towards". The majority of reactions to vessels from bears on ice were "no reaction", however "look" was the most common reaction from bears in the water.

Observers aboard the drillship *Discoverer* recorded three polar bear sightings in the Chukchi Sea during 2012 when the main sea ice edge was close to the prospect; each of these sightings involved a single animal that approached the *Discoverer* in open water while the ship was anchored but not actually drilling. There were no polar bears observed from the *Kulluk* during Shell's 2012 exploratory drilling program in the Beaufort Sea. During seismic surveys, 12 sightings of polar bears were observed in the Chukchi Sea; all but one of these sightings occurred while the full array was active, however, all polar bear sightings were observed on ice. There were no polar bears observed during seismic survey operations in the Beaufort Sea in 2012. From 2006 to 2012, 91 polar bears were recorded where the received sound level in the water was estimated to be <120 dB (rms), 77 of these were on ice or land. Three polar bears were recorded where the received sound level in the water was estimated to be between 159–120 dB (rms), one of which was in the water. Sounds received by marine mammals are considerably reduced for animals at or near the surface, and very little in-water sound is audible to animals that are on ice. In 2006–2012 in the Chukchi Sea there were 36 polar bears sighted from industry vessels that were within the ≥120 dB (rms) isopleth (31 seen on ice) and 12 polar bears were seen within the ≥160 dB (rms) isopleth (11 seen on ice). The polar bears on ice would not have been exposed directly to these sound levels, and the bears seen in the water would likely have been exposed to considerably reduced sound levels given that polar bears typically swim with their heads above water.

# ACKNOWLEDGEMENTS

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Representatives of ASRC Energy Services and NANA Management Systems provided invaluable support and protected species observers (PSOs) to the joint monitoring program. We also thank all of the PSOs who participated in the project. They were essential to the completion and success of this endeavor.

# 1. INTRODUCTION AND REPORT OBJECTIVES

This report presents a comprehensive overview of offshore exploration activities conducted by the oil and gas industry in the Alaskan Chukchi and Beaufort seas during the 2012 Arctic open-water season and the potential influence of those activities on marine mammals. This is the sixth in a series of nearly annual Joint Monitoring Program (JMP) Reports describing offshore industry and other activity in the Chukchi and Beaufort seas since 2006 (Funk et al. 2007, 2010a,b, 2011; Ireland et al. 2009).

Two industry-funded exploration programs were conducted in offshore waters of the Alaskan Chukchi and Beaufort seas during 2012 under incidental harassment authorizations (IHAs) issued by the National Marine Fisheries Service (NMFS). Shell conducted an exploratory drilling program in the Chukchi and Beaufort seas during the open-water season, completing a single top hole in each sea. ION Geophysical (ION) conducted a 2D seismic survey in open-water and newly forming sea ice, primarily in the Beaufort Sea, but with some seismic activity in the Chukchi Sea. Other industry operators conducted exploration activities in 2012, including BP's ocean bottom cable seismic program in Simpson Lagoon, a nearshore area in the Alaskan Beaufort Sea. Other nearshore industry activities were conducted in the Beaufort Sea by Eni, Pioneer, and various vessel operators. The primary focus of this report, however, pertains to oil and gas exploration activities further offshore.

Shell's exploratory drilling activities in the Chukchi Sea in 2012 occurred on the Burger prospect, located within the Chukchi Sea Lease Sale Area 193. Shell's drilling activities in the Beaufort Sea in 2010 occurred on a lease holding known as Sivulliq approximately 30 km (19 mi) offshore between Deadhorse and Kaktovik. ION's seismic survey occurred primarily across the eastern half of the Alaskan Beaufort Sea with smaller amounts of data acquisition east of Barrow and in the northeastern Chukchi Sea.

The Alaskan Arctic offshore oil and gas exploration period from 2006–2011 was characterized by 2D and 3D seismic programs, shallow hazards and site clearance surveys, and related geophysical and geotechnical activities. Offshore exploratory drilling in both the Chukchi and Beaufort seas was conducted by Shell in 2012, an activity that has not occurred in the Alaskan Arctic offshore since 1991 in the Chukchi Sea and 2003 in the Beaufort Sea. This report presents a preliminary, comprehensive analysis of 2012 drilling operations and associated marine mammal monitoring in addition to results from ION's 2012 seismic program. Results of the marine mammal monitoring and mitigation programs conducted by the oil and gas industry during offshore exploration activities in the Chukchi and Beaufort seas since 2006 are presented when relevant for comparisons with 2012 monitoring results.

Marine mammal monitoring and mitigation components were major parts of both Shell's and ION's offshore exploration programs in 2012. Monitoring and mitigation was accomplished by protected species observers (PSOs) onboard the drill rigs *Discoverer* and *Kulluk* (Shell) and the seismic source vessel *Geo Arctic* (ION), which operated airgun arrays. PSOs were also deployed aboard over a dozen support vessels associated with Shell's drilling program, including all ice-management, anchor-handler, and resupply vessels, as well as aboard ION's dedicated monitoring vessel, the icebreaker *Polar Prince*.

Shell conducted aerial surveys as part of its marine mammal monitoring program in the Chukchi and Beaufort seas, which included high-definition digital video and still-frame cameras aboard each survey aircraft. The 2012 Shell aerial survey program was conducted over the nearshore areas in the Chukchi Sea and the offshore Burger Prospect Area, in addition to the Sivulliq Prospect Area in the Beaufort Sea. The high-definition photographic and video-monitoring equipment was used concurrently with PSO observations on flights in the nearshore Chukchi Sea and for all surveys in the Beaufort Sea. The aerial survey programs began in 2006 and were conducted in most years. No aerial program occurred

in 2009 or 2011 due to the reduced size of exploration programs in those years.

An acoustic monitoring program was implemented by Shell and other industry participants in the Alaskan Chukchi and Beaufort seas during 2012. As in previous years, the Chukchi Sea program included underwater passive acoustic monitoring of the nearshore and offshore areas between Pt. Hope and Barrow. These studies were conducted jointly by Shell, ConocoPhillips, Alaska, Inc. (CPAI) and Statoil in 2009–2012, by Shell and CPAI in 2007, 2008, and by Shell, CPAI and GX Technology (GXT) in 2006. Shell's acoustic program in the Beaufort Sea began with testing of recorders in 2006 followed by deployment of arrays of recorders at five sites from eastern Harrison Bay to near Kaktovik in 2007–2012. In addition to open-water season, industry has sponsored numerous overwinter acoustic monitoring programs. Acoustic recorders were deployed in the Chukchi Sea beginning in winter of 2007–2008, and again in each of the following winters through spring of 2013. A similar overwinter program was implemented in the Beaufort Sea beginning in 2011–2012 and again in the winter of 2012–2013.

Sound source characterizations, or SSCs, were conducted using dedicated arrays near each drill site to capture the acoustic properties of vessels, drilling, and related support activities. A SSC was also conducted to measure and characterize vessel and seismic sounds produced during ION's seismic survey in 2012. Preliminary SSC and marine mammal monitoring and mitigation reports from Shell's and ION's 2012 US Arctic offshore exploration programs were reported in 90-Day Reports to the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) by Bisson et al. (2013) and Beland et al. (2013), respectively.

In addition to offshore oil and gas exploration activities conducted by Shell and ION in 2012, other known industry and human activities that occurred in the Chukchi and Beaufort seas are summarized in Chapters 2 and 3. These other activities included barging and vessel traffic related to commerce, a wide range of other industry and agency research, onshore oil and gas activities, tourism, and law enforcement; nearshore oil production operations; BP's ocean bottom cable (OBC) seismic program in nearshore waters of Simpson Lagoon in the Beaufort Sea; and subsistence whaling. A preliminary attempt has been made to summarize available Automatic Identification System (AIS) data from all vessels equipped with this tracking system in the Chukchi and Beaufort seas in 2012.

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 potential impacts on marine mammals in the Chukchi and Beaufort seas during 2012. As part of this integration, comparison of results from 2012 were made with monitoring data collected in 2006–2011, when appropriate, to allow a more comprehensive analysis of marine mammal distribution and potential reaction to various industry activities and underwater sounds. Agency-sponsored and other research are referenced in results and discussions where appropriate. Interested readers are encouraged to obtain the reports from those programs for details of each study.

It is noteworthy that differences in the extent of sea ice among years likely resulted in observable differences in the distribution and behavior of some marine mammals, particularly Pacific walruses (*Odobenus rosmarus divergens*), polar bears (*Ursus maritimus*), ice seals, and other species that are closely associated with ice. Pacific walruses were generally observed swimming in open water offshore or were associated with pack ice in 2006, 2008, and 2012. Similar observations of walruses were also made in 2007 when summer ice retreated north of the Chukchi Sea, however thousands of walruses were also observed hauled out on land along the Chukchi Sea coast between Pt. Hope and Barrow. Pacific walrus use of terrestrial haulouts occurred again in 2009, 2010 and 2011. There were more vessel-based polar bear sightings in 2012 than in previous years likely due to the close proximity of ice to exploratory drilling and related support activities compared to marine survey programs from 2006–2011 when vessels

operated at greater distances from the main ice edge. Observations of bowhead whales during aerial surveys in 2006–2008, 2010, and 2012 suggested a possible increase in bowhead feeding behavior over that observed in previous years in the central and eastern Alaskan Beaufort Sea. Factors likely contributing to differences in marine mammal distributions or activities from 2006 through 2012, both natural and industry-related, are discussed in detail in the various results chapters of this report.

This report focuses primarily on the potential impacts to marine mammals from underwater sounds associated with various industry activities and related vessel traffic during 2012. This and previous reports represent the establishment of 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.

## *Report Objectives, Scope, and Assumptions*

The primary objectives of this report are to honor regulatory obligations and improve the understanding of effects from offshore oil and gas exploration activities in the Alaskan Arctic Outer Continental Shelf (OCS) on marine mammals. Specifically, the report objectives as outlined in NMFS IHAs issued to offshore operators are to:

- deliver a comprehensive report describing vessel, aerial, and acoustic monitoring programs associated with offshore oil and gas exploration activities during 2012;
- describe the methods, results, conclusions, and limitations of each of the individual data sets; and,
- integrate monitoring studies into a broad-based assessment of all industry activities and their potential impacts on marine mammals and related subsistence activities in the Arctic Ocean during 2012.

It is important to recognize the scale and diversity of monitoring programs currently being conducted in the Alaskan Arctic OCS. Monitoring in this region, both industry- and agency-sponsored, occurs on multiple levels from ecosystem based studies to programs focused on various trophic levels and studies of aspects of individual species behavior and ecology. Additional investigations are dedicated to physical oceanography, weather, ice, etc. It is also important to recognize the multitude of other anthropogenic activities occurring in the Alaskan Arctic OCS that are not related to oil and gas exploration, all of which have the potential to impact marine mammal distribution, abundance, and availability to subsistence hunters. Furthermore, Alaska Natives from coastal communities possess traditional ecological knowledge (TEK) pertaining to marine mammal distribution, behavior, and the physical environment that adds another layer to our understanding of the natural system. A truly comprehensive synthesis of all available scientific data and TEK would not be feasible within the timeline of this report. In preparing this report we worked under the following assumptions:

- emphasis on presentation of industry-sponsored monitoring and science related to effects of oil and gas exploration on marine mammals, with references to agency research;
- centralized focus on recent IHA-permitted activities in the Alaskan Arctic offshore;
- placement of new results in the context of current understanding;
- focus on potential direct (as opposed to indirect) effects, particularly those from underwater anthropogenic sounds, on marine mammals from recent IHA-authorized activities; this is not

a comprehensive cumulative effects analysis;

- 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;
- this report is intended to document all current monitoring programs in the Alaskan Arctic and is not intended as a complete retrospective of previous work in the Chukchi and Beaufort seas; and,
- information presented from studies conducted by other companies, organizations, or agencies was usually available in reports issued by those entities; those reports should be consulted for more detailed information and interpretation.

## *Report Organization*

This report provides background information pertaining to physical and ecological systems of the Chukchi and Beaufort seas, describes the various types of industry and other activities that occurred in the Chukchi and Beaufort seas during 2012, summarizes the results of industry studies in these areas, and provides an initial analysis of the effects of human activities on marine mammals in 2012 with comparisons to results from 2006–2011 when relevant and meaningful.

The report structure has been modified significantly from the previous five JMP reports where vessel, aerial, and acoustics programs were addressed separately within each sea. In an effort to minimize redundancy and integrate results from different data streams, each species or species group has a dedicated results chapter. There are 10 report chapters plus appendices as follows:

1. Introduction and Report Objectives
2. Background and Context
3. Description of Offshore Industry Activities and Monitoring in 2012
4. Acoustic Monitoring of Oil and Gas Industry Noise Sources
5. Marine Mammal Sightings by Analysts of Digital Imagery vs. Aerial Surveyors
6. Bowhead Whale Monitoring
7. Beluga, Gray Whale, and Other Cetacean Monitoring
8. Ice Seal Monitoring
9. Pacific Walrus Monitoring
10. Polar Bear Monitoring

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# 2. BACKGROUND AND CONTEXT

## *Introduction*

This chapter presents a wide range of background materials relevant to understanding potential effects of offshore oil and gas exploration on marine mammals of the Alaskan Arctic Outer Continental Shelf (OCS). Specifically, the following subjects are discussed as they relate to the Alaskan Arctic OCS: physical oceanography, sea ice, climate change, resident and migratory mammal species, the acoustic environment, and a history of oil and gas exploration and potential effects on marine mammals and subsistence activities. All of these topics are relevant to monitoring methodologies, results, and discussions found in subsequent chapter. None of the material presented here is intended to be an exhaustive survey of the literature available in these areas. Rather, it is meant to introduce the topics pertinent to the material presented in later chapters and to provide a framework in which the later chapters should be considered.

# PHYSICAL OCEANOGRAPHY OF THE ALASKAN CHUKCHI AND BEAUFORT SEAS

## *The Chukchi Sea*

The inflow of Pacific Ocean waters through the Bering Strait is transported across the Chukchi continental shelf and into the Arctic Ocean. While in transit across the Chukchi continental shelf, the temperature and salinity properties of the Pacific inflow are modified by heat exchange with the atmosphere, and in some places, with other water masses formed on and/or entering the Chukchi continental shelf (such as water transported by the Siberian Coastal Current). This flow of water does not proceed uniformly across the Chukchi continental shelf since this shelf is relatively shallow (40 m to 50 m deep [131 ft to 164 ft]), as shown in the map below. As will be discussed, the shelf bathymetry "guides" the flow and affects water property distributions.

The Chukchi continental shelf is bounded by the Alaskan coast on its east but is open to the East Siberian Sea north and, south of Wrangel Island, to the west (Fig. 2.1). The southern connection is through the 135 km (84 mi) wide and 45 m (148 ft) deep Long Strait, the area between Wrangel Island and the Siberian landmass, while the northern link is across the broad and gently sloping shelf. North of Bering Strait lays the 50 m (164 ft) deep Hope Valley, which broadens to the northwest and then narrows to form the entrance to Herald Valley, which lies to the east of Wrangel Island. This valley has a maximum depth of about 90 m (295 ft) and extends northward across the shelf to open onto the Chukchi continental slope. The Herald Shoal, in the center of the shelf, forms the northern flank of Hope Valley. The diameter of the shoal is about 100 km (62 mi) and minimum depths are about 20 m (66 ft).

FIGURE 2.1. The Chukchi Sea outer continental shelf and primary oceanographic features.

To the east of Herald Shoal is a relatively shallow north-south oriented depression termed the Central Channel, which opens onto the northern shelf. The Central Channel is bordered on its east by a relatively flat 40 m to 45 m (131 ft to 148 ft) deep plain. To the northeast of this plain lies Hanna Shoal, about 100 km (62 mi) long and 75 km (47 mi) wide, with minimum depths of about 25 m (82 ft). Barrow Canyon, which is parallel and close to the Alaskan coast, cuts into the northeast shelf. It begins offshore of Wainwright, extends 150 km (93 mi) to the northeast, and terminates on the continental slope (at about 72º N) in a water depth of 300 m (984 ft). It is 150 km (93 mi) long by approximately 50 km (31 mi) wide with the steeper wall adjacent to the coast. Bottom depths increase smoothly along its length, with depths of 150 m (492 ft) encountered within 25 km (16 mi) of Barrow.

Chukchi continental shelf circulation is primarily driven by water flowing "downhill" from the higher sea level in the Pacific Ocean to the lower sea level in the Arctic Ocean; this northward flow is against the predominant northeast surface winds that tend to force water flow to the southwest (Fig. 2.2). Multiple past investigations now demonstrate that this flow occurs along three main branches – each associated with a particular bathymetric feature. The first branch is composed of flows northward through the Bering Strait; the two water masses (Anadyr Water and Bering Sea Water) mix laterally as they approach southern Hope Valley. The mixture continues northwestward through Hope Valley. Some of this water escapes westward from Hope Valley and into the East Siberian Sea, but most of it enters Herald Valley. While most of this outflow continues to the shelfbreak, some of it may spread onto the shelf north of Herald Shoal and drift eastward toward the central shelf.

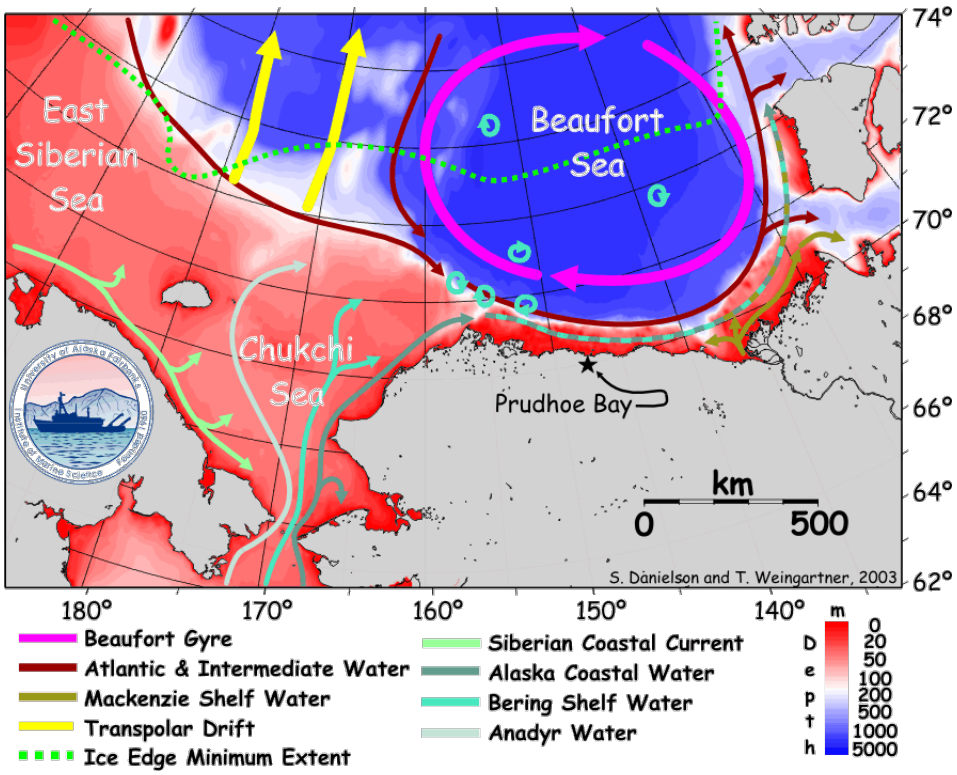


FIGURE 2.2. Summary of the circulation and water masses in the Chukchi and Beaufort Seas. Credit: T. Weingartner, University of Alaska Fairbanks

The second branch flows northeastward along the Alaskan coast towards Barrow Canyon. In the summer, this flow includes the northward extension of the low-salinity and nutrient poor Alaskan Coastal Current flowing through the Bering Strait. The Alaskan Coastal Current begins in British Columbia, Canada and southeastern Alaska as freshwater runoff discharges into the sea. Due to the Earth's rotation, this discharge is forced west and north traveling along Alaska's coast through the Gulf of Alaska, Bering Sea and eventually into the Chukchi and Beaufort Seas. The current maintains its low salinity, warmth, and nutrient-poor characteristics as more and more freshwater river discharges are incorporated. The current also resists mixing with the surrounding seawater. At Barrow Canyon, the Alaskan Coastal Current merges with waters flowing eastward from the central shelf while proceeding down the Canyon toward the shelfbreak.

A third branch, of moderate salinity and nutrient load, flows northward through the Central Channel. Some of this water moves eastward along the south side of Hanna Shoal and eventually enters Barrow Canyon, while another fraction continues northward toward the outer shelf west of Hanna Shoal.

Mean current speeds within Herald Valley and Barrow Canyon are swift (approximately 25 centimeters per second [cm/s]), more moderate in the Central Channel (approximately 10 cm/s), and generally less than 10 cm/s elsewhere on the shelf. The Hanna and Herald Shoals effectively block the flow so that circulation atop these shoals is relatively weak. The magnitude of long-term transport for these three pathways is not precisely known, but it is currently estimated that of the 800,000 $m^3/s$ transported on average through the Bering Strait, about 200,000 $m^3/s$ flows through the Central Channel while the Herald Valley and Barrow Canyon branches each carry about 300,000 $m^3/s$.

The topographic features strongly affect the flow of waters across the shelf, but also strongly affect the patterns of summer ice retreat. They do so by funneling the bulk of the warm Pacific Ocean water into the valleys and channels. Consequently, summer ice retreat does not proceed uniformly from south to north, but instead retreats faster within the channels than over the shoals (Fig. 2.3). This typically results in three north-south oriented "melt-back embayments" that develop over the shelf in the summer (Paquette and Bourke 1981). The annual recurrence of these embayments was well-known to 19th century New England whalers who rendezvoused with companion vessels in the embayments before sailing northward onto the whaling grounds each summer (Bockstoce 1986).

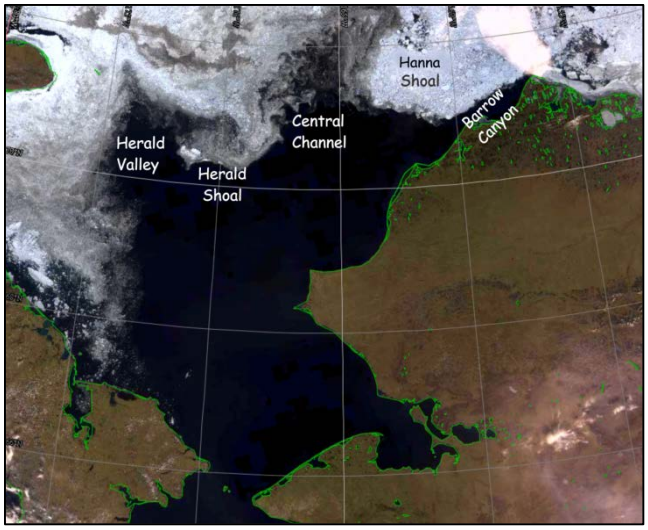


FIGURE 2.3. A 29 June 2004 MODIS image illustrating the meltback embayments in Herald Valley, the Central Channel, and Barrow Canyon. Ice persists over Herald and Hanna Shoal. *Credit: T. Weingartner, University of Alaska Fairbanks*

There are four other distinct water masses that form seasonally or intrude occasionally on the Chukchi continental shelf. These are the 1) Siberian Coastal Current, 2) sea ice meltwater pools, 3) upwelled continental slope waters, and 4) water masses that originate as a result of the formation of recurring polynyas.

The first of these are the waters associated with the Siberian Coastal Current. This current originates in the East Siberian Sea and flows southeastward, at least in summer, along the Siberian coast and enters the Chukchi Sea through Long Strait (shoreward of Wrangel Island). This current consists of cold, low-salinity, and nutrient-poor waters formed from Siberian river runoff and ice melt. It is generally confined to within approximately 60 km (37 mi) of the Siberian coast and bounded on its offshore side by an oceanic front (Weingartner et al. 1999) along which bowhead whales forage in fall (Moore et al. 1995). This front is unstable. It meanders and forms eddies that detach from the coast and propagate into Hope Valley. Thus the current looses mass and narrows as it nears the Bering Strait. Upon encountering the northward flow from the Strait, the Siberian Coastal Current breaks up and mixes with Strait waters. The mixture is likely transported through Herald Valley, but some may also spread onto the central shelf. The Siberian Coastal Current appears to be a seasonal feature; diminishing markedly or ceasing altogether as river discharge from Russia subsides with freeze up. It is also susceptible to summer winds over the

Chukchi and East Siberian shelves and, in some years, may not even enter the Chukchi continental shelf (Münchow et al. 1998).

The second water mass consists of the meltwaters produced as sea ice melts and/or retreats across the shelf from summer through fall. These are relatively cold but low-salinity waters, having much lower density than the cold, saline deeper waters remaining from winter or the relatively warm Pacific waters transported northward from Bering Strait in the summer. Meltwater masses form 10 to 20 m (33 to 66 ft) thick, heavily stratified pools that are separated from ambient shelf waters by 10 to 20 km (6 to 12 mi) wide fronts. These pools and fronts are prominent along the perimeter of the ice edge. They may remain at both Hanna and Herald Shoals for several weeks after ice has disappeared due to the relatively weak circulation atop the shoals. The weak circulation atop the shoals also results in greater amounts of ungrazed plankton material falling onto the shoal and surrounding area, which in turn supports an abundance of clams and other benthic organisms. Not surprisingly, the residual sea ice that persists in the vicinity of Hanna Shoal is used by Pacific walrus to haulout while feeding on the rich benthic fauna present in the vicinity of Hanna Shoal.

The third water mass consists of upwelled continental slope waters that occasionally intrude onto the northeast Chukchi continental shelf through Barrow Canyon. These are upwelled into the Canyon from depths of 150 m (492 ft) or greater most frequently in fall and winter during strong northeasterly wind events. On occasion, the upwelled slope water includes deep (approximately 250 m [820 ft]) relatively warm, salty water whose original source was the Atlantic Ocean. Typically, these upwelling events last a few days before the upwelled water drains back down the Canyon. Most of these events are confined to the Canyon proper, but on occasion continental slope water reaches the head of the Canyon and spills onto the Chukchi shelf.

The fourth distinct water mass originates as a result of the formation of recurring polynyas (Fig. 2.4). Polynyas are open water areas surrounded by sea ice that form under freezing atmospheric conditions. In the Bering and Chukchi Seas, coastal polynyas form episodically throughout winter in the lee of coasts. The largest and most frequently formed polynyas develop in the Chukchi Sea along the northwest coast of Alaska during winter episodes of cold, offshore winds, and, in the Bering Sea, within the Gulf of Anadyr and south of St. Lawrence Island under southward winds (Cavalieri and Martin 1994). The winds displace sea ice offshore, exposing seawater to heat loss to the atmosphere. The cold, saline waters formed within polynyas contribute significantly to the volume of winter waters formed on both the Bering and Chukchi shelves. Bering Sea polynyas are wildlife hot spots for whales that can come up for air, reliably, in the polynya and marine birds that feed on plankton that can bloom because the ice is thin or absent.

Since the seawater is already at the freezing point, cooling also results in rapid formation of new ice, which is continuously swept downwind by the wind so that the polynya remains open. Once the winds weaken sufficiently or reverse direction, the polynya freezes over. Although large volumes of ice can be produced in polynya, their development is episodic since it depends upon large-scale weather systems. The salinity (and density) of the waters within the polynya increases swiftly because salt is rapidly expelled from newly forming ice crystals.

FIGURE 2.4. Radarsat synthetic aperture radar image of recurring lead systems and coastal polynyas off the coast of northern Alaska in the Chukchi Sea between Wainwright and Barrow. Credit: Geographic Information Network of Alaska, University of Alaska Fairbanks.

Consequently, a front develops around the polynya that separates shelf and polynya waters. This front eventually becomes unstable forming thin (approximately 25 m [82 ft]) bottom-confined eddies that propagate across the shelf (Gawarakiewicz et al. 1998) or are swept away by the ambient currents (Danielson et al. 2006). Although, in principle, polynya waters are dense enough to descend to great depths within the Arctic Ocean (Aagaard et al. 1985), it seems most likely that mixing with ambient shelf waters diminishes their density as they move across the Bering and Chukchi Seas.

Due to the orientation of the coast and the prevalence of southward, onshore winds, polynya formation on the Alaskan Beaufort Sea is relatively rare. There are, however, occasional northward wind events that lead to openings within or offshore of the landfast ice that are conducive to the formation of cold, saline waters.

Although the annual temperature and salinity cycles between the Chukchi Sea and Bering Strait are very similar, near bottom waters on the Chukchi continental shelf remain saline and close to the freezing point longer than those in Bering Strait. In part, this is due to the longer freezing season, but it also reflects the time required for cold, saline deep waters moving northward from the Bering Sea to traverse the Chukchi continental shelf. Moreover, winter waters are replaced much more slowly around the shoal regions than along the main flow pathways. Nevertheless, Chukchi waters are eventually flushed from the shelf and enter the Arctic Basin and/or into the Alaskan Beaufort Sea (Fig. 2.5).

The low-density Chukchi summer waters enter the upper 50 m (164 ft) of the Arctic Ocean basin, whereas denser winter waters typically descend to 100 to 200 m (328 to 656 ft) depth upon exiting the Chukchi continental shelf. Here they contribute to the maintenance of the Arctic Ocean's halocline, a salt-stratified layer that separates the fresh, cold surface waters from relatively warm and salty deeper waters originally derived from the Atlantic Ocean.

In summary, circulation in the Chukchi Sea is controlled largely by the opposing tendencies between the pressure gradient that forces water northward though the Bering Strait and across the Chukchi continental shelf and the predominant wind systems that force water southward. The location of various branches of this northward flow of water is primarily due to the shelf topographic features such as the Central Channel and Hanna Shoal.

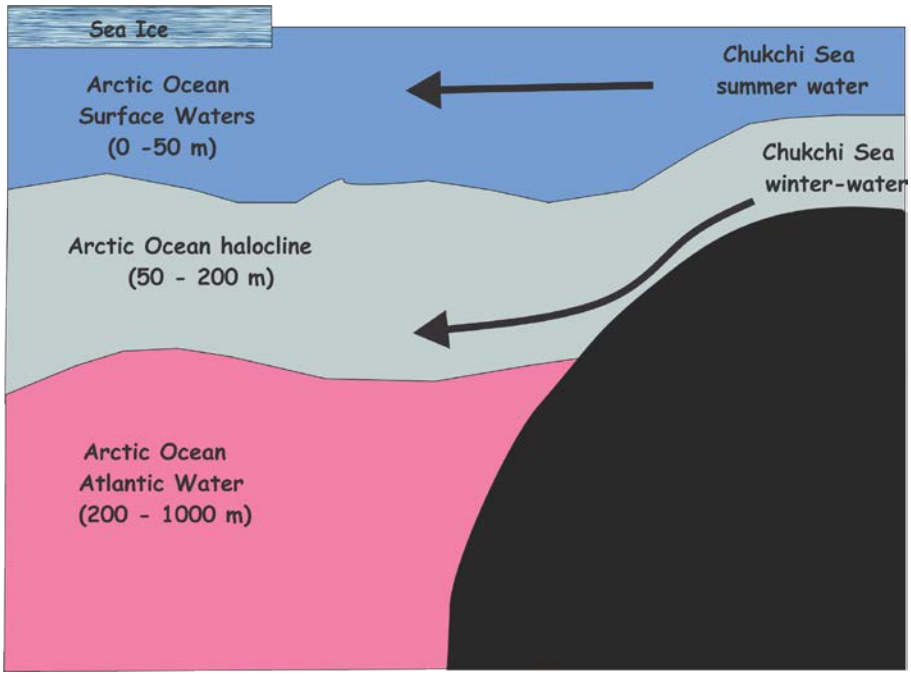


FIGURE 2.5. Schematic drawing of the flushing from the shelf and entry into the deep Arctic Basin. Credit: T. Weingartner, University of Alaska, Fairbanks.

## *The Alaskan Beaufort Sea*

The oceanographic characteristics of the Alaskan Beaufort continental shelf differ substantially from those of the Chukchi for several reasons. These reasons include the Alaskan Beaufort continental shelf's much smaller size, the comparatively smaller and less direct impact of the Pacific inflow through the Bering Strait, the more extensive sea-ice distribution, and the influence of certain oceanic and coastal boundaries. These attributes lead to a substantially different pattern of shelf circulation and water mass properties.

The oceanic boundaries consist of the eastern boundary which adjoins the Mackenzie portion of the Alaskan Beaufort Sea, the western boundary, which connects to the Chukchi continental shelf, and the offshore boundary along the shelfbreak and slope, which controls exchanges between the basin and the shelf proper. The coastal boundary connects the inner shelf to the coastal discharge from North Slope rivers. Exchanges across these boundaries are modulated by the winds, topography, and the annual cycle of freezing and thawing.

Sea ice can cover the Beaufort continental shelf year-round. Typically, the inner shelf, inshore of the 20 m (66 ft) depth contour is ice-free during the summer months. In recent years, however, the entire shelf has been ice-free. The shelf sea ice regime consists of landfast and drifting pack ice. Landfast ice is anchored to the seafloor along the 2 m (7 ft) depth contour (Reimnitz 2000) and begins to form along the coast in October. It typically encompasses about 25% of the shelf area once it has expanded out to about the 20 m (66 ft) depth contour some 20–40 km (12–25 mi) offshore (Reimnitz and Kempema 1984; Macdonald and Carmack 1991; Mahoney et al. 2007). Although the landfast ice zone expands and contracts episodically throughout winter due to wind events, it is virtually immobile once established and remains so until melting occurs in the following summer.

Near the coast, landfast ice is relatively smooth, but it is increasingly deformed offshore due to collisions with pack ice driven by onshore winds from the northeast (Fig. 2.6). The collisions deform the landfast ice edge creating pressure ridges (and grounded ice keels) whose frequency of occurrence and height increases seaward and through winter (Tucker III et al. 1979). The keels can gouge the seafloor (Barnes et al. 1984) and form piles of grounded ice, or stamukhi, along the seaward boundary of the landfast ice. The stamukhi protects the inner shelf (and landfast ice) from pack ice forces (Reimnitz and Kempema 1984) and inhibits exchange between nearshore waters and offshore waters (Macdonald and Carmack 1991) for much of the year.

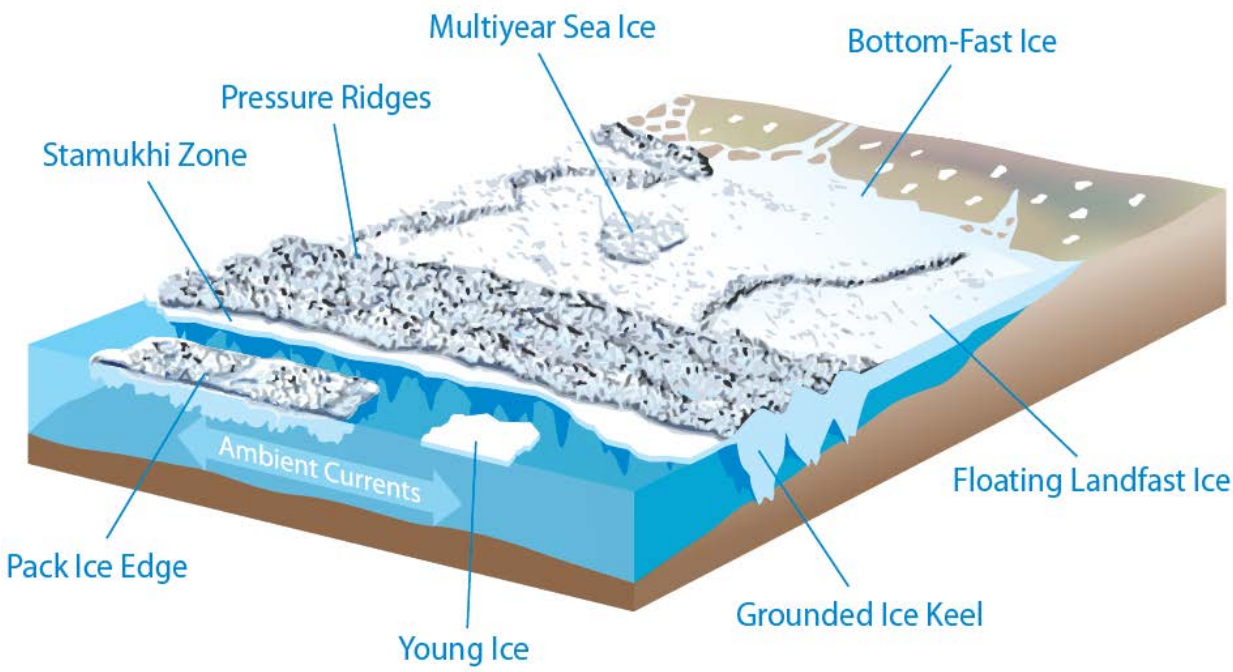


FIGURE 2.6. Conceptual diagram of important sea ice features. Modified from George et al. (2004).

Even in the absence of an extensive stamukhi zone, modeling studies indicate that exchange between the nearshore and offshore waters is reduced in the presence of landfast ice (Kaspar 2010). The near immobility of the landfast ice prevents the direct effects of the wind on the ocean beneath the landfast ice. Consequently, current speeds beneath the landfast ice are weak (less than 5 cm/s) throughout winter and bear no statistically significant relationship with the wind or offshore currents (Kaspar 2010; Weingartner et al. 2009). In contrast, shelf currents seaward of the landfast ice edge and over the slope can be swift (approximately 25 to 100 cm/s) and generally vary with the winds (Aagaard 1984; Pickart et al. 2011).

The western boundary of the Alaskan Beaufort Sea is influenced by the outflow of Chukchi continental shelf waters through Barrow Canyon. In summer and early fall, these include the relatively fresh and warm Alaskan Coastal Water overlying and/or adjacent to the very cold (near-freezing) salty winter-formed waters from the Chukchi Sea (Fig. 2.7). In the winter and spring, the flow consists mainly of winter-formed waters. The outflow encounters various fates, depending upon the winds, the density structure of both the outflow and the receiving waters along the continental slope, and the sea ice extent.

Most of the outflow is constrained by seafloor topography and thus follows the eastern wall of the Canyon before entering the basin. Of the fraction that reaches the mouth of the Canyon, some continues eastward along the Alaskan Beaufort shelfbreak and slope (Aagaard 1984) to form the offshore boundary of the shelf. Some of the Canyon outflow is entrained into surface and subsurface eddies generated near the Canyon mouth along the slope. The subsurface eddies eventually detach from the slope and propagate into the interior of the Arctic Ocean where they may survive intact for several years (Manley and Hunkins 1985; D'Asaro 1988; Plueddemann et al. 1998). Alternatively, when westward winds are particularly strong, some of the Canyon outflow is swept off to the west (Shimada et al. 2001; Shimada et al. 2006). Finally, if westward winds are weak, some of the outflow can turn eastward around Pt. Barrow and bathe the inner and mid-shelf portions of the Alaskan Beaufort continental shelf (Okkonen et al. 2009). How far to the east this intrusion extends depends upon the winds. Recent circulation model results suggest that, in the winter, eastward spreading of Chukchi water on the inner shelf of the Alaskan Beaufort Sea is limited by the landfast ice and unlikely to extend more than 100 km (62 mi) to the east of Barrow Canyon (Kaspar 2010). Model calculations suggest that this water is instead deflected offshore of the landfast ice edge where it will move in response to the winds.

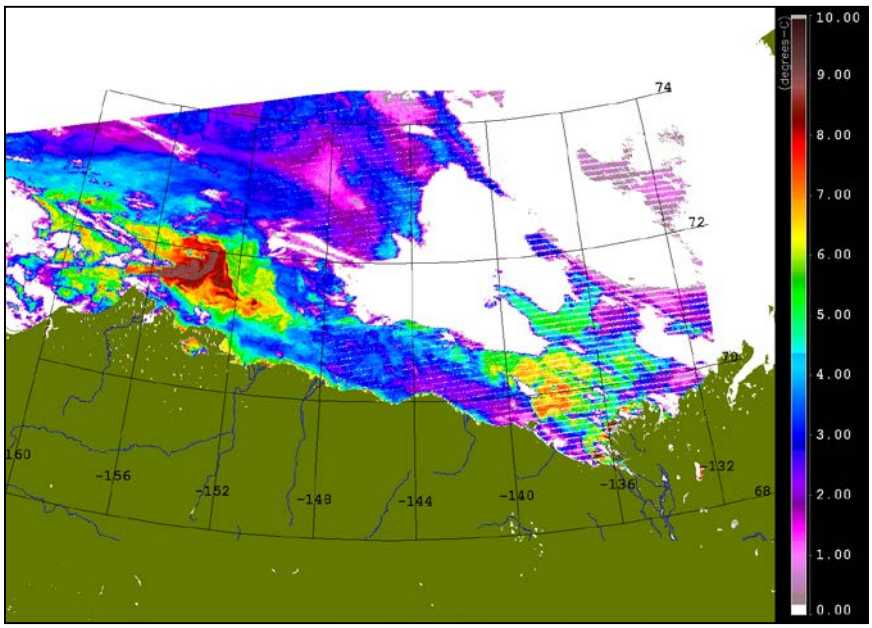


FIGURE 2.7. 11 September 2007 MODIS Sea Surface Temperature image of the Alaska Beaufort continental shelf, showing spreading of warm Alaskan Coastal Water onto the shelf and slope north and east of Barrow. The relatively warm water in the eastern Beaufort Sea likely reflects remnants of the Mackenzie River plume. Image Credit: NASA/Goddard Space Flight Center and Orbimage.

The eastern boundary is influenced by westward wind-driven transport of Mackenzie River plume waters from the Mackenzie Beaufort shelf. In summer, the river outflow forms a broad (greater than 80 km [50 mi]), thin (approximately 10 m [33 ft]), warm, low-salinity plume overriding a strongly stratified layer of subsurface cold, salty winter-formed waters. The plume remains intact because its strong stratification resists vertical mixing by the winds. Thermal infrared satellite imagery suggests that in the summer and fall, the plume is deflected seaward over the Mackenzie Canyon and moves westward along

the shelfbreak and slope of the Alaskan Beaufort Sea. As the plume spreads westward, the lateral front of the plume sheds eddies, gradually reducing the volume. Some of the plume almost certainly spreads directly onto the Alaskan Beaufort continental shelf since fall measurements show a thin, fresh, heavily stratified layer extending across the eastern portion of the shelf (Aagaard 1984).

The lateral inflows from the Mackenzie Shelf and the Chukchi Sea establish the patterns of sea ice decay and retreat over the Alaskan Beaufort Sea. Ice begins retreating at the eastern and western boundaries of the shelf in late May, coincident with the arrival of warmer waters from the Bering Sea and the relatively warm Mackenzie plume, respectively (Fig. 2.8). As the sea ice erodes and retreats the surface albedo of the exposed water and rotting ice decreases, enhancing the absorption of sunlight and accelerating ocean heating and ice melt. By contrast, sea ice over the central Alaskan Beaufort continental shelf melts and detaches from the coast several weeks after the lateral boundaries of the shelf become ice free.

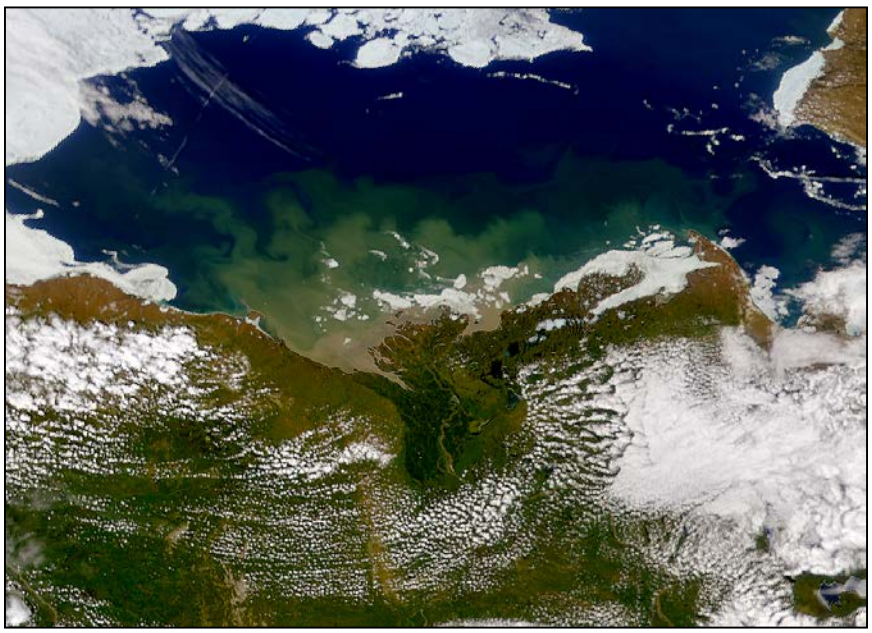

FIGURE 2.8. The plume from the Mackenzie River in northern Canada is quite visible in this image. Credit: NASA Visible Earth.

The offshore boundary of the Alaskan Beaufort continental shelf extends along the shelfbreak and upper continental slope. The flow here consists of the narrow shelfbreak current (approximately 15 km wide [9 mi]) that, in the absence of significant westward winds, carries Bering Sea waters eastward (Aagaard and Roach 1990; Nikolopoulos et al. 2009). The flow includes the outflow from Barrow Canyon and possibly also water flowing from as far west as the mouth of Herald Valley. From fall through spring, the shelfbreak current is a subsurface feature, flowing eastward at 10 to 15 cm/s, at depths between 50 m (164 ft) and 180 m (591 ft) with its core at about 80 m (262 ft). Shallower waters flow westward and consist of the southern limb of the clockwise rotating Beaufort Gyre. In the summer, however, the shallower current is surface-intensified, and can be characterized as a jet, with maximum eastward speeds of more than 20 cm/s. An important aspect of this current is that it dynamically links the Beaufort continental shelf with the considerably deeper Canada Basin.

The shelfbreak current is highly variable in time and tends to be unstable, although its stability depends on the density structure of the water and surface wind stress. In other words, it is a very "leaky" boundary. First, it may generate eddies that exchange mass and momentum across the shelfbreak. Different eddy structures may form with some rotating clockwise, carrying relatively warm waters and being surface intensified and others rotating counterclockwise, with cold, sub-surface interiors (Fig. 2.9). The shelfbreak circulation is sensitive to the surface winds and its velocity and density structure can change drastically and rapidly. Storm winds from the west will accelerate the shelfbreak jet eastward and move surface water from the basin onto the shelf and downwell shelf water into the basin near the bottom. In contrast, strong winds from the east can weaken or even reverse the shelfbreak jet and induce upwelling (Pickart 2004). In this case, basin waters are carried inshore along the bottom of the outer shelf from depths of as much as 200 m (656 ft) while surface waters are simultaneously expelled offshore.

The coastal boundary is largely in effect during the summer months and includes the direct effects of the 2-week period of maximum river discharge in June and the indirect and long-lasting effects that the discharge has over the inner shelf through the summer. During the initial increase in discharge, river waters flow over the top of the landfast ice, decreasing the surface albedo and accelerating ice melt along the 2-m "ice anchored" depth contour. The spreading overflow gradually percolates through the ice and into the ocean where it forms a thin (1 to 2 m thick [3 to 7 ft]) under-ice plume of nearly fresh water that overrides cold and salty water formed in the winter (Mahoney et al. 2007). Vertical mixing between the plume and ambient shelf waters is impeded since tidal currents are weak and the landfast ice prevents wind mixing. Meltwaters from the ice also add to the plume and enhance the stratification. The plume spreads seaward with speeds of nearly 10 cm/s (Mahoney et al. 2007); speeds much greater than the current speeds typical of the landfast ice zone. By late June or early July, the landfast ice detaches from the coast and begins to drift in response to the winds. At this point, wind mixing can begin to erode the plume stratification. This takes time, however, and the inner shelf remains heavily stratified into August due to the cumulative freshening by numerous Arctic rivers and melting ice. This process varies from year-to-year because the breakdown of stratification on the inner shelf depends upon the magnitude and the direction of the winds for any given summer season.

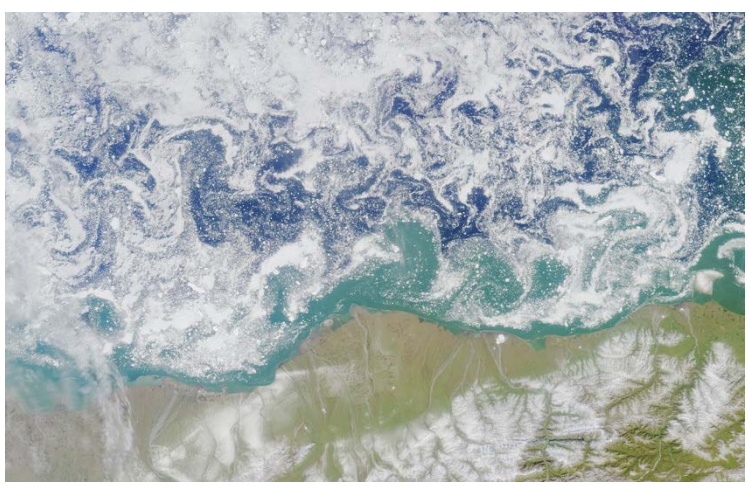

FIGURE 2.9. The swirling patterns apparent on the Beaufort Sea are small ice floes driven by turbulent water patterns, or eddies, caused by the interactions of water masses of differing salinity and temperature. Credit: NASA/GSFC/Jet Propulsion Laboratory.

Eastward winds cause coastal downwelling, which traps the plume near to the coast and transports water to the east. It also generates a cross-shelf flow that causes low-density plume water to move seaward along the bottom and denser offshore water to move onshore at the surface. As the less dense water flows beneath denser water vigorous vertical mixing occurs and the stratification rapidly erodes. Westward winds generate westward transport and coastal upwelling. In this case, warm, low-salinity (and low density) plume waters move offshore at the surface and cold, high salinity waters move onshore along the bottom. While plume stratification weakens under upwelling winds, the rate of erosion is much slower than for downwelling winds.

On the stratified inner shelf of the Alaskan Beaufort Sea, a westward or upwelling favorable wind causes a westward transport (i.e., the total amount of water moving between the surface and bottom) that is surface intensified and strongly sheared. In contrast, an eastward or downwelling-favorable wind of the same speed causes an eastward transport of the same magnitude. However, surface current speeds and the shear will be smaller because stratification under eastward winds is weak.

Wind-driven current speeds on the inner part of the Alaskan Beaufort continental shelf can be quite variable and while these are typically about 20 cm/s, speeds of approximately 100 cm/s have been observed during strong wind events. Energetic fall winds are particularly effective in generating along-shore transport. For example, T. Weingartner and his colleagues estimate that nearly the entire volume of the Alaskan Beaufort Sea, within 50 km (31 mi) of the coast, was flushed in a 1-month period between late September and late October of 2006 (Mahoney et al. 2007).

The stratification of the water column weakens through fall because of the cumulative effects of the winds through the summer, the increase in wind strength, and the reduction in river discharge. By October, regardless of the direction of the winds, stratification is almost nonexistent and currents over most of the shelf become nearly uniform with depth.

As with the Bering Strait and the Chukchi Sea, the water mass properties of the Alaskan Beaufort Sea undergo a pronounced annual cycle. By mid-fall, ocean temperatures begin to decrease rapidly due to atmospheric cooling. Ice begins to form once shelf waters reach the freezing point, initially inshore and somewhat later offshore. Throughout winter the shelf consists of nearly homogenous saline waters at the freezing point. Water temperatures remain at the freezing point until breakup begins the following summer. Interestingly, bottom temperatures over the middle and outer shelf may also remain close to the freezing point throughout the summer. In late fall, shelf salinities increase rapidly, and then more gradually through the winter, due to the expulsion of salt from growing sea ice.

In summary, circulation in the Beaufort Sea is controlled largely by the winds that force upwelling, downwelling, and cross-shelf transport, depending on the direction, strength, and duration of the winds. In the summer, the water property distribution can be quite complex reflecting the effects of ice melt and solar heating, but also water remnant from winter and the various contributions from the Chukchi Sea, Mackenzie Shelf, coastal freshwater discharge, and exchanges across the shelfbreak. Mixtures of these various source waters are also present, depending upon the integrated effects of wind mixing and the wind-forced circulation.

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# SEA ICE IN THE ARCTIC

## *Introduction*

The Arctic is set apart from lower latitude systems by its strong seasonality, overall cold temperatures, and the presence of vast shelf seas situated around a deep ocean basin (Kovacs et al. 2010). However, the most significant characteristic of the Arctic is a sea-ice cover that varies in thickness and spatial extent (Polyak et al. 2010). Numerous species of marine mammals are inherently connected to this sea ice, as are the lifestyles and subsistence practices of indigenous Arctic cultures. The relationships between Arctic sea ice, marine mammals, and local cultures evolved over millennia. Given these strong and intricate ties, it would be impossible to accurately interpret the results of this report without at least considering the potential influence of sea ice, or its absence.

Since the first polar ice coverage satellite data were collected in 1979, records have shown the overall density and extent of Arctic sea ice have been decreasing (Stroeve et al. 2008). The minimum ice extent in 2012 was 3.4 million km$^2$ (1.32 million mi$^2$), which was only half of the average annual sea-ice minimum for 1979–2000 and is the lowest minimum ice extent since data collection began in 1979 (Fig. 2.10). The six lowest Arctic sea-ice minimums in the satellite record occurred during the last six years (2007–2012; Fig. 2.11). Some recent climate simulations suggest that the Arctic Ocean may become seasonally ice-free as soon as 2040 (Holland et al. 2006; Wang and Overland 2009).

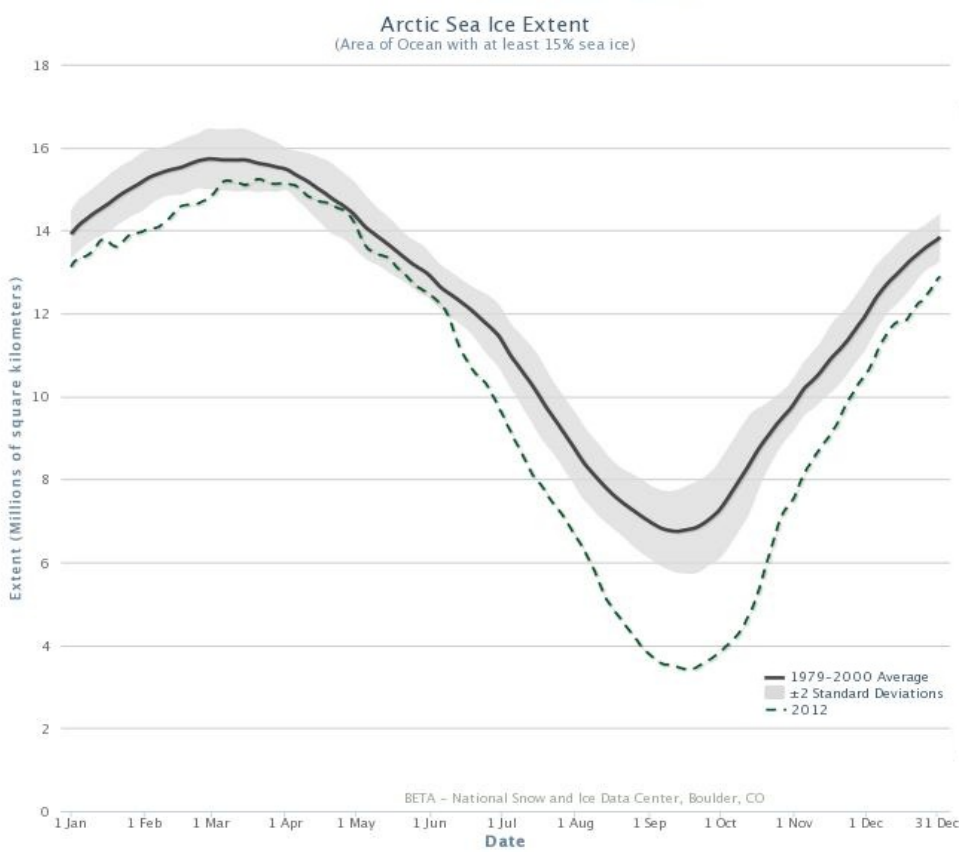


FIGURE 2.10. Arctic sea ice extent comparing the long-term mean (1979–2000), with the record low sea ice extent experienced in 2012. Credit: National Snow and Ice Data Center, Boulder, CO.

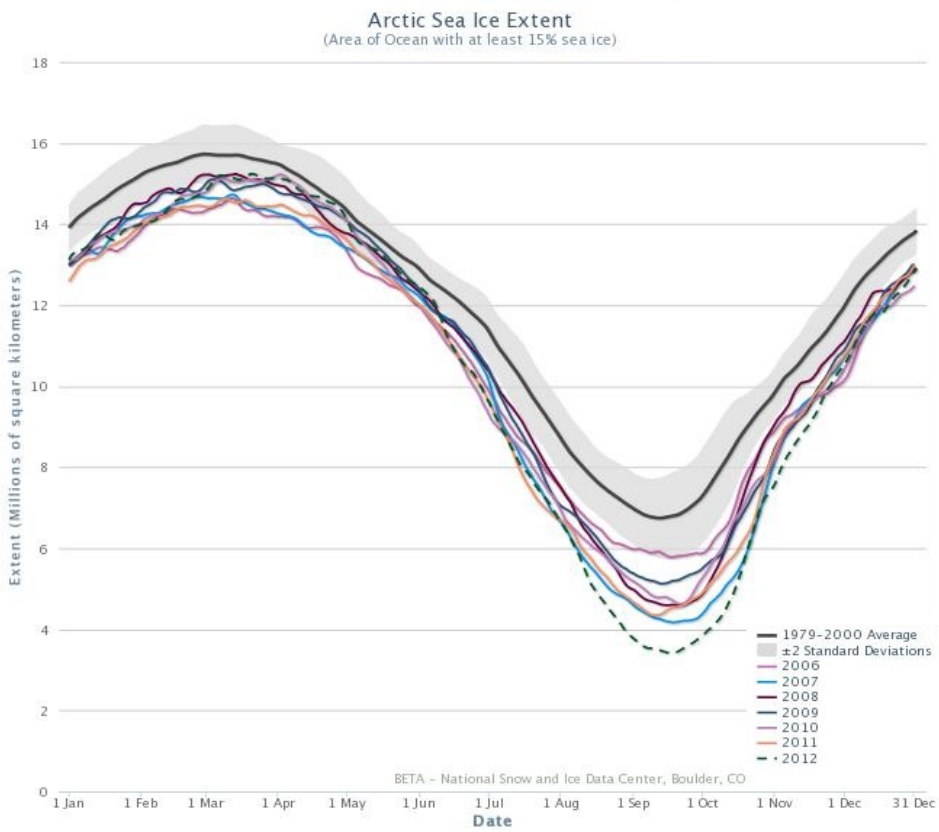


FIGURE 2.11. Arctic sea ice extent comparing the long-term mean 1979–2000), with Arctic sea-ice extent 2006–2012. Credit: National Snow and Ice Data Center, Boulder, CO.

Sea ice is important to the Arctic ecosystem and also to the global climate. It provides global temperature moderation through its high solar reflectivity. Less ice cover allows greater absorption of solar radiation in the Arctic Ocean and is correlated with trends in higher global temperatures (Polyak et al. 2010). Sea ice also influences global climate patterns by maintaining the cold and warm currents that exchange water between equatorial zones and the Arctic. Further, it helps moderate high-energy wave systems. As sea ice cover decreases, increased coastal erosion is likely in some areas and evidence of this has already begun to accumulate (Jones et al. 2009). The loss of sea ice is associated with a number of positive climate feedback loops, which appear to amplify climate change in the Arctic and may eventually alter the habitat on which numerous species depend, including marine mammals.

Wide seasonal variation in sea ice cover is driven by Arctic-wide seasonal variations in temperature, and atmospheric and oceanographic processes. Arctic sea ice extent is at its greatest in March when it begins melting. The melt extends through the warmer summer months reaching the annual Arctic sea ice minimum in September prior to the return of subfreezing temperatures in autumn when it begins to reform. Figure 2.12 illustrates the annual temporal and spatial variations of Arctic sea ice. This annual temporal and spatial variation in Arctic sea ice-cover influences the distribution of ice-associated marine mammals and also the related subsistence activities of Alaska Natives.

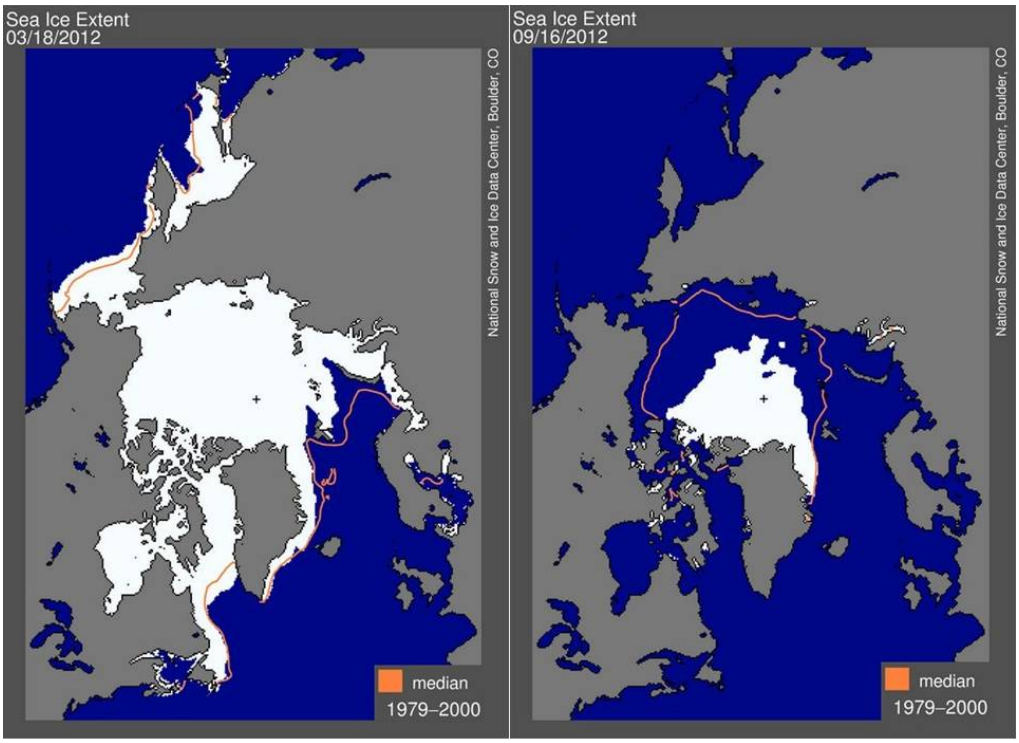


FIGURE 2.12. Arctic sea ice extent (millions of km$^2$) comparing the long-term mean (1979–2000) with the record low experienced in 2012. Source: National Snow and Ice Data Center, Boulder, CO.

## *Marine Mammals and Sea Ice in the Chukchi and Beaufort Seas Study Areas*

Marine mammal species using the Chukchi and Beaufort seas regularly interact with, and in some cases depend on sea ice during all or part of their life histories. The spatial and temporal variability in sea-ice cover and other aspects of the environment drive large-scale movements of many of the marine mammal species that inhabit the Arctic. These movements lead to wide seasonal variation in habitat use and marine mammal abundance in particular areas, and to a large degree determine the timing and success of subsistence hunts of these resources by Alaska Natives in the area (George et al. 2004). For example, the location of the bowhead whale fall migration corridor has been shown to be influenced by the amount of ice that is present in the Beaufort Sea (Treacy et al. 2006), which in turn can affect the subsistence hunt.

The absence of sea ice can be just as influential on the distribution of marine mammals in the Arctic as the presence of ice. Species such as gray whale (*Eschrichtius robustus*) that occur in the Arctic offshore project area but inhabit waters that are predominately sea-ice free may occur more commonly at higher latitudes in the future as sea ice continues to recede during the open-water season. Four other whale species that fall into this group include fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), minke (*Balaenoptera acutorostrata*), and killer (*Orcinus orca*) whales (Moore and Huntington 2008). Additional details on the abundance, distribution, and relationship to sea ice for species likely to be found in the project area can be found below in, *Marine Mammals of the Chukchi and Beaufort seas*.

Results from marine mammal monitoring programs need to be considered within the context of ice when assessing potential impacts from offshore oil and gas exploration activities, particularly for localized abundance estimates and related analyses. For example, acoustic and aerial monitoring of a shallow hazards seismic survey in the Beaufort Sea during 2010 suggested that ice had a greater impact on bowhead whale distribution than did other measured variables, including survey activities (Funk et al. 2011). It is also important to consider the nature of the exploratory operations in the context of ice when interpreting results. Seismic and related exploration activities from 2006–2011 typically avoided sea ice due to its potential to harm equipment during these types of surveys. Exploratory drilling in 2012, however, often occurred much closer to areas of sea ice.

## *Quantifying Localized Sea-ice Cover from 2006–2012*

Sea-ice cover varied greatly among years from 2006–2012 in the Beaufort and Chukchi seas. It is important to recognize that localized ice cover often differed considerably from the larger, Arctic-wide scale. In order to make meaningful comparisons of the area covered by ice during industry exploration activities among years, a standardized area was defined within each sea in which to measure ice coverage (Fig. 2.13). The extent of sea-ice cover within these standardized areas of the eastern Chukchi and Beaufort seas were measured using satellite imagery (RadarSAT, MODIS, AVHRR, and SSM/I) throughout the field season of each survey year. Satellite ice data were grouped by week and plotted across the study area in 10 $km^2$ (3.9 $mi^2$) grid cells, and the number of weeks with any measurable ice present within a grid cell from 18 July–10 October was calculated for each year from 2006–2012.

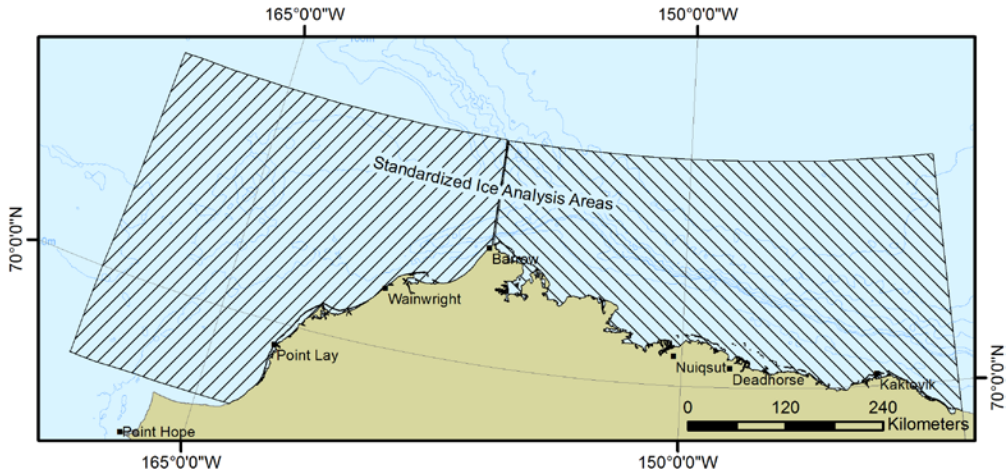


FIGURE 2.13. Standardized ice study areas for the Beaufort and Chukchi seas.

In general from 2006–2012, spatial and temporal sea-ice extents in the Chukchi Sea study area were less than in the Beaufort Sea study area (Figs. 2.14–2.20). Residual sea ice remained scattered over the continental shelf in the Chukchi Sea into August and September in 2006, 2008, and 2012. The National Snow and Ice Data Center (NSIDC) reported the lowest Arctic sea-ice minimum in the satellite record in 2012; however, localized areas of the northeast Chukchi Sea had relatively high ice concentrations well into September when most adjacent areas were sea-ice free (Fig. 2.20). Similar scenarios occurred in 2006 and 2008 when sea-ice lingered in Chukchi Sea prospect areas while much of the surrounding Arctic basin was sea-ice free (Figs. 2.14 and 2.16).

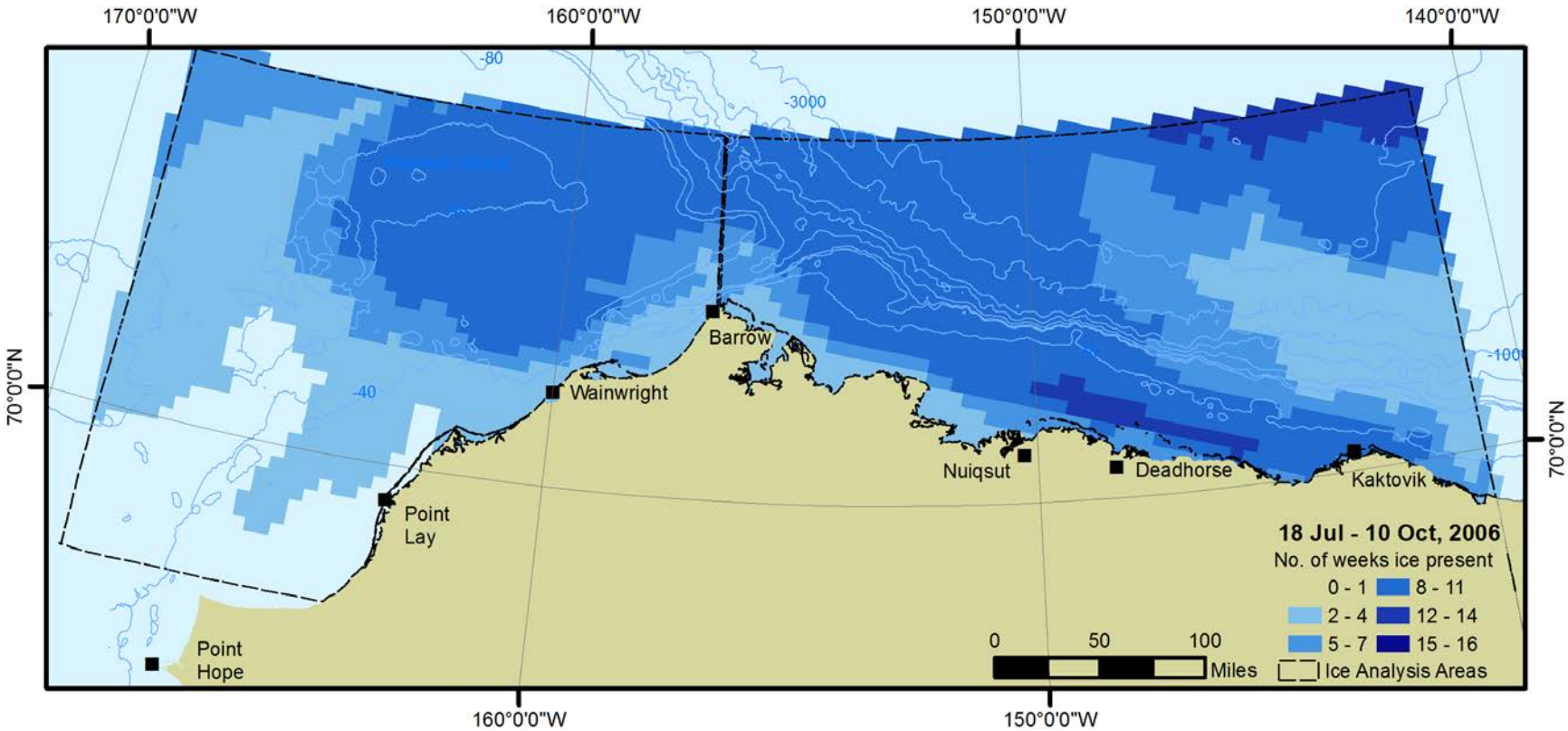


FIGURE 2.14. Average weekly ice presence in 10 km (6.2 mi) grid cells across the Chukchi and Beaufort seas study areas from 18 July–10 October, 2006. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

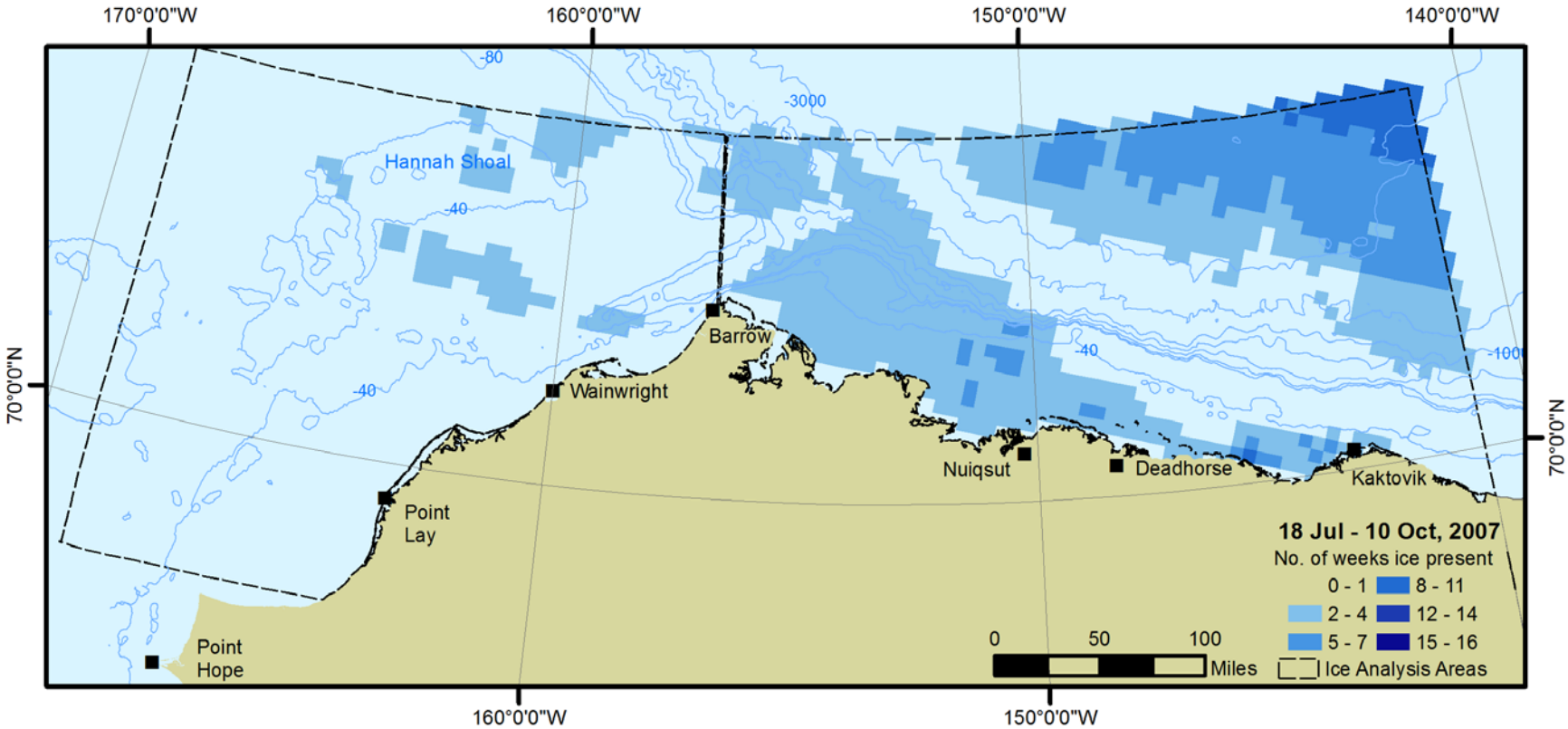


FIGURE 2.15. Average weekly ice presence in 10 km (6.2 mi) grid cells across the Chukchi and Beaufort seas study areas from 18 July–10 October, 2007. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

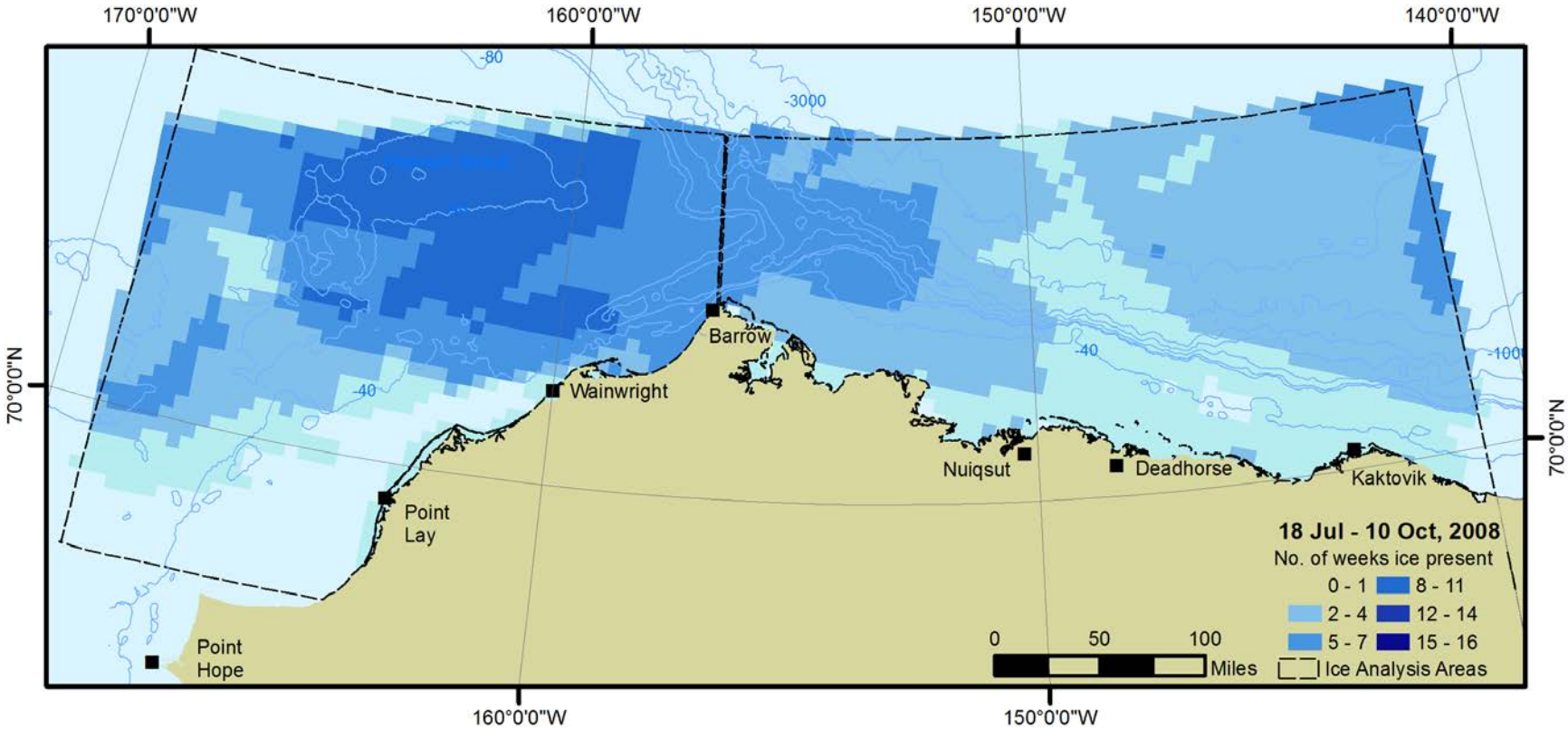


FIGURE 2.16. Average weekly ice presence in 10 km (6.2 mi) grid cells across the Chukchi and Beaufort seas study areas from 18 July–10 October, 2008. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

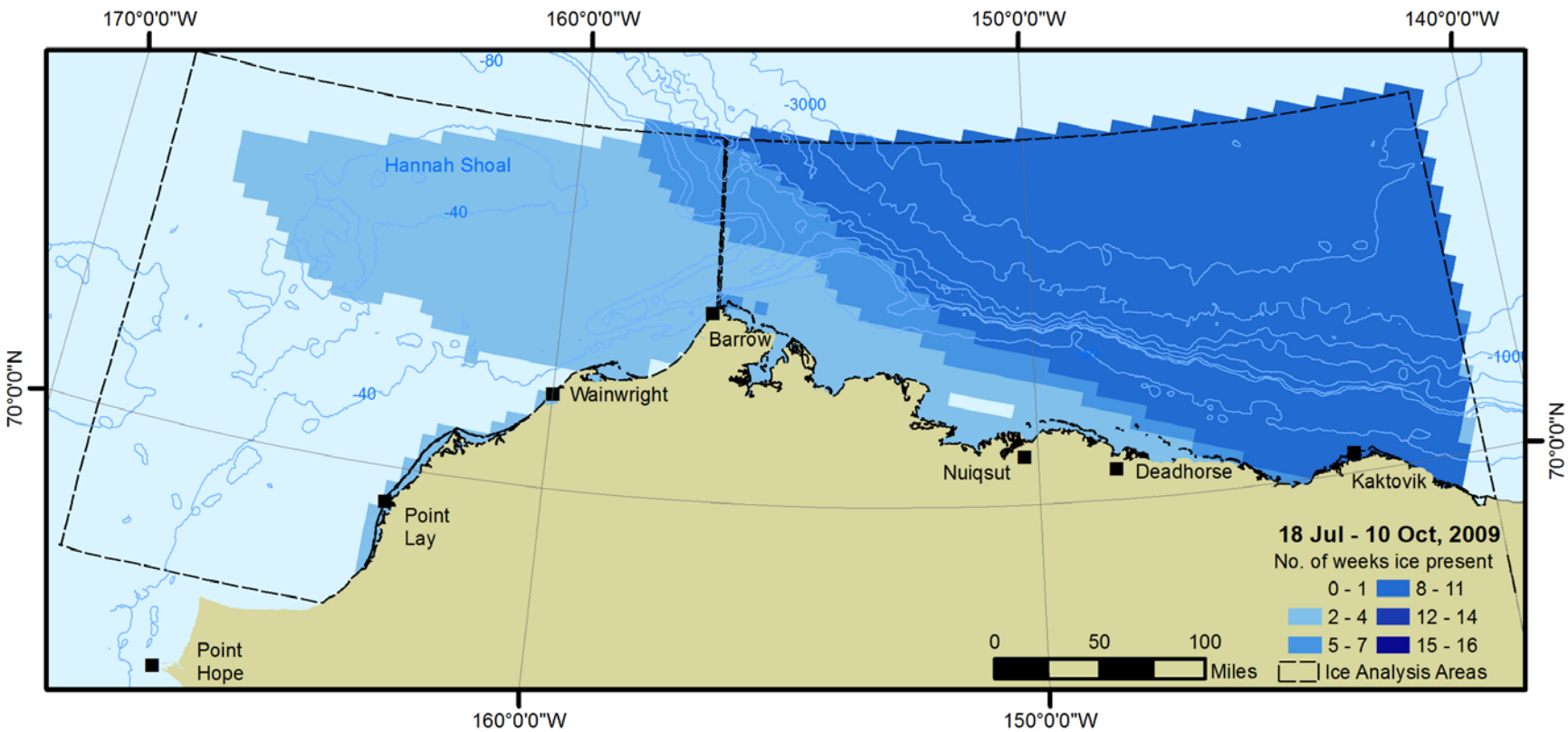


FIGURE 2.17. Average weekly ice presence in 10 km (6.2 mi) grid cells across the Chukchi and Beaufort seas study areas from 18 July–10 October, 2009. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

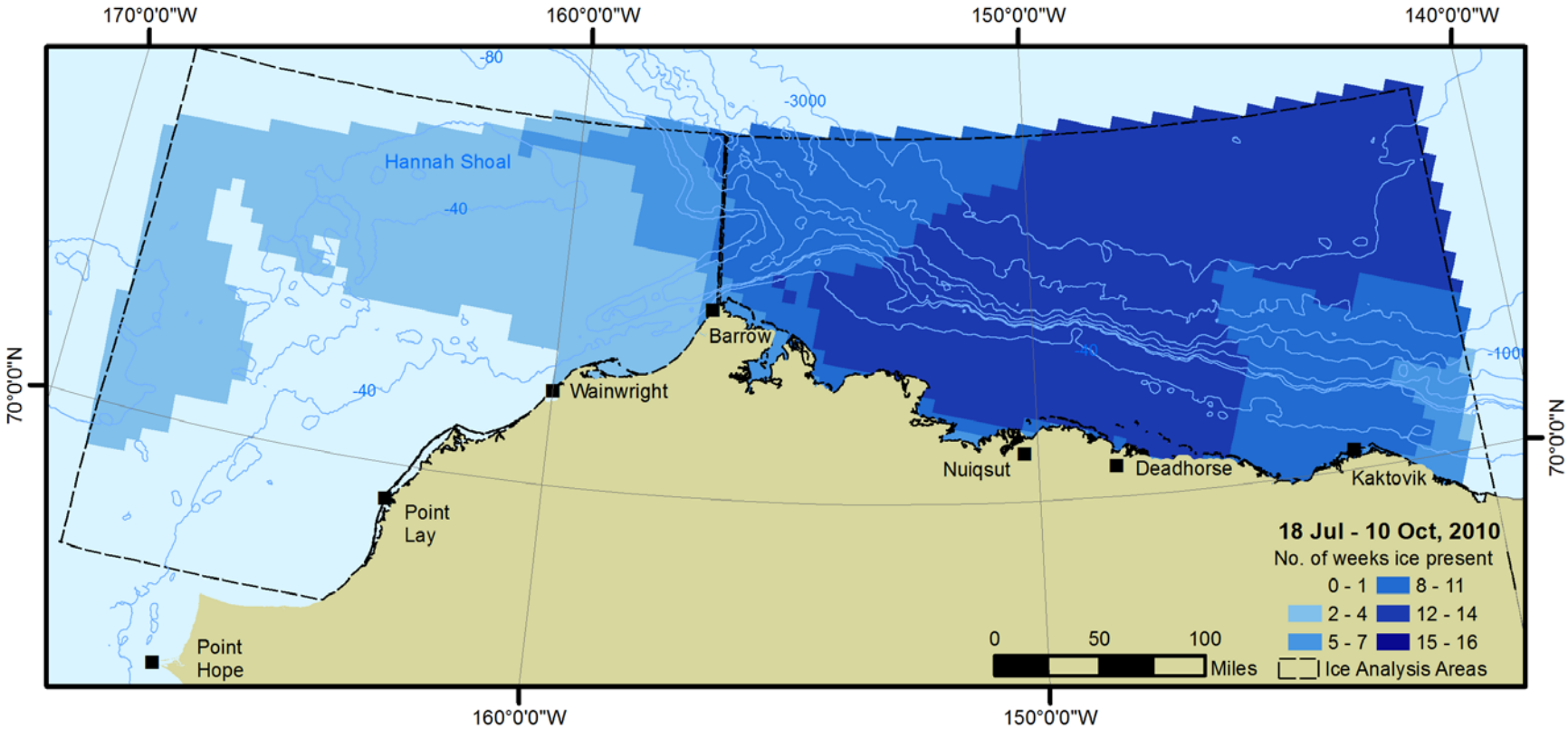


FIGURE 2.18. Average weekly ice presence in 10 km (6.2 mi) grid cells across the Chukchi and Beaufort seas study areas from 18 July–10 October, 2010. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

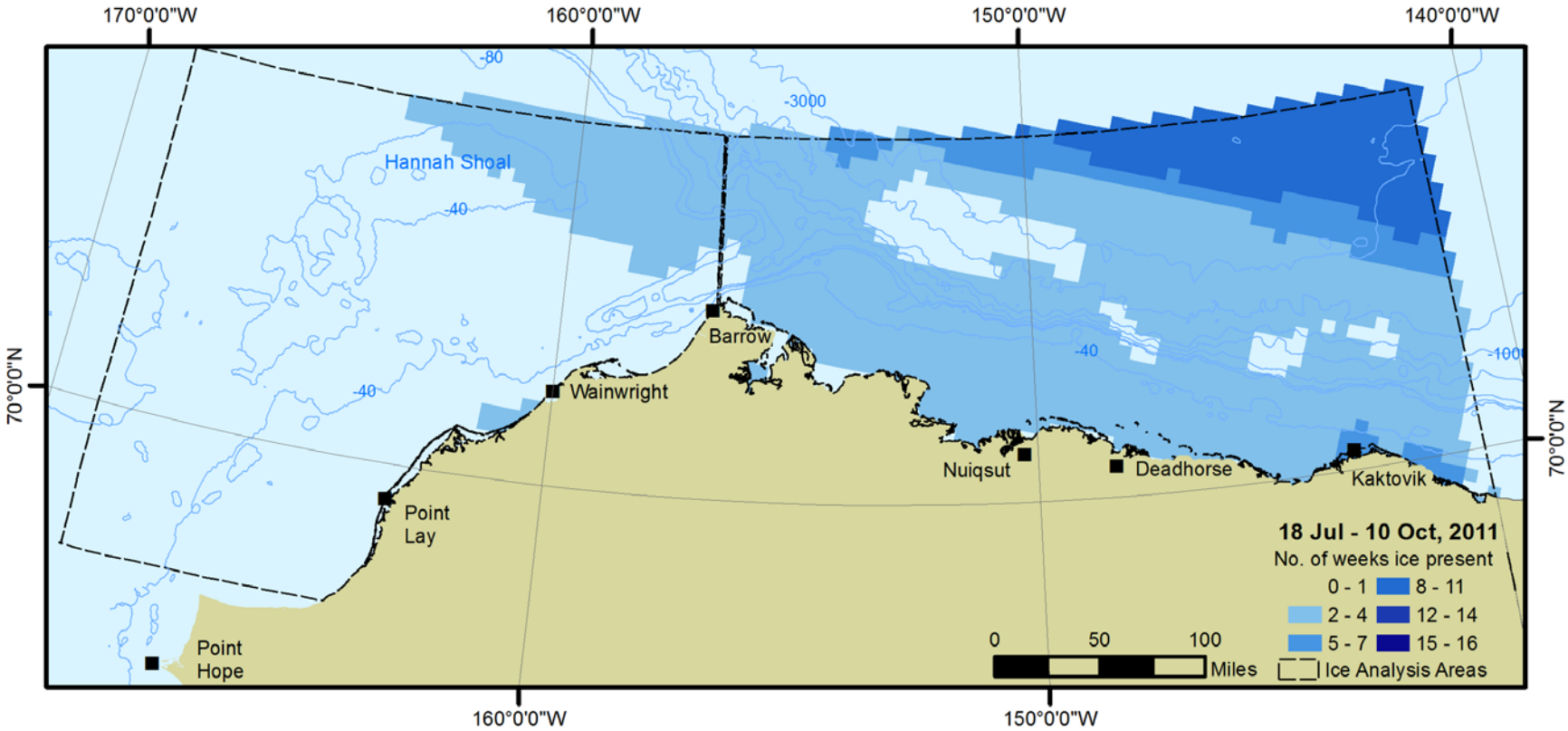


FIGURE 2.19. Average weekly ice presence in 10 km (6.2 mi) grid cells across the Chukchi and Beaufort seas study areas from 18 July–10 October, 2011. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

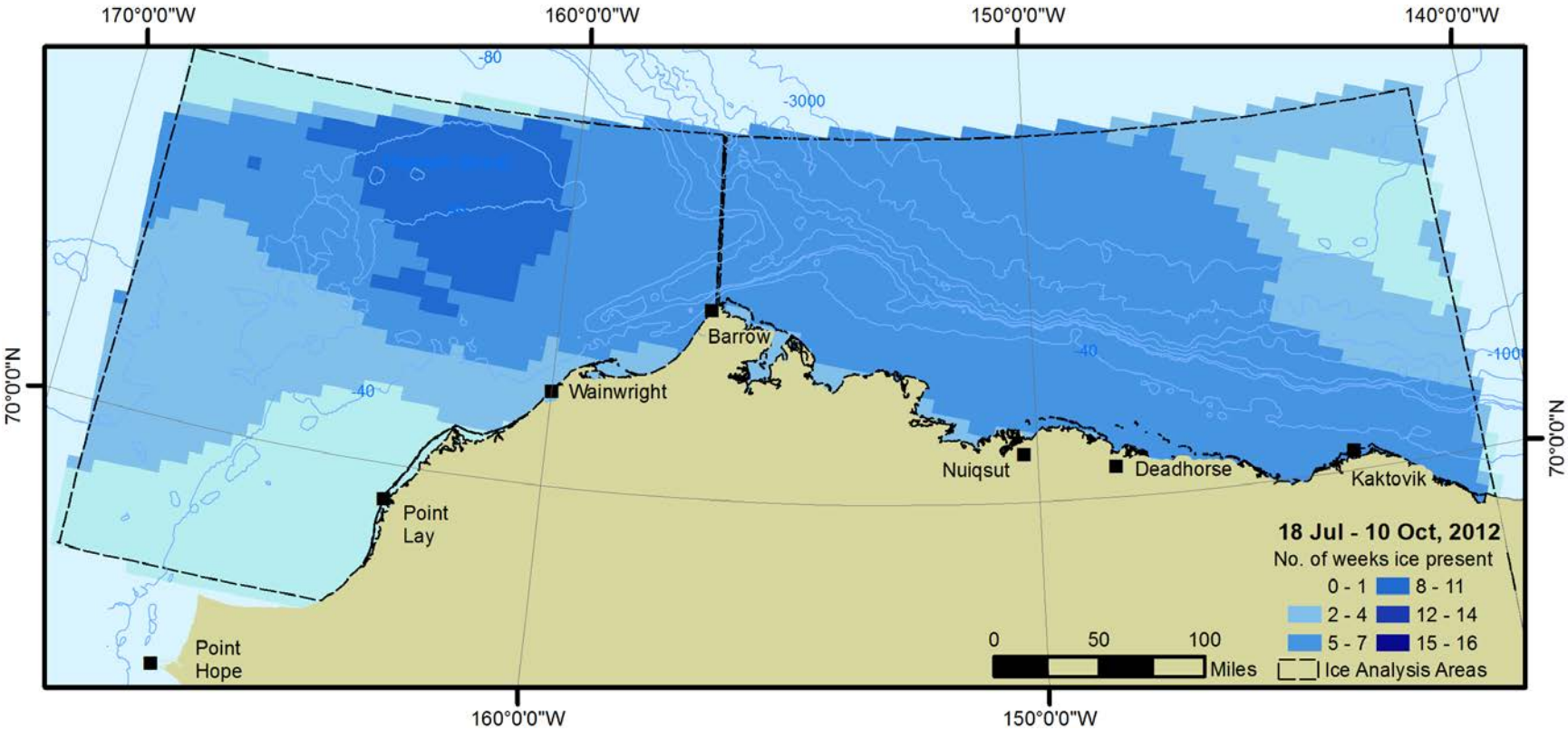


FIGURE 2.20. Average weekly ice presence in 10 km (6.2 mi) grid cells across the Chukchi and Beaufort seas study areas from 18 July–10 October, 2012. Source: Shell Ice and Weather Advisory Center (SIWAC).

The average area covered by any amount of sea ice in the study area in the northeast Chukchi Sea from 18 July–10 October by year from 2006–2012 is shown in Table 2.1. Average ice cover was highest in 2006 and lowest in 2007, and interannual variability was high. The average ice cover in 2007 during the period analyzed was only 16% of that in 2006. Ice cover was present through July in each year and highest in 2006 and 2012. In general, ice cover during August was highest in 2008 and similar levels were seen in 2006, 2009 and 2012. The Chukchi Sea project area was free of ice by the beginning of August of 2007 and after the third week of August in 2009 and 2010. The project area near the Burger well site in 2012 was not ice free until mid September even though much of the rest of the study area was ice-free. Ice cover gradually receded through September at approximately the same rate in 2006 and 2008, and receded faster in all other years. Little to no ice cover remained by early October in all seven years (Fig. 2.21).

TABLE 2.1. Average area (km$^2$) within the Chukchi Sea study area covered by any amount of ice during the period 18 July–10 October, by year from 2006–2012. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

| Average area covered by any amount of ice (km$^2$) 18 July–10 October | | | | | | |
|---|---|---|---|---|---|---|
| **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** |
| **48,485** | **2353** | **42,119** | **14,226** | **8846** | **9074** | **47,353** |

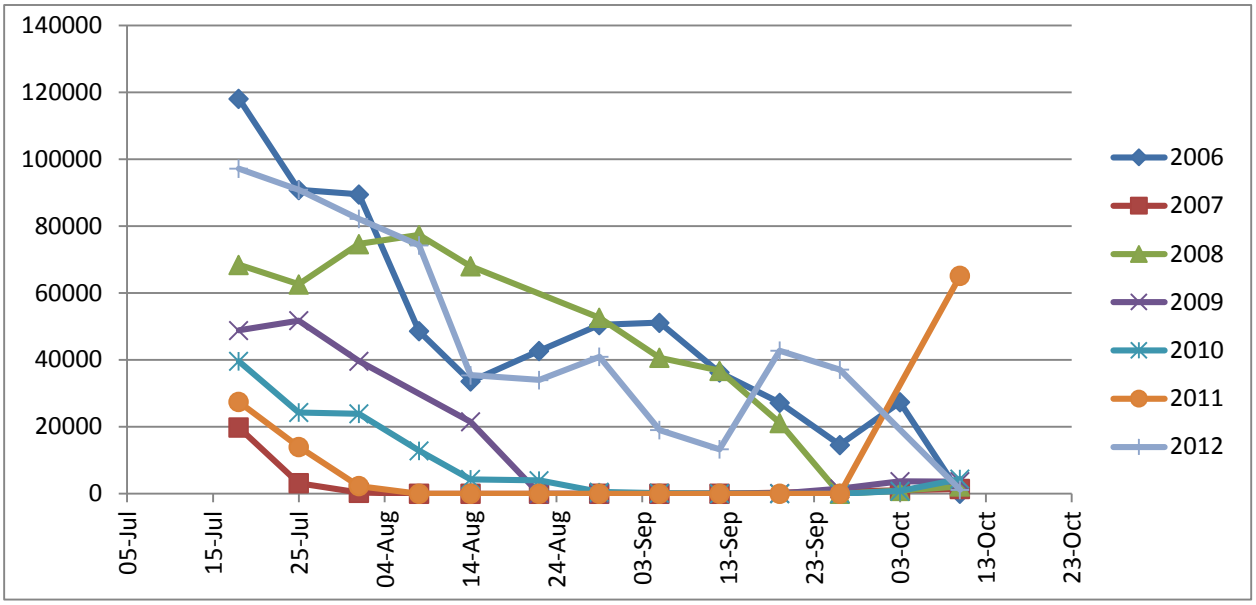


FIGURE 2.21. Number of square kilometers with any measureable sea ice cover in the Chukchi Sea study area by week in 2006–2012. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

Sea-ice cover generally persisted longer over a greater percentage of the Beaufort Sea study area compared to the Chukchi Sea study area (Figs. 2.14–2.20). The average area covered by sea ice in the Beaufort Sea project area from 18 July–10 October 2012 was slightly higher than the mean across the period from 2006–2012 (Table 2.2). Average ice cover in the Beaufort Sea study area since 2006 was highest in 2010 due to a relatively large floe of multiyear ice that stretched from Harrison Bay to Camden Bay throughout much of the open-water season while the remainder of the Beaufort Sea was largely sea-ice free. Relatively large amounts of small, scattered ice floes remained in the project area during 2009. Average ice cover in this area since 2006 was lowest in 2007, and interannual variability was high (Table 2.2). Figure 2.22 also demonstrates the high degree of interannual variability of sea ice cover within the Beaufort Sea study area from 18 July–10 October of 2006–2012. Ice cover persisted much later into the open-water seasons of 2006, 2009, and 2010 compared to 2007, 2008, 2011, and 2012 (Fig. 2.22).

TABLE 2.2. Average area (km$^2$) within the Beaufort Sea study area covered by any amount of ice during the period 18 July–10 October, by year from 2006–2012. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

| Average area covered by any amount of ice (km$^2$) 18 July–10 October | | | | | | |
|---|---|---|---|---|---|---|
| **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** |
| **70,787** | **25,419** | **39,531** | **104,387** | **111,183** | **40,370** | **42,840** |

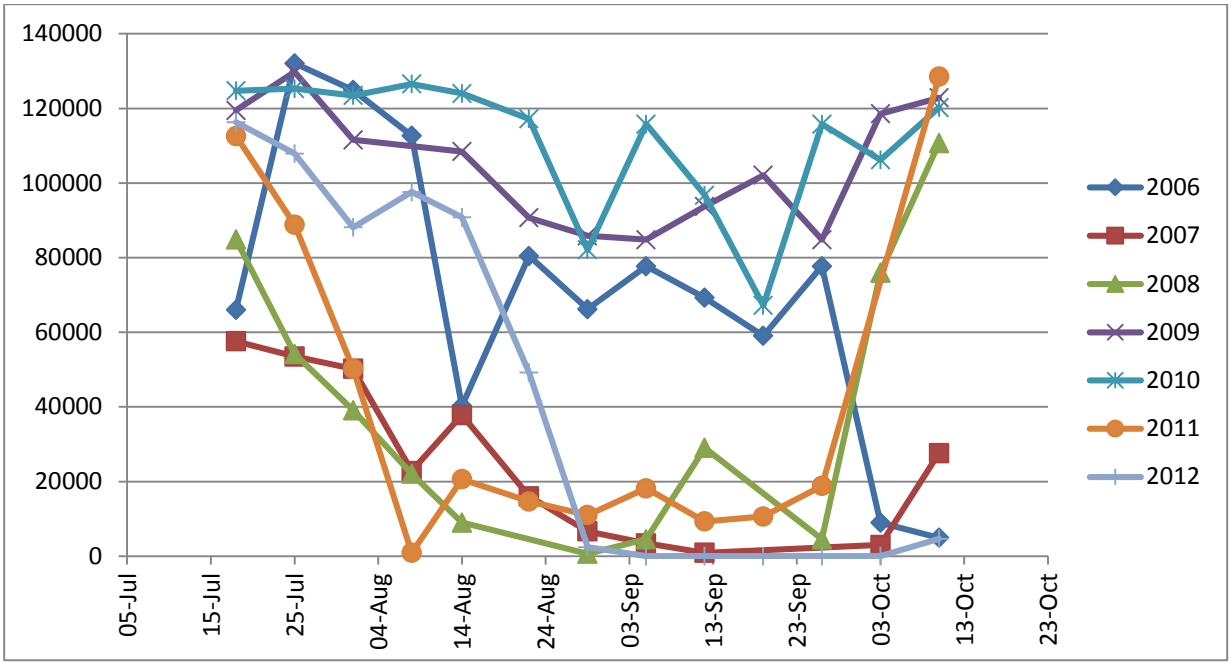


FIGURE 2.22. Number of square kilometers with any measureable sea ice cover in the Beaufort Sea study area by week in 2006-2012. Source: Shell Ice and Weather Advisory Center (SIWAC) and the National Oceanic and Atmospheric Administration (NOAA).

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# CLIMATE CHANGE

## *Introduction*

There has been concern for several decades that the earth may be undergoing global climate changes that impact environmental patterns such as ocean temperatures, extent and persistence of the polar pack ice, and weather patterns. Climate models consistently indicate that the Arctic is the most sensitive region of the Northern Hemisphere in terms of potential changes in climate, particularly near sea-ice margins. Changes in the Arctic climate have the potential to impact marine mammals in numerous ways. The following section presents a high-level summary of results from recent investigations into climate change as well as the possible implications for marine mammals of the Arctic. Although the scientific community has produced a wealth of evidence showing that climate change is occurring, the range and extent of effects on physical and biological systems will not be fully recognized for many years. It is still important, however, to consider the potential influence of changing climactic conditions when interpreting the monitoring results presented within the report.

## *Evidence of Climate Change and Potential Effects on Marine Mammals*

Temperatures in Alaska and throughout the Arctic are thought to have fluctuated considerably over the past few centuries (Mann et al. 1999). Despite this fluctuation, the last 100 years appear to have been the warmest in the last 400 years (Overpeck et al. 1997). While it is unclear to what extent anthropogenic green house gases (GHGs) have contributed to climate warming, the Arctic marine environment has shown changes over the past several decades that are suggestive of a broader global warming that exceeds the range of natural variability over the past 1000 years (Walsh 2008).

A synthesis of climate model projections for arctic environments indicates additional warming of several degrees Celsius in much of the Arctic marine environment by 2050 (Walsh 2008). The greatest warming is projected to occur in fall and winter, resulting in longer periods of open water and further retreat of sea ice, which reached record minima in recent years including 2012 (Stroeve et al. 2008; Wang and Overland 2009; Polyak et al. 2010; Perovich et al. 2012). These changes, coupled with hydrographic changes in temperature, salinity and stratification in ocean waters due to freshening and changes in circulation (Bryden et al. 2005) have the potential to affect biological resources in the Beaufort and Chukchi seas. In particular, continued loss of sea ice during summer has been projected to affect the distribution of marine mammals (Tynan and DeMaster 1997; Laidre et al. 2008; Kovacs et al. 2010). Coincident with these potential effects on marine mammals, the lower ice extent and thickness, and the greater duration of the ice-free periods (Wang and Overland 2009; Kwok and Rothrock 2009; Douglas 2010) may increase human activities in Arctic offshore areas. Such changes may increase use of Arctic shipping routes and allow activity later into the year than has occurred in the past.

Changes in the marine environment due to climate change may interact with other impacts associated with increased human use of these areas, including offshore oil and gas development, and could result in cumulative impacts to various taxa. Further, the dynamics of climate change may drive variability in the system to such an extent that any relationship to other factors impinging on these populations may be largely or completely obscured. For example, acoustic and aerial monitoring of a shallow hazards seismic survey in the Beaufort Sea during 2010 suggested that ice had a greater impact on bowhead whale distribution than did other measured variables, including survey activities (Funk et al. 2011). The potential impacts of global climate change on marine mammals in the Arctic may be much greater than those that are likely to result from industrial activities or subsistence hunting. The potential

effects of climate change on marine mammals in the Chukchi and Beaufort seas will vary greatly among species.

The Minerals Management Service (MMS now BOEM 2007) described numerous activities or situations related to global climate change that have the potential to impact marine mammals in the Chukchi and Beaufort seas. These include factors such as:

- potential changes in the distribution, concentration and availability of marine mammal prey species such as fish, benthic invertebrates, and plankton;
- changes in distributions of marine mammals in response to changes in distribution of prey species;
- impacts to subsistence hunting of marine mammals resulting from changes in marine mammal distribution;
- potential expansion of the ranges of some predators such as killer whales that prey on marine mammal species;
- increased shipping and research vessel traffic through the Northwest passage and other areas of the Arctic, which could result in increased disturbance to marine mammals, and the potential for collisions of marine mammals with vessels;
- potential for commercial fishing activities to occur in the Chukchi and Beaufort seas accompanied by increased disturbance from vessel traffic, and potential for marine mammal collision with vessels, entanglement with fishing gear, and possible competition with marine mammals for prey species;
- increased risk of contaminants such as oil or fuel spills from vessel traffic being released into marine environments;
- increased potential for conflicts between humans and polar bears.

As mentioned above, the most obvious impact to the environment resulting from climate change in the Arctic has been the retreat of the polar pack ice. Stroeve et al. (2008) reported a declining trend in the extent of Arctic sea ice since 1953. The extent of Arctic sea ice declined to a then-unprecedented low in 2007 which was a 23% reduction from the previous low in 2005. Since 2007, Arctic sea ice has continued to decline with the 2012 September ice minimum reaching the lowest level in the satellite record (Perovich et al. 2012).

It is likely that some effects of global warming on polar bears have already been observed. Regehr et al. (2006) reported reduced survival of polar bear cubs in the southern Beaufort Sea region of the U.S. and Canada that appeared to be related to warming conditions in the Arctic. Regehr et al. (2006) also reported a reduction in the body weight and skull size of adult male polar bears captured from 1990 to 2006 compared to bears captured prior to 1990. Relatively high numbers of polar bears were seen along the Beaufort Sea coast in 2007 and 2008 and along the Chukchi Sea coast in 2008. Most of these bears were seen during periods when vessels from oil and gas exploration programs were not actively working or during aerial surveys. Movement of polar bears to coastal areas has been suggested as an early result of climate warming and has been predicted to increase as the climate warms and the pack ice retreats. In 2008, the USFWS listed the polar bear as threatened under the Endangered Species Act (USFWS 2008). USGS information from recent studies presenting the relationships of polar bears to present and future sea-ice environments is available online at http://www.usgs.gov/newsroom/special/polar_bears/.

Pacific walruses (and possibly bearded seals) are probably more common in the Chukchi than the Beaufort Sea due to the greater concentrations of benthic biomass in the Chukchi Sea (Dunton et al. 2005). Both walruses and bearded seals tend to move with the ice edge from the Bering Sea during the winter to the Chukchi Sea (and Beaufort Sea for bearded seal) in the spring and summer. Walruses and bearded seals feed primarily on benthic invertebrates, and the ice edge provides them with a platform for resting adjacent to feeding habitat. Pacific walruses and bearded seals are known to feed in relatively shallow water to ~80 m (262 ft) in depth although deeper dives have been recorded (Fay and Burns 1988). Most of the Chukchi Sea is relatively shallow with depths generally <50 m (164 ft) providing extensive feeding habitat for benthic-feeding marine mammals. Pacific walruses normally haul out on ice to rest during the summer in the Chukchi Sea and generally do not haul out on land in large numbers along the Chukchi Sea coast. However, in the summers of 2007 and 2009–2011, the pack ice retreated north of the Chukchi Sea Outer Continental Shelf (OCS) into the Arctic Ocean where water depths were much greater. Subsequently, large numbers of Pacific walruses were observed hauled out along coastal locations from Barrow to Cape Lisburne. We suspect that the pack ice retreated to water too deep for walrus feeding and that the use of land-based haulouts along the Chukchi Sea coast was an effect of increasing temperatures due to climate change. How the use of land-based haulouts along the Chukchi Sea coast rather than haulout locations on the pack ice will impact walruses is unknown. However, there may be potential for mortality of young walruses to result during stampedes of large walrus groups at land-based haulouts, as occurred in 2009 (Fischbach et al. 2009). The USFWS was petitioned to list Pacific walrus as a threatened or endangered species under the Endangered Species Act (CBD 2008). Much of the rationale in the petition was based on the potential effects of global climate change. Pacific walrus was subsequently given candidate species status.

The retreating pack ice may also increase the likelihood of walrus calf mortality due to cow/calf separation. Cooper et al. (2006) reported the occurrence of walrus calves that had been separated from adult female walruses on ice floes in the Canadian Arctic. Pack ice in the area had retreated and the ice floes were located in water depth of >3000 m (9843 ft), well over depths within which walruses are known to feed.

How changes in environmental variables resulting from global climate change are likely to affect cetaceans in the Arctic is unknown; however, some preliminary analyses have found positive correlations between the extent of open water in bowhead whale summer feeding areas and bowhead calf production. Moore and Huntington (2008) suggested that reductions in sea ice may actually enhance feeding opportunities for bowhead whales, and recent population estimates indicate that decades of sea-ice loss do not appear to have hindered growth of the population. The most recent population estimate (Givens et al. 2013) suggests that the bowhead population continues to expand and ~3.5% per year. MMS (now BOEM 2007) concluded that the potential effects of climate change on bowhead whale populations are uncertain, and there is no current evidence of negative effects from climate change on the whales. Thus, some types of environmental changes may be beneficial to some species while other changes may have negative impacts.

Other cetaceans not normally found in the Arctic in large numbers could also extend their ranges northward and compete with arctic cetaceans for food. Sightings of humpback whales in the Chukchi and Beaufort seas, fin whales in the Chukchi Sea and increased numbers of harbor porpoises in the Chukchi and Beaufort seas and Minke whales in the Chukchi Sea (Funk et al. 2007; Reiser et al. 2008; Green et al. 2007) may be early examples of such changes. The increasing numbers of sightings of these animals in the Beaufort and Chukchi seas is in part due to greater human activity in the area but is also suggestive of changes in ecological boundaries for some species.

Changes to the Arctic's physical and chemical oceanographic properties could impact the distribution and abundance of marine mammal prey within the Arctic including fish, benthic invertebrates, and plankton. This could be beneficial to marine mammals if food availability increased. Alternatively, invasions of new species either through range expansion or as introduced species may impact the availability of various prey species via increased competition among organisms. Very few introduced species are currently known from high latitudes probably due to environmental resistance due to cold-water temperatures, seasonal fluctuations in resources, and the relative lack of human disturbance (Ruiz and Hewitt 2009). As temperatures change, environmental resistance would be lowered for some species, potentially allowing range expansion. Increased ship traffic and development of coastline and offshore structures will increase the numbers of introduced species reaching northern waters, and the lower environmental resistance may increase the potential for introduced species to become established.

Polar marine habitats are characterized by well-oxygenated waters with narrow, cold temperature ranges (Rose et al. 2000). Because of their narrow temperature limits, even slight changes in polar temperatures may cause fish populations to shift their migratory patterns and geographical ranges. Cold-water adapted fishes may need to seek deeper water for cooler temperatures. Depending on how the ocean currents change, if some areas become isolated and remain very cold, the potential for horizontal migration would also exist. Further, changes in prey availability due to climate factors could also result in changes in the distributions of fish populations and communities. The effects, however, of such migrations on fish foraging patterns and life history strategies are unknown (Roessig et al. 2004).

Hydrographic changes that result is changes in salinity may also affect fish distributions in the Arctic. At present, there is little information available on the salinity tolerances or preferences of polar fishes. If polar fishes are intolerant of wide salinity ranges (stenohaline), they will be limited to the area below the halocline or will have to migrate to more haline areas. On the other hand, these polar waters may eventually resemble the physical conditions in our present-day temperate waters. This may allow temperate fishes to colonize these areas, but such colonization may be at the expense of the polar species (Roessig et al. 2004).

Perry et al. (2005) found that the distributions of both exploited and nonexploited North Sea fishes responded markedly to recent increases in sea temperature, with nearly two-thirds of species shifting in mean latitude or depth or both over a 25-year period. For species with northerly or southerly range margins in the North Sea, half-showed boundary shifts with warming, and all but one shifted northward. Species with shifting distributions had faster life cycles and smaller body sizes than nonshifting species. Similar changes have been reported in the Bering Sea (ACIA 2004, 2005) and would be expected in the Chukchi and Beaufort seas as well.

Reductions in the persistence and extent of sea ice could impact ice associated marine plankton (Clarke 1988). The lower surface of the ice and interstices in the ice are highly productive habitats for plankton which provide an important food source for herbivores both while the sea ice is in place and when it breaks up in the spring (Mellilo et al. 1990). Gulliksen and Lonne (1989) indicated that sea ice habitat was quantitatively important to the marine food web of high latitude systems for fishes, sea birds and marine mammals. Hydrographic changes in currents, water temperatures, salinity and stratification of ocean waters may affect the productivity and distribution of plankton blooms with subsequent effects on species that utilize these organisms for food. Similarly, hydrographic changes may also alter the distributions and structures of benthic and epibenthic communities and organisms. If invertebrate and fish species or assemblages shift to match changes in the geographic positioning of their preferred oceanographic conditions, the resulting spatial distribution of marine mammals relying on these food resources may shift relative to the locations of industrial activities and subsistence hunting activities.

## *Conclusion*

How the many potential direct and indirect effects of climate change will impact Arctic marine mammals remains unclear. While such effects are currently largely speculative it is important to recognize their potential influence on Arctic marine system dynamics and to consider other potential effects on marine mammals, including those from offshore oil and gas exploration within the context of these system-wide changes. The vast majority of evidence indicates that offshore oil and gas industry activities result in only localized effects on marine mammals lasting only for the duration of the activity. Climate change, however, is occurring on much greater temporal and spatial scales, particularly in higher latitudes. This requires that extra caution be given to interpreting the results of monitoring programs focused on relatively small areas in the Arctic offshore.

Additionally, the physical and biological systems of the Arctic are inherently dynamic with considerable interannual variation. The confounding effects of rapid climactic changes on a system that is already highly variable complicates the objective of isolating potential effects from offshore exploration on marine mammals.

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# MARINE MAMMALS OF THE CHUKCHI AND BEAUFORT SEAS

The following section presents high-level overviews of the life histories of resident and migratory marine mammal species of the Alaskan Chukchi and Beaufort seas. Emphasis is placed on geographic range and distribution, population estimates, diet, and the importance of these marine mammals to Alaska Native culture and subsistence practices.

## *Bowhead Whale (Agvik, Balaena mysticetus)*

Bowhead whales are the largest marine mammal commonly found in the Beaufort and Chukchi Seas and one of only three species of cetacean that spend their entire lives in the Arctic. Their distribution is circumpolar, though not continuous, and four geographically distinct stocks are recognized for management purposes: the western Arctic (Bering, Chukchi, and Beaufort seas) of northeastern Russia, Alaska, and northwestern Canada; the Canadian High Arctic and West Greenland (Nunavut, Baffin Bay, Davis Strait, and Hudson Bay); the Okhotsk Sea (eastern Russia); and the Northeast Atlantic from Spitzbergen westward to eastern Greenland. Of these, the largest is the Western Arctic or Bering−Chukchi−Beaufort (BCB) stock. These animals winter in the Bering Sea and migrate through the Bering Strait, Chukchi Sea, and Alaskan Beaufort Sea to summer feeding areas in the Canadian Beaufort Sea (Fig. 2.23). Satellite tracking data reported by the Alaska Department of Fish and Game (ADFG) indicate that, during the fall migration, most bowhead whales continue west past Barrow and through the northern Chukchi Sea in to Russian waters and then south toward the Bering Sea (Moore et al. 1995; Mate et al. 2000; Quakenbush et al. 2010). Some of these animals reach a latitude of nearly 75°N before turning south during the fall migration (Quakenbush et al. 2010).

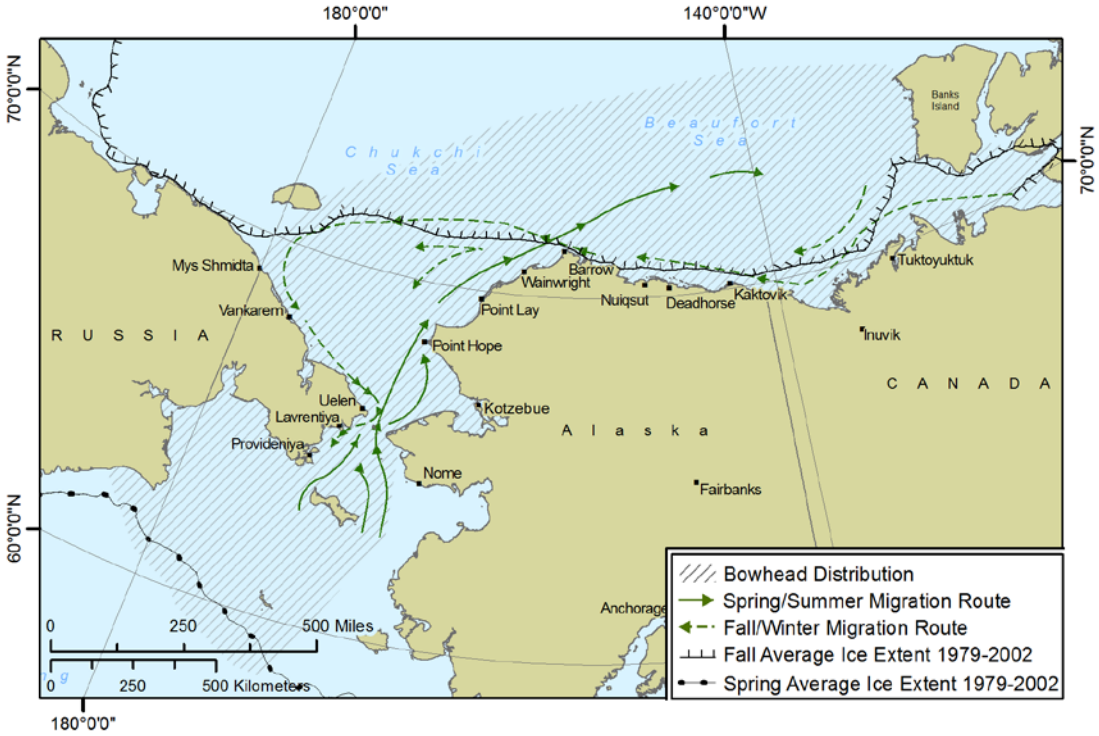


FIGURE 2.23. Distribution and generalized migration routes of bowhead whales (*Balaena mysticetus*) in Alaskan and Arctic waters.

The primary feeding grounds are in the Canadian Beaufort Sea and Amundsen Gulf. Migrating animals arrive as early as late May and many remain in this area, swimming and feeding among offshore pack ice. As they migrate west in the fall, bowheads will feed opportunistically if prey are available. A feeding "hotspot", arising from fronts formed by currents and winds, has been identified at Barrow Canyon (Okkonen et al. 2011). Groups of bowheads are known to pause their westward migration when this front effectively traps large concentrations of plankton such as krill and copepods, which are key prey items of bowheads. Recent research is showing that bowheads frequently prey upon hyperbenthic crustaceans (including mysids) in addition to pelagic plankton in both the Canadian arctic (Pomerleau et al. 2010) and Alaskan waters (Moore et al. 2010). In both studies, the relative abundance of krill, copepods, and mysids found in the stomachs of bowhead whales varied from year to year and no clear seasonal or geographical patterns have yet emerged.

Bowhead whale populations were significantly impacted by commercial whaling in the late 1800s and early 1900s. It is estimated that a pre-exploitation population of between 10,400 and 23,000 was reduced to as few as 3000 whales (Woodby and Botkin 1993). After commercial hunting ended, no whaling occurred until the subsistence harvest by Inupiat hunters resumed in 1973. Between 1973 and 1997, 14−74 animals were taken annually (Suydam et al. 1995), however the annual population growth between 1978 and 2001 was estimated at 3.4 percent, bringing the total population up to 10,470 (George et al. 2004), a figure which was revised to 10,545 by Zeh and Punt in 2005. Using aerial survey data collected in 2004, Koski et al. (2010) estimated the population to be 12,631, which is consistent with a 3.4 percent annual growth rate. The most current BCB bowhead whale population estimate, based on data collected during the spring of 2011, is 16,892 (95% confidence interval of 15,704–18,928; Givens et al. 2013). Additionally, the estimated annual growth rate of the bowhead whale population is 3.7% (Givens et al. 2013), an increase from the estimated 3.4% annual growth rate from the previous population estimates (George et al. 2004; Koski et al. 2010).

Agviq (bowhead whales) are an integral part of the diet and culture of the Inupiat people of the Beaufort and Chukchi coasts. Hunts occur during spring and fall, although hunters from one community will generally hunt only once per year (with the exception of Barrow), dependent upon ice conditions and the distance from shore of migrating whales. Communities along the Chukchi coast and the northern Bering Sea have traditionally only hunted in the spring as the fall migration route is quite far offshore; however, they have recently taken a whale in the fall in two different years. Communities along the Beaufort Sea (east of Point Barrow) generally hunt during the fall as ice leads close to shore typically remain unnavigable until after the whales have passed through on their migration to summer feeding grounds in the Canadian Beaufort Sea.

The subsistence hunt for agviq (bowheads) is regulated by the International Whaling Commission (IWC), NMFS and the Alaska Eskimo Whaling Commission (AEWC). The number of whales taken has ranged between 14 and 72 animals per year, totaling 832 animals harvested between 1974 and 2003. Between 2004 and 2011, the number of whales struck (including animals both landed and lost) has ranged between 40 and 67 animals (USDC 2013). Advances in technology, incorporating both modern and traditional equipment, has improved the rate of successfully landing struck animals. The current rate of harvest represents 0.1–0.5% of the BCB bowhead population and the annual growth rate has been 3% per year over the last 30 years. It is expected that the population will continue to grow unimpeded by subsistence hunting activities.

## *Beluga Whale (Sisuaq, Delphinapterus leucas)*

The beluga whale has a circumpolar distribution in the Northern Hemisphere, occurring in the arctic and subarctic waters between 50º and 80ºN latitude (Reeves et al. 2002). Beluga whales winter in ice-covered seas and migrate to warmer coastal estuaries, bays, and rivers to molt (Finley 1982; Fig. 2.24). It is likely that the lower salinity and higher temperature increase the turnover rate and proliferation of skin cells, thereby assisting the molting process (St. Aubin et al. 1990).

While traveling or resting, beluga whales tend to form small groups, however migrating belugas may form groups of 100 to 600 animals (Braham and Krogman 1977). Pod structure appears to be along matrilineal lines, with males forming separate aggregations (Colbeck et al. 2013). Relational ties are closer in small, localized feeding groups than those found in larger, migratory groups (Colbeck et al. 2013). This is consistent with reports from Inupiaq hunters suggesting that belugas form family groups with whales of different ages while migrating (Huntington 2000). Belugas are very social and exhibit a lot of physical contact and vocal communication.

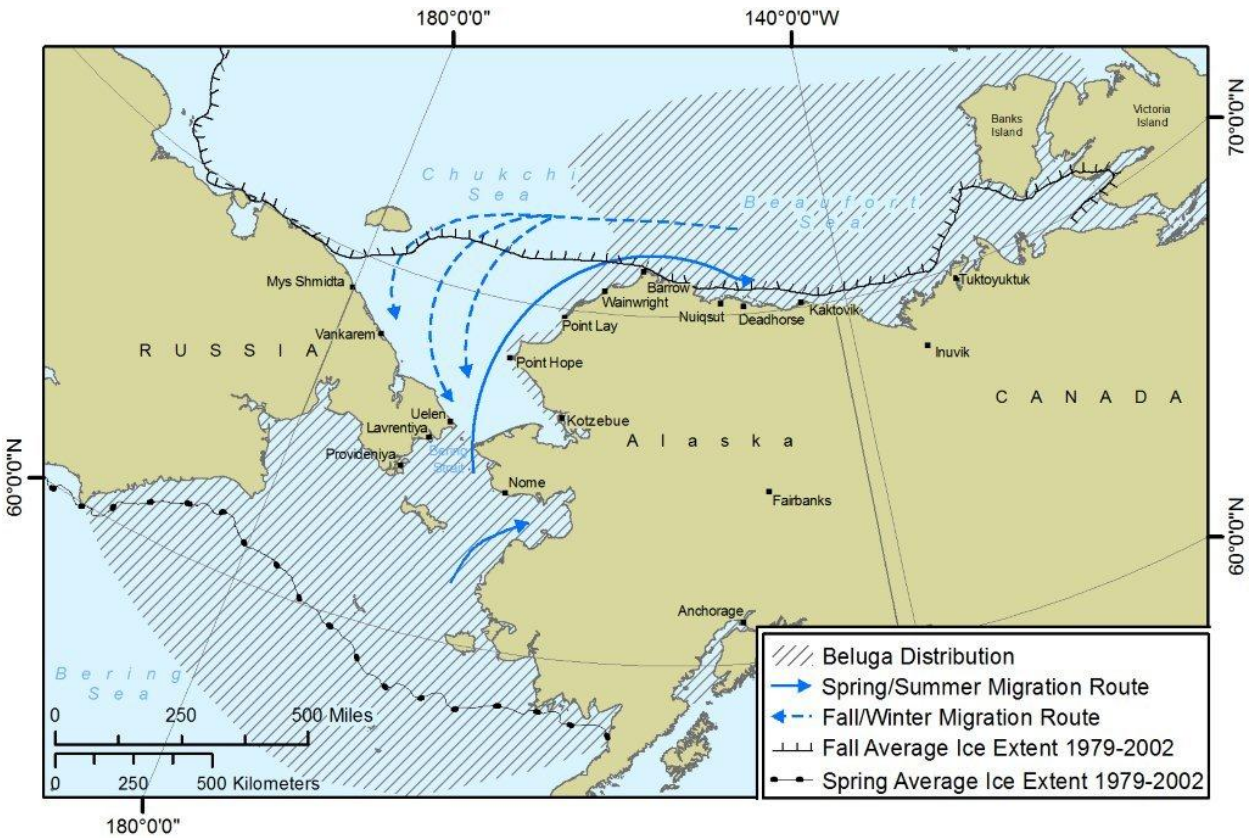


FIGURE 2.24. Distribution and migration routes of beluga whales (*Delphinapterus leucas*) in Alaskan and Arctic waters.

Five geographically distinct stocks of beluga whales are recognized in Alaska: Beaufort Sea, eastern Chukchi Sea, eastern Bering Sea, Bristol Bay, and Cook Inlet (O'Corry-Crowe et al. 1997). In addition to these five stocks, there is a small sub-population of animals in Yakutat Bay that is ecologically and behaviorally distinct from other stocks, and initial genetic analyses suggest that this group may be reproductively isolated as well (O'Corry-Crowe et al. 2006).

The most recent estimate of the eastern Chukchi Sea population is 3710 animals (Allen and Angliss 2013). This estimate was based on surveys conducted in 1989–1991. Survey effort was concentrated on the 106 mi (171 km) long Kasegaluk Lagoon where belugas are found during the open-water season. The actual number of beluga whales recorded during the surveys was much lower. Correction factors to account for animals that were underwater and for the proportion of newborns and yearlings that were not observed due to their small size and dark coloration were used to calculate the estimate. The calculation was considered to be a minimum population estimate for the eastern Chukchi Sea stock because the surveys on which it was based did not include offshore areas where belugas are also likely to occur. This population is considered to be stable. It is assumed that beluga whales from the eastern Chukchi stock winter in the Bering Sea (Allen and Angliss 2013).

Although beluga whales are known to congregate in Kasegaluk Lagoon during summer, evidence from a small number of satellite-tagged animals form this stock suggests that some of these whales may subsequently range into the Arctic Ocean north of the Beaufort Sea. Suydam et al. (2005) put satellite tags on 23 beluga whales captured in Kasegaluk Lagoon in late June and early July 1998–2002. Five of these whales moved far into the Arctic Ocean and into the pack ice to 79–80°N latitude. These and other whales moved to areas as far as 685 mi (1102 km) offshore between Barrow and the Mackenzie River Delta, spending time in water with 90 percent ice coverage.

During aerial surveys from mid-July through October in nearshore areas ~37 km (~23 mi) of the Chukchi Sea in 2006 and 2007, peak beluga sighting rates were recorded in July. Lowest monthly sighting rates were recorded in September (Thomas et al. 2010). When data from the two years were pooled, beluga whale sighting rates and numbers of individuals were highest in the band 26–35 km (16–22 mi) offshore. However the largest single groups were sighted at locations near shore in the band within 5 km (3 mi) of the shoreline.

Sisuaq (beluga whales) from the eastern Chukchi Sea stock are an important subsistence resource for residents of the village of Point Lay, adjacent to Kasegaluk Lagoon, and other villages in northwest Alaska. Each year, hunters from Point Lay drive belugas into the lagoon to a traditional hunting location. The belugas have been predictably sighted near the lagoon from late-June through mid- to late-July (Suydam et al. 2001). In 2007, approximately 70 belugas were also harvested at Kivalina located southeast of Point Hope.

The Beaufort Sea population was estimated to contain 39,257 individuals as of 1992 (Allen and Angliss 2013). This estimate was based on the application of a sightability correction factor of 2× to the 1992 uncorrected census of 19,629 individuals made by Harwood et al. (1996). This estimate was obtained from a partial survey of the known range of the Beaufort Sea population and may be an under-estimate of the true population size. This population is not considered a strategic stock by NMFS and is believed to be stable or increasing (Allen and Angliss 2013).

Beluga whales of the Beaufort Sea stock winter in the Bering Sea, summer in the eastern Beaufort Sea, and migrate between these two general locations via inshore waters during spring and via offshore waters of western and northern Alaska during fall (Allen and Angliss 2013). The majority of belugas in the Beaufort Sea stock migrate through the Chukchi Sea and into the Beaufort Sea in April or May, although some whales may pass Point Barrow as early as late-March and as late as July (Braham et al. 1984; Ljungblad et al. 1984; Richardson et al. 1995a). Recent tagging data suggests that belugas head westward again in late summer and early fall and may be present in Alaskan and Russian Chukchi waters as late as October before heading south in to the Bering Sea (Suydam et al. 2005).

## *Gray Whale (Aqviqluaq, Eschrichtius robustus)*

Historically, gray whales inhabited both the North Atlantic and North Pacific Oceans, however the Atlantic populations were hunted to extinction by the early 1700s. There are two geographically and genetically distinct populations in the North Pacific Ocean, one in the western Pacific and one in the eastern Pacific. The western gray whale population is quite small at approximately 125 animals (Swartz et al. 2006). The location of the wintering grounds of the western stock is as yet unknown. The majority of this population summers off Sakhalin Island, though some animals have been sighted feeding in coastal waters in the northern Sea of Okhotsk (Weller et al. 2002).

Protection under the MMPA (and ESA until 1994) has enabled the eastern Pacific population of gray whales to recover substantially from commercial whaling. In 1997, the population was estimated to be 29,758 ±3122 (Rugh et al. 2005). The annual mortality rate spiked in 1999 and 2000, and gray whale numbers declined sharply to 18,178 ±1780 in winter 2001–2002 (Rugh et al. 2005) and then increased to 20,110 ±1766 in winter 2006–2007 (Rugh et al. 2008). The causes of higher mortality during 1999–2000 are not known, though the numbers of deaths were within the range expected of a population of animals reaching carrying capacity (Moore et al. 2001). Eastern Pacific gray whales are not considered endangered, nor are they a strategic stock.

From January–April, eastern Pacific gray whales calve in protected lagoons along the west coast of Baja California and the east coasty of the Gulf of California (Swartz and Jones 1981; Jones and Swartz 1984). At the end of the calving season, gray whales migrate up to 8000 km (5000 mi) northwards along the west coast of North America to feeding grounds in the northern Bering and Chukchi seas (Fig. 2.25; Tomilin 1957; Rice and Wolman 1971; Nerini 1984; Moore et al. 2003; Bluhm et al. 2007). Most gray whales begin the southward migration in November with breeding and conception occurring in early December (Rice and Wolman 1971).

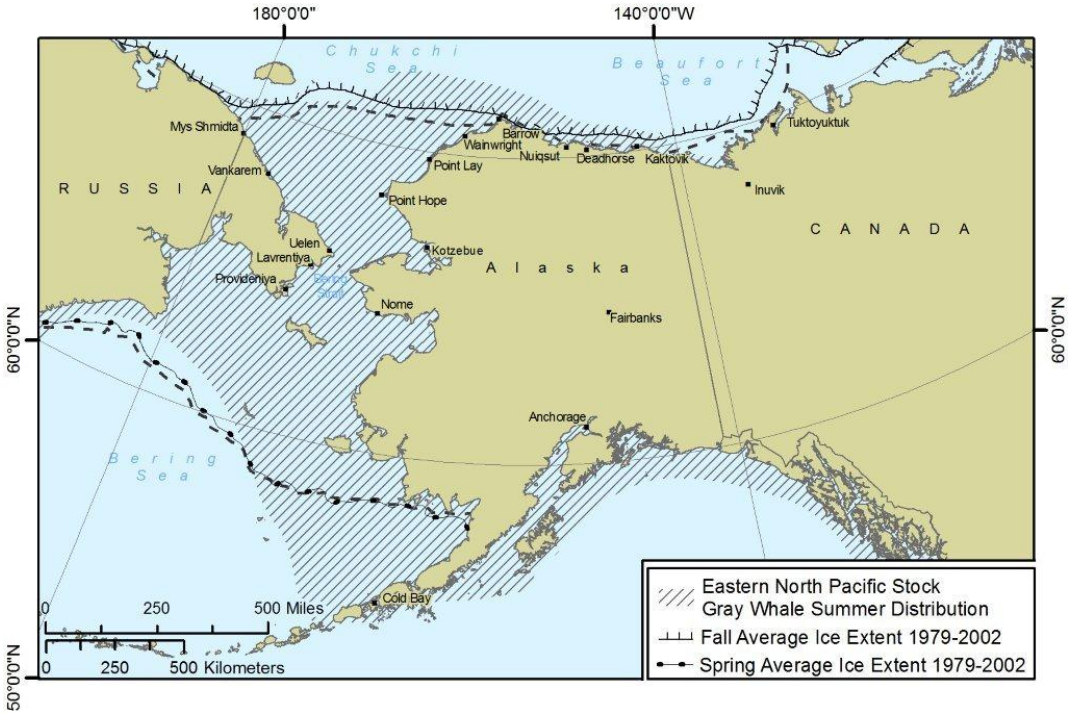


FIGURE 2.25. Distribution of gray whales (*Eschrichtius robustus*) during the open water season in Alaskan and Arctic waters.

Gray whales are generalists and have a very flexible diet. It is thought that the plasticity in the diet of gray whales enabled them to survive glaciation of their "primary" feeding grounds during the Pleistocene with only weak genetic bottlenecking (Pyenson and Lindberg 2011). It was previously believed that nearly all of the population migrated to the northern Bering and Chukchi Seas to feed upon ampeliscid amphipods. However, gray whales have been observed returning annually to areas along the west coast of North America to feed on benthic, hyperbenthic, or pelagic prey (Dunham and Duffus 2001; Sumich 1984; Rice and Wolman 1971). More recently, Moore et al. (2003) suggested that gray whale use of Chirikov Basin has decreased, likely as a result of the combined effects of changing currents resulting in altered secondary productivity dominated by lower-quality food. Coyle et al. (2007) noted that ampeliscid amphipod production in the Chirikov Basin had declined by 50 percent from the 1980s to 2002–2003 and that as little as three to six percent of the current gray whale population could consume 10–20 percent of the ampeliscid amphipod annual production. These data support the hypotheses that changes in gray whale distribution may be caused by changes in food production and that gray whales may be approaching or have surpassed the carrying capacity of their summer feeding areas. Bluhm et al. (2007) noted high gray whale densities along ocean fronts and suggested that ocean fronts may play an important role in influencing prey densities in eastern North Pacific gray whale foraging areas.

Nevertheless, it is believed that most of the eastern Pacific population of gray whales feed in the western and northern Bering and Chukchi seas during the summer months (Allen and Angliss 2013). Moore et al. (2000) reported that during the summer, gray whales in the Chukchi Sea were clustered along the shore primarily between Cape Lisburne and Point Barrow and were associated with shallow, coastal shoal habitat. In autumn, gray whales were clustered near shore at Point Hope and between Icy Cape and Point Barrow, as well as in offshore waters southwest of Point Barrow at Hanna Shoal and northwest of Point Hope. In contrast, recent surveys showed little utilization of the Hanna Shoal area (Clarke et al. 2012). During 2007, 2008, and 2010, gray whales were consistently sighted in nearshore areas along the Chukchi coast between early August and late September; however, in 2006 there were fewer sightings during surveys that followed the coastline and more sightings during surveys extending to 37 km (23 mi) from shore (Thomas and Koski 2011). In 2006, gray whales were most abundant along the coast south of Wainwright and offshore of Wainwright (Thomas et al. 2007), and in 2007, gray whales were most abundant in nearshore areas from Wainwright to Barrow (Thomas et al. 2010). Gray whales occur fairly frequently near Point Barrow, but historically only a small number of gray whales have been sighted in the Beaufort Sea east of Point Barrow. Although they are most common in portions of the Chukchi Sea close to shore, gray whales may also occur in offshore areas of the Chukchi Sea, particularly over offshore shoals.

Aqviqluaq (gray whales) of the eastern Pacific population are taken by subsistence hunters in Russia and, historically, Alaska. Subsistence hunters from Chukotka villages in Russia harvested 609 gray whales from 2007 through 2011, ranging from 115 to 127 whales each year (Blokhin et al. 2012). The last reported harvest of a gray whale in Alaska occurred in 1995, when two whales were taken by subsistence hunters.

### *Harbor Porpoise (Aavisuaq, Phocoena phocoena)*

The harbor porpoise is a small (~1.5 m or 5 ft) odontocete that inhabits shallow coastal waters in the temperate, subarctic, and arctic regions of the Northern Hemisphere (Read 1999). Harbor porpoises may dive to depths of 220 m (722 ft) for more than 5 minutes (Harwood and Wilson 2001) while they forage on small schooling fish (Read 1999) and invertebrates such as squid and octopus (ADFG 2008).

Generally, harbor porpoises are found in bays, fjords, inshore straits, estuaries, and waters between the continental shelf edge and land, however they occasionally venture to deep offshore waters during winter (ADFG 2008). Harbor porpoises typically occur alone or in groups of up to 10 individuals (ADFG 2008) and have a tendency to avoid vessels (Richardson et al. 1995b). Their predators include killer whales, large dolphins, and sharks. Entanglement in fishing nets and weirs is a significant cause of mortality in some regions.

There are three geographically distinct subspecies of harbor porpoise; *Phocoena phocoena phocoena* in the North Atlantic Ocean, *Phocoena phocoena relicta* in the Black Sea, and *Phocoena phocoena vomerina* in the North Pacific Ocean. In Alaska, *P. phocoena vomerina* is found in the Chukchi Sea, Pribilof Islands, Unimak Island, Bristol Bay, and southeast Alaska (Fig. 2.26). Point Barrow Alaska is likely the northeastern extent of their regular range (Suydam and George 1992), though there are records of sightings as far east as the mouth of the Mackenzie River in the Northwest Territories, Canada. The range of *P. phocoena vomerina* extends south from Alaska along the inshore and coastal waters of the North American coast including southeast British Columbia, Washington State, Oregon, and California to San Luis Obispo, California.

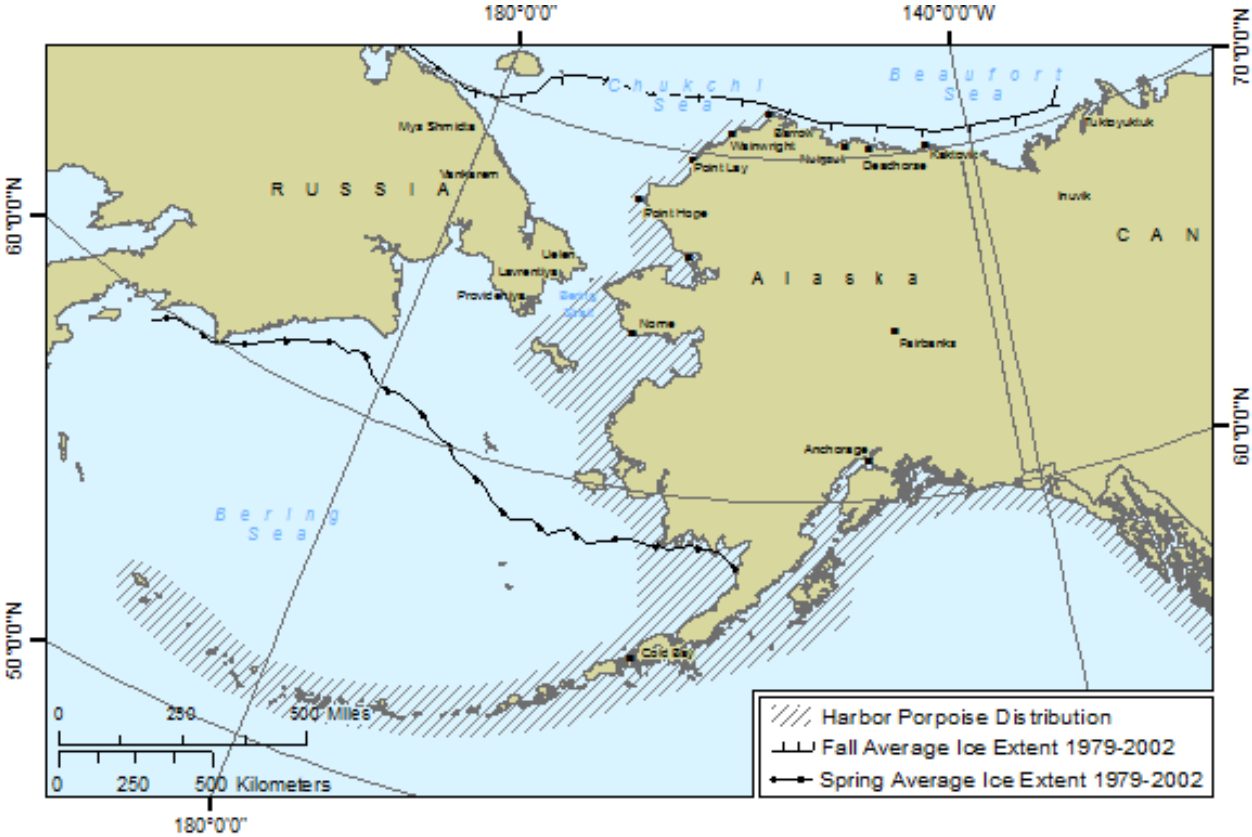


FIGURE 2.26. Distribution of harbor porpoise (*Phocoena phocoena*) in Alaskan and Arctic waters.

Although separate harbor porpoise stocks for Alaska have not been identified, Alaskan harbor porpoises have been divided into three groups for management purposes. These groups include animals from southeast Alaska, Gulf of Alaska, and Bering Sea populations. Harbor porpoises present in the Chukchi Sea belong to the Bering Sea group, which includes animals from Unimak Pass northward. Based on aerial surveys in 1999, the Bering Sea population was estimated at 66,078 animals, although

this estimate is likely conservative as the surveyed area did not include known harbor porpoise range near the Pribilof Islands or waters north of Cape Newenhan (~55°N latitude; Allen and Angliss 2013). Suydam and George (1992) suggested that harbor porpoises occasionally occur in the Chukchi Sea and reported nine records of harbor porpoise in the Barrow area in 1985–1991. More recent vessel-based surveys in the Chukchi Sea found that the harbor porpoise was commonly encountered during summer and fall from 2006–2008 (Haley et al. 2010).

Harbor porpoises were traditionally hunted and eaten throughout their range and they are still consumed by Inuit people in Greenland and Arctic Canada. There is concern that harbor porpoise meat and blubber are significant dietary sources of toxic chemicals, such as polychlorinated biphenyls (PCBs) and organochlorines (OCs), among Greenland Inuit (Borrell et al. 2004).

## *Extralimital and Occasional Cetaceans*

In addition to the species discussed above, there are some cetacean species that are only occasionally sighted in the Chukchi and Beaufort seas, but are not expected to be encountered regularly. **Narwhal** (**Aavisuaq, *Mondon monoceros***) have a discontinuous Arctic distribution, however the Alaskan Beaufort Sea is not defined as a portion of a narwhal population's range and it is considered extralimital in this region (Allen and Angliss 2013). Historically, narwhals have been reported in both the Chukchi and Beaufort seas, but we are not aware of any recent verified sightings. **Killer whales** (**Aaglu, *Orcinus orca***) are common in temperate waters, but are also frequently reported in tropical and polar latitudes in both hemispheres and in all oceans. PSOs aboard industry vessels in the Chukchi Sea recorded killer whale sightings in 2006, 2007, 2008, 2010 (Haley et al. 2010) and 2012 (Bisson et al. 2013). Acoustic detections have been made in all years between 2006 and 2009 (Blackwell et al. 2010; Martin et al. 2010). Recent Increases in killer whale sightings in the Alaskan Arctic and subarctic waters may be a function of increased vessel and aerial observation effort. **Minke whales** (***Balaenoptera acutorostrata***) have a cosmopolitan distribution at ice-free latitudes (Stewart and Leatherwood 1985), and also occur in some marginal ice areas of both the Northern and Southern Hemispheres. The range of minke whales does extend into the Chukchi Sea, but the level of use of the Chukchi Sea is unknown. Minke whales have been observed from vessels during industry activities in the Chukchi Sea from 2006 through 2008 and again in 2010, and were also sighted in the Beaufort Sea in 2007 and 2008 (Haley et al. 2010) and during aerial surveys conducted by the NMML (Clarke et al. 2012). **Fin whales** (***Balaenoptera physalus***) are widely distributed in all the world's oceans (Gambell 1985), but typically occur in temperate and polar regions. Recent data from recorders placed north of the Aleutians indicate the presence of aggregations of prey and fin whales during winter and early spring (Stafford et al. 2010), however no estimates for fin whale abundance during the summer in the Chukchi Sea are available. Reiser et al. (2009) reported a fin whale sighting during vessel-based surveys in the Chukchi Sea in 2006 and one sighting of seven animals was recorded during the 2010 COMIDA cruise (Clarke et al. 2012). **Humpback whales** (***Megaptera novaeangliae***) are considered extralimital in the Arctic (Allen and Angliss 2013). However, sightings in the Bering Sea have been recorded southwest of St. Lawrence Island, the southeastern Bering Sea, and north of the central Aleutian Islands (Moore et al. 2002; Allen and Angliss 2013). Recently there have been sightings of humpback whales in the Chukchi Sea and one sighting in the Beaufort Sea near Smith Bay (Ireland et al. 2007; Green et al. 2007). Reiser et al. (2009) reported four humpback whales during vessel-based surveys in the Chukchi Sea in 2007 and Haley et al. (2009) reported one humpback whale sighting during 2008 operations.

## *Ringed Seal (Natchiq, Phoca hispida)*

Ringed seals have a circumpolar distribution and occur in all seas of the Arctic Ocean (King 1983). They are closely associated with ice and, in the summer, they often occur along the receding ice edges or farther north in the pack ice. Five subspecies are recognized: *P.h. hispida* of the Arctic Ocean, *P.h. botnica* of the Baltic Sea, *P.h. ochotensis* of the Sea of Okhotsk, *P.h. ladogensis* of Lake Ladoga in Russia, and *P.h. saimensis* of Lake Saimaa in Finland. Of these, *P.h. hispida* is and the most widely distributed. The Arctic subspecies is likely composed of multiple distinct subpopulations. The status of ringed seals was recently reviewed (Kelly et al. 2010). As a result, the Arctic, Baltic, and Okhotsk subspecies were listed as "threatened" under the ESA, and the Ladoga and Saimaa subspecies were listed as "endangered."

Ringed seals are year-round residents in the Chukchi and Beaufort seas and the ringed seal is the most frequently encountered seal species in the area (Fig. 2.27). During winter, ringed seals occupy landfast ice and offshore pack ice of the Bering, Chukchi, and Beaufort seas. In winter and spring, the highest densities of ringed seals are found on stable shorefast ice. However, in some areas where there is limited fast ice but wide expanses of pack ice, including the Beaufort Sea, Chukchi Sea and Baffin Bay, total numbers of ringed seals on pack ice may exceed those on shorefast ice (Burns 1970; Stirling et al. 1982; Finley et al. 1983). Ringed seals maintain breathing holes in the ice and occupy lairs in accumulated snow (Smith and Stirling 1975). They give birth in lairs from mid-March through April, nurse their pups in the lairs for five to eight weeks, and mate in late April and May (Smith 1973; Hammill et al. 1991; Lydersen and Hammill 1993).

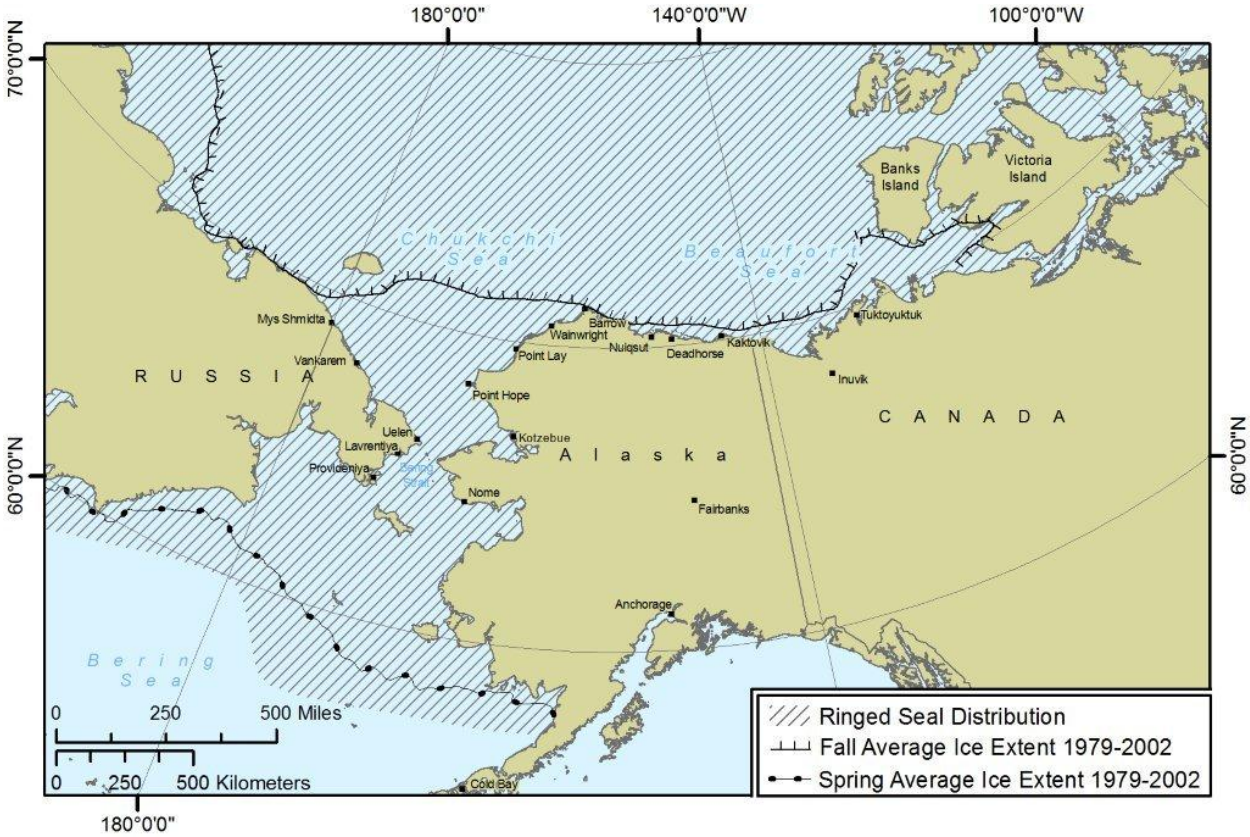


FIGURE 2.27. Distribution of ringed seals (*Phoca hispida*) in Alaskan and Arctic waters.

The diet of ringed seals is composed mainly of several species of cod, shrimp, and planktonic crustaceans; the relative importance of each type of prey is dependent upon locality and season (Lowry et al. 1998). Ringed seals are hunted by killer whales and polar bears. Spatial distributions and population fluctuations of ringed seals and polar bears appear tightly correlated in at least some areas (Stirling and Øritsland 1995).

Past ringed seal population estimates in the Bering-Chukchi-Beaufort area ranged from 1–1.5 million (Frost 1985) to 3.3–3.6 million (Frost et al. 1988). During aerial surveys in 1999, Bengtson et al. (2005) reported ringed seal densities offshore from Shishmaref to Barrow ranging from 0.4 to 3.7 seals/km$^2$ (1.0 to 9.6 seals/mi$^2$) and estimated the total Chukchi Sea population at 245,048 animals in 1999. Densities were higher in nearshore than offshore locations. During vessel-based observations from industry activities in the Chukchi Sea, Haley et al. (2010) reported seal densities (assumed to be almost entirely ringed seals) from 0.07 to 0.74 seals/km$^2$ (0.18 to 1.92 seals/mi$^2$) in summer and fall, respectively. There is currently no statistically robust population estimate available for ringed seals; Kelly et al. (2010) presented one million animals as the best estimate for the Bering, Chukchi, and Beaufort Seas based on a review of currently available data.

Natchiq (ringed seals) are an important resource for the Inupiat people of Alaska. Meat, blubber, and oil are eaten, and bones and hides are used as materials in artworks and handicrafts. The number of seals taken varies from year to year, depending upon ice conditions and the availability of other marine mammal species, such as bowhead or beluga whales, to subsistence hunters. The best estimate of the annual take of ringed seals by subsistence hunters in Alaskan waters is 9567 (Allen and Angliss 2013).

### *Spotted Seal (Qasigiaq, Phoca largha)*

Spotted (or largha) seals are found in the Beaufort, Chukchi, Bering, and Okhotsk Seas, and as far south as the northern Yellow Sea and the western Sea of Japan (Fig. 2.28; Shaughnessy and Fay 1977). Three Distinct Population Segments (DPS) are recognized: the Southern DPS, which includes seals breeding in the Yellow Sea and Sea of Japan; the Okhotsk DPS, which includes seals in the Sea of Okhotsk; and the Bering DPS, which includes seals in the Beaufort, Chukchi, and East Siberian Seas. Very little recent data are available concerning the abundance of spotted seals and the latest reliable comprehensive estimate is based on surveys performed during the late 1970s. The world population was estimated at 370,000–420,000 animals and it was estimated that the Bering Sea DPS, including animals in Russian waters, was 200,000–250,000 animals (Bigg 1981). In 2007, NMML conducted aerial surveys of the Bering Sea ice pack and calculated a provisional estimate of the Bering DPS to be 101,568 ±17,869 (Boveng et al. 2009). The spotted seal's status under the ESA was recently reviewed (Boveng et al. 2009) and the Southern DPS was subsequently listed as "threatened." The Okhotsk and Bering DPS remain unlisted. Allen and Angliss (2013) estimate the Alaskan population at 59,214 animals.

In the Chukchi Sea, Kasegaluk Lagoon and Icy Cape are important areas for spotted seals. Spotted seals haul out in this region from mid-July until freeze-up in late October or November. Lowry et al. (1998) reported a maximum count of about 2200 spotted seals in the lagoon during aerial surveys. No spotted seals were recorded along the shore south of Pt. Lay. Based on satellite tracking data, Frost et al. (1993) reported that spotted seals tagged at Kasegaluk Lagoon spent 94 percent of the time at sea. Extrapolating the count of hauled-out seals to account for seals at sea would suggest a Chukchi Sea population of about 36,000 animals.

Spotted seals are also present in the Beaufort Sea from July through late August. A small number of spotted seal haulouts are (or were) located in the central Beaufort Sea in the deltas of the Colville River

and previously the Sagavanirktok River. Historically, these sites supported as many as 400–600 spotted seals, but in more recent surveys, fewer than 20 seals have been seen at any one site (Johnson et al. 1999). A total of 12 spotted seals were positively identified near the source vessel during open-water seismic programs in the central Alaskan Beaufort Sea during the six years from 1996 to 2001 (Moulton and Lawson 2002, p. 317). Numbers seen per year ranged from zero (in 1998 and 2000) to four (in 1999). More recently Green et al. (2007) reported 46 spotted seal sightings during barge operations between West Dock and Cape Simpson. Most sightings occurred from western Harrison Bay to Cape Simpson with only one sighting offshore of the Colville River delta. Some of these could have been repeat sightings of the same individuals as the barges traversed the same area on numerous occasions.

During spring when pupping, breeding, and molting occur, spotted seals are found along the southern edge of the sea ice in the Okhotsk and Bering seas (Quakenbush 1988; Rugh et al. 1997). In late April and early May, adult spotted seals are often seen on the ice in female-pup or male-female pairs, or in male-female-pup triads. Subadults may be seen in larger groups of up to 200 animals. During the summer, spotted seals are found primarily in the Bering and Chukchi seas, but some range into the Beaufort Sea (Rugh et al. 1997; Lowry et al. 1998) from July until September. At this time of year, spotted seals haul out on land part of the time, but also spend extended periods at sea. Spotted seals are commonly seen in bays, lagoons and estuaries, but also range far offshore as far north as 69–72ºN latitude. In summer, they are rarely seen on the pack ice, except when the ice is very near shore. As the ice cover thickens with the onset of winter, spotted seals leave the northern portions of their range and move into the Bering Sea (Lowry et al. 1998).

A survey of literature concerning the diet of spotted seals shows that they are very flexible and consume several species of fish, shrimp, crab, squid, octopus, and a variety of pelagic and hyperbenthic crustaceans (Boveng et al. 2009). Their main predators are killer whales and polar bears.

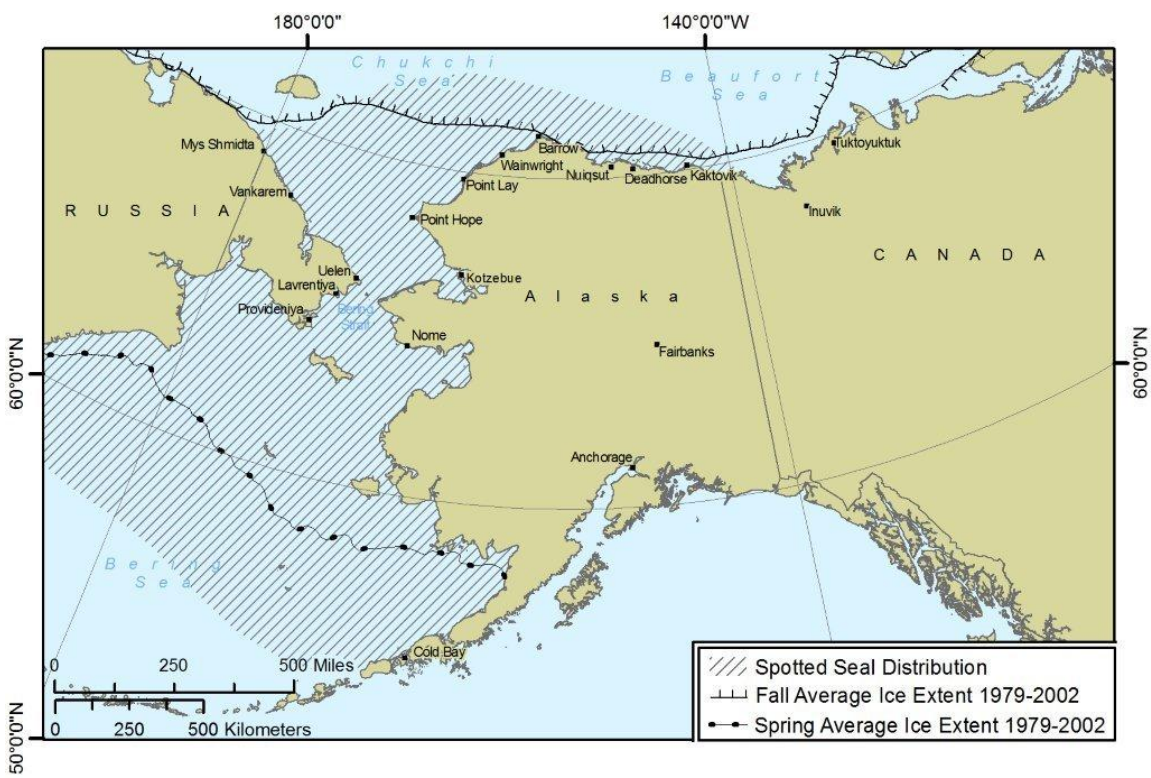


FIGURE 2.28. Distribution of spotted seals (*Phoca largha*) in Alaskan and Arctic waters.

## *Bearded Seal (Oogruk, Erignathus barbatus)*

Bearded seals are associated with sea ice and have a circumpolar distribution (Burns 1981). Two subspecies are recognized: *E.b. barbatus*, which inhabits Hudson Bay, the North Atlantic Ocean, the Barents sea, and the Laptev Sea; and *E.b. nauticus*, which inhabits Arctic waters of eastern Russia and Alaska, the Bering Sea, the Sea of Okhotsk, and the northwestern Canadian Arctic (Fig. 2.29). The two subspecies are not geographically discrete, and there is some gradation of intermingling surrounding the demarcation points at 112°W and 145°E. The subspecies *E.b. nauticus* is further divided in to two distinct population segments (DPS) – the Okhotsk DPS and the Beringia DPS. A status review was recently conducted (Cameron et al. 2010), and both DPS were listed as "threatened" under the ESA because of threats to habitat, specifically loss of sea ice.

Seasonal movements of bearded seals are directly related to the advance and retreat of sea ice and to water depth (Kelly 1988). During winter, most bearded seals in Alaskan waters are found in the Bering Sea. In the Chukchi and Beaufort seas, favorable conditions are more limited, and consequently, bearded seals are less abundant there during winter. They have occasionally been reported to maintain breathing holes in sea ice and broken areas within the pack ice, particularly where water depth is <200 m (<656 ft) (e.g., Harwood et al. 2005).

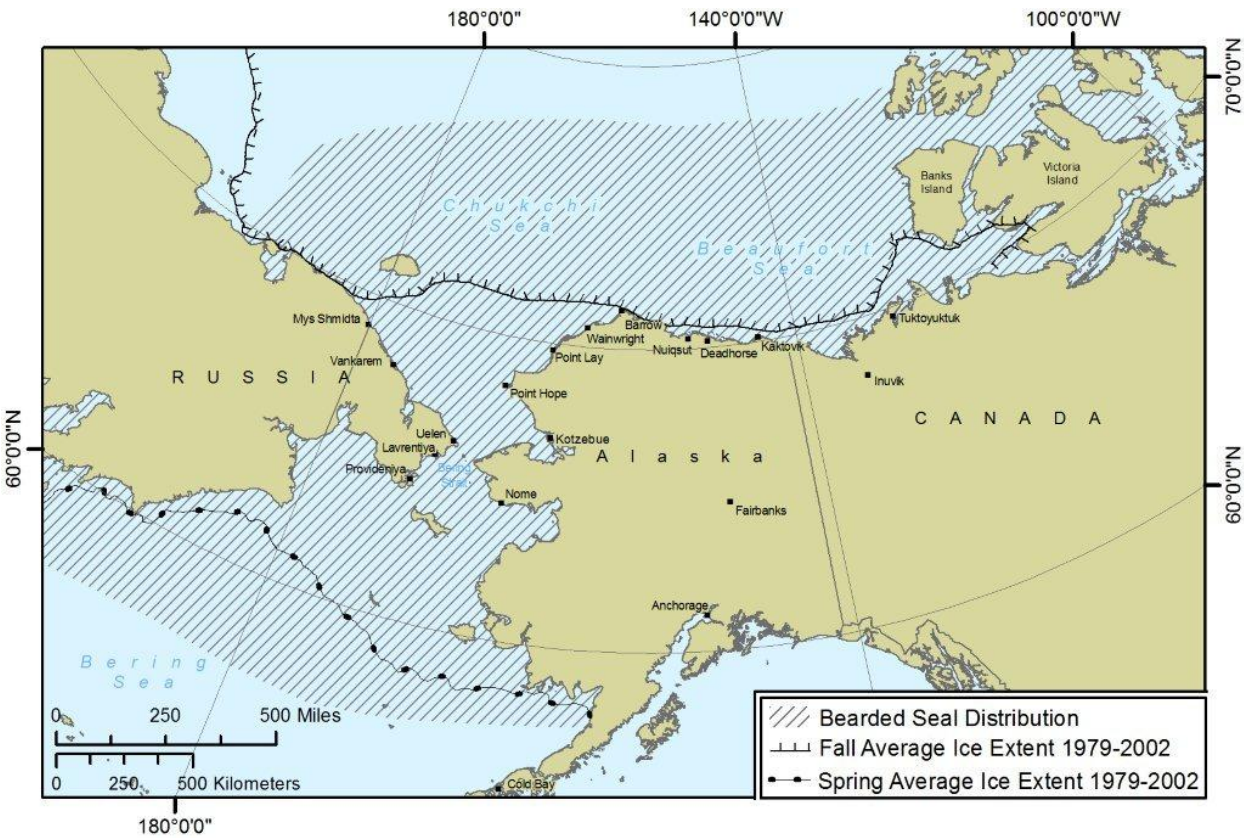


FIGURE 2.29. Distribution of bearded seals (*Erignathus barbatus*) in Alaskan and Arctic waters.

From mid-April to June as the ice recedes, some of the bearded seals that overwintered in the Bering Sea migrate northward through the Bering Strait. During the summer, they are found near the widely fragmented margin of multi-year ice covering the continental shelf of the Chukchi Sea and in nearshore areas of the central and western Beaufort Sea. Bearded seals apparently also feed on ice-associated organisms when they are present, and this allows a few bearded seals to live in areas where water depth is considerably greater than 200 m (656 ft; Cameron et al. 2009). During the summer period, bearded seals occur mainly in relatively shallow areas because they feed predominantly upon benthic bivalves (Burns 1981).

In Alaskan waters, bearded seals occur over the continental shelves of the Bering, Chukchi, and Beaufort Seas (Burns 1981). Bengtson et al. (2005) reported bearded seal densities in the Chukchi Sea ranging from 0.07 to 0.14 seals/square kilometers ($km^2$; 0.18 to 0.36 seals/square miles [$mi^2$]) in 1999 and 2000, respectively. No population estimates could be calculated since these densities were not adjusted for haulout behavior. Bearded seals are common in offshore pack ice, but there have been high bearded seal numbers observed closer to shore south of the project area near Kivalina (Bengtson et al. 2005). There is currently no statistically robust population estimate available for bearded seals; Cameron et al. (2010) presented 155,000 animals as the best estimate of the Beringia DPS based on a review of currently available data.

Oogruk (bearded seals) are hunted not only for their meat, but for their skins, which are used to make umiaq- the boats used by Inupiat during the spring bowhead hunt. Seal skins were also used to make floats attached to harpoons to help to tire and locate a bowhead that had been struck. Several methods of reporting and collecting data on the annual harvest of bearded seals have been used with varying results. The best estimate available is that, since 2000, 6788 animals have been taken per year (Allen and Angliss 2013).

## *Ribbon Seal (Qaiquliq, Histriophoca fasciata)*

Ribbon seals are distributed along shelf regions of the Aleutian Islands, Bering Sea, Sea of Okhotsk, and the northern tip of the Sea of Japan (Fig. 2.30). There are two main breeding areas – the Bering Sea and the Sea of Okhotsk, but it is not yet known whether the animals at these locations can be considered genetically distinct stocks (Boveng et al. 2008). Little is known about the diet of ribbon seals, particularly during winter months, but stomach samples collected to date have contained remains of various fish, crustaceans, and cephalopods. The best estimate of the worldwide ribbon seal population is somewhere between 200,000 and 250,000 animals, with approximately 49,000 of those animals living primarily in the eastern Bering Sea (Boveng et al. 2008). The ribbon seal is not listed under the ESA, nor is it considered a strategic stock under the MMPA (Allen and Angliss 2013).

In the southern Bering Sea, Ribbon seals are found along the pack-ice margin during late winter and early spring and they move north as the pack ice recedes during late spring to early summer (Burns 1970; Burns et al. 1981). Little is known about their summer and fall distribution, but Kelly (1988) suggested that they move into the southern Chukchi Sea, based on a review of sightings during the summer. However, there is remarkably little history of ribbon seals with Inupiaq hunters from villages on the Chukchi coast. During recent vessel-based surveys in 2006–2008 there were only two ribbon seal sightings among the total of 1390 seal sightings identified to species (Haley et al. 2010). In contrast, out of 26 animals equipped with satellite tags during 2007, eight moved to the Bering Strait, Chukchi Sea, or Arctic Ocean basin as ice retreated during summer, and then returned to the Bering Sea as ice formed in northern waters (Boveng et al. 2008). Part of the lack of sightings may be attributable to the ribbon seal's

very low profile while in water, however there is still a large knowledge gap concerning ribbon seals' distribution.

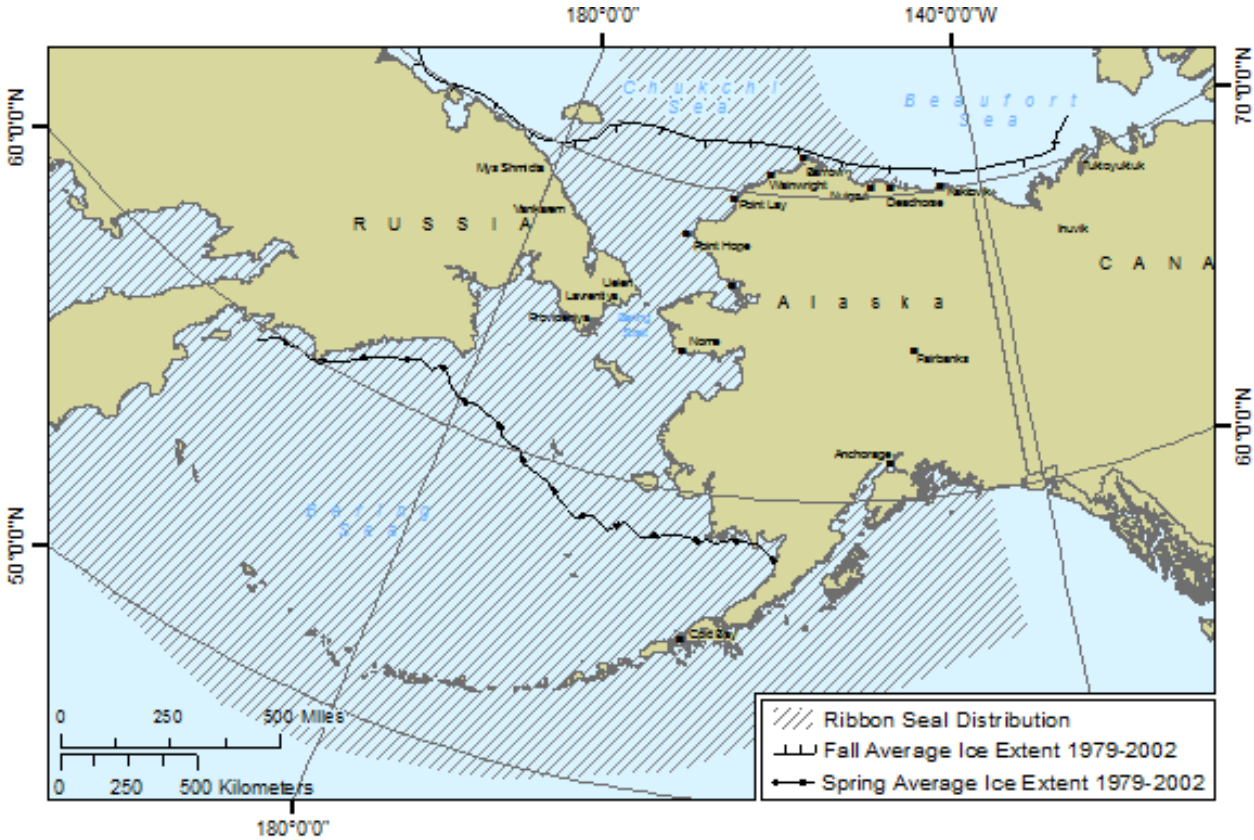


FIGURE 2.30. Distribution of ribbon seals (*Histriophoca fasciata*) in Alaskan and Arctic waters.

## *Pacific Walrus (Aiviq, Odobenus rosmarus divergens)*

There are two recognized subspecies of walrus: the Pacific (*O.r. divergens*) and the Atlantic walrus (*O.r. rosmarus)*. Both subspecies are migratory, moving south with the advancing ice in autumn and north as the ice recedes in spring (Fay 1981). The Pacific walrus spends the winter in the Bering Sea (Fig. 2.31). Spring migration usually begins in April, and most of the walruses move north through the Bering Strait by late June. Females with calves comprise most of the early spring migrants and nearly all the adult females with dependent young migrate into the Chukchi Sea during the summer, while a substantial number of adult males remain in the Bering Sea (USFWS 2013). Although most of the population of Pacific walrus moves to the Chukchi Sea during summer, several thousand aggregate in the Gulf of Anadyr and in Bristol Bay (Allen and Angliss 2013). Two large arctic areas are occupied — from the Bering Strait west to Wrangel Island and along the northwest coast of Alaska from about Point Hope to north of Point Barrow. Although a few walruses may move east throughout the Alaskan portion of the Beaufort Sea to Canadian waters during the open-water season, the majority of the Pacific population occurs west of 155°W, with the highest seasonal abundance along the pack-ice front (Sease and Chapman 1988). During low-ice years (e.g., 2007, 2009), the number of walrus hauling out on land along the Alaskan Chukchi Sea coast has been in the tens of thousands as opposed to dozens, as was previously seen (Jay et al. 2011). With the southern advance of the pack ice in the Chukchi Sea during the fall

(October–December), most of the walrus population migrates south through the Bering Strait. Solitary animals occasionally may overwinter in the Chukchi Sea and in the eastern Beaufort Sea.

Walruses are benthic feeders and their chief prey are clams and crabs, though they may occasionally take other prey such as fish, shrimp, large plankton, cephalopods, and seals. Hunting mainly at night, walruses use the vibrissae surrounding their noses and mouths to detect prey in the sediment. They then suction water through their noses and force jets of water over the sediment to uncover the buried food. Tusks are not used in feeding, as is commonly believed.

The size of the Pacific walrus population has never been known with certainty and is believed to have fluctuated markedly in response to varying levels of human exploitation (Fay et al. 1989). The North Pacific walrus population was estimated at about 201,039 animals in 1990 (Gilbert et al. 1992 referenced in Allen and Angliss 2013), comprising about 80% of the world population. After 1990, aerial survey efforts to estimate population size were suspended due to unresolved problems with survey methods. Aerial surveys were undertaken again in 2006 and resulted in an estimate of 129,000 animals (Speckman et al. 2011). During the 2006 season, poor weather limited the number of flights and so Speckman et al. caution that it is certain that this number is significantly lower than the true population, though it is not known by how much.

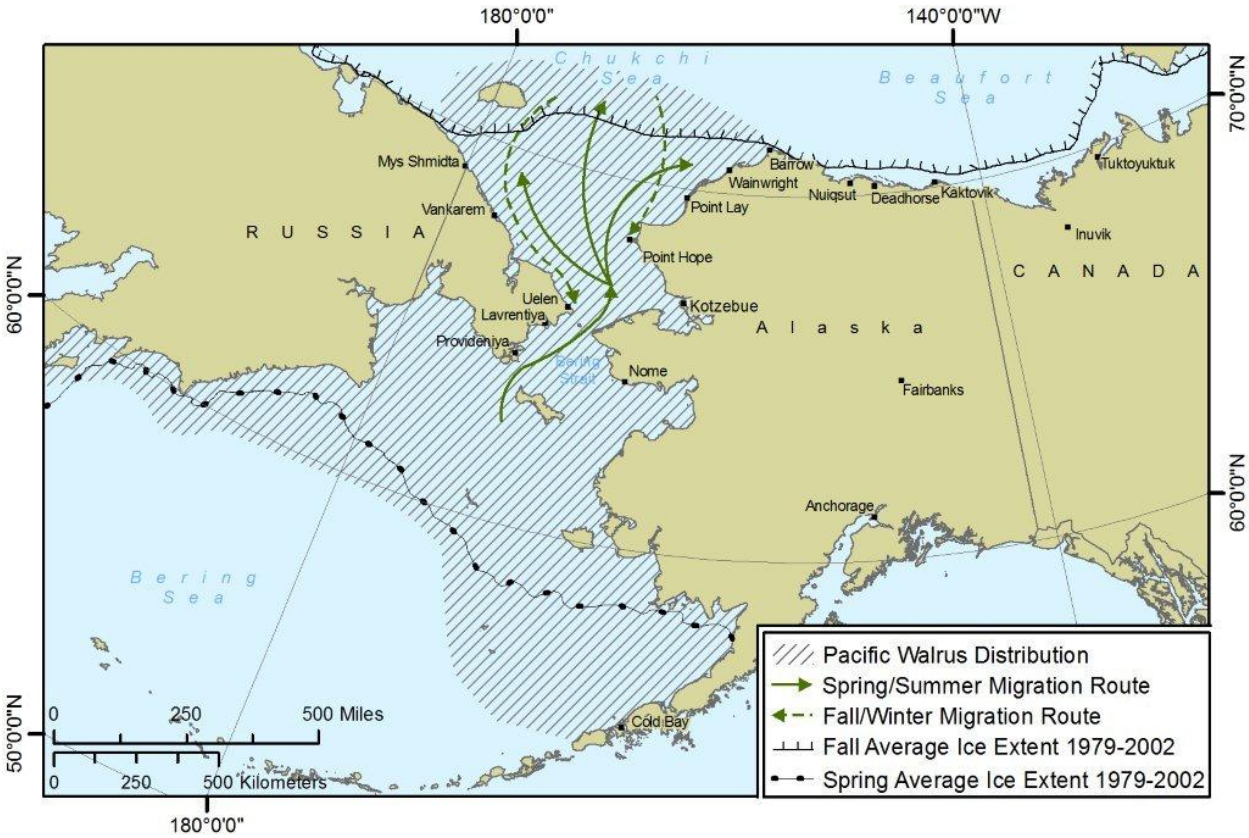


FIGURE 2.31. Distribution and migration routes of Pacific walrus (*Odobenus rosmarus rosmarus*) in Alaskan and Arctic waters.

Aiviq (Pacific walrus) have been hunted for meat, skin, and their ivory for centuries. Since 1960, the annual harvest of walrus from Alaska and Russia has ranged from 2000 to 16,000 animals, peaking in 1984 and 1985 (USFWS 2013). Since 1990, the number of walrus harvested in Alaska has ranged between 2000 and 4000 animals per year. In the Chukchi Sea, walruses are hunted primarily from June through mid-August to the west of Point Barrow and southwest to Peard Bay. Harvest effort peaks in July and August and in many years is conducted simultaneously with the hunt for bearded seals.

### *Polar Bear (Nanuq, Ursus maritimus)*

Polar bears have a circumpolar distribution throughout the northern hemisphere (Amstrup et al. 1986) and occur in relatively low densities throughout most ice-covered areas (DeMaster and Stirling 1981). They are common in the Chukchi and Beaufort seas north of Alaska throughout the year, including the late summer period (Fig. 2.32; Harwood et al. 2005). They also occur throughout the East Siberian, Laptev, and Kara Seas of Russia and the Barents Sea of northern Europe. They are found in the northern part of the Greenland Sea, and are common in Baffin Bay, which separates Canada and Greenland, as well as through most of the Canadian Arctic Archipelago. Polar bears typically range as far north as 88°N (Ray 1971; Amstrup and Durner 1995) above which their population thins dramatically. However, polar bears have been observed across the Arctic, including close to the North Pole (van Meurs and Splettstoesser 2003). Stirling (1990) reported that of 181 sightings of bears, only three were above 82°N.

Six major populations are recognized, each of which is divided into sub-populations. These populations were identified through mark-and-recapture data (Lentfer 1983) and radio telemetry (Amstrup and Gardner 1994) to establish the geographical ranges of animals. Two of these populations occur in Alaskan waters. The Southern Beaufort Sea population ranges westwards from the Baillie Islands in the Canadian Beaufort to Point Hope, Alaska. The Bering/Chukchi Sea population ranges from Point Barrow westwards to the Eastern Siberian Sea. The two populations overlap between Point Hope and Point Barrow.

The Bering/Chukchi and Southern Beaufort populations have been extensively studied by tracking the movement of tagged females (Garner et al. 1990). Radio-tracking studies indicate significant movement within populations and occasional movement between populations (Garner et al. 1990; Amstrup 1995). A female polar bear within sight of the Prudhoe Bay oilfields was captured, fitted with a satellite-tracking collar, and her movements monitored for 576 days. She traveled north and then south to Greenland, traversing ~7162 km (~4476 mi) in 576 days (Amstrup and Durner 1995).

Polar bears usually forage in areas where there are high concentrations of ringed and bearded seals, sniffing out lairs and breathing holes in both moving and landfast ice (Larsen 1985; Stirling and McEwan 1975). Polar bears can also be opportunistic and will take whatever foods are available, including beluga whales, arctic cod, geese and their eggs, walruses, bowhead whale carcasses, and reindeer (Smith 1985; Jefferson et al. 1993; Smith and Hill 1996; Derocher et al. 2000). Throughout large expanses of their range polar bears subsist almost exclusively on ringed seals. Where this is the case, the numbers, spatial distributions, and reproductive capacities of polar bears and ringed seals are tightly linked (Stirling and Øritsland 1995; Hammill and Smith 1991).

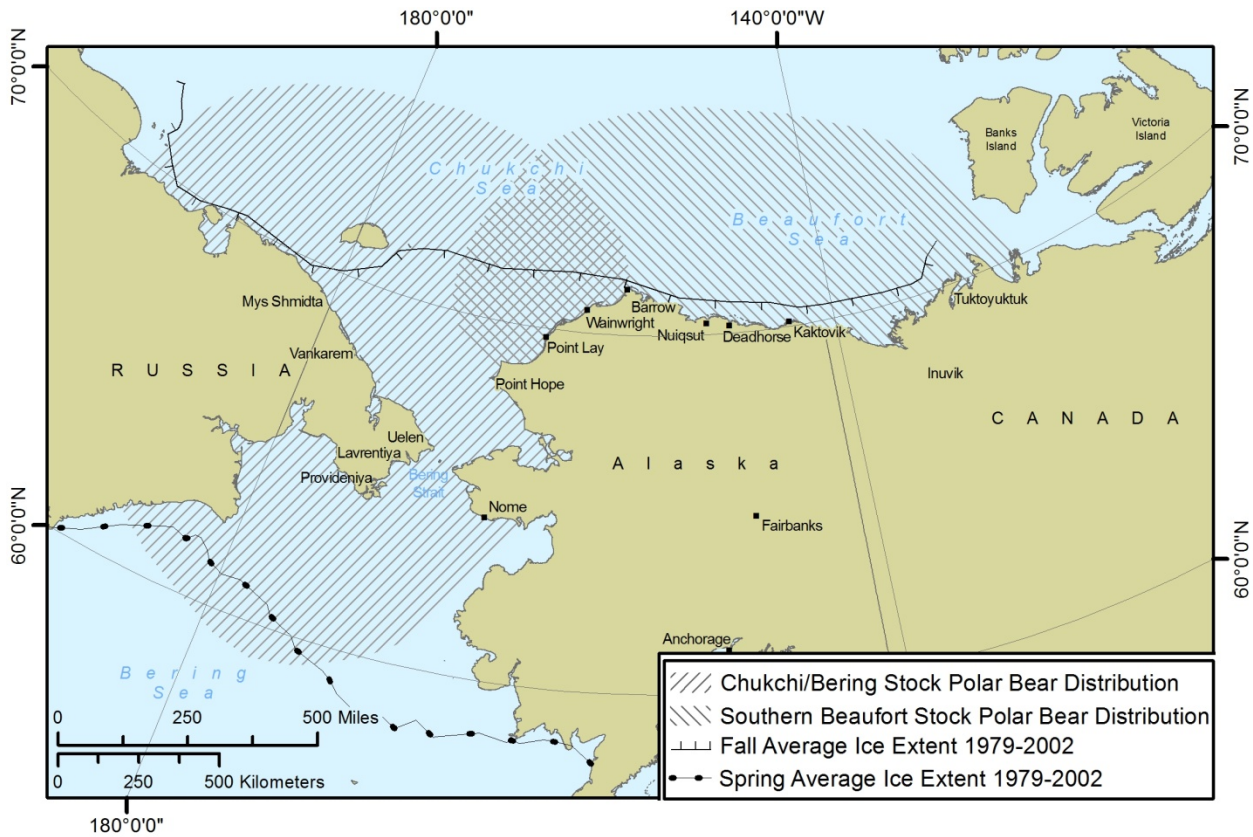


FIGURE 2.32. Distribution of polar bears (*Ursus maritimus*) in Alaskan and Arctic waters.

The population of polar bears has fluctuated during the last 60 years, largely as a function of harvest numbers. Prior to commercial hunting in 1960, it is likely that polar bear numbers were at carrying capacity. Populations declined between 1960 and 1972, when the MMPA was enacted, and the population began to recover. Currently, polar bear populations are protected by the International Agreement on the Conservation of Polar Bears, ratified in 1976. Countries participating in the latter treaty include Canada, Denmark, Norway, Russia (former USSR), and the USA. The polar bear was listed as "vulnerable" on the IUCN red list in 2005, and remains listed as "vulnerable", based on the likelihood of an overall decline in the size of the total population of more than 30% within the next 35 to 50 years. In 2008, the polar bear was listed as "threatened" under the ESA due to concerns for loss of habitat as a function of declining sea ice. The best estimate of the Southern Beaufort population is 1526 and is believed to be declining at roughly 3% per year (USFWS 2010a). The Chukchi/Bering population is estimated at approximately 2000 animals and is also declining (USFWS 2010b).

Nanuq (polar bears) have been taken by subsistence hunters for food as well as fur, bones, and teeth to be used for clothing, tools, and art. Subsistence hunts for polar bears in Alaska are not currently based on quota, rather based on voluntary actions of subsistence hunters in local communities. Between 2003 and 2007, the average number of polar bears taken by Alaskan Inupiat from the Chukchi / Bering and Southern Beaufort populations was 37 and 33, respectively (USFWS 2010a; USFWS 2010b). There is a certain amount of concern about the number of Chukchi / Bering animals taken by hunters in Russia. This number may be up to 200 animals annually, which is in line with the peak annual harvest by sport hunters in the late 1960s, and likely not sustainable (USFWS 2010b).

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# ACOUSTIC ENVIRONMENT OF THE ALASKAN CHUKCHI AND BEAUFORT SEAS

The underwater acoustic environment is comprised of sounds from natural, biologic, and anthropogenic sources. Underwater sound levels in the ocean vary temporally as these sources fluctuate on daily, seasonal, and annual scales. Natural sources of sound include geologic processes, earthquakes, wind, lightning, thunder, rain, waves, ice, etc. Biologic sources, including marine mammals and fish, generate sounds used for communication, navigation, and prey detection, among others. Anthropogenic noises are those generated by human activities including sound from vessels and offshore machinery.

The Chukchi Sea continental shelf is characterized by a very uniform water depth of 30–50 m (98–164 ft) which tends to support long-range propagation of sounds at frequencies between 50 and 500 Hz (Hannay 2008). These are likely the frequencies of greatest sensitivity for bowhead whales and are the dominant frequencies of sounds emitted by anthropogenic sources like vessels and airguns. In contrast, the Beaufort Sea has a narrow continental shelf that drops off to the north into the Beaufort Plateau, a deep basin with depths of roughly 2000–3000 m (6500–10,000 ft). These deep waters allow long-range propagation of high amplitude sounds, such as airgun pulses, on a basin-wide scale.

Underwater sound levels in shallow water environments, like the Chukchi Sea or the Beaufort Sea continental shelf, generally increase with increasing wind speed (Wenz 1962; Roth et al. 2012). Both the Beaufort and Chukchi seas are covered by sea-ice during most of the year. When there is 100% ice cover, the ambient sound field lacks sounds from bubbles and agitation generated by surface waves so underwater sound levels tend to be lower compared to those for open water conditions (Richardson et al. 1995). As well, there is less anthropogenic noise when there is ice cover. Recent measurements in the Chukchi Sea indicated that levels at frequencies between 100 Hz and 3 kHz were roughly 10 dB less in winter than those recorded during the open-water season (Delarue et al. 2013). Sea-ice can, however, be an intermittent source of high-intensity sound during cracking, formation, and movement (Milne and Ganton 1964; Delarue et al. 2013). The propagation of sound is also influenced by sea-ice presence; scattering at the rough underside of the ice reduces the distances to which natural and biologic sounds travel under ice (NRC 2003).

Ambient sound in the Beaufort and Chukchi seas contains a substantial contribution from the seasonal presence of marine mammals such as bowheads, walrus, and seals. Beluga vocalizations also contribute to the underwater sounds recorded within the industry-sponsored studies in the Chukchi Sea, particularly during their spring migration (Delarue et al. 2012). Vocalizations from marine mammals have been monitored since the late 1970s and early 1980s, using seafloor-mounted passive acoustic monitoring devices. Such devices deployed near Barrow over several years were part of an acoustic census of bowhead whales (e.g., Clark and Johnson 1984). Since 2006, passive acoustic monitoring recorders have been deployed in the Chukchi and Beaufort seas as part of oil and gas-sponsored environmental studies (Cornell 2010; Delarue et al. 2012; Blackwell et al. 2011). In the Chukchi Sea, recorders have been placed from Cape Lisburne to Barrow, at distances of 5 to >100 nautical miles (nmi) from shore. In the Beaufort Sea, deployment locations cover a 280 km (174 mi) east-west distance between Harrison Bay and Barter Island, ~8–30 nmi from shore. Bowhead whales pass through these regions during their spring and fall migrations. They produce a variety of sounds in the 20–3500 Hz frequency range consisting of frequency-modulated moans, usually below 600 Hz, and complex calls (Clark and Johnson 1984; Cummings and Holliday 1987; George et al. 2004; Cornell 2010; Delarue et al. 2012). Walruses are in the Chukchi Sea from late spring through the fall. They produce a variety of sounds ranging from grunts to knocks that are fairly broadband (100 Hz–10 kHz). Walrus sounds are

detected most frequently between Hanna Shoal and Wainwright as well as near to Point Lay (Delarue et al. 2012). Seals are detected in all months of the year on recorders throughout the Chukchi Sea, but during the breeding season (May), sounds from the male bearded seals increase the ambient background levels by as much as 20 dB in the 400 Hz range (Delarue et al. 2012).

Anthropogenic noise sources in both seas include mainly vessel traffic and sources associated with oil and gas exploration (airgun arrays, geophysical survey sources, drillships, etc). Vessel traffic includes a wide range of vessel types, with varying noise levels: small skiffs for whaling, scientific research vessels, tugs towing re-supply barges for the communities, large barges transporting equipment to the North Slope oil fields, tourism and recreation vessels, icebreakers, and vessels associated with oil and gas exploration activities. Source levels for smaller vessels are typically between 120 and 150 dB re 1 µPa at 1 m with most of the energy below 5000 Hz (Richardson et al. 1995), while source levels for tugs pulling large barges are typically lower frequency (below 1000 Hz) with greater source levels (~170–180 dB re 1 µPa at 1 m). There have been no production islands, ports or docks constructed in the Chukchi Sea to date, meaning that construction noise from sources such as pile driving or dredging are not presently a source of noise in this region.

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# RECENT OFFSHORE OIL AND GAS INDUSTRY ACTIVITIES, OTHER VESSEL ACTIVITIES AND POTENTIAL EFFECTS ON MARINE MAMMALS AND SUBSISTENCE

## *Introduction*

Offshore oil and gas exploration activities in the US Arctic began nearly five decades ago. The emergence of the Alaskan Arctic Outer Continental Shelf (OCS) as a potential source of hydrocarbon resources was accompanied by several unique considerations: the region is remote, covered in sea ice for the majority of the year, prone to large storms, and logistically difficult to access and operate within. Perhaps most notable, however, is the biological productivity of the Arctic OCS and the Alaska Native communities along the coastlines of the Chukchi and Beaufort seas. Numerous marine mammal species are present year round or seasonally, and subsistence harvests of several of these species are central to Alaska Native cultures of the region. All of these attributes have resulted in a specialized approach to oil and gas exploration of the Arctic OCS that strives to integrate contributions from industry, western science, and Alaska Native traditional knowledge (TK).

## *Historical Overview*

Marine seismic programs in support of offshore drilling operations have operated in the Alaskan Beaufort Sea since the late 1960's, and similar surveys began in the Chukchi Sea as early as 1970. The Endicott oil field was discovered in the nearshore coastal area of the Beaufort Sea in the Sagavanirktok River Delta in 1978. In 1979, the United States Minerals Management Service (MMS, now the Bureau of Ocean Energy Management [BOEM]) conducted a lease sale which stimulated the first serious Arctic offshore exploration for oil and gas (BOEM 2011). Exploratory drilling in offshore areas of the US Beaufort Sea began in 1981 and a total of 30 wells were drilled by 2003 by various industry participants, although the majority of the wells were drilled by the early-1990s (Fig. 2.33). Seismic mapping in conjunction with the drilling of "wildcat" wells (wells not known to be in an oil field) began in offshore areas of the Chukchi Sea around the mid-1980s. The first lease sale in the Chukchi Sea Outer Continental Shelf Planning Area occurred in 1988 (BOEM 2011). Between 1989 and 1991, industry drilled five exploration wells up to 225 km (140 mi) offshore (Fig. 2.34).

Oil and gas are currently being produced from BP's offshore development at Northstar Island, Pioneer's Ooguruk Drill site (ODS) in eastern Harrison Bay, and Eni's Spy Island Drill site (SID). Northstar Island, ODS, and SID are man-made, gravel islands in the Alaskan Beaufort Sea. Northstar is located outside of the barrier islands ~10 km (6 mi) offshore of Pt. Storkerson in the Prudhoe Bay area. ODS and SID are located inside the barrier islands near the Colville River delta. No other offshore oil and gas production developments currently exist in the Alaskan Beaufort Sea, and no similar production developments exist in the Chukchi Sea.

Offshore seismic activity in previous decades was much higher compared to the last 10 years (Fig. 2.35). For example, >100,000 km (~62,000 mi) of marine seismic surveys were conducted from 1977–1987 whereas <50,000 km (~31,000 mi) were completed in the most recent decade (2002–2012; Fig. 2.35). More than 16,000 km (~10,000 mi) of seismic survey activity was conducted in four different years, only one of which occurred in the last 10 years (2006; Fig. 2.35). The highest level of seismic survey activity since 1985 occurred in 2006 due to the presence of three source vessels in the Chukchi Sea conducting deep seismic surveys following renewed interest in Alaska OCS exploration activities. Deep

seismic surveys as well as site clearance and shallow hazards surveys were performed in 2007, 2008, and 2010, with much greater seismic activity in 2008 than in 2007 and 2010. The relatively high amount of seismic activity in 2008 compared to similar years resulted from inclusion of ocean bottom cable (OBC) seismic activity in nearshore areas of the Beaufort Sea in the 2008 total. Site clearance and shallow hazard seismic survey activity occurred in 2009 and 2011 over Shell and Statoil leases, respectively. ION Geophysical conducted a deep seismic survey mainly in the Beaufort Sea in 2012. Also in 2012, BP performed a 3D OBC survey in the Simpson Lagoon, Beaufort Sea, which was included in the 2012 total in Figure 2.35.

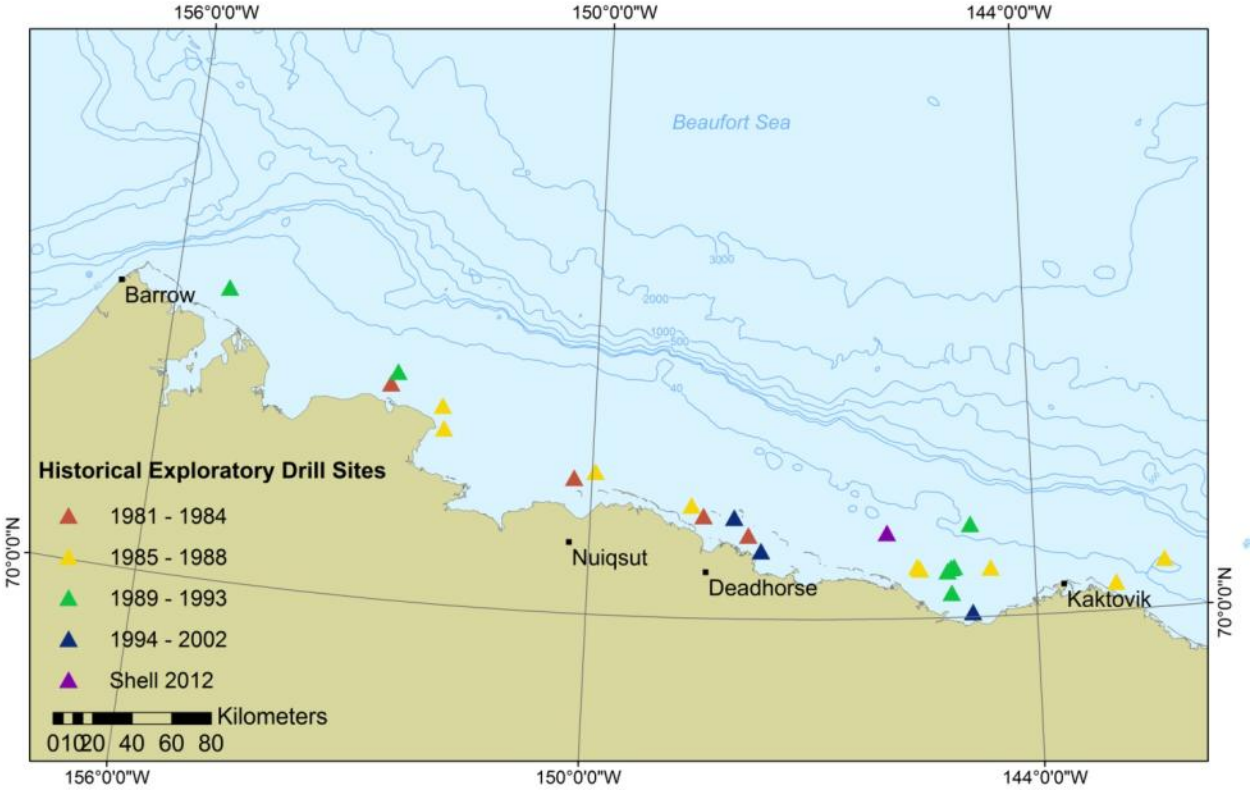


FIGURE 2.33. Location of historical, offshore exploratory drill sites in the Alaskan Beaufort Sea. The first offshore well was drilled in 1981 and the most recent was Shell's top hole in 2012.

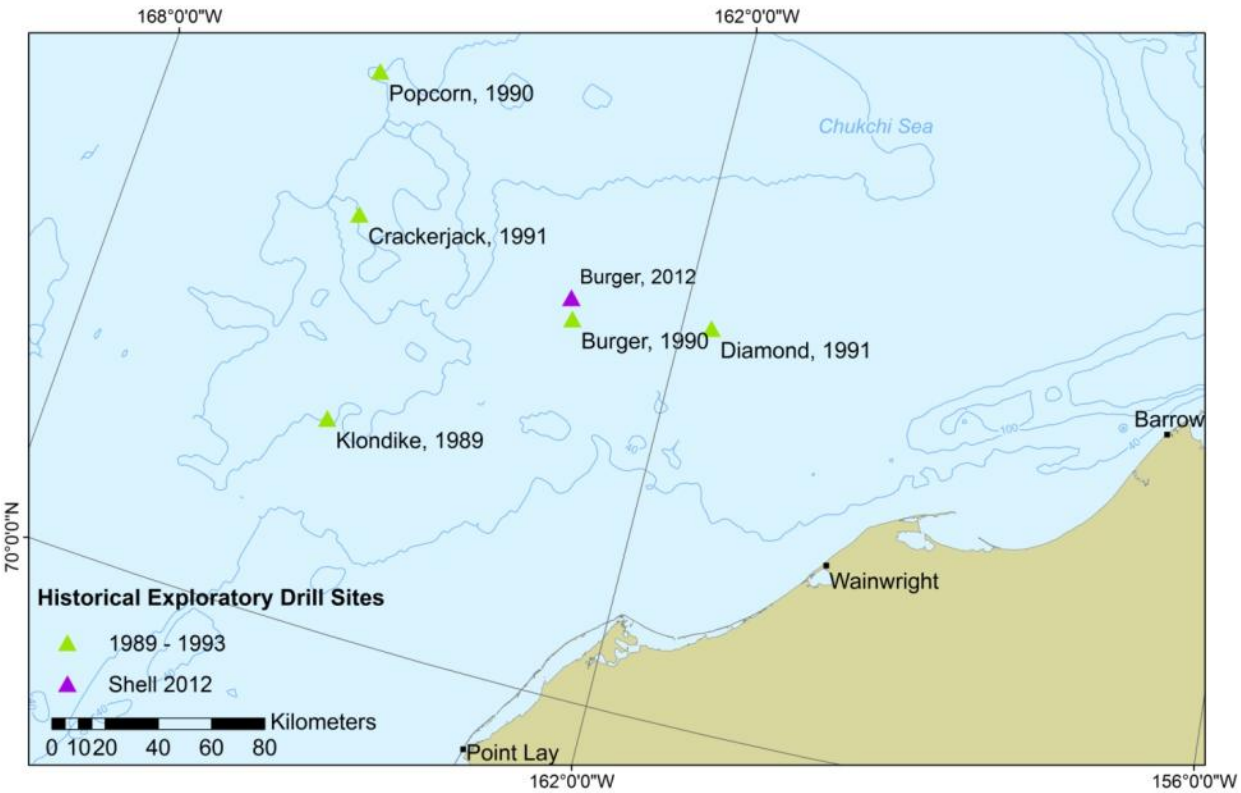


FIGURE 2.34. Location of historical, offshore exploratory drill sites in the Alaskan Chukchi Sea. The first offshore well was drilled in 1989 and the most recent was Shell's top hole in 2012.

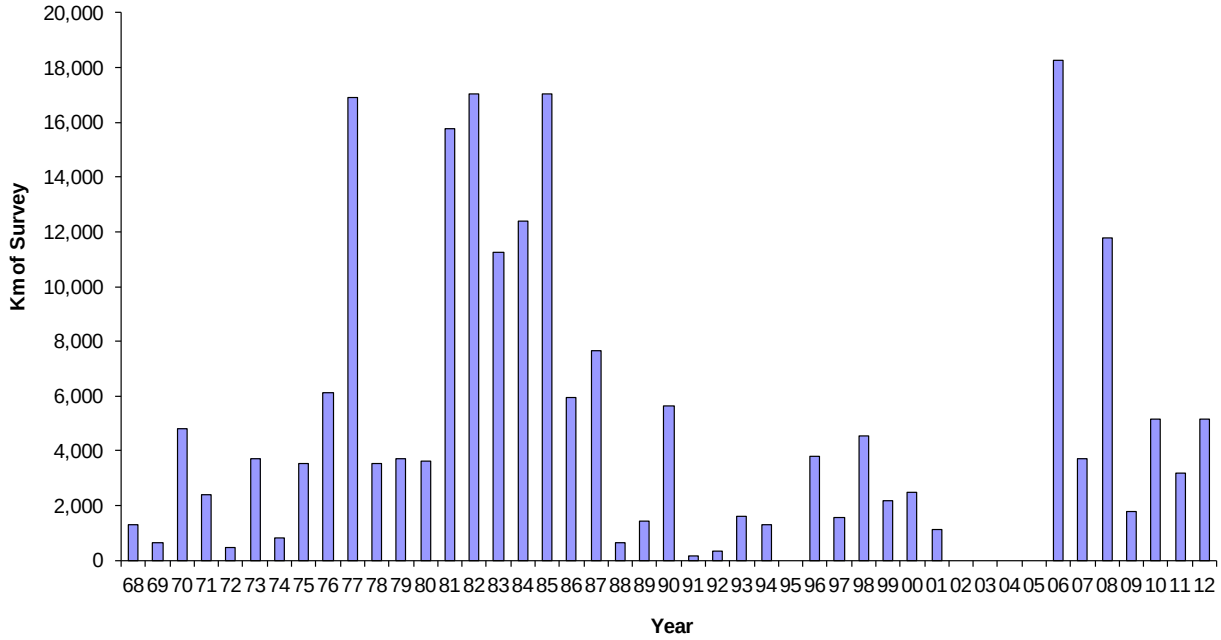


FIGURE 2.35. Kilometers of seismic survey activity using towed arrays from 1968 through 1994, and 2006 through 2012 in the Alaskan Chukchi and Beaufort seas. Ocean bottom cables (OBC) were used for seismic survey activity in 1996–2001, 2008, and 2012 in the Beaufort Sea. Total kilometers in 2008 and 2012 includes both seismic and OBC survey activities.

## *Recent Offshore Exploration Activities*

As suggested above and in Figure 2.35, a renewed interest in offshore oil and gas exploration in the Alaskan Arctic OCS began in 2006. Offshore seismic activities since 2006 have consisted of both deep seismic and shallow hazard surveys. A much smaller airgun array is used during shallow hazard compared to deep seismic surveys. The amount of vessel trackline along which airguns were active during deep seismic and shallow hazard surveys in the Alaskan Chukchi and Beaufort Seas since 2006 is shown in Figures 2.36 and 2.37.

The majority of recent deep seismic and shallow hazard survey activity in the Alaskan Arctic OCS has been conducted in the Chukchi Sea, with more airgun activity occurring in 2006 than in 2007–2012 combined (Figs. 2.36 and 2.37). Airguns were active along more than 18,000 km (11,185 mi) of vessel trackline in the Chukchi Sea in 2006 during three different deep seismic surveys compared to less than 100 km (62 mi) of trackline during a single shallow hazard survey in the Beaufort Sea in 2006 (Figs. 2.36 and 2.37). From 2006–2012, airguns operated along less than 4000 km (2485 mi) of vessel trackline in offshore waters of the Beaufort Sea each year, and along less than 5000 km (3107 mi) of trackline annually in the Chukchi Sea from 2007–2012.

All of the airgun activity in the Alaskan Chukchi Sea during 2006 was from deep seismic surveys compared to relatively equal amounts of deep seismic and shallow hazard activities from 2007 through 2012 (Fig. 2.36). About two thirds of the seismic airgun activity in offshore waters of the Alaskan Beaufort Sea since 2006 originated from deep seismic as opposed to shallow hazard surveys (Fig. 2.37). The majority of airgun activity from deep seismic and shallow hazard surveys since 2006, however, occurred in the Chukchi Sea (Figs. 2.36 and 2.37).

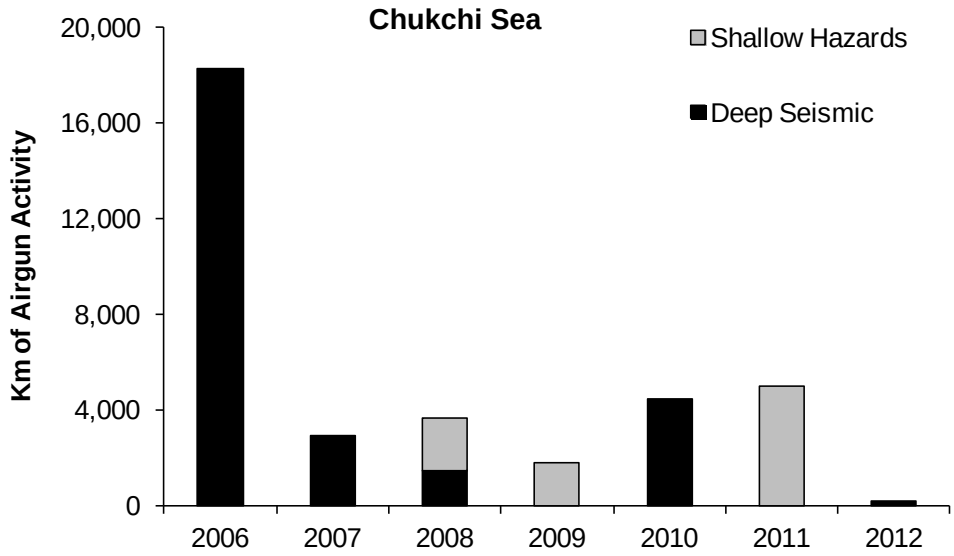


FIGURE 2.36. Kilometers of airgun activity during deep seismic and shallow hazard survey activities in the Alaskan Chukchi Sea, 2006–2012.

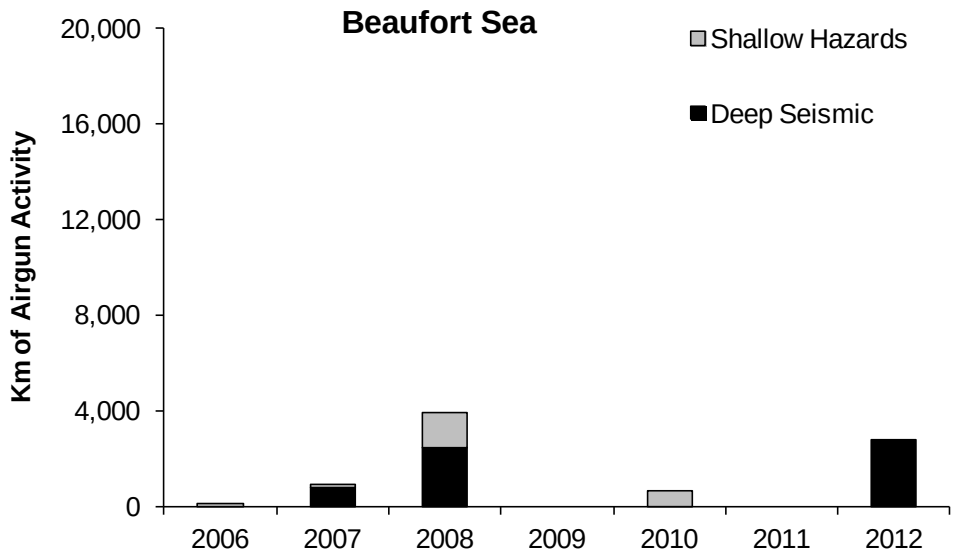


FIGURE 2.37. Kilometers of airgun activity during deep seismic and shallow hazard survey activities in the Alaskan Beaufort Sea, 2006–2012.

Geotechnical coring operations occurred during brief periods in the Chukchi Sea in 2010 using a Vibracore coring system from a stationary vessel and for longer periods in 2011 using a dedicated drillship. In 2012, Shell conducted exploratory drilling activities in the Chukchi and Beaufort seas. A single, shallow top hole in each sea was completed. Numerous support vessels including ice management and anchor handling vessels assisted exploratory drilling operations. The top holes drilled by Shell in 2012 were the first exploratory wells drilled in the Alaskan Chukchi and Beaufort seas since 1991 and 2003, respectively (Figs. 2.33 and 2.34).

Most offshore oil and gas exploration activities in the Alaskan Arctic require dedicated support and/or monitoring vessels, particularly larger seismic and drilling programs. Support vessel traffic associated with these exploration programs often is greater, in terms of both ship numbers and distances traveled, than the activity of the primary survey vessels or drillships alone. It is, therefore, important to consider support vessels when assessing potential impacts to marine mammals from exploration activities. Support vessel traffic also has the potential to be spread out over a larger geographical area. Recent large seismic programs in the Alaskan Arctic have involved two to three dedicated support/monitoring vessels in part to assist with monitoring of 180 and 160 dB (rms) marine mammal safety and harassment zones, respectively. Shell's 2012 drilling program required approximately 15 vessels to support two dedicated drill rigs. The total vessel traffic associated with offshore oil and gas exploration programs in the Alaskan Chukchi and Beaufort seas since 2006 is shown in Figures 2.38 and 2.39.

The amount of vessel traffic from offshore oil and gas exploration programs since 2006 was greater each year in the Chukchi compared to the Beaufort Sea, most notably in 2006 (Figs. 2.38 and 2.39). There was considerable variation in the amount of exploration-related vessel traffic among years in both the Chukchi and Beaufort seas. Total vessel traffic from offshore exploration programs from 2006–2012 in the Chukchi Sea was twice that from the Beaufort Sea during the same period. The largest single-season amount of exploration-related vessel traffic in each sea since 2006 was from seismic programs as opposed to drilling, although drilling-related vessel traffic was much greater than that from seismic programs in 2012 (Figs. 2.38 and 2.39). Vessels associated with Shell's 2012 drilling program spent nearly half of the season in a stationary or near-stationary (<1 kt or 1 mph) position, which reduced the amount of vessel traffic in the Alaskan Chukchi and Beaufort seas in 2012.

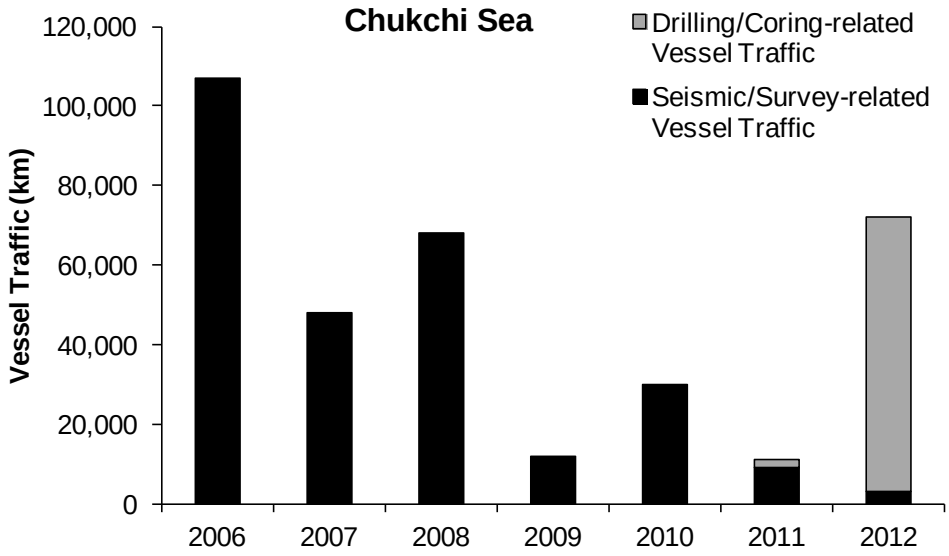


FIGURE 2.38. Kilometers of vessel traffic, including support vessels, from offshore oil and gas exploration programs from drilling/coring versus seismic/marine survey in the Alaskan Chukchi Sea, 2006–2012.

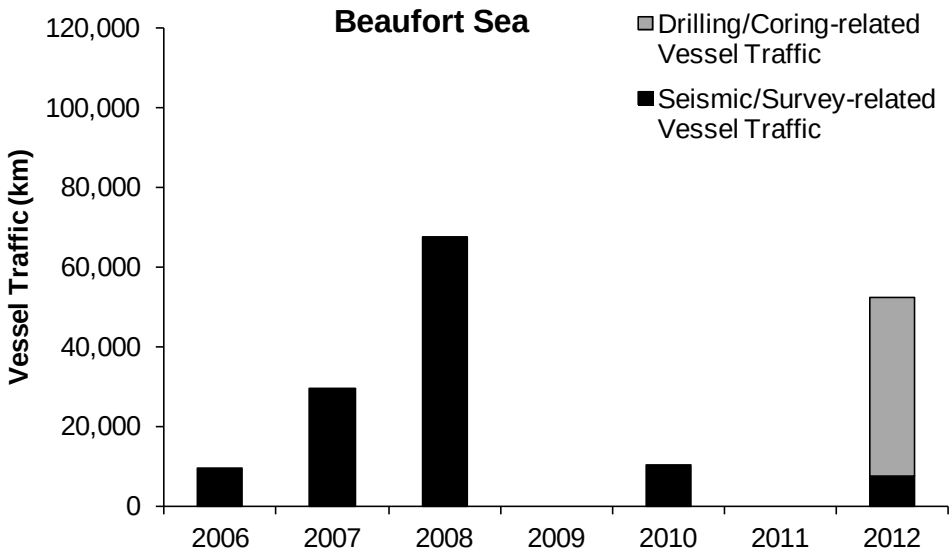


FIGURE 2.39. Kilometers of vessel traffic, including support vessels, from offshore oil and gas exploration programs from drilling/coring versus seismic/marine survey in the Alaskan Beaufort Sea, 2006–2012.

## *Recent Other-vessel Activities*

In addition to recent vessel-based offshore oil and gas exploration programs in the Alaskan Arctic OCS, numerous other vessel activities occurred in the Chukchi and Beaufort seas. These other vessel activities were associated with onshore oil and gas exploration and production, seismic acquisition in the Canadian Beaufort Sea, general commerce, research (including seismic programs conducted by the

United States Geographical Survey [USGS]), the United States Coast Guard (USCG), recreation and tourism, and Alaska Native subsistence activities. Previous comprehensive reports (e.g., Funk et al. 2011) quantified trackline totals from other vessel activities, primarily barging and vessel traffic associated with commerce on the North Slope of Alaska, when data were available. A new approach was implemented for this report using Automatic Identification System (AIS; Marine Exchange of Alaska 2013), a remote tracking system for larger vessels. The opportunistic other-vessel trackline data from previous reports are not directly comparable to AIS data, which support a more thorough review of the number of vessels that operated in the Alaskan Chukchi Beaufort seas within several of the categories above.

AIS data, however, do not capture all vessels present within the Chukchi and Beaufort seas and should not be viewed as an exhaustive summary. The USCG requires only certain vessels to be equipped with AIS, particularly passenger and larger commercial vessels (>300 gt) as well as tankers. Many smaller vessels and skiffs do not utilize AIS, including those used for subsistence and recreation activities. Vessels equipped with AIS send automatic position reports to either shore-based or satellite servers where data are logged. The AIS vessel data presented in this report originated from shore-based servers as opposed to satellites. Vessels equipped with AIS transmitters need to be within ~323 km (200 mi) of a land-based server to be detected; vessels beyond this distance are likely to be captured only by satellite servers, which require special permissions from vessel operators to be accessed and published.

The numbers of AIS-equipped vessels that were present in the Alaskan Arctic OCS during 2012 are presented below (Figs. 2.40 and 2.41). Data from 2011 are also presented to allow for comparisons of the presence of other vessels with those from oil and gas exploration activities in a year with relatively low amounts of exploration activities compared to greater levels of activity in 2012. The spatial resolution and accuracy of AIS data vary considerably among vessels for a variety of reasons, which makes direct comparisons of trackline totals between vessels or categories of vessels tenuous and perhaps biased. For this reason, the AIS data presented below show only raw tallies of vessel numbers within broad categories to serve as a relative index of the level of activity within each category. Methods are currently being investigated that will allow for more thorough and accurate comparisons of AIS trackline totals in the future. The presentation of AIS data below should be interpreted as a preliminary exercise to further our understanding of the nature and relative amount of vessel traffic within areas of the Alaskan Arctic offshore that are being explored for oil and gas resources.

Considerably more AIS-equipped vessels operated in the Chukchi Sea when compared to the Beaufort Sea in both 2011 and 2012 (Figs. 2.40 and 2.41). The vast majority of vessels with AIS in the Chukchi Sea during 2011 and 2012 were associated with ‘commerce’ followed by ‘oil and gas’ and ‘research’ (Fig. 2.40). Most ‘commerce’ vessels in the Chukchi Sea were supporting activities at Red Dog Mine in the southern Chukchi Sea along the west coast of Alaska. AIS vessels in the Beaufort Sea in 2011 and 2012 were more evenly distributed across activity categories compared to the Chukchi Sea, although there was a notable increase in the number of AIS vessels associated with oil and gas exploration in 2012 as a result of Shell’s drilling program, ION’s seismic shoot, and BP’s nearshore seismic shoot in Simpson Lagoon. The number of ‘commerce’-related vessels in the Beaufort Sea during 2011 and 2012 was nearly an order of magnitude lower compared to the Chukchi Sea (Fig. 2.41). An increased USCG vessel presence in both the Chukchi and Beaufort Seas was notable in 2012 (Figs. 2.40 and 2.41).

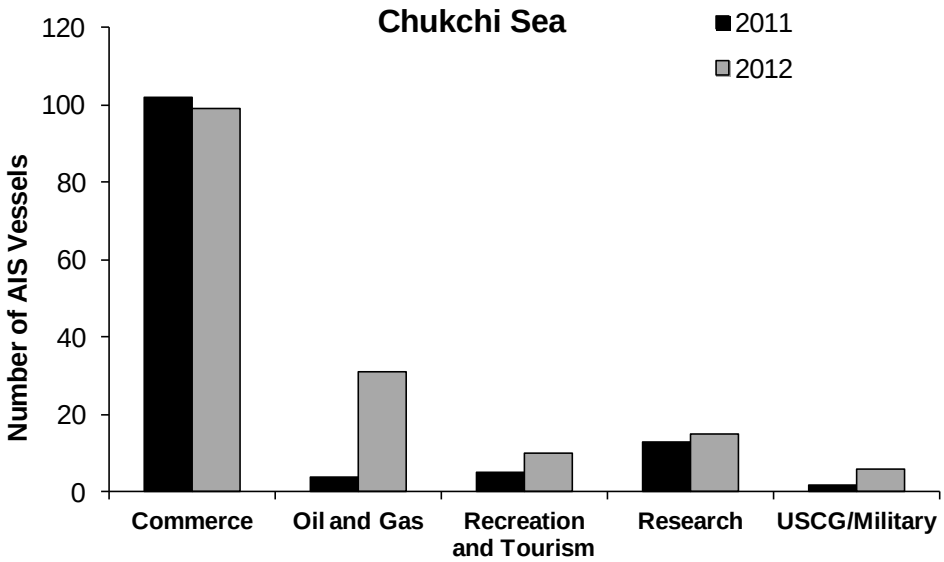


FIGURE 2.40. Number of AIS-equipped vessels by category in the Alaskan Chukchi Sea, 2011 and 2012.

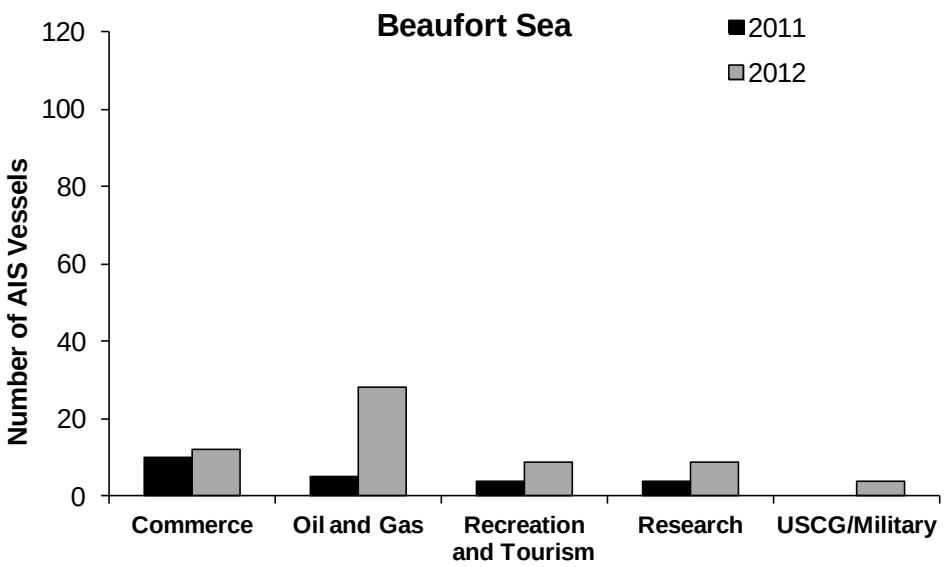


FIGURE 2.41. Number of AIS-equipped vessels by category in the Alaskan Beaufort Sea, 2011 and 2012.

An increased presence of the USCG in the Alaskan Arctic OCS is related to an overall increase in vessel activity in this region. The USCG estimates an increase in the number of vessels present in the Alaskan Arctic from ~130 in 2009 to ~250 in 2012, and the number of vessel transits through the Bering Strait from ~220 in 2008 to more than 480 in 2012 (Table 2.3; USCG 2013). McConnell et al. (2013) presented all AIS-equipped vessel tracks from the Alaskan Chukchi and Beaufort Seas, which shows widespread vessel activities across numerous categories from the Bering Strait to the Alaska-Canada border (Fig. 2.42).

TABLE 2.3. Number of estimated vessels present in the Alaskan Arctic and number of estimated transits through the Bering Strait, 2008–2012. Credit: USCG 2013.

| | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|
| **Total Vessels in Arctic:** | 120+ | 130 | 160 | 185 | 250 |
| **Bering Strait Transits:** | 220 | 280 | 425 | 400+ | 480+ |

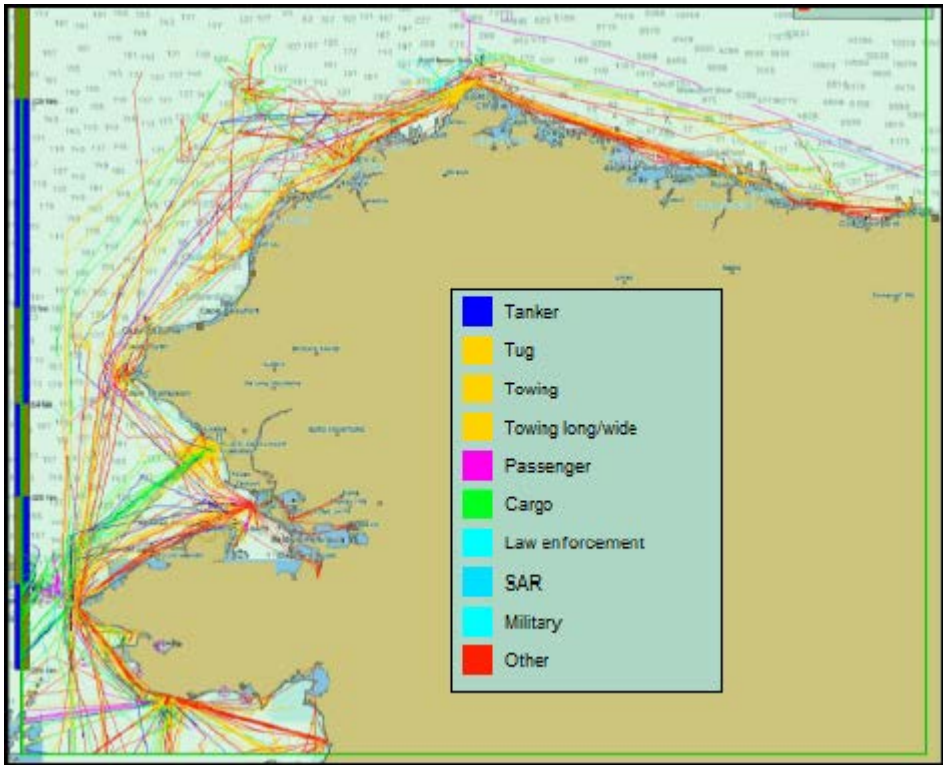


FIGURE 2.42. Marine vessel activity during 2012 tracked by AIS. Credit: McConnell et al. 2013.

## *Potential Effects of Offshore Exploration and Other Vessel Activities on Marine Mammals*

The predominant concerns associated with Arctic OCS oil and gas exploration activities and impacts on marine mammals center around the potential effects of underwater sound and the possibility of an oil spill. Concerns have also been raised over the potential for collisions between vessels and marine mammals, separation of groups, habitat alteration, drilling discharges, and indirect effects such as impacts on the distribution of prey. A large oil spill, although a legitimate concern, remains a highly unlikely event that is outside the scope of this report. There has never been a marine mammal mortality event associated with oil and gas exploration reported in the Alaskan Chukchi or Beaufort seas during several decades of exploration activities, nor has any of the extensive monitoring of these exploration activities revealed any significant, long-term effects from habitat alteration or drilling discharges on marine mammals.

The western population of bowhead whales has grown steadily since the 1980s, a period that coincided with offshore oil and gas exploration activities in the Alaskan Chukchi and Beaufort seas (see *Recent Offshore Oil and Gas Industry Activities, Other Vessel Activities, and Potential Effects on Marine Mammals and Subsistence* above). Givens et al. (2013) reported the most recent BCB bowhead whale population estimate of 16,892, which was based on data collected during the spring of 2011. The estimated annual growth rate of the BCB bowhead stock was 3.7% (Givens et al. 2013), an increase from the estimated 3.4% annual growth rate from the previous population estimate (George et al. 2004; Koski et al. 2010). Recent NMFS's marine mammal stocks assessments concluded that impacts to bowhead whales from Arctic oil and gas exploration activities likely were minor (Allen and Angliss 2010, 2011).

Although less is known about the populations of other marine mammal species in the Chukchi and Beaufort seas, there is no evidence that oil and gas exploration activities in this area have resulted in population-level effects to any species of marine mammal. Species such as ringed seals, gray whales, and Pacific walruses remain abundant in areas where offshore exploration activities have occurred since the 1970s. Intensive monitoring of recent exploration activities in the Arctic OCS have suggested that impacts to marine mammals were limited to localized and short term effects (Funk et al. 2007, 2010a,b, 2011; Ireland et al. 2009). Potential impacts from climate change, particularly related to observed and projected reductions in Arctic sea ice, are the primary reasons behind recent listings of ringed and bearded seals and polar bears under the Endangered Species Act. See *Marine Mammals of the Chukchi and Beaufort Seas* above for more detailed reviews of Alaskan Arctic marine mammal populations.

One of the primary objectives of this report is to assess the potential effects of Arctic OCS oil and gas exploration activities on marine mammals, particularly as this topic relates to underwater sound. Few subjects have received greater investigative attention in the Arctic OCS, both from western scientists as well as Alaska Natives, than marine mammals and underwater sound. Underwater sound has the potential to cause disturbance to marine mammals and there is concern that high levels of sound may cause temporary or permanent hearing impairment to individual marine mammals. Disturbance reactions including avoidance and displacement, and masking of calls are the most likely impacts of increased sound levels on marine mammals.

Various types and levels of underwater sound are produced during activities associated with offshore oil and gas exploration and development. Sounds from seismic vessels using airgun arrays produce pulsed sound pressure levels which may extend tens or hundreds of kilometers from the source before declining below ambient levels. The extent of above-ambient sound levels depends on numerous variables including output of the airgun arrays, water depth, bathymetry, sediment composition, presence of permafrost, and currents. Above-ambient sounds are also produced by engine and propeller activity of seismic and support vessels. Some types of vessels, such as icebreakers, which are often used as support vessels during exploration in the Arctic, may produce greater underwater sound levels than others, especially when activity managing or breaking sea ice (see Chapter 4; Greene 1987a; Hall et al. 1994). Increased sound levels during icebreaking activity primarily result from propeller cavitation rather than the actual physical contact between the vessel and sea ice (Richardson et al. 1995). Underwater sound is also produced during exploratory drilling from drill ships or from offshore islands (Greene 1987b). Underwater sound from drilling and vessel activity occurs at lower levels than that produced from large airgun arrays; however, unlike seismic sound which is *pulsed*, drilling and vessel sounds are *continuous*.

Masking can occur if sound levels in the water interfere with a marine mammal's ability to detect calls from conspecifics or predators, echolocation pulses, or other important natural sounds in the environment (Richardson et al. 1995). Some behavioral changes such as temporary changes in breathing or diving rates, or avoidance behavior, may not result in biologically significant impacts to individual

marine mammals or to marine mammal populations. Disturbance that causes avoidance of preferred feeding or resting areas however could affect energy budgets and result in reduced rates of adult or calf survival. Potential effects of underwater sounds from industry to marine mammal energy budgets, survival rates, and impaired hearing remain speculative, but worthy of ongoing investigations. There have been no reported biologically significant effects from underwater sound on Arctic marine mammal populations, even though seismic activities have been conducted in the Alaskan Arctic for decades. The most recent estimate for bowhead whale abundance suggests a stable rate of population increase which is indicative of low conservation risk (Givens et al. 2013).

Arctic cetaceans are known to avoid seismic activities (Richardson et al. 1995; Miller et al. 1999, 2005), while there may be less avoidance of such sounds by some pinniped species (Harris et al. 2001; Miller et al. 2005). Individual marine mammals appear to respond differently to sound stimuli depending on their activities. Richardson et al. (1986) reported that most bowhead whales began to orient away from seismic airguns in the Canadian Beaufort Sea at a distance of 7.5 km (4.7 mi), but that some whales continued feeding until the vessel was 3 km (1.9 mi) away. Richardson et al. (1999) reported that most bowhead whales during their autumn migration avoided areas within ~20 km (12.4 mi) of operating seismic airguns. Miller et al. (2005) reported numerous sightings of bowhead whales during aerial surveys at distances from 5.3 to 19.9 km (3.3 to 12.4 mi) from an operating seismic vessel, and substantial numbers of bowheads were recorded at closer distances by observers onboard the vessel. During the same study, Miller et al. (2005) reported that beluga whales appeared to avoid the seismic operations by distances up to 20 km (12.4 mi).

There has also been concern that underwater seismic energy may have the potential to impact benthic invertebrates and plankton that are important food resource for some marine mammals. A number of studies have been conducted on the impacts of seismic activity on marine invertebrates. Christian et al. (2004) reported that snow crabs did not show any chronic or long-term effects after exposure to single airgun and seven-airgun array sources. The crabs were positioned 2–4 m (6.5–13 ft) from the sound sources where received levels were 221 to 224 dB re 1 μPa $_{0\ to\ peak}$ (~218 to 221 dB rms). Payne et al. (2007) reported no effects on mortality or mechanosensory systems of lobsters exposed to low level (~202 dB $_{peak\ to\ peak}$) or high level (~227 dB $_{peak\ to\ peak}$) sound pulses. Andriguetto–Filho et al. (2005) did not detect significant impacts to several shrimp species after exposure to seismic energy. However, sublethal effects were observed with respect to feeding and serum biochemistry weeks to months after exposure. These initial experiments were meant to be exploratory and the authors stressed the need for caution when interpreting the results. In particular, these animals were exposed repeatedly to high levels of seismic sound. Exposure during actual seismic surveys would be reduced because of the limited amount of exposure time (and seismic sound impulses) as the seismic vessel moved along the survey line. In a review of available information on the effects of seismic sound on invertebrates, DFO (2004) reported that lethal or sublethal effects from exposure to seismic energy have been reported for some invertebrates exposed close to airguns, but considered exposure to seismic sound unlikely to result in direct invertebrate mortality. Results from these studies suggest impacts from seismic surveys on invertebrate resources used by marine mammals would be minor.

BOEM conducted a workshop on the effects of noise on fish and invertebrates in March of 2012. Workshop conclusions recognized the existence of a fair amount of available information on this subject, but also identified key gaps and objectives for future research. Recommendations included the need to learn more about specific hearing abilities of invertebrate species, standardization of universally acceptable acoustic metrics for reporting and comparing results, closer investigation of effects on survival

and reproductive success, and development of meaningful mitigation measures (Normandeau Associates, Inc. 2012).

Drilling activities also increase suspended sedimentation in the water column immediately around equipment that contacts the seafloor. Studies by the EPA (2006) and Neff (2005) indicate that planktonic organisms are extremely sensitive to environmental conditions (e.g., temperature, light, availability of nutrients, and water quality); however, due to the small area affected by increased sedimentation from drilling, risks to benthic and planktonic populations are low.

Since 2006 there has been a general increase in vessel traffic, though there is high annual variation since some activities may only occur for one or two years. Most of the increase in vessel traffic since 2006 in the Chukchi and Beaufort seas has been associated with commerce and various industry developments; however there has been a corresponding increase in other types of vessel traffic (e.g., barge traffic, tourism, and Coast Guard) as sea ice recedes. Incremental increases in the number of ships moving through the Chukchi and Beaufort seas increase the likelihood of ship strikes of marine mammals. Currently, such impacts from vessel traffic in the Arctic are considered negligible and do not affect any of the populations of marine mammals in the area, including bowhead whales (Reeves et al. 2012; George et al. 1994). Even with substantial increases in the amount of ship traffic in the Chukchi and Beaufort seas it is unlikely that ship strikes would increase to a point where they would affect any marine mammal populations.

## *Potential Effects of Industrial Activity on Subsistence*

Subsistence hunting and fishing continue to be prominent in the household economies and social welfare of some Alaskan residents, particularly among those living in small, rural villages (Wolfe and Walker 1987). Subsistence remains the basis for Alaska Native culture and community. Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives and comprise 60% to 80% of total subsistence harvest in the coastal communities; species hunted include bowhead and beluga whales; ringed, spotted, ribbon, and bearded seals; walruses, and polar bears. The importance of each of the various species varies among the communities based largely on availability.

Offshore oil and gas industrial activities in the Chukchi and Beaufort seas have potential direct and indirect effects on subsistence in coastal communities. Possible short-term effects include displacing, reducing, or contaminating subsistence species could affect traditional subsistence patterns. Industry has designed projects both temporally and spatially with regard to regional subsistence hunting to minimize these potential impacts.

Access to subsistence resources and traditional subsistence hunting areas is a critical concern to Alaska Native subsistence users. Drilling and seismic activity near the bowhead whale migration route could make subsistence whaling more difficult, as potential changes in distribution might result in fewer animals being available for harvesting during subsistence activities. While most of the potential for deflection may be due to sound from drilling and seismic activities, vessel presence and vessel discharge may also have an effect on the movements of whales (Brower 2010). Vessel presence near shore may push whales out of the range of hunters. After vessel presence increased in the Bering Sea due to construction of the Red Dog Mine, no belugas have been harvested successfully in the summer by residents of Kivalina and Point Hope (Adams 2011; Kingik 2011). Also, Napageak (2010) reported that the presence of a single barge diverted a large group of bowhead whales.

An increased risk or cost is associated with having to travel greater distances to harvest animals. Hunters prefer to take bowheads close to shore because they hunt in small skiffs and dangerous situations

can occur out at sea (Brower 2012). Vessel presence may make travel to subsistence resources more difficult, such as blocking traditional hunting routes or causing ice leads (Nukapigak 2010). Also, hunters prefer to avoid a long tow during which the meat can spoil (Brower 2008).

Other potential direct effects include a delay in migratory movements, behavioral changes, and injury. The timing of traditional hunts is in response to both the movement of animals and the weather; any change in timing of migratory behaviors might result in an unsuccessful hunt. Hunters report a recent increase in skittish (or "spookiness") behavior in whales, causing whales to be more difficult to approach and thus to harvest (Nukapigak 2010). Another concern is that species are not moving significantly away from industry activities. If that were the case, animals would be more likely to suffer the deleterious effects from anthropogenic noise mentioned above, such as temporary or permanent threshold shifts. This is not likely to impact subsistence use in the near future, but could impact the populations over time and thus impact the future of subsistence.

Contamination (real or perceived) of food sources due to drilling discharge or oil spills would affect important subsistence resources by making them unavailable or undesirable. One concern is that animals will either swim through contaminants, thus rendering them unfit for human consumption. Secondly, animals may swim around contaminants which will deflect animals away from feeding locations or push mothers with young too far into the open water and affect the health of the populations (Edwardson 2012).

Agency-approved industry exploration plans require that operators must minimize or altogether stand down operations in subsistence-use areas to avoid interfering with hunts, particularly the fall bowhead whale hunt. There have been no known conflicts between industry and bowhead subsistence users since the increase in offshore oil and gas exploration activities began in 2006.

## *History of Industry Supported Science*

For the last 100 years, physical and biological oceanographic studies have been conducted in the Alaskan Arctic. Before the 1970s, most of this research was funded by the U.S. government for military purposes. Between 1970 and 1985, the Arctic Petroleum Operators Association funded over 200 research projects to gather environmental and ecological baseline data. This surge in industry-funded investigations was paralleled by an extensive body of research facilitated by MMS (now BOEM). Research tapered somewhat in the 1990s as industrial involvement in the Alaskan Arctic OCS lessened; however, research programs have recently increased in both quantity and quality of biological data as technology and interest in Arctic oil and gas reserves has progressed.

Since 2006, renewed interest in oil and gas exploration in both the Chukchi and Beaufort seas has driven large-scale multiplatform research programs by the oil and gas industry. State of the art acoustic arrays have been used in the Beaufort Sea since 2000 to collect information on the occurrence and distribution of vocalizing bowhead whales, as well as to measure ambient and industrial sounds. Larger-scale acoustic arrays have been deployed in multiple locations across the Alaskan Chukchi and Beaufort seas since 2006 and 2007, respectively. Directional recorders in the Beaufort Sea locate bowhead whale calls to monitor the migratory pathway as whales move from the Beaufort Sea into the Chukchi Sea in the fall. Also, satellite tagging studies tracking the movements of bearded and ringed seals, bowhead whales (since 2006), and Pacific walrus (since 2007) help address the concerns of hunters as well as provide information on changes in animal movement in response to industrial activity or climate change. A variety of multidisciplinary and ecosystem-wide studies, both sea-wide and site specific, complement the results of species-specific investigations. Ecosystem based studies funded by industry in the Alaskan

Arctic concerning physical oceanography, fisheries, plankton and benthic communities, and bowhead whale feeding ecology provide a better understanding of potential impacts from offshore exploration activities. Such programs also contribute baseline information on the current state of the ecosystem and help scientists understand the ecosystem components that control productivity and diversity.

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# 3. DESCRIPTION OF OFFSHORE INDUSTRY ACTIVITIES AND MONITORING IN 2012

This report focuses on two industry-funded, offshore exploration programs that were conducted in the Chukchi and Beaufort seas during 2012. Shell conducted an exploratory drilling program in the Chukchi and Beaufort seas during the open-water season, completing a single top hole in each sea. ION conducted a 2D seismic survey mainly in the Beaufort Sea but with some seismic activity in the Chukchi Sea. Marine mammal monitoring and mitigation components were major parts of Shell and ION programs.

Other industry operators conducted exploration activities in 2012, including BP's ocean bottom cable seismic program in Simpson Lagoon (a nearshore area in the Alaskan Beaufort Sea). Other near shore industry activities were conducted by ENI, Pioneer, and Exxon Mobile. The primary focus of this report, however, pertains to oil and gas exploration activities further offshore. Operators that met this criterion in 2012 were Shell and ION.

Various other industry and human activities also occurred in the Chukchi and Beaufort seas. These included barge and vessel traffic, oil production operations, subsistence hunting, scientific research cruises, and tourism, as well as area-wide monitoring programs sponsored by various agencies with participation from industry.

## *Shell Exploratory Drilling Program*

Shell conducted exploratory drilling activities in the Chukchi and Beaufort seas during the 2012 open-water period. The drill rigs M/V *Noble Discoverer* (*Discoverer*) and the *Kulluk* each completed a single, shallow top hole in the Chukchi and Beaufort seas, respectively.

### *Dates of Operations*

On 20 July, the *Nordica* was the first Shell vessel in 2012 to sail northward from Dutch Harbor. The *Nordica* passed through the Bering Strait and entered the Chukchi Sea on 23 July. On 15 August, the *Nordica* was the first project vessel to enter the Beaufort Sea. All Shell vessels departed the Beaufort Sea on 25 August after laying anchors at the Sivulliq-N well site in preparation for the future anchoring of the *Kulluk* drill rig. Several vessels returned to the Beaufort Sea on 8 September and staged in a standby location to await the completion of Nuiqsut and Kaktovik whaling activities. The *Aiviq*, towing the *Kulluk,* were the last Shell vessels to depart the Beaufort Sea on 10 November. The *Aiviq* and *Kulluk* also were the last of Shell's vessel assets to depart the Chukchi Sea on 14 November en route to Dutch Harbor. Most 2012 project vessels arrived back in Dutch Harbor in early- to mid-November, and the *Aiviq* and *Kulluk* were the last to return to this port on 21 November. Most vessels operated primarily in either the Chukchi Sea or the Beaufort Sea; however, several vessels operated in both seas (See Figs. 3.1 and 3.2 for time spent by each vessel in each sea).

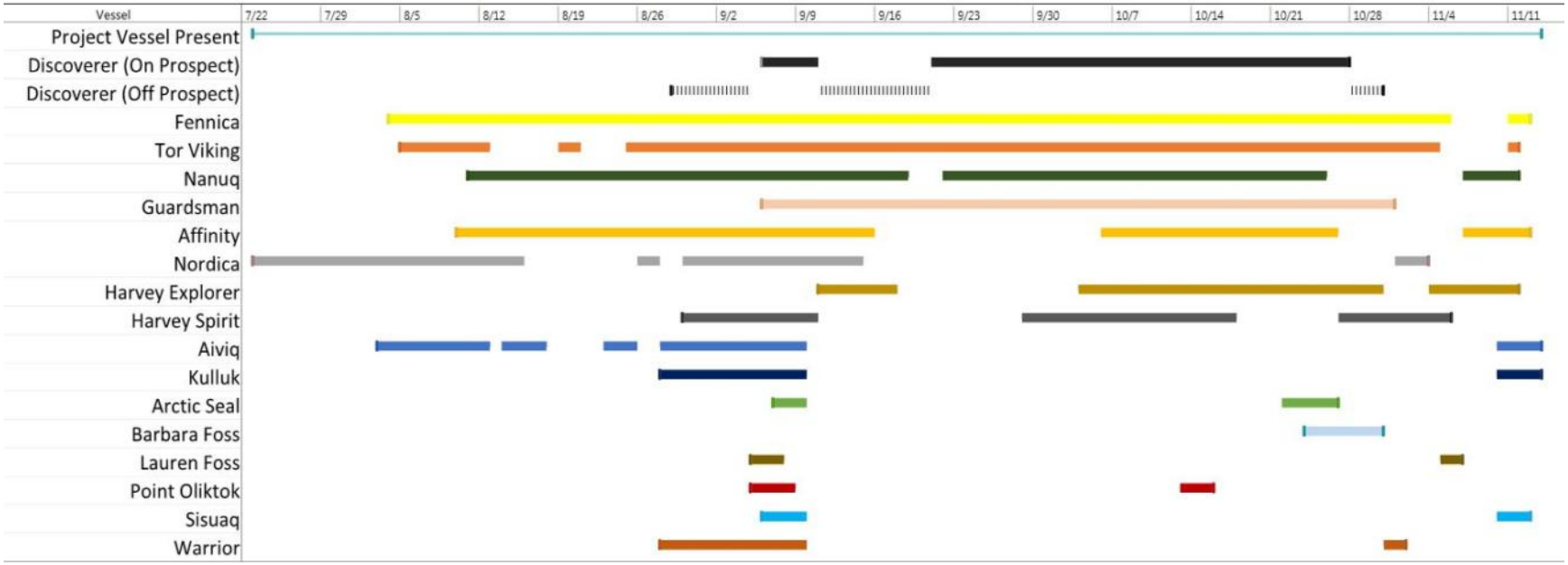


FIGURE 3.1. Periods when project vessels were present in the Chukchi Sea during Shell's exploratory drilling program, 2012.

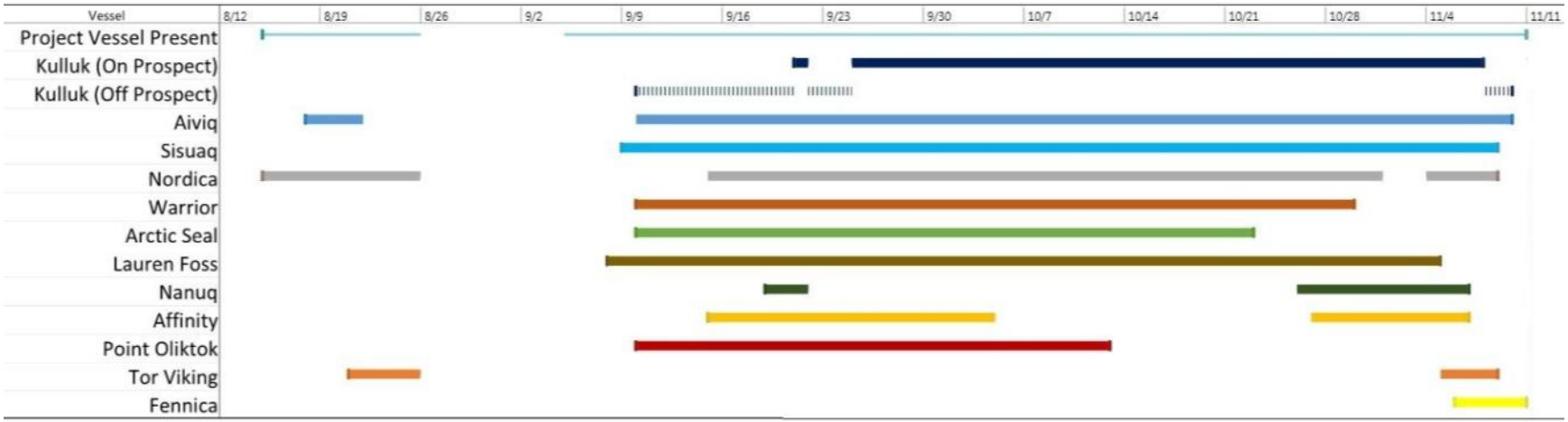


FIGURE 3.2. Periods when project vessels were present in the Beaufort Sea during Shell's exploratory drilling program, 2012.

The vessels used during Shell's 2012 program, all of which were staffed with protected species observers (PSOs), included:

- **Drill Rigs** – *Discoverer* (self-propelled drillship) and *Kulluk** (platform that requires towing)
- **Ice Management Vessels** – *Fennica* and *Nordica**
- **Anchor Handlers and Secondary Ice Management Vessels** – *Tor Viking* and *Aiviq**
- **Two Offshore Supply Vessels (OSVs)** – *Harvey Explorer* and *Harvey Spirit*
- **OSV and Waste Storage** – *Harvey Sisuaq**
- **Shallow-water Landing Craft** – *Arctic Seal**
- **Arctic Oil Storage Tanker (OST)** – *Affinity*
- **Offshore Spill Response (OSR) Vessel** – *Nanuq* and *Guardsman*
- **General Logistics and Support** – *Pt. Oliktok*, *Barbara Foss*, *Lauren Foss** and *Warrior**

* Indicates vessel was dedicated primarily to the Beaufort Sea exploratory drilling program. Several vessels operated in both the Chukchi and Beaufort seas during different operational periods throughout the season.

Shell also operated fixed wing and rotary aircraft to support logistical and monitoring components of the 2012 exploratory drilling program. A combined total of 562 helicopter flights were flown by Shell in the Alaskan Arctic in 2012, largely in support of crew change operations offshore but also as part of an onshore ecological studies program. Twin Otter fixed wing aircraft were used to fly aerial surveys for marine mammals in each sea (these surveys are described in detail in the *Aerial-based Monitoring Program* section below). A total of 20 aerial surveys were flown in the Beaufort Sea and 23 in the Chukchi Sea (18 offshore and five nearshore) during 2012.

## *Exploratory Drilling in the Chukchi Sea*

Shell's 2012 Chukchi Sea exploration drilling program occurred on the Bureau of Ocean Energy Management (BOEM) Alaska Outer Continental Shelf (OCS) lease holdings in the Chukchi Sea Planning Area designated by Oil and Gas Lease Sale 193 (Fig. 3.3). The Burger-A drill site was located approximately 103 km (64 mi) offshore and approximately 126 km (78 mi) northwest of the closest village of Wainwright, which is located on the northwestern coast of Alaska. Water depths in the Burger prospect area averaged 40–48 m (25–30 ft).

### *Description of Operations*

The *Discoverer*, an industry-standard, ice strengthened drillship, performed the exploratory drilling operations in the Chukchi Sea at the Burger-A drill site. Exploratory drilling was conducted using standard rotary drilling technology and seawater. One top hole, which included a pilot hole, construction of a mud-line cellar (MLC), and hole-opening operations to set conductor and surface casing, was completed at the Burger-A drill site. The depth of the well when operations were completed for the season was ~457 m (1500 ft). The top hole did not penetrate the hydrocarbon-bearing zones in compliance with BOEM and Bureau of Safety and Environmental Enforcement (BSEE) regulations. As part of the top-hole construction, a series of holes with various diameters ranging from 21.6 cm (8.5 in) to 91.4 cm (36 in) were drilled. The initial pilot hole was drilled ~396 m (1300 ft) into the sea floor to check for any physical obstructions or shallow pockets of gas over the drill site. A 91.4 cm (36 in) diameter

hole was then drilled to ~106 m (348 ft) in preparation for a base conductor pipe, to which a blowout preventer will be connected in a subsequent season.

Anchor handling, ice management, and support vessels were active on and near the drill site during exploratory drilling activities. The *Tor Viking* served as the primary anchor handling vessel in the Chukchi Sea. The drillship *Discoverer* had an 8-point anchored mooring system with a maximum anchor radius of ~910 m (2986 ft). The drillship was affixed to the seafloor using eight 7000 kg (15,432 lb) Stevpris anchors arranged in a radial array. The *Tor Viking* and *Aiviq* conducted the early season anchor handling operations. The different phases of anchor handling referred to in Figure 3.4 include anchor setting, anchor hook-up, disconnection, and anchor retrieval. Each phase of anchor handling was accomplished in relatively short time periods ranging from two to seven days.

The exploration drilling program was located in an area characterized by active sea-ice movement, ice scouring, and storm surges. Potentially hazardous ice was encountered during the 2012 program in the Chukchi Sea and ice management and scouting were a part of the exploration drilling activities. In general, ice management activities included physical pushing or breaking of drift ice to allow the drill rig ample time to move off prospect prior to the arrival of hazardous ice. As seen in Figure 3.4, ice management activities were limited to discrete, isolated events. Ice management occurred upwind within 10 km (6 mi) north-northeast of the Burger-A drill site. The *Fennica* and *Tor Viking* were involved in ice scouting and ice management activities near the drill site in the Chukchi Sea, with the *Fennica* serving as the primary ice management vessel.

Additional support vessels included the *Harvey Explorer, Harvey Spirit, Nanuq, Affinity,* and *Guardsman*. Due to changing operational needs throughout the season, certain support vessels worked in both the Chukchi and Beaufort seas.

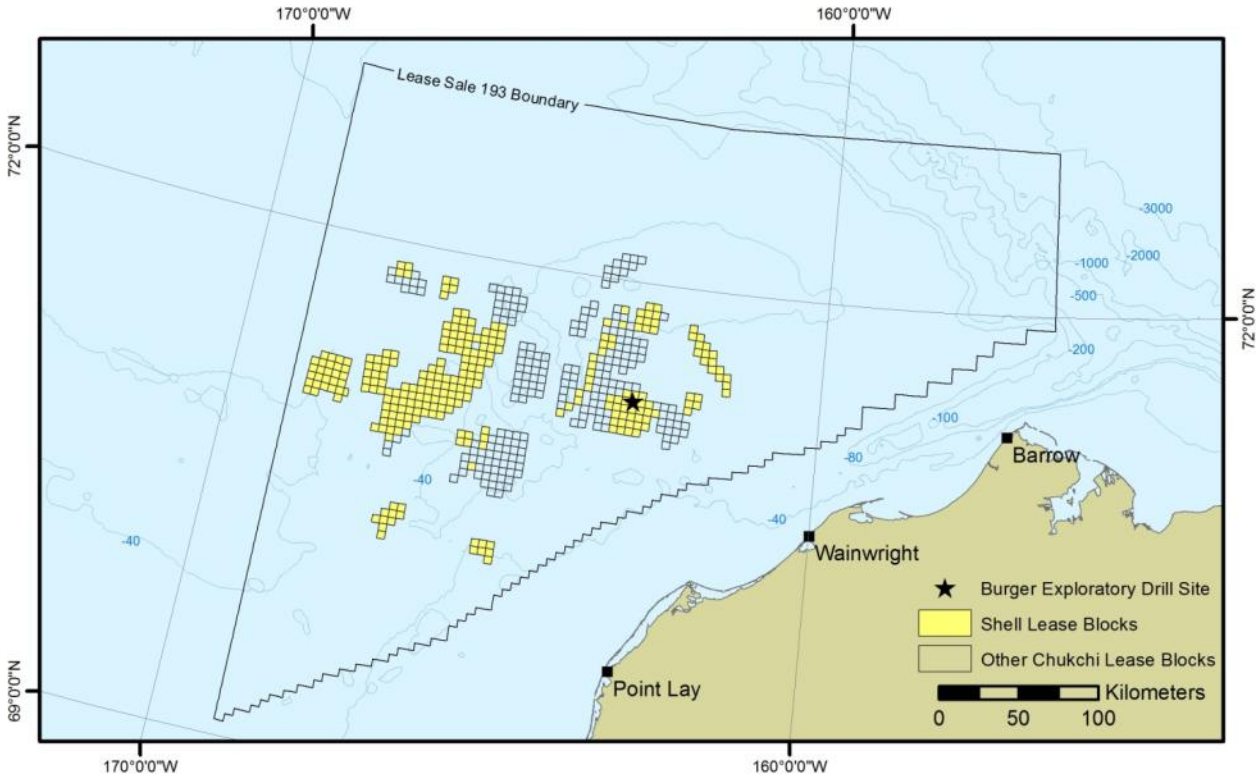


FIGURE 3.3. Location of Shell lease holdings in the Alaskan Chukchi Sea and the exploratory drill site in 2012.

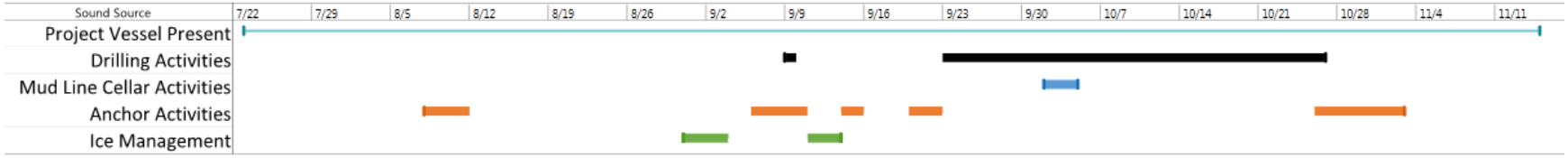


FIGURE 3.4. Periods when exploratory drilling and related support activities were conducted by Shell in the Chukchi Sea, 2012.

## *Exploratory Drilling in the Beaufort Sea*

The geographic region for the 2012 Beaufort Sea drilling program was in the eastern Alaskan Beaufort Sea leases acquired from BOEM. The OCS lease site was located at the Sivulliq prospect north of Point Thompson near Camden Bay, AK, approximately ~26 km (16 mi) offshore (Fig. 3.5). Water depth at the Sivulliq prospect was approximately 33 m (108 ft).

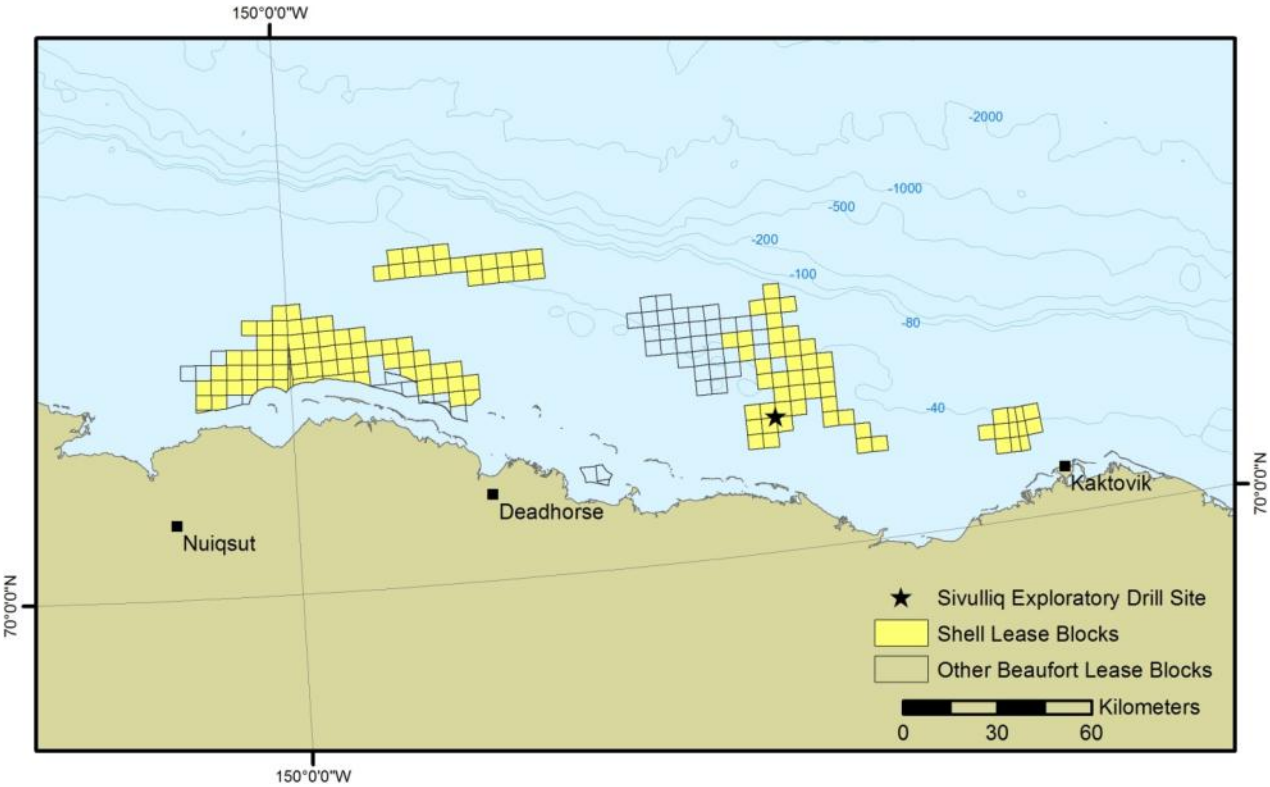


FIGURE 3.5. Location of Shell lease holdings in the Alaskan Beaufort Sea and the exploratory drill site in 2012.

### *Description of Operations*

Exploratory drilling operations in the Beaufort Sea were performed by the *Kulluk,* a conically shaped, ice-strengthened, floating drill rig designed and constructed for extended season drilling operations in Arctic waters. The *Kulluk* has an Arctic Class IV hull designed to maintain its location in drilling mode in moving ice with thickness up to 1.2 m (3.9 ft). Exploratory drilling was conducted using standard rotary drilling technology and seawater. One top hole with an MLC was completed at the Sivulliq-N drill site in 2012. The top hole was drilled to a depth of <457 m (1500 ft) and did not penetrate the hydrocarbon-bearing zones in compliance with BOEM and BSEE regulations. As part of the top-hole construction, a series of holes with various diameters ranging from 21.6 cm (8.5 in) to 91.4 cm (36 in) were drilled. The initial pilot hole was drilled ~396 m (1300 ft) into the sea floor to check for any physical obstructions or shallow pockets of gas over the drill site. A 7.3 m (24 ft) diameter hole was then drilled to ~11.3 m (37.1 ft) below the mudline in preparation for a base conductor pipe, to which a blowout preventer (BOP) will be connected in a subsequent season.

Ice management, anchor handling, oil spill response, refueling, and resupply vessels supported exploratory drilling operations in the Beaufort Sea. The *Kulluk* was moored using a 12-point anchor system and the maximum anchor radius was ~950 m (3117 ft). The *Kulluk* was affixed to the seafloor using 12, 15-metric ton (33,000 lbs) Stevpris anchors arranged in a radial array. The *Aiviq* was the primary anchor handling vessel in the Beaufort Sea. The different phases of anchor handling activities referred to in Figure 3.6 included anchor setting, anchor hook up, disconnection, and anchor retrieval. No ice management activity occurred in the Beaufort Sea during the 2012 season. The support vessels included the *Nordica, Aiviq, Sisuaq, Lauren Foss, Arctic Seal, Warrior, Pt. Oliktok, Affinity* and *Nanuq*. Depending on operational needs the *Affinity* and *Nanuq* were operated in both Chukchi and Beaufort seas during the season.

## *ION Seismic Program*

The 2D geophysical survey (seismic reflection/refraction) by ION Geophysical occurred primarily in the Alaskan Beaufort Sea from 20 October to 15 November, 2012. The seismic survey vessel (M/V *Geo Arctic*) used a 26-airgun configuration (with a total discharge volume of 4380 $in^3$) for seismic data acquisition and a single 70 $in^3$ airgun for mitigation purposes. The M/V *Geo Arctic* was escorted by the medium class (100A) icebreaker M/V *Polar Prince* during some survey operations in open-water and during most survey operations in heavily ice-covered waters. ION collected 1844 km (1146 mi) of seismic data in the Chukchi and Beaufort seas in 2012 (Fig. 3.7). Periods of full array firing including periods of lead in, lead out, seismic testing, and ramp up occurred along 2408 km (1496 mi) of trackline.

### *Location of Activities*

Most of the planned survey lines were in the Alaskan Beaufort Sea; however, two survey lines extended west past Point Barrow into the Chukchi Sea and there were three short tie lines near the U.S.–Russian border in the north-central Chukchi Sea. Survey lines actually completed in 2012 were almost entirely in the Beaufort Sea, primarily running in an east-west direction (Fig. 3.7). Seismic data were collected along ~50 km (31 mi) of trackline in the Chukchi Sea.

### *Date of Operations*

Periods when project vessels were present in the Chukchi and Beaufort seas in 2012, and periods when airguns were operated, are shown in Figure 3.8. The two vessels left Nome on 11 October and entered the Chukchi Sea on 12 October. The vessels transited through the Chukchi Sea and rounded Pt. Barrow on 14 October, and then crossed the Alaskan Beaufort Sea and entered Canadian waters on 16 October. No seismic survey activities were conducted during this transit. The vessels waited out poor weather and then took fuel from a barge near Herschel Island from 16 October to 18 October. While transiting to the eastern edge of the survey area on 19 October, the *Geo Arctic* began deploying and testing the airgun array.

Sound source measurements were conducted from 20 October to 23 October and seismic data collection began on 24 October. Survey activities continued in the Beaufort Sea until 9 November, at which time the seismic equipment was recovered and the vessels transited to the Chukchi Sea. One seismic line in the Chukchi Sea was surveyed on 14 and 15 November before the vessels began transiting south to Dutch Harbor. The *Geo Arctic* and *Polar Prince* passed through the Bering Strait on 17 November. During their transit of the Bering Sea they remained on the east side of St. Lawrence Island and arrived in Dutch Harbor on 20 November. No airgun activity occurred during this transit period.

FIGURE 3.6. Periods when exploratory drilling and related support activities were conducted by Shell in the Beaufort Sea, 2012.

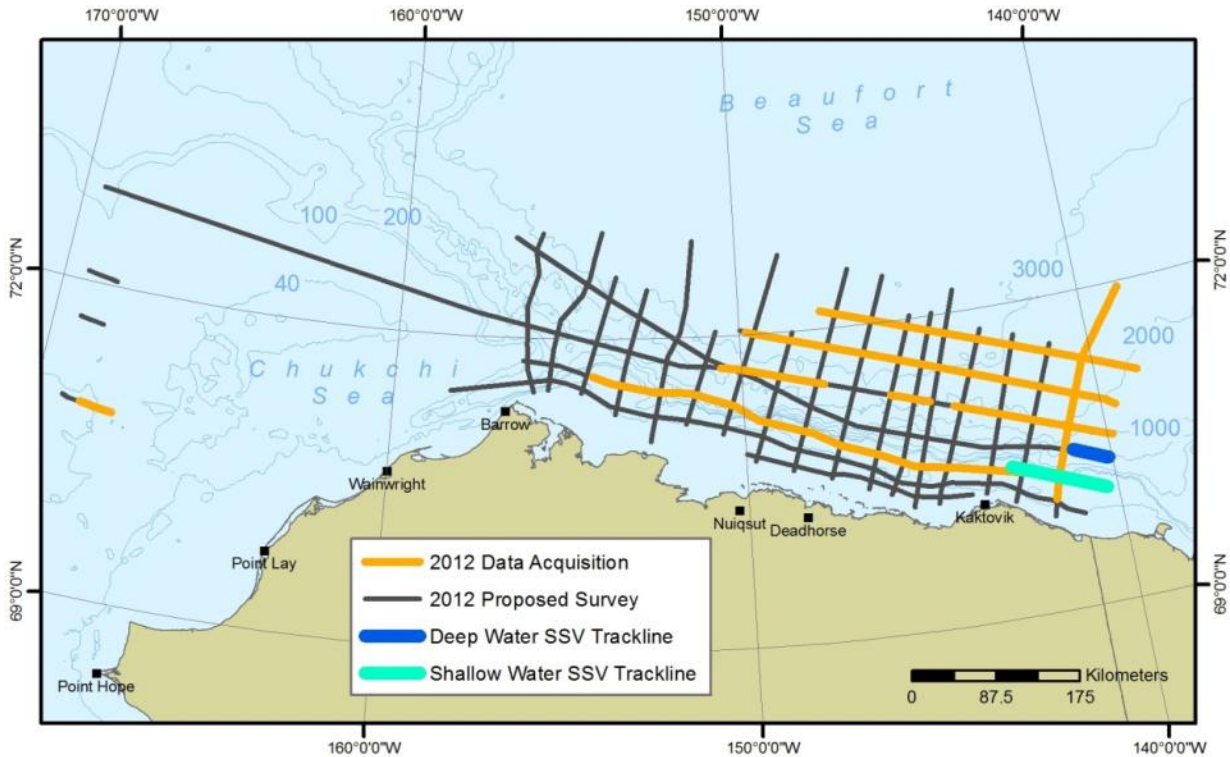


FIGURE 3.7. ION's planned seismic survey lines in the Chukchi and Beaufort seas, 2012.

### *Airgun Description*

The *Geo Arctic* towed an airgun array comprised of 28 Sercel G-gun airguns, of which 26 were active during seismic acquisition. Total discharge volume was 4380 $in^3$. The 28 airguns were distributed in two sub-arrays with 14 airguns per sub-array. Individual airgun sizes ranged from 70 to 250 $in^3$, and were operated at 2000 psi. The sub-arrays were deployed 23 m (75 ft) astern of the vessel at a depth of ~8.5 m (28 ft). The *Geo Arctic* travelled along the pre-determined survey lines at ~4 kts (4.6 mph). The shot interval was 18–20 s. The *Geo Arctic* towed a single 9 km (6 mi) long streamer to receive the reflected signals from the bottom and transfer the data to an on-board processing system. The streamer was towed at ~9.5 m (31 ft) below the water surface.

## *Other Industry and Human Activities*

In addition to the Shell and ION offshore exploration programs discussed above, numerous other industry and human activities occurred in the Alaskan Arctic OCS during 2012. These other activities included BP's ocean bottom cable (OBC) seismic program in Simpson Lagoon, a nearshore area in the Alaskan Beaufort Sea, oil production operations by Eni, Pioneer, and BP in nearshore waters of the Beaufort Sea, vessel activities associated with onshore oil and gas exploration and production, seismic acquisition in the Canadian Beaufort Sea, intra and interstate commerce, research, the United States Coast Guard (USCG), recreation and tourism, and Alaska Native subsistence activities.

### *BP-Simpson Lagoon Seismic Survey*

BP conducted a three-dimensional (3D) ocean bottom cable (OBC) shallow water seismic survey of the Simpson Lagoon area, located in the Beaufort Sea during the 2012 open-water season. The survey took place between Oliktok and Milne points in relatively shallow waters out to 70°39'N latitude. The survey area consisted of ~181 $km^2$ (70 $mi^2$), of which ~60% was located inside the barrier islands and the remaining ~40% extended a short distance beyond the barrier islands (Fig. 3.9; HDR 2012).

Seismic operations occurred in water depths of up to ~3 m (9 ft) inside the barrier islands and ~14 m (45 ft) outside of the barrier islands. Cable-laying activities commenced on 26 July and seismic acquisition began on 3 August. The OBC survey outside of the barrier islands was completed on 25 August and on 7 September within the lagoon. A total of 14 vessels were utilized to conduct the survey, three of which served as dedicated source vessels with airguns. The remaining 11 vessels served as support platforms throughout various stages of the operation. Each of the three source vessels was staffed by teams of two PSOs to conduct marine mammal monitoring and mitigation. Vessels used in this operation were transported to the project area via truck and mobilized/demobilized at West Dock and Milne Point (HDR 2012).

FIGURE 3.8. Periods when ION project vessels were present and airguns were active in the Beaufort and Chukchi seas, 2012.

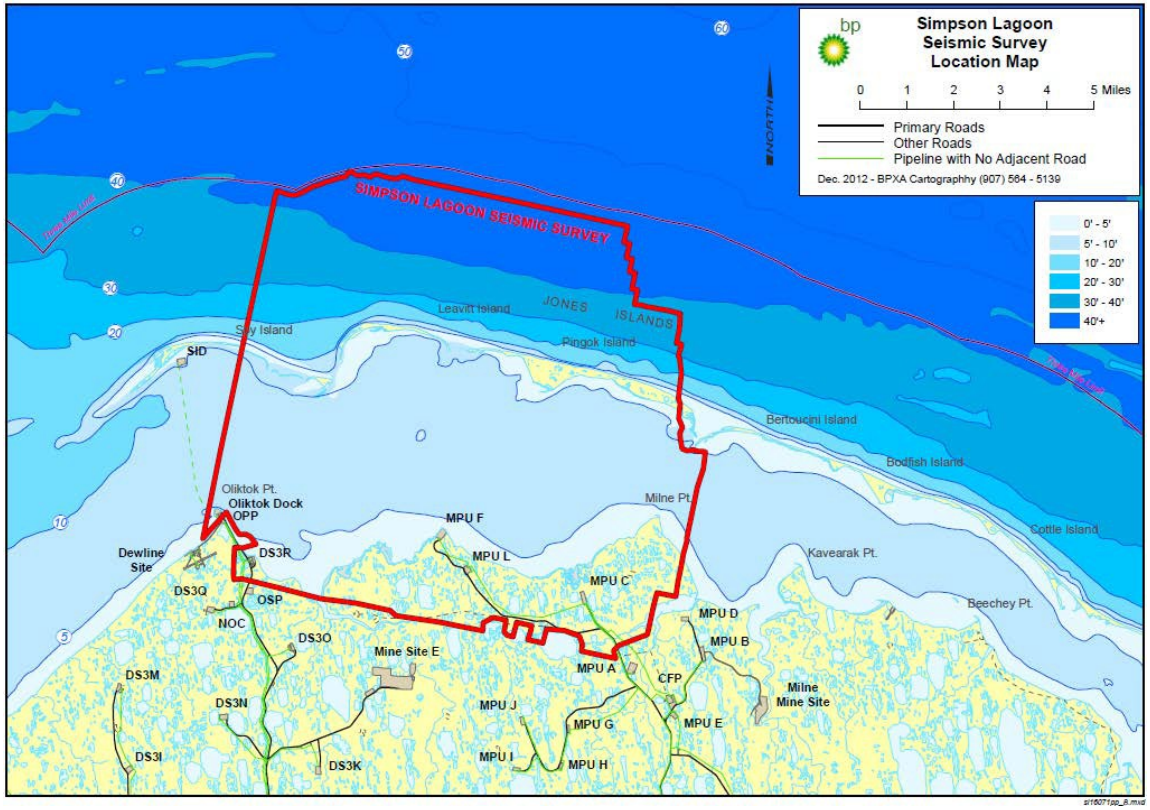


FIGURE 3.9. Location of BP's OBC seismic survey in Simpson Lagoon, Beaufort Sea, 2012. Credit: HDR 2012

### *Greater Prudhoe Bay Area Industry Activities in the Beaufort Sea*

Nearshore industry activities during the 2012 open-water season in the Greater Prudhoe Bay area, Alaskan Beaufort Sea, were generally consistent with oil production activities observed in previous years as discussed in Funk et al. (2011). Routine operation of the various nearshore production facilities requires a minimum level of vessel activity to maintain safe operation and support resupply, crew change, and response preparedness activities. In addition, three commercial tug boats operated almost exclusively within the Greater Prudhoe Bay area in 2012 compared to four commercial tugs in 2011.

The following summary of the Greater Prudhoe Bay area includes onshore and nearshore facilities operated by BP, Eni, ExxonMobil and Pioneer located between the Canning River to the east and the Colville River to the west, or approximately 146° to 151° West Longitude, respectively. Brief summaries of each operation's vessel and aerial utilization are included where information was available.

#### *BP Northstar Operations*

BP has been producing crude oil from Northstar Island, a man-made island in the Beaufort Sea, since late 2001 (Rodrigues 2013). Northstar Island is located ~10 km (~6 mi) offshore, north of the Prudhoe Bay oil field (Fig. 3.10). The gravel island serves as a work surface to support 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.

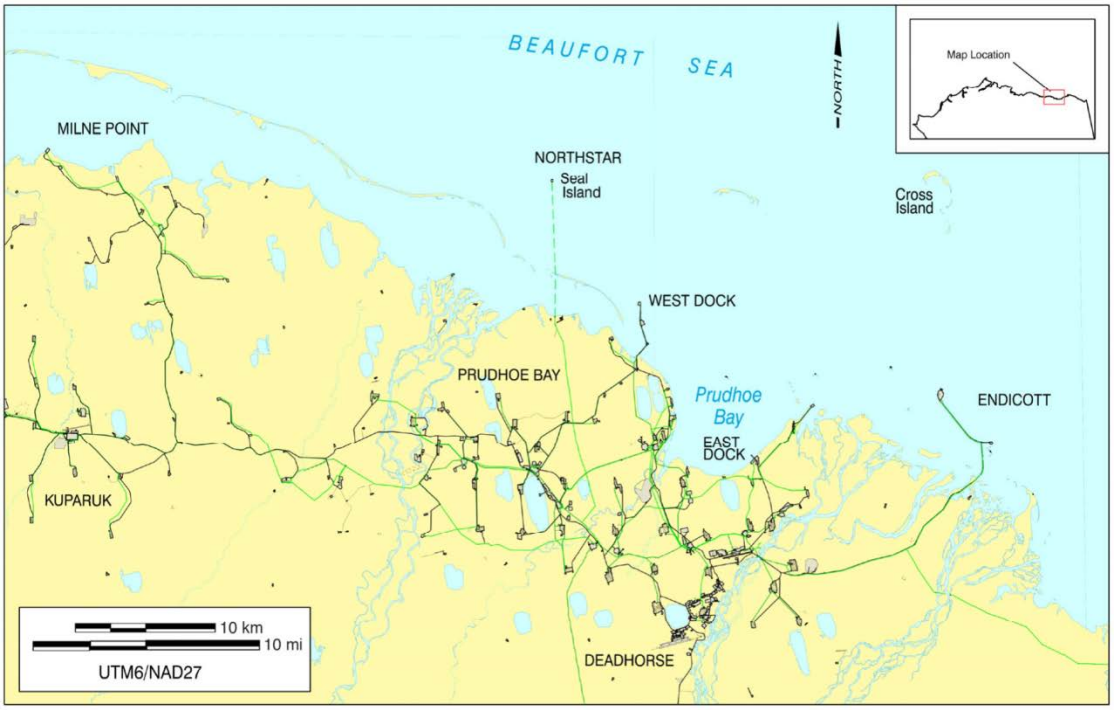


FIGURE 3.10. Location of BP's Northstar Development at Seal Island in the central Alaskan Beaufort Sea. Seal Island was an artificial gravel island constructed for exploration drilling in the 1980s. Northstar facilities were built on Seal Island in 2000.

Transportation to and from Northstar during the 2012 open-water season was accomplished with a Griffon 2000 TD hovercraft and a Bell 212 helicopter (Rodrigues 2013). As in previous years,

helicopters were mainly used during transition periods (freeze-up and break-up), and intermittently at other times when ice and water conditions did not permit boat traffic. More helicopter traffic to Northstar occurred in October 2012 than all other open-water months combined (Table 3.1). Hovercraft trips to Northstar in 2012 peaked in July and August (Table 3.1) when conditions were most favorable for this mode of transport compared to earlier or later in the open-water season.

Supply runs to Northstar Island during the 2012 open-water season were conducted primarily by tugs and barges with additional support provided by ACS *Bay*-class boats (Rodrigues 2013). There was a total of 30 tug and barge, and 40 ACS vessel roundtrips made to Northstar during 2012 (Table 3.1). Peak vessel activity associated with Northstar Island in 2012 occurred in August, however, overall vessel activity in 2012 was lower compared to recent years (Rodrigues 2013).

There were no drilling or pile driving activities at Northstar Island during the 2012 open-water season (Rodrigues 2013). The most significant construction project during this period occurred during August when ~1000 six-ton boulders were barged to the island as part of an effort to rebuild the southeast corner of the island. Oil was produced on Northstar almost continuously in 2012 with the exception of a planned shutdown for maintenance activities from 23 August to 10 September (Rodrigues 2013). Additional information on 2012 activities associated with Northstar Island can be found in Richardson and Kim (2013), which includes summaries of marine mammal monitoring and subsistence whaling at Cross Island.

TABLE 3.1. Number of helicopter, hovercraft, tug/barge, and ACS boat roundtrips to Northstar Island for each month during the open-water season, 2012. Source: Rodrigues 2013.

| Month | Helicopters | Hovercrafts | Tugs/Barges | ACS Boats |
|---|---|---|---|---|
| 16-30 June | 0.5 | 59.5 | 0 | 0 |
| July | 6 | 140 | 8 | 10 |
| August | 12 | 129 | 10 | 19 |
| September | 44 | 36.5 | 9 | 0 |
| October | 25.5 | 42.5 | 3 | 11 |
| ***Totals*** | ***88*** | ***407.5*** | ***30*** | ***40*** |

### *Pioneer-Oooguruk Drill Site*

Pioneer Natural Resources Alaska, Inc. (Pioneer) constructed the Oooguruk Drill Site (ODS), in eastern Harrison Bay offshore of the Colville River delta in 2006 for oil drilling and production operations. ODS is located ~6 km (4 mi) southwest of Thetis Island and ~15 km (9 mi) west of Oliktok dock in ~1–2 m (3–7 ft) of water (Fig. 3.11). The seabed footprint of ODS covers ~4.4 hectares (10.9 acres) and the above-water surface area is ~2.4 hectares (5.9 acres). Drilling began during winter 2007–2008 with the first disposal well spudded in December 2007. Drilling is conducted on a year-round basis and continued through the 2012 open-water period. Oil production began in June 2008 and was ongoing through the 2012 open-water season.

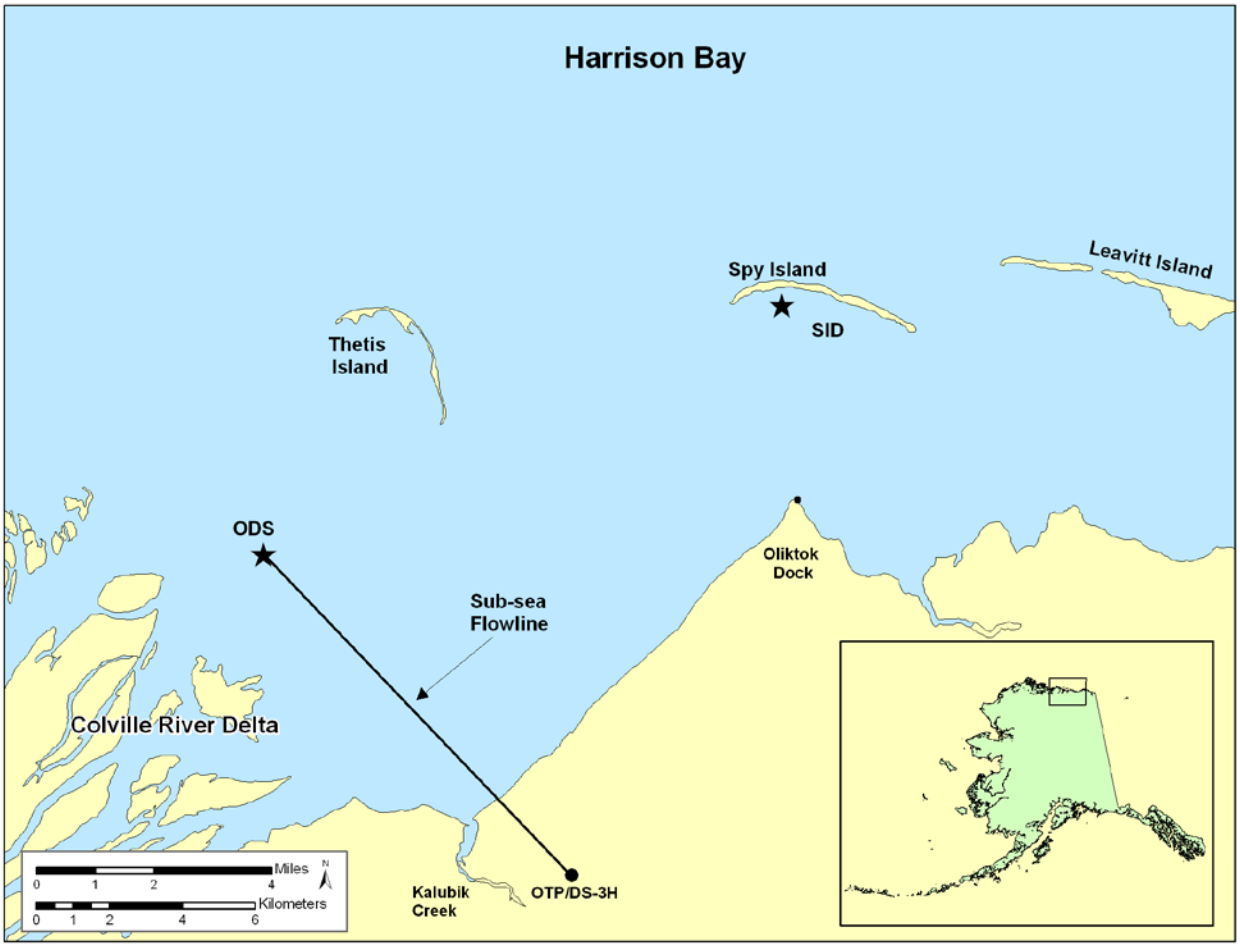


FIGURE 3.11. Location of Pioneer's (ODS) and Eni's (SID) nearshore drilling locations and onshore development sites in eastern Harrison Bay, central Alaskan Beaufort Sea.

Activities during the 2012 open-water period were in support of ongoing drilling and oil production activities. Pioneer utilized helicopters, a crew vessel, tugs/barges, and small numbers of other vessels for the transportation of personnel and equipment between Oliktok dock and ODS during the 2012 open-water season. Barge and crew vessel activity during the open-water season in 2012 was greatest in August and September with fewer trips in June, September, and October (Table 3.2).

A helicopter was used for transportation of personnel to and from ODS throughout the 2012 open-water period, although the majority of trips occurred in June and October before and after the peak window for vessel movements (Table 3.2). The number of helicopter and vessel trips associated with ODS during the 2012 open-water period was similar to past years (e.g., 2010; Funk et al. 2011).

TABLE 3.2. The number of helicopter, crew boat, tug/barge, and other vessel roundtrips to Pioneer's ODS for each month during the open-water season, 2013 ( personal communication, Pioneer Natural Resources Alaska, Inc. 2013).

| Month | Helicopters | Crew Boats | Tugs/Barges | Other Vessels |
|---|---|---|---|---|
| June | 286 | 1 | 0 | 0 |
| July | 59.5 | 89 | 19 | 4 |
| August | 39.5 | 130 | 27 | 2 |
| September | 43.5 | 118 | 36 | 1 |
| October | 274.5 | 33 | 8 | 0 |
| ***Totals*** | ***703*** | ***371*** | ***90*** | ***7*** |

*Eni-Spy Island Drill Site*

Eni began construction of a gravel island, Spy Island Drill site (SID), in 2008 to be used as a platform for future oil drilling and production activities. SID is located in the lagoon system inside barrier islands approximately 60 m (200 ft) south of the western end of Spy Island in eastern Harrison Bay (Fig. 3.11). SID is ~6.1 km (3.8 mi) offshore of Oliktok Point. Water is shallow between Oliktok dock and SID; water depth at SID is ~1–2 m (3–6 ft).

Eni began producing oil from SID in early 2011 and continued to do so through the 2012 open-water season. Summaries pertaining to Eni's vessel and other logistical activities in support of SID production drilling were not available at the time of this report's publication.

*ExxonMobil-Point Thomson*

ExxonMobil is developing the Point Thomson Unit oil and gas field located approximately 97 km (60 mi) east of Prudhoe Bay. Point Thomson production facilities will be shore based and development activities are primarily confined to locations on land. ExxonMobil did not conduct any barging or other vessel-based activities associated with the Point Thomson development project in 2012. Air traffic during the 2012 open-water season consisted of limited overland helicopter flights between Deadhorse and Point Thomson in support of summer survey and environmental studies programs.

## *Offshore Industry Monitoring Studies in 2012*

There has been wide-spread interest in understanding impacts to marine mammals from anthropogenic sounds introduced into the marine environment by oil and gas exploration activities. A marine mammal mitigation and monitoring program was first implemented in 2006 to acquire data on marine mammal movement, behavior, and distribution in relation to offshore industry activity. The three-tiered program consists of 1) dedicated protected species observers (PSOs) onboard most vessels, 2) aerial surveys, and 3) wide-area arrays of acoustic recorders deployed on the seabed and from vessels in both the Chukchi and Beaufort seas. The design of these monitoring programs is intended to inform responsible operational practices by minimizing potential impacts to marine mammals and local subsistence users. Each of these monitoring components is tied to a specialized set of objectives that together provide a big-picture look at marine mammal distribution around offshore activities and provide key data to help understand the response of marine mammals to those activities.

The vessel-based component integrates local Alaska Native PSOs with professional biologists into teams of observers. PSOs are tasked with monitoring offshore exploration activities from project vessels

and also with implementing a variety of real-time mitigation measures. These mitigation measures are designed to minimize encounters between vessels and marine mammals and maximize the distance between operations and animals.

The aerial survey component is designed to provide systematic assessment of the distribution of marine mammals in areas within and adjacent to offshore exploration activities. Of particular interest is an assessment of bowhead whales during their annual fall migration through the Beaufort Sea, and also beluga whale and Pacific walrus distributions throughout the survey area.

Number and type of vessel activities and duration of aerial surveys varied from year to year. Monitoring effort is a quantifiable way to represent these differences. Vessel and aerial observer effort is a systematic collection of observation records that captures the distance or amount of time spent with at least one vessel-based or aerial observer 1) actively searching for marine mammals, and 2) documenting environmental conditions. Effort, quantified by distance traveled, varied greatly between years from 2006–2012, with the greatest overall effort in 2008 (Table 3.3). However, 2012 vessel activities were characterized by many stationary periods which are perhaps better represented by effort over time (Bisson et al. 2013).

TABLE 3.3. PSO monitoring effort on vessels and aerial surveys in kilometers traveled. Offshore Chukchi Sea effort from 2012 refers only to photographic effort subsequently reviewed by observers; no observers were physically present on these surveys.

| Total Observer Effort (km) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| **Vessel** | | | | | | | |
| Chukchi Sea | 72,760 | 29,262 | 53,251 | 10,241 | 41,338 | 8724 | 50,824 |
| Beaufort Sea | 5807 | 15,532 | 41,347 | 2112 | 13,350 | -- | 33,515 |
| **Aerial Survey** | | | | | | | |
| Chukchi Sea | 22,657 | 22,365 | 21,691 | -- | 8675 | -- | 4596 |
| Offshore Chukchi Sea* | -- | -- | -- | -- | -- | -- | 10,953 |
| Beaufort Sea | 2687 | 7363 | 23,745 | -- | 16,535 | -- | 9112 |

*photographic effort only, no observers physically present on survey

The acoustic monitoring program is designed to measure the ambient soundscape, document sound characteristics and propagation resulting from exploration and vessel activities, and collect information on the occurrence, distribution, and movement of marine mammals both in general and relative to industry activities. Custom-built acoustic recorders have been deployed across large areas of the Beaufort and Chukchi seas since 2006. These instruments are designed to record industrial sounds produced by anthropogenic sources and also the vocalizations of marine mammals around exploration activities. In the Beaufort Sea, bowhead whale calls can be localized to identify the position of the animal relative to industry activities and related sound sources.

The vessel-based monitoring in 2012 for Shell's exploratory drilling program and ION's seismic program consisted of nearly 160 PSOs who deployed to 19 project vessels. Shell's 2012 monitoring plan

included two aerial survey platforms and tested the efficacy of offshore monitoring using unmanned aircraft systems.

The visual components of the monitoring program provide real-time mitigation capability to help protect marine mammals that may be near operations. Integration of the individual monitoring components – vessel, aerial, and acoustic – data (particularly aerial and acoustic) provide insight to more complex questions than can be addressed by using any single tool. The following sections provide a high-level overview of various monitoring methods and designs. Detailed monitoring and data-analysis methods are found in subsequent chapters with results in Appendices A, B, and C.

### *Vessel-based Monitoring Program*

The vessel-based component of the 2012 offshore exploration programs integrated local Alaska Native PSOs with professional biologists into teams of observers. The specific objectives of the vessel-based program provide:

- the basis for real-time mitigation, if necessary, as required by the various permits,
- information needed to estimate the number of "takes" of marine mammals by harassment, which must be reported to NMFS and USFWS,
- data on the occurrence, distribution, and activities of marine mammals in the areas where the exploration program was conducted,
- information to compare the distances, distributions, behaviors, and movements of marine mammals relative to the exploration program vessel activities (e.g., drilling, seismic), and
- a communication channel to coastal subsistence communities, including Inupiat whalers.

PSOs in 2012 were tasked with monitoring exploration activities from each project vessel and also with implementing a variety of real-time mitigation measures. These mitigation measures were designed to minimize encounters between vessels and marine mammals and maximize the distance between operations and animals. In ION's 2012 seismic program, as in previous seismic programs, sound threshold "safety radii" were monitored by PSOs to ensure that marine mammals were not exposed to levels of industrial sound that may have the potential to injure or impair their hearing abilities. PSOs were able to enact mitigation measures such as a "shut-down" of seismic airguns if marine mammals were observed within or about to enter the "safety radii".

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around industrial sound sources are customarily defined as the distances within which received pulse levels are ≥180 dB re 1 μPa (rms) for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. These safety criteria are based on an assumption that sound energy received at lower levels will not injure these animals or impair their hearing abilities, but that higher received levels might have some such effects. Disturbance or behavioral effects to marine mammals from underwater sound may occur after exposure to sound at distances greater than the safety radii (Richardson et al. 1995). NMFS assumes that marine mammals exposed to underwater impulsive sounds at received levels ≥160 dB (rms) have the potential to exhibit behavioral reactions great enough to meet the definition of "harassment" in the MMPA. For continuous sounds, such as those produced during drilling, NMFS has established the disturbance threshold at ≥120 dB (rms).

#### *Vessel-based Monitoring Methods*

The visual monitoring methods that were implemented during the 2012 exploration programs were similar to those used during seismic and other geophysical marine surveys in 2006–2011. Vessel-based

marine mammal monitoring and mitigation methods were designed to meet the requirements and objectives specified in the IHAs and LOAs. The main purposes of PSOs aboard the vessels were to conduct visual watches for marine mammals to serve as the basis for implementation of mitigation measures, to document numbers of marine mammals present, record any reactions of marine mammals to exploration related activities, and identify whether there was any possible effect on accessibility of marine mammals to subsistence hunters in Alaska.

The distribution and amount of vessel-based PSO monitoring effort during Shell's and ION's 2012 offshore exploration programs are presented in Figure 3.12. This figure shows considerable PSO monitoring effort at each of Shell's 2012 exploratory drill sites and also in areas clustered outside of a 40 km (25 mi) radius around each drill site. The radius around each drill site originated from air emissions permits that significantly restricted vessel activities within 40 km (25 mi) of each drill site while the drill rigs were moored at the wells. Support vessels associated with drilling at Burger in the Chukchi Sea occupied a standby location to the southeast of the drill site, and a similar standby location was chosen for vessels due east of the Sivulliq site in the Beaufort Sea (Fig. 3.12). These restrictions limited the amount of vessel-based PSO monitoring effort in areas directly adjacent to drilling operations, and spread support vessels out across large areas (Fig. 3.12). Another area of intensive vessel-based PSO monitoring effort took place in the Beaufort Sea north of Nuiqsut (Fig. 3.12), which was the standby location for Shell's vessels during the 2012 fall whaling blackout period.

PSOs were typically stationed on the bridge or from a position on the vessel that allowed the safety and disturbance zones to be monitored for marine mammals. PSOs were on duty during nearly all daylight periods on vessels and during the night if permits or specific operations required it (e.g., ramp ups of airguns). Depending on the vessel, watches were conducted with the unaided eye or specialized monitoring equipment listed below.

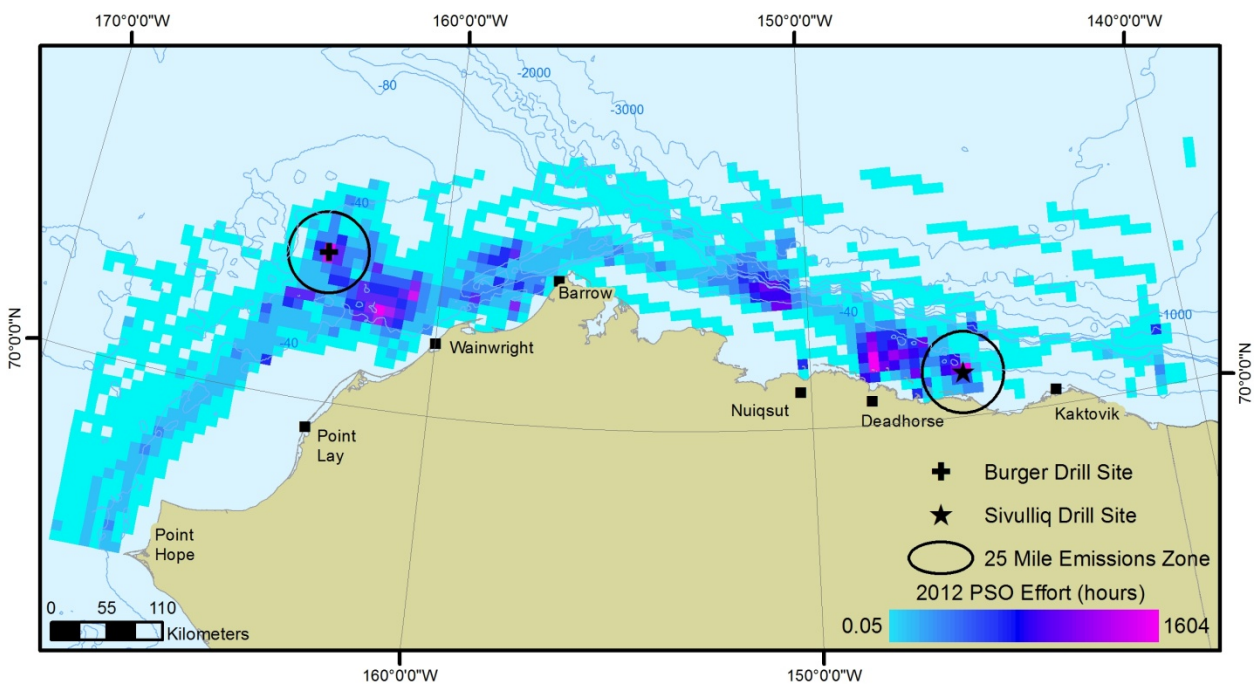


FIGURE 3.12. Distribution and duration of vessel-based PSO monitoring effort during Shell's and ION's 2012 exploration programs in the Chukchi and Beaufort seas.

PSOs onboard monitoring and support vessels conducted watches similar to those of PSOs onboard "high-profile" vessels such as seismic source vessels, drill vessels, and icebreakers. When practicable, PSOs onboard monitoring and support vessels worked with the "high-profile" vessels to notify PSOs if whales or other marine mammals were present within or approaching the project area, which allowed the critical vessels to request appropriate mitigation if necessary. This inter-vessel communication allowed vessels to maximize distances between operations and marine mammals.

For each marine mammal sighting, specific information such as species, number of animals, behavior, direction of travel, reaction, etc. was recorded. Environmental and observation effort data, such as the ship's position and general activity, airgun status, sea state, ice cover, visibility, number of PSOs on watch were also collected. Effort data were recorded at the start and end of each watch period, every 30 minutes during a watch, and whenever there was a substantial change in any of the variables being recorded.

### *PSO Equipment*

PSOs used specialized field equipment to monitor and collect data on marine mammals including 7×50 reticle binoculars, Fujinon "Big-eye" 25×150 binoculars, Canon 18×60 image stabilized binoculars, GPS units, laptop computers, night vision binoculars, and digital still cameras.

Various factors, including high sea state or poor visibility resulting from darkness of fog, can make detection of marine mammals difficult. There is stakeholder interest to evaluate technologies that improve visual detection of marine mammals by PSOs from the vessels. PSOs regularly perform surveys using new technologies in the field allowing evaluation of those tools and possible inclusion into future monitoring programs.

In 2012, ION's late season survey provided an opportunity to evaluate tools used to detect marine mammals in periods of darkness. Both night vision devices, which amplify low levels of ambient light, and a forward looking infrared (FLIR) camera system, which detects thermal contrasts, were tested on ION's seismic survey. The FLIR camera was mounted on a high point near the bow of the escort icebreaker (*Polar Prince*) to assist with detecting the presence of marine mammals. Based on some prior testing by other research groups, it was expected that the FLIR camera would primarily be useful for detecting pinnipeds and polar bears on ice.

A custom-built marine mammal computerized data entry system was introduced in 2012 to streamline data collection and allow PSO's to maintain focus on their observation tasks. The accuracy of data entry was verified in the field by validity checks built into the data entry software and by subsequent manual checking of the database exports. These procedures allowed initial summaries of data to be prepared during and shortly after the field season and facilitated the transfer of the data to statistical, graphical or other programs for further processing. In addition to routine PSO duties, observers used Traditional Knowledge and Natural History datasheets and hand-held voice recorders to collect observations that are not captured by the sighting or effort data.

## ***Aerial-based Monitoring Program***

Aerial surveys of marine mammals in the Chukchi and Beaufort seas were conducted in 2006–2008, 2010 and 2012 in support of seismic and shallow hazards exploration programs. The aerial survey component is designed to provide a systematic assessment of the distribution of marine mammals in areas within and adjacent to exploration operations. Of particular interest is an assessment of bowhead whales during their annual fall migration through the Beaufort Sea, and also beluga whale and Pacific walrus distributions throughout the survey area. The specific objectives are to:

- advise operating vessels as to the presence of marine mammals (primarily cetaceans) in the general area of operation, and particularly, within or near disturbance/safety radii;
- collect and report data on the distribution, number, movement and behavior of marine mammals near the exploration operations with special emphasis on migrating bowhead whales;
- support regulatory reporting requirements related to the estimation of impacts of exploration activities on marine mammals;
- investigate potential deflection of bowhead whales during migration by documenting how far east of exploration activities a potential deflection may occur, and where whales return to normal migration patterns west of the operations; and
- monitor the accessibility of bowhead whales and other marine mammals to Inupiat hunters.

### *Aerial Photographic Surveys*

The 2012 Shell aerial survey program was conducted in the Chukchi Sea over the nearshore areas between Barrow and Pt. Hope as well as offshore at the Burger prospect area. In the Beaufort Sea, surveys were conducted over the Sivulliq prospect area. High definition digital still and video cameras were installed aboard each survey aircraft for use during all flights in 2012. The high-definition photographic and video-monitoring equipment was used concurrently with PSO observations on flights in the nearshore Chukchi Sea and for all surveys in the Beaufort Sea. Aerial photographic surveys using these cameras and high-definition video were also flown by a pilot and co-pilot without PSOs over the Burger Prospect Area in the Chukchi Sea. The incorporation of marine mammal sightings data from digital imagery is part of an ongoing effort to develop and validate technology allowing use of unmanned aerial systems (UAS) to conduct aerial surveys in future years. The use of UAS technology is expected to result in several improvements to the aerial survey program, including reduced risk to human observers flying in offshore areas and a quieter platform with less potential to disturb marine mammals and subsistence users.

### *Aerial Survey Procedures*

Standard aerial survey procedures used in previous marine mammal projects were followed in 2012. This allows the data to be compared and integrated with other aerial survey data from past years and other aerial survey projects. The aircraft were flown at 110–120 kts (127–138 mph) ground speed and usually at an altitude of 305 m (1000 ft). In accordance with stipulations issued by USFWS, survey aircraft were flown at 457 m (1500 ft) over the Ledyard Bay Critical Habitat Unit for spectacled eiders (*Somateria fischeri*) and in any area with known aggregates of walruses or polar bears.

Two primary observers were seated at bubble windows on either side of the aircraft and a third PSO observed part-time and recorded data the rest of the time into a custom marine mammal database program called PSO Tracker. Data such as the species, number, size/age/sex, activity, heading, etc. were recorded onto a handheld voice recorded by each observer whenever a sighting was made. Transect information and environmental data (ceiling height, cloud cover, Beaufort wind force, etc.) were also recorded and entered into a GPS-linked computer by the third observer.

### *Chukchi Sea Survey Area*

The nearshore surveys were flown in a saw-toothed pattern between the shore and 37 km (23mi) offshore as well as along the coast from Point Barrow to Point Hope (Fig. 3.13). Saw-tooth transects were designed by placing transect start/end points every 55 km (34 mi) along the offshore boundary of

this 37 km (23 mi) wide nearshore zone, and at midpoints between those points along the coast. The coastline transect simply followed the coastline or barrier islands. The nearshore/sawtooth surveys were flown with both a full PSO crew and digital still and video cameras in 2012.

The offshore survey grid was designed to cover a circular area with a radius of 40 km (25 mi) around the exploratory drilling well site as shown in (Fig. 3.14). Transects were spaced 7.2 km (4.5 mi) apart, which allowed even coverage of the survey area during a single flight if weather conditions permitted completion of a survey. A random starting point was selected for each survey and the evenly-spaced lines were shifted northeast or southwest along the perimeter of the circular survey area based on the start point. The total length of survey lines was approximately 1200 km (746 mi) and the exact length depended on the location of the randomly selected start point.

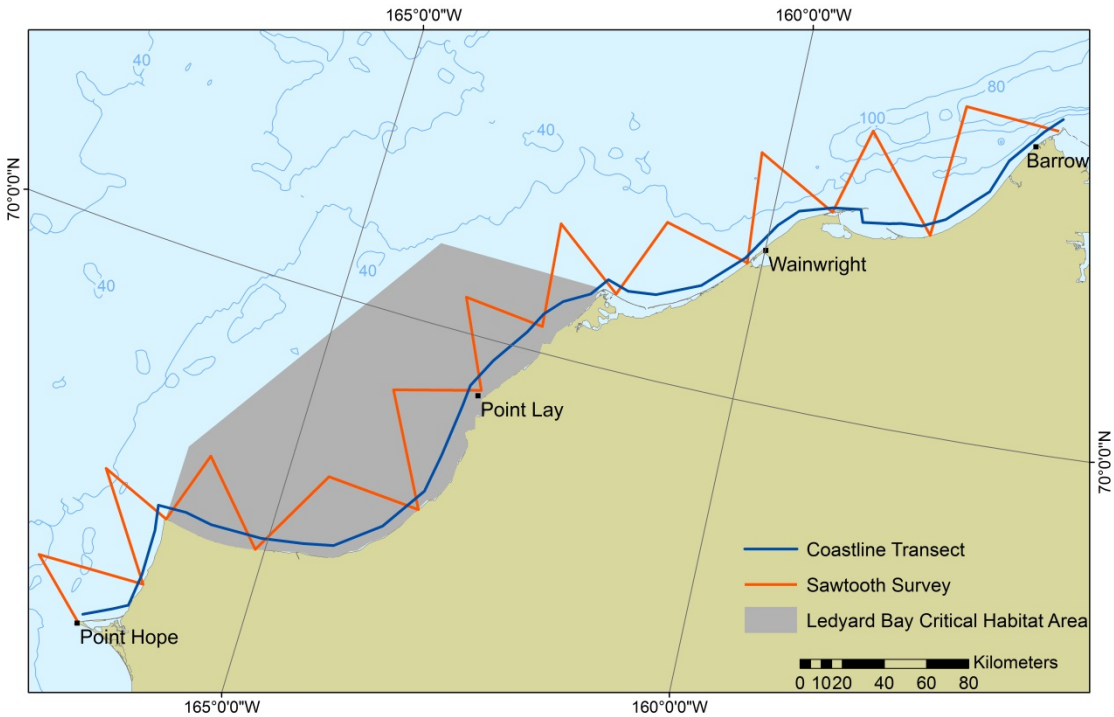


FIGURE 3.13. Nearshore aerial survey transect locations and general survey patterns for the eastern Chukchi Sea, summer and fall 2012.

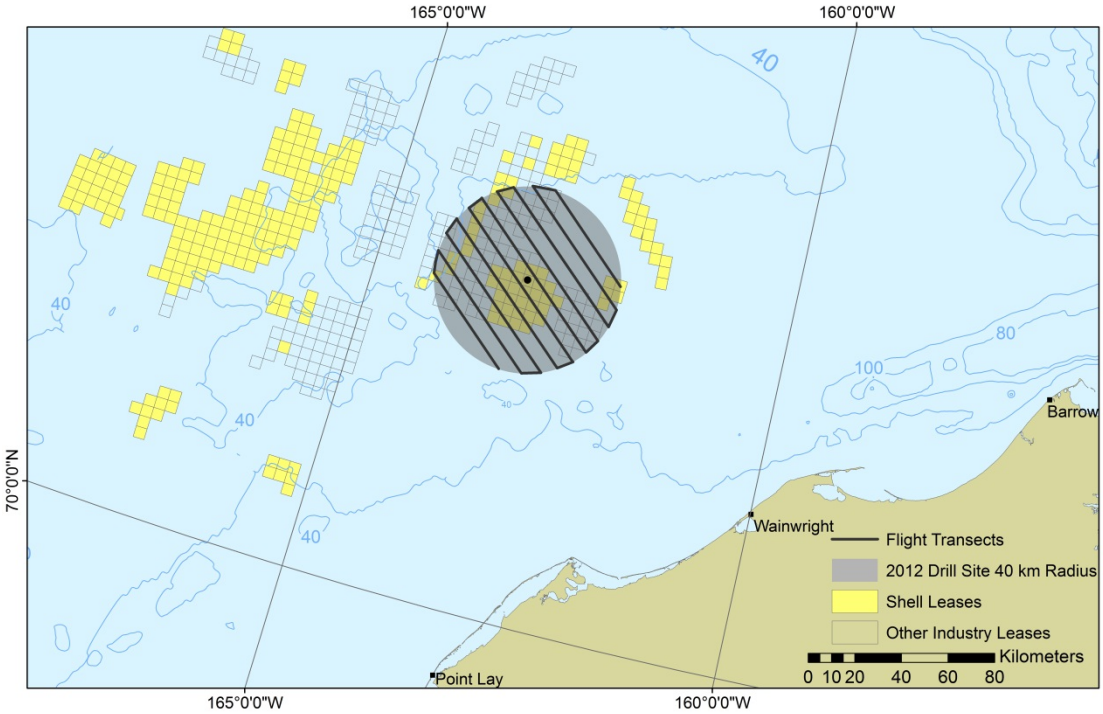


FIGURE 3.14. Offshore aerial photographic survey transect locations and general survey pattern for the eastern Chukchi Sea, summer and fall 2012.

### *Beaufort Sea Survey Area*

Shell conducted aerial surveys over their drill site on the Sivulliq prospect in the Beaufort Sea during 2012. The transect lines were oriented north-south and the total survey transect distance was similar to prior years (~1350 km or 839 mi); however, transects were stratified in 2012 with closer transect spacing over the drill site compared to transects in the outer regions of the survey grid (Fig. 3.15). Stratified sampling was implemented to increase the statistical power of analyses to detect a potential difference in bowhead whale densities in areas close to the drilling operation compared to those farther away from drilling activities. Aerial surveys in the Beaufort Sea were flown with a full PSO crew in addition to digital still and video camera systems aboard aircraft.

Aerial surveys in the Beaufort Sea were primarily designed to detect migrating bowhead whales and an altitude of 274–305 m (900–1000 ft) is the lowest survey altitude that can normally be flown without concern about potential aircraft disturbance; it is also the altitude recommended by NMFS for IHA monitoring efforts for bowhead whales.

During the late summer and fall, the bowhead whale is the primary species of concern; however, belugas (and occasionally gray whales) are also present. To address concerns regarding potential deflection of bowhead whales, the survey pattern around exploration drilling operations was designed to document whale distribution from about 40 km (25 mi) east of the exploration drilling operations to about 60 km (37 mi) west of operations.

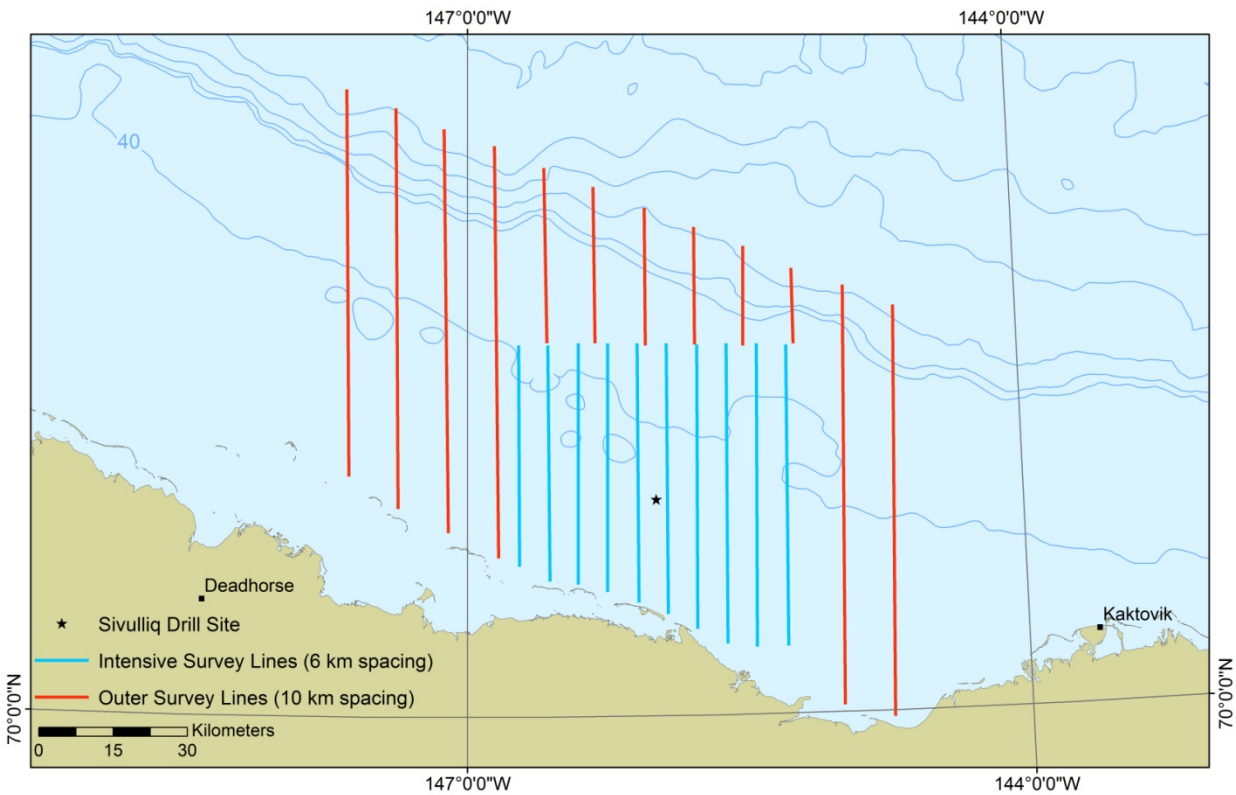


FIGURE 3.15. Aerial survey sub-areas (outer and intensive grids) and transect lines in the Alaskan Beaufort Sea surveyed during 15 August–3 November 2012. The Shell exploratory drilling location, located in the center of the survey area, is also shown.

## *Acoustics Monitoring Program*

An acoustic monitoring program in support of offshore exploration activities was first implemented in the Alaskan Chukchi and Beaufort seas in 2006. The acoustic monitoring program was designed to serve three primary functions: 1) record and characterize industry sound levels and sound propagation, 2) observe call distributions of marine mammals over a large area, and 3) investigate the possible effects of anthropogenic sounds on measureable aspects of bowhead whale behavior, such as call detection rates and locations in the Beaufort Sea. Custom-designed autonomous recorders have been deployed to record industrial sounds produced by anthropogenic activities and also the vocalizations of marine mammals around these activities. In addition to large-scale acoustic monitoring programs in each sea, focused sound source characterization and sound source verification studies, specific to particular industry activities, have also been conducted since 2006. Distinct objectives of the Chukchi and Beaufort Sea acoustic monitoring programs are discussed below.

### *Sound Source Characterization*

A sound source characterization (SSC) is the measurement and characterization of underwater sounds produced from various aspects of an exploration program, including sounds produced by vessels, drilling, ice management, and related support activities. Drilling and vessel sounds from Shell's 2012 exploration drilling program were measured with dedicated underwater acoustic recorders.

The specific goals associated with the sound source characterization program were to:

- establish distances from vessels where root mean square (rms) sound pressure levels (SPLs) reached threshold levels between 190 dB re 1 µPa (rms) and 120 dB re 1 µPa (rms) in 10 dB steps,
- characterize sound emissions from support vessels as a function of direction (fore, aft, and broadside) from the vessel,
- characterize the spectral composition of sounds from all vessels and drilling equipment, and
- establish source sound levels for vessels and drilling equipment.

There were two types of SSCs performed in both seas; one involved temporary placement of three AMARs offset from a vessel trackline, and the other consisted of four AMARs placed at specific distances from the drill sites for the duration of the season.

In the first SSC type, three AMARs were deployed on a line perpendicular to a 15 km (9 mi) vessel track line—at 0, 500, and 1000 m (0, 1640, and 3280 ft; Fig. 3.16). Each AMAR recorded acoustic data to internal memory with 24-bit resolution at a 64 kHz sample rate, a configuration that captured acoustic frequencies from 10 Hz to 32 kHz. Measurements of vessel source levels and associated sound propagation features were obtained by having each vessel in the exploratory program perform sail-pasts of the monitoring locations. These dedicated measurements provided sound level versus distance from the respective vessels and were processed to compute source levels in 1/3-octave bands referenced to 1 m (3 ft) range.

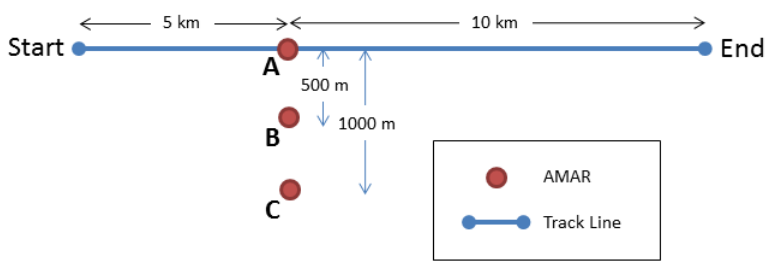


FIGURE 3.16. AMAR deployment geometry and vessel track line for the vessel SSC.

Vessel and drilling sounds were also measured with AMARs at both the Burger and the Sivulliq prospect sites. The AMARs were deployed directly on the seabed with their hydrophones approximately 30 cm (12 in) above the ocean floor. Four AMARs were deployed at ranges of 1, 2, 4, and 8 km (0.6, 1, 2, and 5 mi) from the drilling site at each prospect (Figs. 3.17 and 3.18). In addition, an acoustic telemetry buoy was deployed at Sivulliq at 500 m (1640 ft) from the drilling site to transmit real-time acoustic and acoustic Doppler current profiler (ADCP) data to computers on the *Kulluk*. The telemetry buoy contained an AMAR and a downward-facing ADCP. The data were digitized at a 64 kHz sample rate and 24 bit sample resolution, then streamed back to the *Kulluk* with a digital radio system. Also, before the *Kulluk's* arrival at the Sivulliq prospect, an AMAR was deployed at 1500 m (4921 ft) from the drilling site to measure sounds from anchor laying activities. This AMAR remained in place throughout the drilling activities, providing an additional point of measurement at the Sivulliq prospect. These recorders provided a capability to examine sound levels produced by different drilling activities.

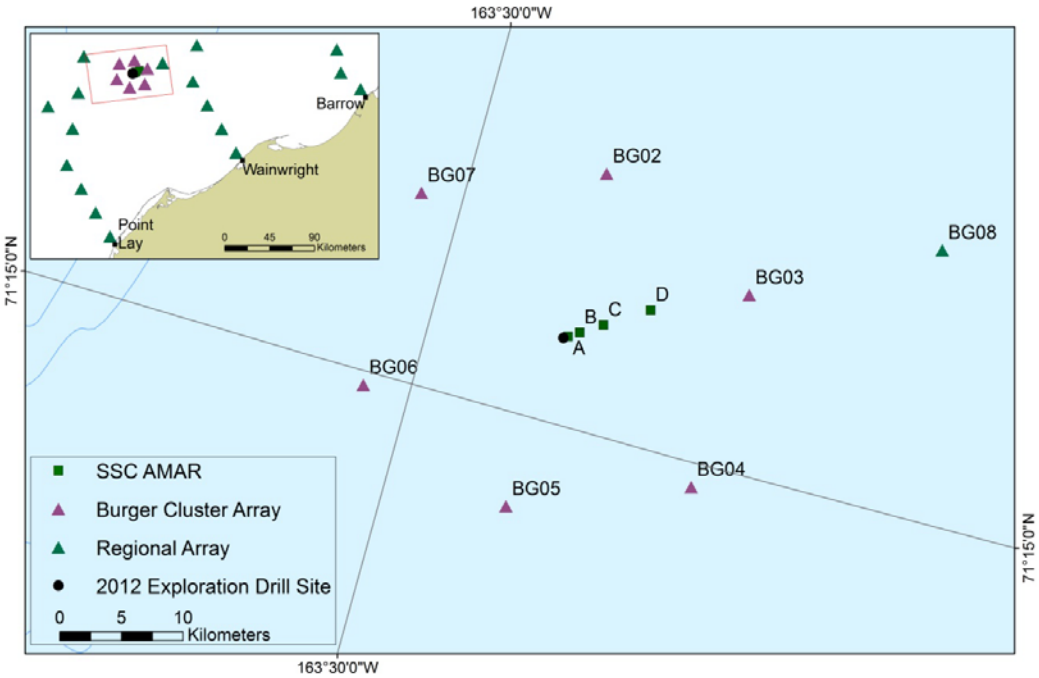


FIGURE 3.17. Drill SSC recorder deployment locations relative to Burger-A drill site in the Chukchi Sea, 2012.

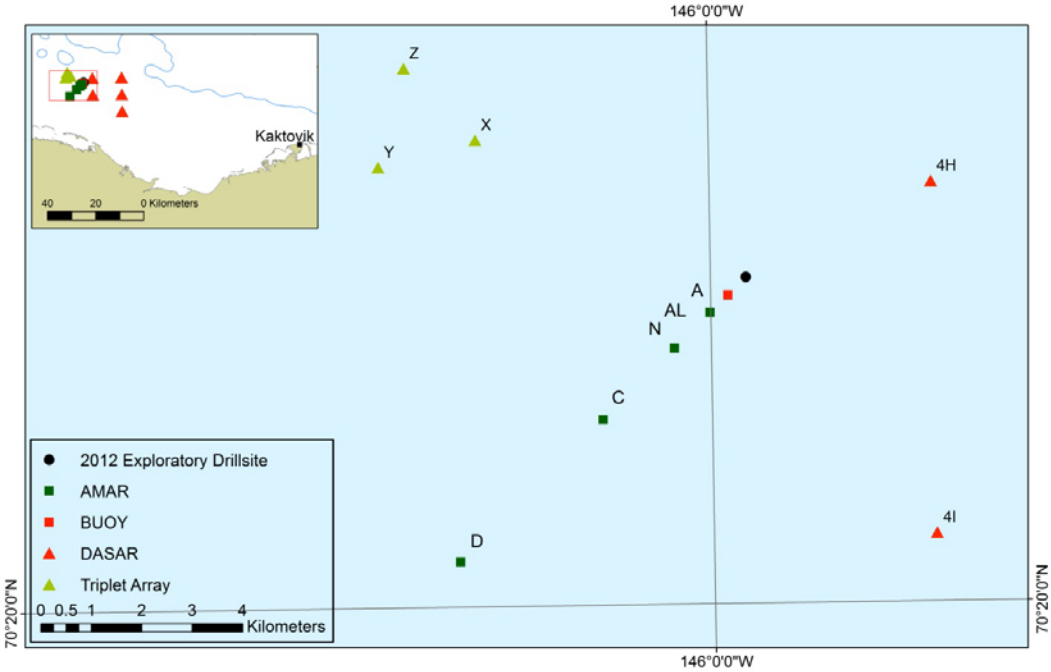


FIGURE 3.18. Drill SSC and DASAR recorder deployment locations relative to Sivulliq-N drill site in the Beaufort Sea, 2012.

Sound data were analyzed to extract a record of the frequency-dependent sound levels as a function of time. Detailed descriptions of data acquisition and analysis can be found in the 2012 90-Day report (Austin et al. 2013). These resulting sound level measurements were correlated with specific drilling activities and were used to compute radii to specific sound level thresholds for each activity.

*Sound Source Verification*

A sound source verification (SSV) involves the measurement of sound source levels and associated propagation properties to verify distances at which rms sound pressure levels reached threshold levels between 190 dB re 1 µPa (rms) and 120 dB re 1 µPa (rms) in 10 dB steps. The threshold sound radii are used as criteria for the implementation of mitigation measures for marine mammals.

Sound source verification measurements were performed in the Alaskan Beaufort Sea for ION's full 26-airgun array and single mitigation gun used in 2012. Measurements were made in shallow water (~50 m or 164 ft depth) and in deep water (~500 m or 1640 ft depth; Fig. 3.19) using JASCO's Ocean Bottom Hydrophone (OBH) recorders. Signals from RESON TC4032 and TC4043 hydrophones were digitized and recorded on Digital Audio Recorders at a sample rate of 96 kHz. For each SSV track, the 4380 in$^3$ full-volume array and the 70 in$^3$ single airgun were fired alternately. The three recorders for the shallow water SSV were deployed on the seafloor at approximately 50 m, 1.5 km, and 20 km (164, 4921, and 6561 ft) from the closest point of approach (CPA). The shallow SSV track was approximately 100 km (62 mi) long. At the deep SSV site, an acoustic recording system was deployed over the side of the *Polar Prince* as the source vessel (*Geo Arctic*) traversed the deep SSV track while alternately firing the full-volume airgun array and the single airgun. Per NMFS IHA requirements, SSV measurements were analyzed within five days and the results were used to adjust pre-SSV marine mammal exclusion zones used by PSOs for the purpose of implementing mitigation.

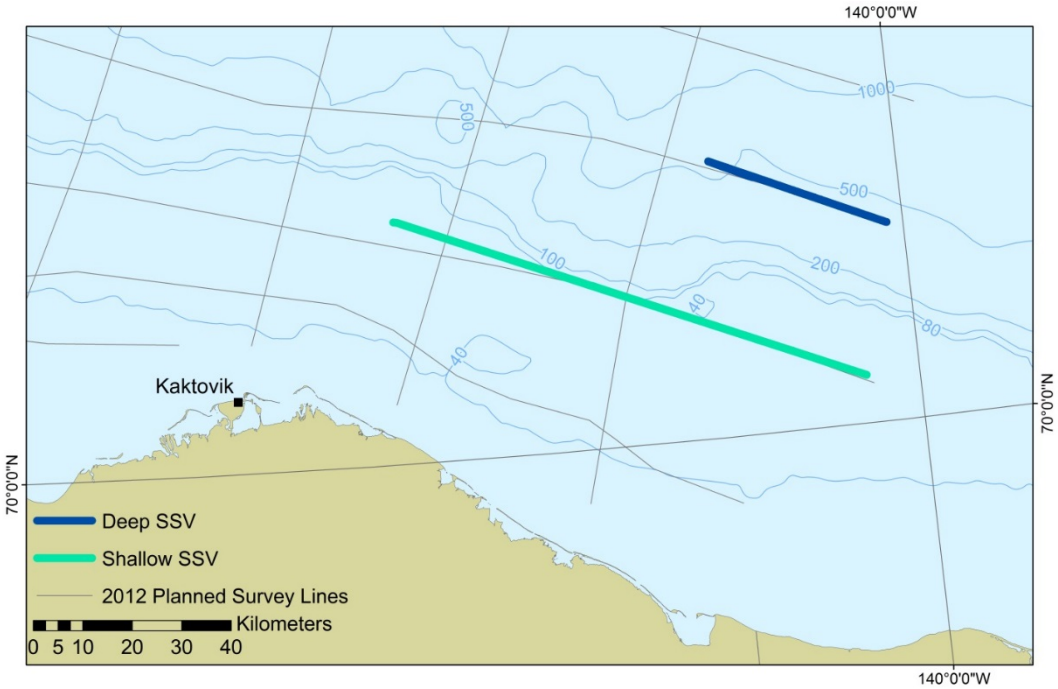


FIGURE 3.19. The Deep and Shallow SSV tracks during ION's 2012 2D seismic survey in the Alaskan Beaufort and Chukchi seas.

### *Chukchi Sea Acoustics Program*

The large-scale acoustics program in the Chukchi Sea employs autonomous acoustic recording systems deployed on the seabed for extended periods over large areas of the northeastern Chukchi Sea. An acoustic "net" array, used since 2006, was designed to accomplish several main objectives: 1) to collect information on the occurrence and distribution of marine mammals (including beluga whale, bowhead whale, and walrus) that may be available to subsistence hunters near villages located on the Chukchi Sea coast, 2) to document their relative abundance, habitat use, and migratory patterns, and 3) to measure the ambient soundscape throughout the northeastern Chukchi Sea and to record received levels of sounds from industry and other activities further offshore in the Chukchi Sea. The recorders operate at a sampling frequency of 16 kHz to capture vocalizations from bowhead, beluga, gray, fin, humpback, and killer whales, as well as walruses, seals, and most other marine mammals known to be present in the Chukchi Sea. Over-winter recorders have been deployed in the Chukchi Sea since 2008 at five sites to monitor late fall, winter, and spring distributions of marine mammals.

Summer 2012 acoustic data were acquired with 31 Autonomous Multichannel Acoustic Recorders (AMARs) deployed from early August through mid-October 2012 throughout the northeastern Chukchi Sea. Twenty-two AMARs were deployed in a regional array along four lines extending offshore from Cape Lisburne, Point Lay, Wainwright, and Barrow (Fig. 3.20). Two single AMARs were deployed within the Klondike and Statoil lease areas. A greater focus was placed around the Burger lease area because of the presence of the *Discoverer* drill ship and numerous associated vessels. The drill location was surrounded by seven AMARs.

The acquired acoustic data were analyzed to quantify ambient sound levels, presence of anthropogenic activity (such as vessels and seismic surveys), and the acoustic presence of marine mammals. The program focus remains on bowhead whales, walrus, and beluga whales, but many other detected species have been detected including fin, minke, gray, humpback and killer whales as well as bearded, ringed, and ribbon seals.

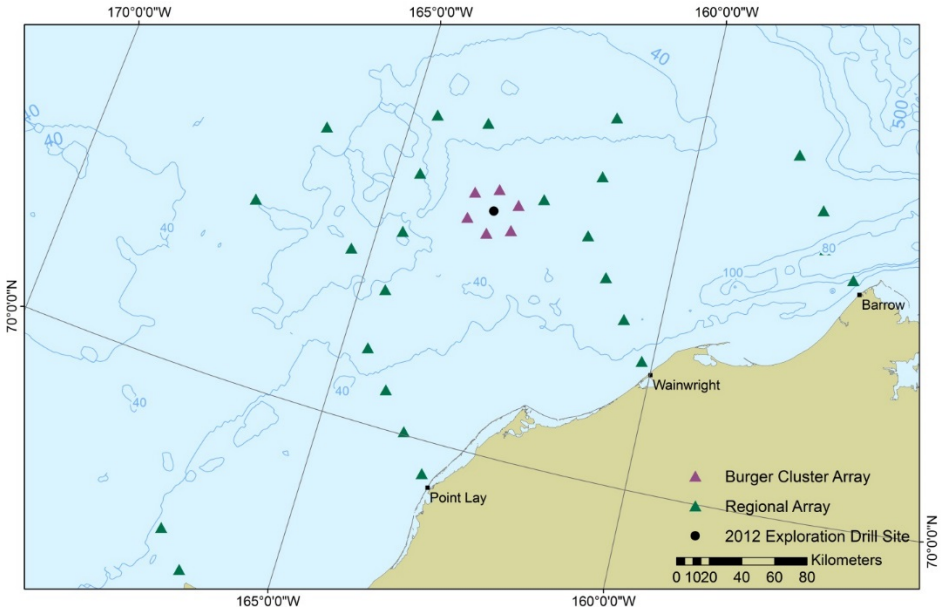


FIGURE 3.20. Deployment locations of hydrophones in acoustic arrays in the eastern Chukchi Sea, Alaska 2012.

Analysis of acoustic data from arrays in the Chukchi Sea can address the following questions: 1) determine when, where, and what species of animals are acoustically detected on each recorder, 2) analyze data as a whole to determine offshore distributions as a function of time, 3) quantify spatial and temporal variability in the ambient sound energy, and 4) measure received levels of exploration activity events. The detection data were used to develop spatial and temporal animal detection distributions as a function of different variables (e.g., time of day, season, environmental conditions, ambient sound energy, and vessel sound levels).

### *Beaufort Sea Acoustics Program*

The acoustics program conducted in the Beaufort Sea in 2012 primarily used passive acoustics with directional autonomous seafloor acoustic recorders (DASARs) to localize the calls of bowhead whales and to determine industrial sound levels. These directional acoustic systems allowed localization of bowhead whale and other marine mammal vocalizations. The primary goal of the Beaufort Sea Acoustics Program was to provide information on the distribution of calling bowhead whales along the coast during fall migration. Of particular importance were any potential effects of the industrial activities on the distribution of whale calls. DASARs were deployed in mid-August prior to the start of the main bowhead migration across the Alaskan Beaufort Sea.

The locations of calling whales were recorded for a continuous monitoring period by DASAR arrays deployed at five coastal sites (Fig. 3.21), spanning an east-west distance of ~280 km (174 mi). The basic unit of a DASAR array is an equilateral triangle with 7 km (4 mi) spacing. Each array consisted of a north-south stack of such triangles, from one at site 1 to nine at site 4. This layout optimizes the best geometry for call localization with the widest area coverage across the migration corridor. Calibration transmissions were made to determine each recorder's orientation on the seafloor and compensate for clock drift. These calibrations were done right after DASAR deployments and right before their retrieval.

The array locations were roughly the same as those used since 2007; however, the layout of the DASAR recorders at sites 1 and 4 were modified from previous years to improve the ability to detect whale calls during the drilling-related activities. In 2010, two DASARs were added to the west of site 4 to provide better ambient sound monitoring near the Sivulliq drill site. These recorders were deployed in the same locations again in 2012. In addition, a small array of three DASARs with 2 km (1 mi) spacing, referred to as a triplet, was deployed northwest of the drill site, with the closest DASAR 6 km (4 mi) from the drill rig (Fig. 3.18). The triplet array was positioned to detect and triangulate calls that might originate from near the drill rig. The five sites were placed specifically to provide information on possible changes in the distribution of bowhead calls well in advance of whales encountering an industry operation in Alaskan waters and after passing such operations.

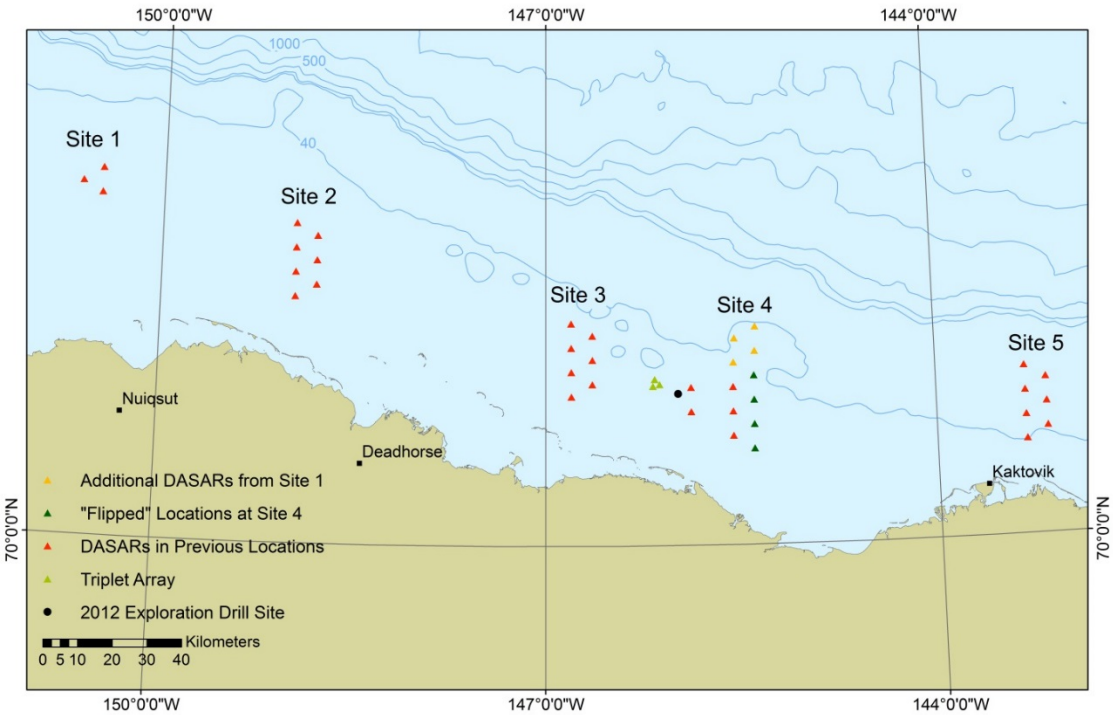


FIGURE 3.21. The Alaskan Beaufort Sea coast showing DASAR site locations for whale call location studies in 2012.

After the DASARs were collected in October, call detection and localization took place as in previous years using both manual analysis and automated call detection software to accelerate the analysis. The main analysis being undertaken aims to gauge the relative contribution of various measures of industrial sound to changes in calling behavior in bowhead whales. The measures of industrial sound used include the presence of tones from machinery, the amount by which anthropogenic activities heightened broadband sound levels, and the presence and level of airgun pulses.

In October when the DASAR arrays were retrieved, five acoustic recorders (AURAL M-2) were placed in some of the same locations as during the 2011–2012 winter season. This will allow a comparison between data from a fall with little to no offshore industrial activity to a fall with more industrial activity (ION's seismic survey in October–November 2012). The acoustic data retrieved from the over-winter recorders will be analyzed to address the following objectives: 1) to characterize the sounds produced by ION's seismic survey and icebreaker, 2) to characterize ambient sounds and marine mammal calls during ION's seismic survey, and 3) to characterize ambient sounds and marine mammal calls during the late winter when little or no anthropogenic sounds are expected.

In addition to the over-winter acoustic recorders, ION used data collected on the seismic streamer to characterize vessel noise in the frequency band 15–410 Hz. This was done in an effort to characterize the level of sound produced by their vessels when transiting through newly forming sea ice as compared to open-water. Once every hour during the seismic survey, the airguns were not fired for two consecutive intervals and the data collected during these breaks were used to analyze the sounds generated by the vessels. Together, these programs described sound characteristics and propagation of ambient and industrial sound levels in the Beaufort Sea in 2012.

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Richardson, W.J., C.R. Greene, Jr., C.I. Malme and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego. 576 p.

Rodrigues, R. 2013. Introduction, description of BP's activities, and record of seal sightings, 2012. Chapter 1 *In*: Richardson, W.J. and K.H. Kim (eds.). 2013. Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 2012: Annual Summary Report. LGL Rep. P1259. Rep. from LGL Alaska Res. Assoc. Inc. (Anchorage, AK), Greeneridge Sciences Inc. (Santa Barbara, CA) and Applied Sociocult. Res. (Anchorage, AK) for BP Explor. (Alaska) Inc., Anchorage, AK. 85 p.

# 4. ACOUSTIC MONITORING OF OIL AND GAS INDUSTRY NOISE SOURCES

Underwater sounds generated through offshore oil and gas exploration activities have the potential to cause the incidental harassment of marine fauna by noise. This could potentially lead to disruption of natural marine mammal behaviors and deflection of marine mammals from traditional migration paths. This becomes a particular concern when the industrial activities occur in locations that are also important for subsistence harvesting of marine mammals. For this reason, acoustic monitoring and reporting is typically a required component of authorizations provided through federal permitting of such activities in US Arctic waters. The goal of such acoustic monitoring is to characterize the emitted noise - its magnitude, nature, and spatial extent - as well as to understand and limit marine mammal noise exposures. This chapter is a review of oil-industry-sponsored acoustic monitoring studies that have been performed offshore Alaska since 2006. Following this general overview is a more detailed review of the acoustic monitoring conducted in 2012. Particular attention is paid to noise from Shell's drilling activities in 2012. First is a review of the results of focused sound-source characterization measurements that focused on specific activities at relatively confined temporal and spatial scales. Finally, the data are examined from a broader consideration of the complete acoustic footprint of Shell's activities.

## *History of Acoustic Monitoring Studies 2006–2012*

Sound Source Verifications (SSVs) of oil and gas exploration activities have been performed in the Chukchi and Beaufort seas every year from 2006 to 2012 in response to regulatory permitting requirements (Tables 4.1 and 4.2). These studies have summarized underwater sound levels for airgun arrays, vessels, and sources associated with drilling, shallow hazard surveys, coring, and geotechnical survey programs. The SSV data have been analyzed to provide distances from the sources to species-specific sound level impact thresholds. This information provides a means to quantify marine mammal sound exposure estimates. Seismic airgun arrays and vessels have been the most prevalent low-frequency oil-industry noise sources since 2006. This section summarizes the measured distances from these sources to the important sound level thresholds. This is a compilation of results collected on behalf of various operators in the oil and gas industry, taken from reports publicly available on the website of the NOAA Fisheries Office of Protected Resources (NMFS 2013a).

The majority of the SSVs in the Chukchi Sea occurred at locations with waters 35–45 m (115–148 ft) deep, clustered in different areas (Fig. 4.1). The highest level of seismic survey activity in the Chukchi Sea occurred in 2006, with three separate 2D or 3D surveys occurring that year. Figures 4.2 and 4.3 are summary plots of the distances to sound level thresholds from large-volume and small-volume airgun arrays, respectively, from each seismic survey measured in the Chukchi Sea since 2006. In this report, large volume arrays are those used for 2D or 3D seismic surveys and small volume arrays are those used for shallow hazards surveys and for mitigation purposes.

In the Beaufort Sea, SSVs occurred in areas with water depths ranging from 2 m to 1000 m (7–3281 ft), at various locations within 48 km (30 mi) of shore (Fig. 4.4). Primarily, the acoustic sources measured in the Beaufort Sea were airgun arrays, survey vessels, and support vessels. The highest level of activity in the Beaufort Sea occurred in 2008 with two nearshore Ocean Bottom Cable (OBC) surveys, one offshore 3D seismic survey, and one offshore shallow hazards survey program. Figures 4.5 and 4.6 summarize the resulting threshold radii from each SSV in the Beaufort Sea since 2006, grouped by source type.

TABLE 4.1. Sound Source Verification (SSV) studies in the Chukchi Sea from 2006–2012 (NMFS 2013b).

| Project Operator and Year of Survey | Survey Type | Water Depths (m) | Acoustic Sources Measured | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | | | Airgun Array | Survey Vessel | Support Vessel | Sidescan/Multibeam Sonars | Sub-bottom Profiler | Sparker/Boomer/ Pulser | |
| Shell Offshore Inc. 2006 | 3D | 40 | * | * | * | | | | Blackwell 2007 |
| GX Technology (GXT) 2006 | 2D | 40–46 | * | | | | | | Austin and Laurinolli 2007 |
| ConocoPhillips Alaska 2006 | 3D | <50 | * | * | | | | | MacGillivray and Hannay 2007 |
| Shell Offshore Inc. 2007 | 3D | >40 | * | | | | | | Hannay 2008 |
| ConocoPhillips Alaska 2008 | SH | 32 | | * | | | | * | Turner and Trivers 2008 |
| Shell Offshore Inc. 2008 | 3D, SH | 19–44 | * | * | * | | * | * | Hannay and Warner 2009 |
| Shell Offshore Inc. 2009 | SH | 48, 41 | * | * | | | * | | Warner et al. 2010 |
| Statoil 2010 | 3D | 38–43 | * | | | | | | O'Neill et al. 2010 |
| Shell Offshore Inc. 2010 | SH, GT | 46–51 | | * | | * | * | | Chorney et al. 2011 |
| Statoil 2011 | SH, GT, GC | 37 | * | * | * | * | * | | Warner and McCrodan 2011 |

**Notes:**

2D = 2-Dimensional seismic survey using airgun array sources.

3D = 3-Dimensional seismic survey using airgun array sources.

SH = Shallow hazards or site clearance survey using small airgun arrays, or sparkers, boomers, or bubble pulsers.

GT = Geotechnical survey using sidescan, multibeam, and/or single beam sonars.

GC = Geotechnical Coring.

TABLE 4.2. Sound Source Verification (SSV) studies in the Beaufort Sea from 2006–2012 (NMFS 2013b).

| Project Operator and Year | Survey Type | Water Depths (m) | Acoustic Sources Measured | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | | | Airgun Array | Survey Vessel | Support Vessel | Sidescan/Multibeam Sonars | Sub-bottom Profiler | Sparker/Boomer/ Pulser | |
| Shell Offshore Inc. 2006 | 3D, SH | 40–50 | * | * | * | | | * | Blackwell 2007 |
| Shell Offshore Inc. 2007 | 3D, SH | > 40 | * | * | * | | * | | Hannay 2008 |
| Eni and PGS 2008 | OBC | 2–14 | * | * | * | | | | Warner et al. 2008 |
| BP Alaska 2008 | OBC | 0.3–7.6 | * | * | * | | | | Aerts et al. 2008 |
| Shell Offshore Inc. 2008 | 3D, SH | 19–44 | * | * | * | | * | * | Hannay and Warner 2009 |
| Shell Offshore Inc. 2010 | SH, GT | 15–38 | * | * | | * | * | | Chorney et al. 2011 |
| BP Alaska 2012 | 2D | 2–18 | * | * | | | | | McPherson and Warner 2012 |
| ION 2012 | 2D | 50, 500–1000 | * | * | * | | | | Wladichuk et al. 2013 |

**Notes:**

2D = 2-Dimensional seismic survey using airgun array sources.

3D = 3-Dimensional seismic survey using airgun array sources.

OBC = Ocean Bottom Cable survey using airgun array sources.

SH = Shallow hazards or site clearance survey using small airgun arrays, or sparkers, boomers, or bubble pulsers.

GT = Geotechnical survey using sidescan, multibeam, and/or single beam sonars.

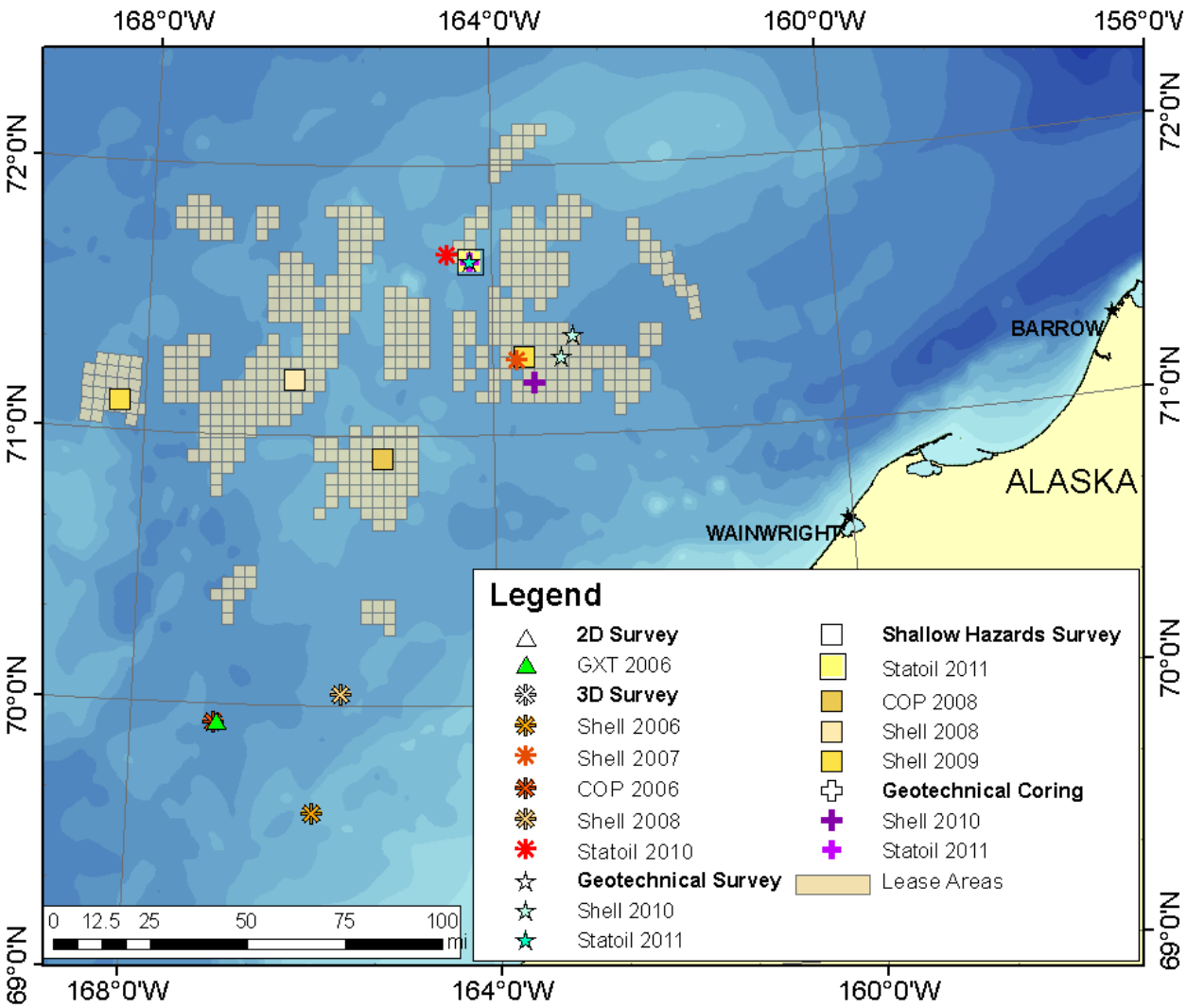


FIGURE 4.1. Sound Source Verification (SSV) studies in the Chukchi Sea from 2006–2012.

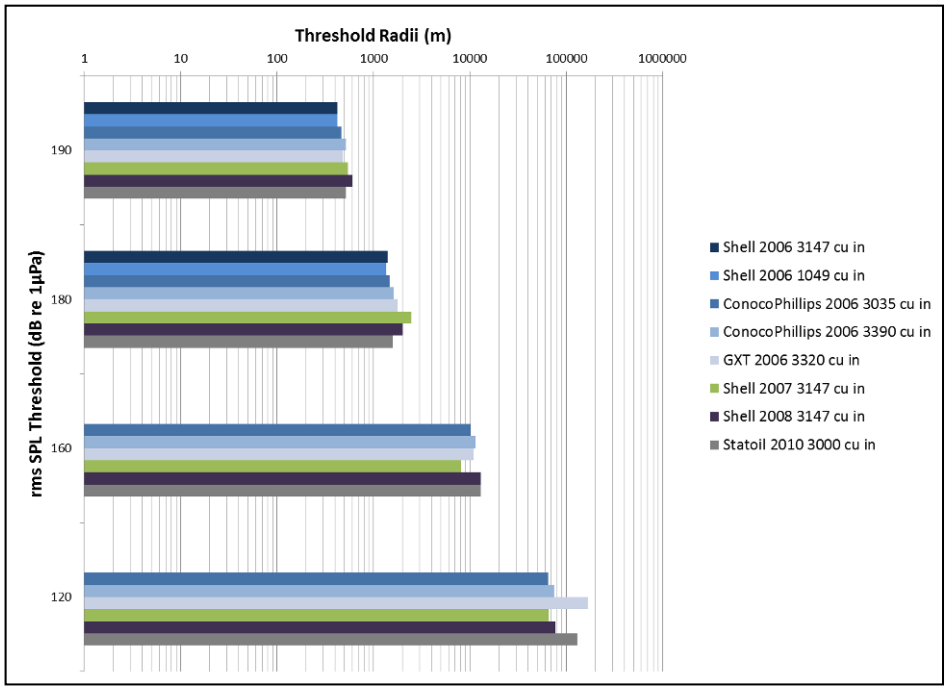


FIGURE 4.2. Threshold radii for 2D and 3D seismic surveys in the Chukchi Sea, 2006–2012. Note: Shell 2006 radii were calculated from best-fit results, which produced smaller threshold radii compared to 90th percentile fits in all other cases.

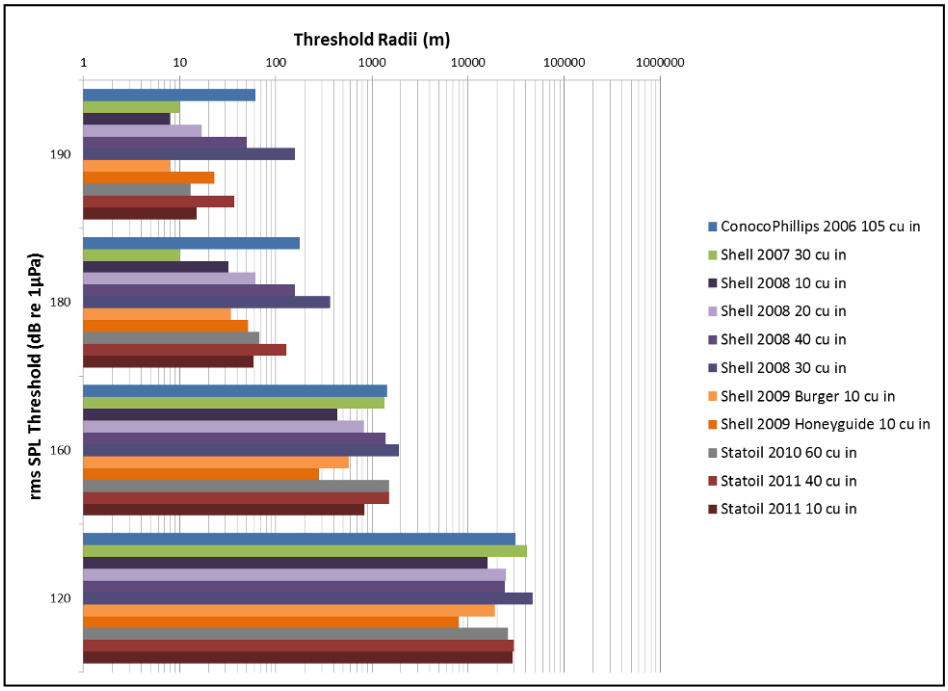


FIGURE 4.3. Threshold radii for shallow hazard surveys and mitigation airgun arrays in the Chukchi Sea, 2006–2012.

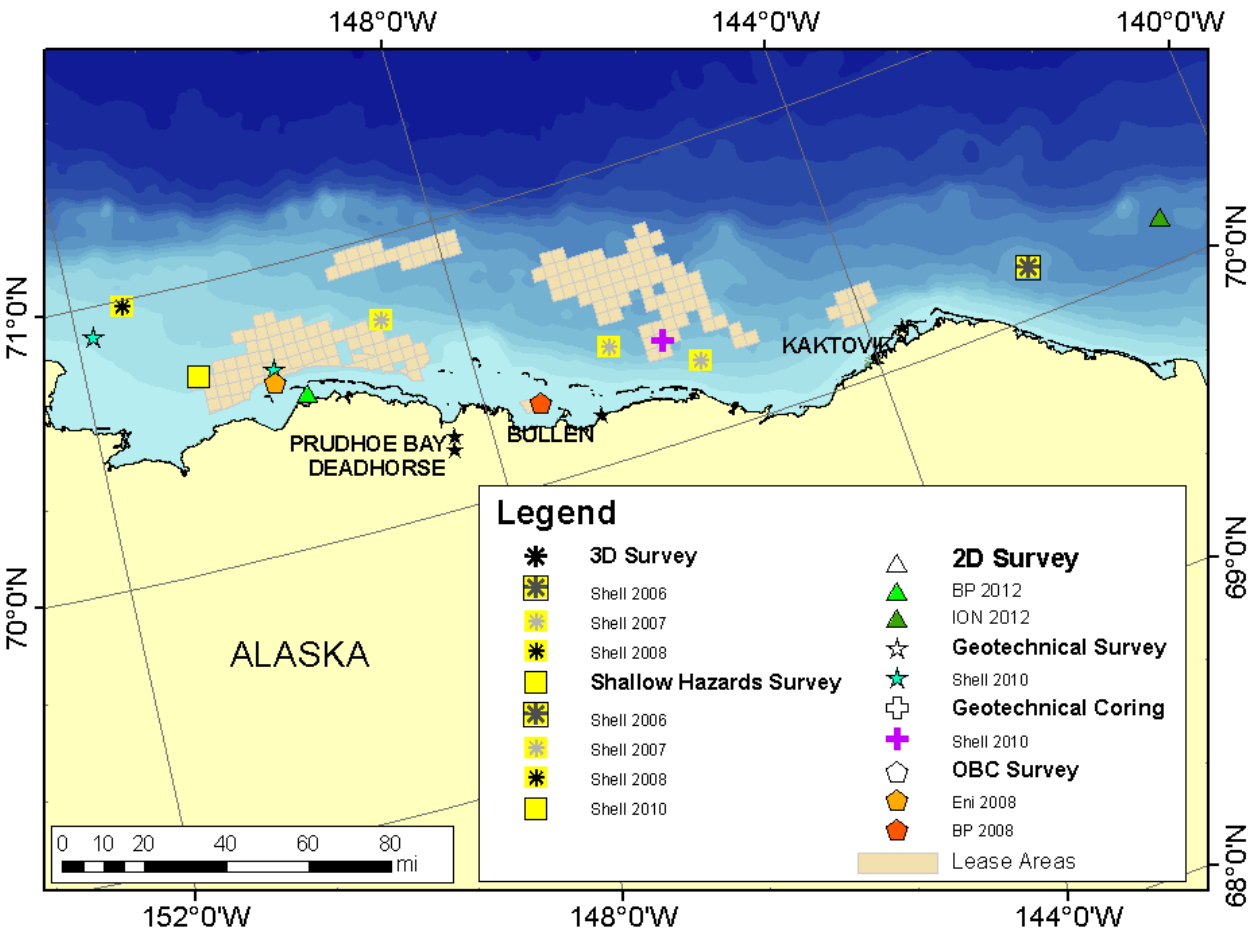


FIGURE 4.4. Sound Source Verification (SSV) studies in the Beaufort Sea from 2006–2012.

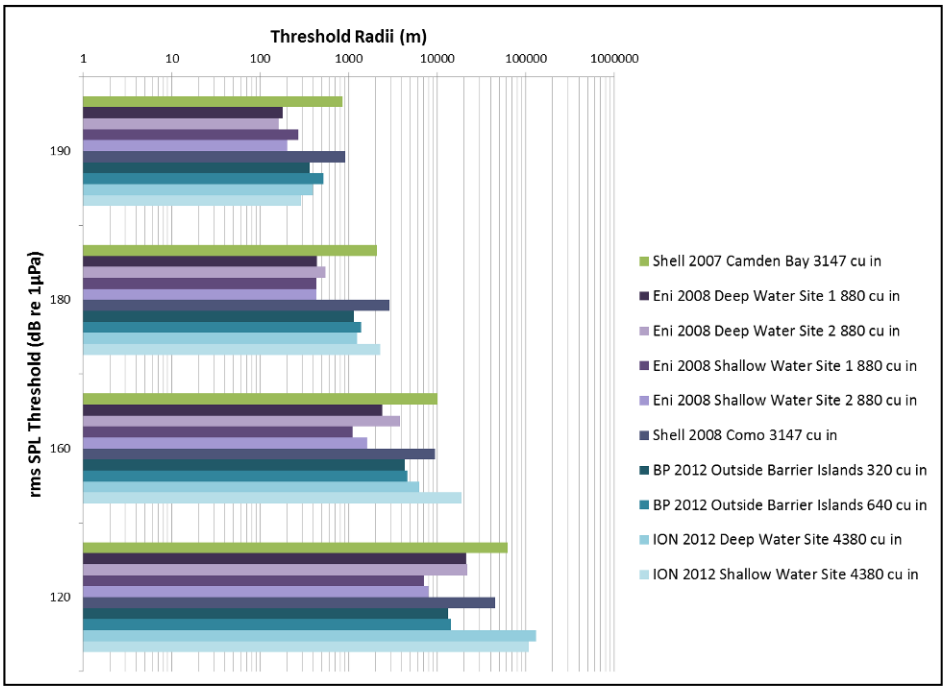


FIGURE 4.5. Threshold Radii for 2D, 3D, and Ocean Bottom Cable (OBC) Seismic Surveys in the Beaufort Sea, 2006–2012.

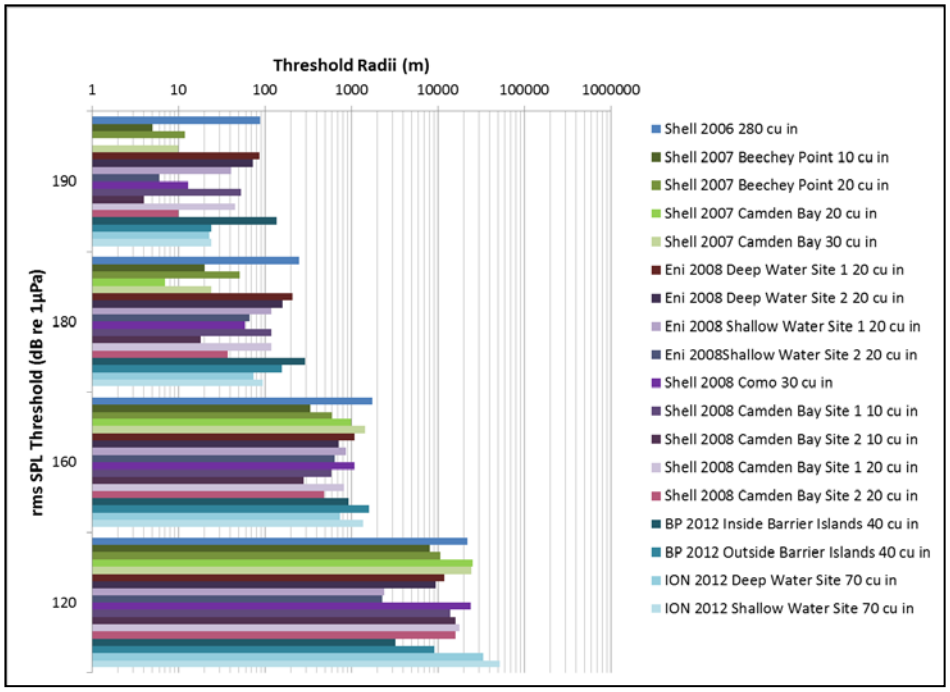


FIGURE 4.6. Threshold radii for shallow hazard surveys and mitigation airgun arrays in the Beaufort Sea, 2006–2012.

Variability of the measured airgun threshold-radii is attributed to differences in the array sizes and configurations and, more importantly, to site-specific sound propagation conditions including the water column sound speed profile, the seafloor properties, and the water depth at the measurement location. As expected, the radii for the large-volume arrays used in 2D and 3D surveys exceed those for the smaller arrays used for shallow hazards surveys and mitigation in similar environments. There is more variability in the radii corresponding to the small-volume arrays than there is in the radii for the large-volume arrays. This is because the array-volume differences between the various small-volume arrays are proportionally greater than the volume differences between the large-volume arrays, relative to the total array volumes. Table 4.3 gives the mean and standard deviation of the measured radii for each array class in each sea. The large standard deviations reflect the fact that the radii are not simply a function of the airgun array volumes but the radii are also strongly influenced by the site-specific environmental conditions.

Measured vessel sound levels varied with the size and type of vessel, as well as with the vessel operating conditions. Figure 4.7 is a plot of the reported radii to the continuous noise disturbance threshold of 120 dB re 1 μPa SPL from vessel SSC measurements in the Chukchi and Beaufort Seas since 2007. Measurements of vessel sounds in the Chukchi Sea yielded radii to 120 dB re 1 μPa between 360 m (1180 ft) for smaller vessels and 19,000 m (82,020 ft) for the largest vessels with powerful thrusters, with a mean value of 4399 m (14,432 ft). Measurements of vessel sounds in the Beaufort Sea yielded radii to 120 dB re 1 μPa between 120 m (390 ft) for smaller vessels and 13,000 m (42,650 ft) for large vessels, with a mean value of 2256 m (7402 ft).

TABLE 4.3. Mean and standard deviation of radii from SSV measurements for large-volume and small-volume arrays measured in the Chukchi and Beaufort Seas between 2006 and 2012.

| | Mean rms SPL Threshold Radii (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 190 dB re 1 μPa | | 180 dB re 1 μPa | | 160 dB re 1 μPa | | 120 dB re 1 μPa | |
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Chukchi Sea | | | | | | | | |
| Large-volume Arrays – 2D and 3D surveys | 491 | 63 | 1677 | 363 | 10,844 | 1849 | 100,082 | 39,351 |
| Small-volume Arrays | 37 | 39 | 107 | 92 | 1066 | 548 | 25,928 | 10,323 |
| Beaufort Sea | | | | | | | | |
| Large-volume Arrays – 2D and 3D surveys | 615 | 320 | 2132 | 682 | 11,136 | 5316 | 86,722 | 40,060 |
| Large-volume Arrays – OBC surveys | 254 | 133 | 637 | 399 | 2635 | 1383 | 14,175 | 6913 |
| Small-volume Arrays | 33 | 37 | 96 | 77 | 860 | 375 | 16,505 | 12,639 |

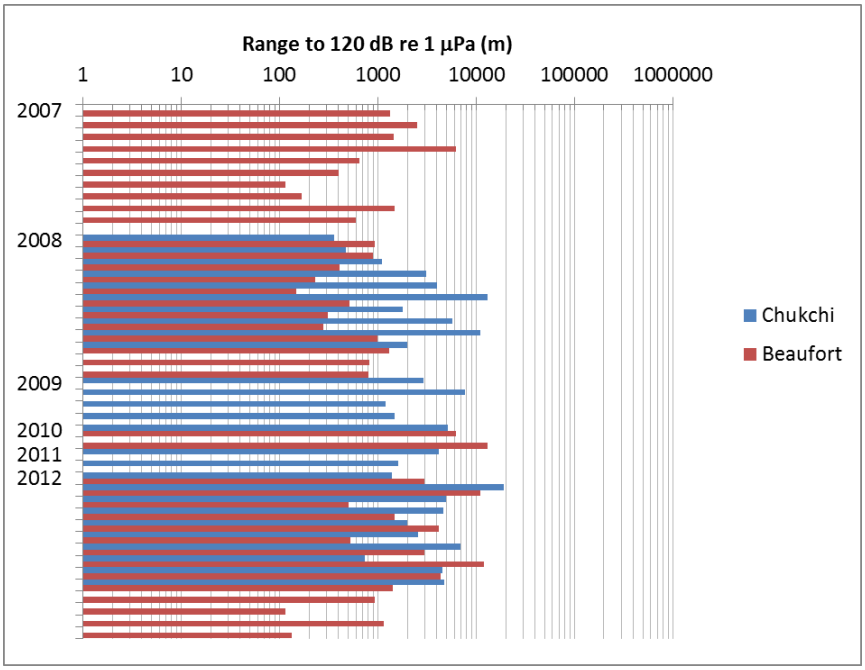


FIGURE 4.7. Ranges to 120 dB re 1 µPa from vessel SSC measurements reported for programs in the Chukchi and Beaufort Seas since 2007.

## *Acoustic Monitoring of Seismic Survey Activities in 2012*

ION and BP each performed offshore seismic surveys in 2012. SSV measurements were conducted for each survey as detailed in the 90-day report to NMFS from each company. This section highlights the key SSV results, which were also included in the summary in the preceding section.

### *Sound Source Verification (SSV) for ION*

Distances corresponding to important sound thresholds from ION's 4380 in$^3$ airgun array and 70 in$^3$ mitigation airgun were calculated from measured sound levels in both deep and shallow water environments (Table 4.4). Detailed descriptions of the sound measurements and analysis methods can be found in Chapter 3 of ION's 90-day report to NMFS (Wladichuk et al. 2013). At thresholds for which measured data were unavailable, distances were extrapolated using empirical curve fits from the sound level versus range data or using spherical spreading loss (i.e., 20logR) to back-propagate the loudest measured pulse level. These extrapolations provided the best estimates of the threshold distances given the available data, but their accuracy is limited.

### *Sound Source Verification (SSV) for BP*

Sound level threshold radii were computed for BP's 2012 seismic sources operating both inside and outside the barrier islands (Table 4.5). Detailed descriptions of the sound measurements and analysis methods can be found in JASCO's Acoustic Monitoring Report provided in Appendix A of BP's 90-day report to NMFS (McPherson and Warner 2012). Recordings from a dipping hydrophone system, used for long-range acoustic monitoring, did not show any seismic pulses outside the barrier islands at times when the BP seismic sources were active inshore of the islands. Long-term measurement data over the duration of the OBC survey showed that the 320 in$^3$ airgun array source operating inside the barrier islands never produced received pulse levels outside the islands that exceeded the 120 dB (rms SPL) threshold. These

results indicate that the acoustic environment of the lagoon substantially attenuated the seismic source pulse amplitude as that sound propagated through the seabed to emerge outside the barrier islands.

TABLE 4.4. Sound level threshold distances for ION's 4380 in$^3$ airgun array and 70 in$^3$ mitigation airgun for two water depth environments. Distances shown are the maxima of forward endfire and broadside measurements and are based on 90$^{th}$ percentile fit lines to measured sound levels versus range.

| Airgun Source | rms SPL Threshold Radii (m) | | | |
|---|---|---|---|---|
| | 190 dB re 1 µPa | 180 dB re 1 µPa | 160 dB re 1 µPa | 120 dB re 1 µPa |
| 4380 in$^3$ Array – Shallow water | 287[a] | 2290 | 18,700 | 109,000[e] |
| 4380 in$^3$ Array – Deep water | 395[b] | 1250[b] | 6260 | 131,000[f] |
| 70 in$^3$ gun – Shallow water | 24[c] | 94[c] | 1360 | 52,000 |
| 70 in$^3$ gun – Deep water | 23[d] | 74[d] | 741[d] | 33,400[g] |

[a] Extrapolated beyond minimum measurement range of 1 km using the 90$^{th}$ percentile fit.
[b] Extrapolated by back-propagating the loudest measured pulse (175 dB re 1 µPa at 2240 m) using spherical spreading (i.e., 20logR).
[c] Extrapolated beyond minimum measurement range of 401 m using the 90$^{th}$ percentile fit.
[d] Extrapolated by back-propagating the loudest measured pulse (150 dB re 1 µPa at 2230 m range) using spherical spreading (i.e., 20LogR).
[e] Extrapolated beyond maximum measurement range of 76.8 km using the 90$^{th}$ percentile fit.
[f] Extrapolated beyond the farthest measurement range of 20.5 km using the 90$^{th}$ percentile fit.
[g] Extrapolated beyond the farthest measurement range of 7340 m using the 90$^{th}$ percentile fit.

TABLE 4.5. Sound level threshold distances for BP's 630 in$^3$, 320 in$^3$, and 40 in$^3$ airgun arrays operating inside and outside of the barrier islands. Distances shown are the maxima of forward endfire and broadside measurements and are based on 90$^{th}$ percentile fit lines to measured sound levels versus range.

| Airgun source | rms SPL Threshold Radii (m) | | | |
|---|---|---|---|---|
| | 190 dB re 1 µPa | 180 dB re 1 µPa | 160 dB re 1 µPa | 120 dB re 1 µPa |
| Outside the Barrier Islands | | | | |
| 640 in$^3$ | 516 | 1386 | 4616 | 14,163 |
| 320 in$^3$ | 360 | 1134 | 4265 | 13,313 |
| 40 in$^3$ | 24 | 158 | 1602 | 9221 |
| Inside the Barrier Islands | | | | |
| 320 in$^3$ | 260 | 472 | 1545 | 5700* |
| 40 in$^3$ | 138 | 293 | 933 | 3242 |

*Based on pre-season model estimate (actual range from measurements was 2528 m in the endfire direction)

## *Acoustic Monitoring of Drilling Activities in 2012*

This section provides an overview of the acoustic monitoring of Shell's 2012 drilling programs. The section begins with a review of sound source characterization (SSC) results, which provide ranges to specific sound level thresholds for isolated sources during restricted windows of intense activity. This is followed by a broader examination of sound levels measured on arrays of sound recorders distributed throughout the Chukchi and Beaufort seas over longer time windows.

Figure 4.8 is a full time history of hourly-averaged underwater sound pressure levels (SPLs) recorded between 12 August and 26 October on an AMAR at 1 km (3280 ft) from Burger. The spectral distribution shows that the sound energy during the recording period was concentrated in the decade band from 100–1000 Hz. Peaks in the recorded sound levels often corresponded with the approach and departure of support vessels relative to the AMAR, though high sound levels were also recorded during acoustically intense drilling-program activities. The received SPLs were greatest when other vessels (most often the *Tor Viking II*) were performing duties within 5 km (16,400 ft) of the AMAR. Elevated sound levels, with SPLs around 140 dB re 1 µPa at 1 km (3280 ft), were also measured during the excavation of the mud-line cellar (MLC) between 2 and 5 October. This elevation of sound levels was simultaneously recorded on the AMARs at 2, 4 and 8 km (6560, 13,120, and 26,240 ft) from Burger. There were no ancillary vessels within 10 km (6 mi) of the AMARs at that time; therefore, the increased sound levels can be directly attributed to MLC excavation. Similarly, elevated sound levels were also recorded during anchor connection/disconnection (6–9 September, 14–15 September and 20 September) and from 11–13 September while the ice management vessels were actively managing ice at the drill site.

Hourly-averaged SPLs, recorded between 18 August and 22 October at 1.5 km (4921 ft) from Sivulliq, are shown in Figure 4.9. The spectral distribution shows that the sound energy during the recording period was concentrated in the decade band from 100–1000 Hz. Elevated SPLs were often attributed to vessel noise from the *Nordica*, *Sisuaq*, and *Aiviq* when these vessels were in close proximity of the AMAR. However, elevated received levels were recorded on all AMARs during anchor handling activities (anchor setting 18–22 August, anchor hook-up 25–27 September) and during MLC excavation (14–18 October and 22 October) when there were no ancillary vessels near the AMARs.

FIGURE 4.8. Chukchi drilling recordings at 1 km (0.6 mi) from the Burger drill site.

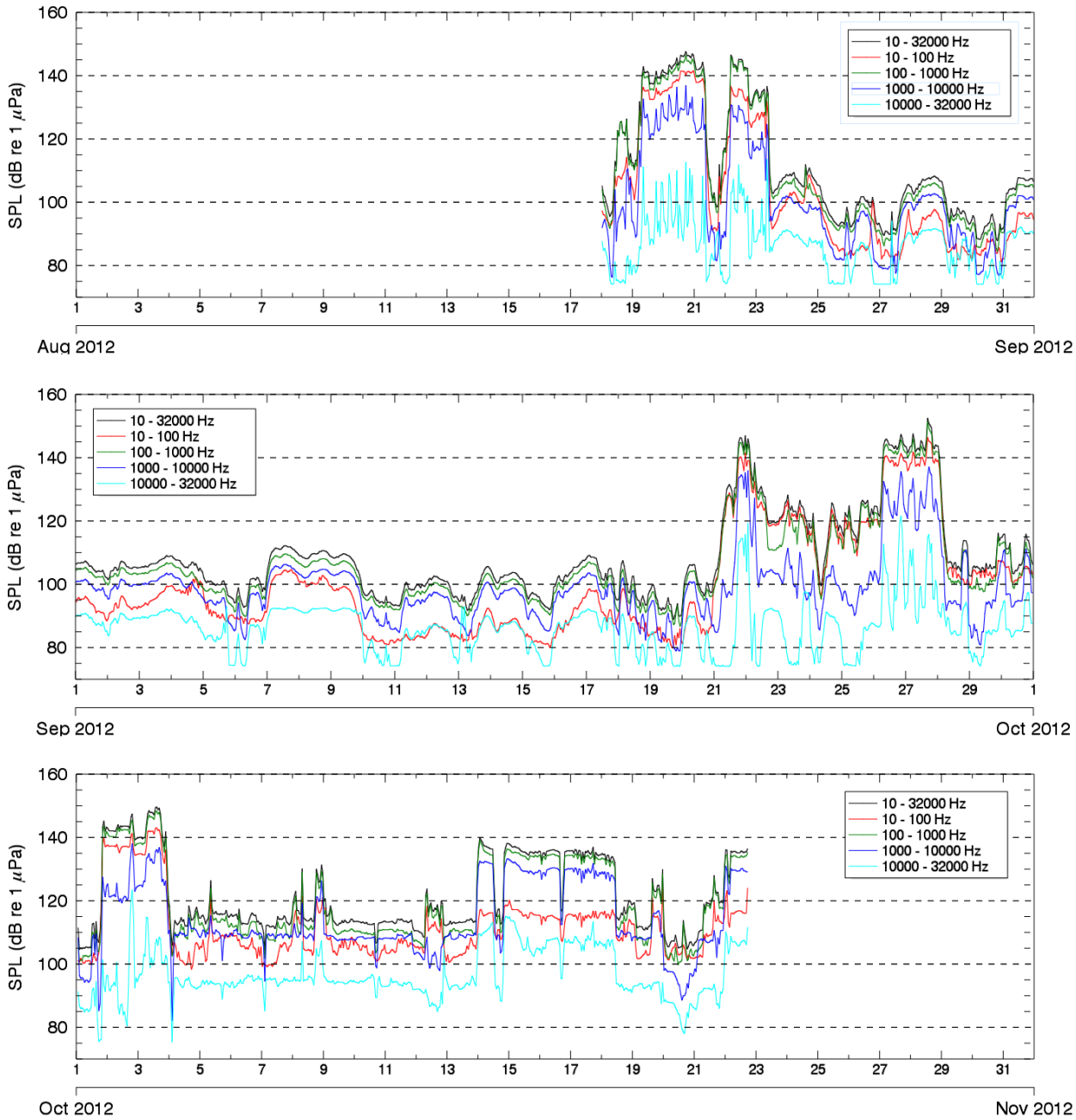


FIGURE 4.9. Beaufort drilling recordings at 1 km (0.6 mi) range from Sivulliq.

### *Sound Source Characterization (SSC) for Shell*

This section provides an overview of the 2012 sound source characterization (SSC) measurements collected during Shell's drilling operations. SSC results were extracted from underwater sound levels measured using AMARs at ranges of 1, 2, 4 and 8 km (3280, 6560, 13,120, and 26,240 ft) from each drill site. Detailed descriptions of the sound measurements and analysis methods can be found in Chapter 3 of the Shell 2012 90-day report to NMFS (Austin et al. 2013). Daily spectrogram plots were prepared to examine the spectral distribution of the received sound levels at fine time scales. These spectrograms were annotated to show the presence/absence of support vessels and the times at which drilling activities occurred (Austin et al. 2013). Using these spectrograms, in combination with field logs, analysis time windows were identified which captured distinct sound signatures during the most intense periods of particular drilling activities. Average SPLs were computed for these times and ranges to sound thresholds between 190 and 120 dB re 1 µPa were obtained for each drilling activity.

#### *Burger Prospect Site, Chukchi Sea*

Sound level threshold distances were calculated for the following activities at Burger: drilling in absence of ancillary vessels, drilling with a support vessel on DP alongside the drill ship, MLC excavation, ice management, and anchor connection. Table 4.6 is a list of the analysis time-periods chosen for each activity. SPLs from each AMAR were averaged over these times and plotted versus distance to estimate average sound-level-threshold ranges for the activities (Table 4.7). Appendix E includes the corresponding plots of average received sound levels versus range. These results include additions and updates to those detailed in the Shell 90-day report. Recordings of drilling noise, free from noise of nearby vessels, were measured while the *Discoverer* drilled a 26" hole. A broadband (10 Hz–32 kHz) source level of 181 dB was calculated from those measurements (Austin et al. 2013).

Sounds from drilling support vessels in the Chukchi Sea were recorded while the vessels transited at normal operating speed along a prescribed track. From these data, received SPL versus range plots were generated for each vessel (Austin et al. 2013). Table 4.8 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile fits to these data. Source levels, also in the tables, were computed from the sound levels recorded at the closest range to each vessel assuming spherical spreading loss.

TABLE 4.6. Time periods used for SSC analysis of drilling activities at Burger.

| Activity | Analysis Period (UTC) |
|---|---|
| Drilling 26" hole with *Fennica* on DP alongside | 17 Oct 05:58 – 17 Oct 07:57 |
| Drilling 26'' hole (no ancillary vessels present) | 17 Oct 09:00 – 18 Oct 03:00 |
| | 18 Oct 07:00 – 18 Oct 18:40 |
| | 19 Oct 07:30 – 19 Oct 10:00 |
| Excavation of MLC | 2 Oct 11:50 – 2 Oct 18:00 |
| Ice Management | 13 Sep 18:50 – 13 Sep 19:10 |
| Anchor connection | 7 Sep 08:00 – 7 Sep 10:00 |

TABLE 4.7. Sound level threshold distances for drilling activities at the Burger drill site. Distances were obtained from best-fit lines to averaged sound levels versus range for the respective activity (Appendix E).

| Drill Site Activity | rms SPL Threshold Radii (m) | | | |
|---|---|---|---|---|
| | 190 dB re 1 µPa | 180 dB re 1 µPa | 160 dB re 1 µPa | 120 dB re 1 µPa |
| Drilling 26" hole with *Fennica* on DP alongside* | <10 | <10 | 11 | 2700 |
| Drilling 26" hole (no ancillary vessels present) | <10 | <10 | <10 | 1500 |
| Excavation of MLC** | <10 | <10 | 71 | 8200 |
| Ice management | <10 | <10 | 60 | 9600*** |
| Anchor connection* | <10 | 20 | 180 | 14,000*** |

* New analysis following 90-day report.
** Updated since 90-day Report to remove coast guard vessel noise contamination.
*** Extrapolated beyond measurement range.

TABLE 4.8. Sound level threshold distances for vessels involved with the Burger drilling program in the Chukchi Sea. Distances were obtained from the 90th percentile fits to sound level versus range for the respective vessels.

| Vessel Name | Source Level (dB re 1 µPa) | rms SPL Threshold Radii (m) | | | |
|---|---|---|---|---|---|
| | | 190 dB re 1 µPa | 180 dB re 1 µPa | 160 dB re 1 µPa | 120 dB re 1 µPa |
| *Affinity*–8.8 kts | 177 | 0 | 0 | <10 | 1300 |
| *Affinity*–9.0 kts | 179 | 0 | 0 | <10 | 1400 |
| *Aiviq* (towing the Kulluk) | 196 | <10 | <10 | 110 | 19,000 |
| *Fennica*–8.0 kts | 180 | 0 | <10 | 11 | 2000 |
| *Fennica*–12.0 kts | 184 | <10 | <10 | 26 | 5000 |
| *Guardsman* (towing the *Klamath*) | 185 | <10 | <10 | 70 | 4700 |
| *Harvey Explorer* | 179 | 0 | <10 | 16 | 2000 |
| *Harvey Spirit* | 184 | 0 | 0 | <10 | 2600 |
| *Nanuq*–9.1 kts | 191 | <10 | <10 | 42 | 5200 |
| *Nanuq*–10.8 kts | 191 | <10 | <10 | 60 | 6900 |
| *Noble Discoverer* (towed by *Tor Viking II*) | 171 | 0 | 0 | <10 | 740 |
| *Nordica* | 186 | <10 | <10 | 40 | 4600 |
| *Tor Viking II* (towing the *Noble Discoverer*) | 185 | <10 | <10 | 25 | 4800 |

### *Sivulliq Prospect Site, Beaufort Sea*

Sound level threshold distances were calculated for the following activities at Sivulliq: drilling in absence of ancillary vessels, drilling with a support vessel on DP alongside drill ship, MLC excavation, anchor setting. Table 4.9 is a list of the analysis time-periods chosen for each activity. These results include additions to those detailed in the 90-day report. SPLs from each AMAR were averaged over the duration of each identified activity and were plotted versus range to estimate sound level threshold ranges (Table 4.10). Appendix E contains the corresponding plots of average received sound levels versus range. Recordings of drilling noise, free from noise of nearby vessels, were measured while the *Kulluk* drilled the pilot hole. A broadband (10 Hz–32 kHz) source level of 172 dB was calculated from those measurements (Austin et al. 2013).

Sound levels recorded while the *Tor Viking II* deployed the *Kulluk* mooring anchor #10 were selected to represent the SPL associated with anchor setting. The average SPL received during this activity was 143 dB re 1 µPa at an average range of 860 m (2820 ft). Since there was only a single measurement range for this activity, distances to sound level thresholds were estimated assuming spreading losses of 15log(range) and 20log(range). The true sound threshold ranges would have likely fallen between these two estimates.

Sounds from drilling support vessels in the Chukchi Sea were recorded while the vessels transited at normal operating speed along a prescribed track. From these data, received SPL versus range plots were generated for each vessel (Austin et al. 2013). Table 4.11 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90$^{th}$-percentile fits to these data. Source levels, also in the tables, were computed from the sound levels recorded at the closest range to each vessel assuming spherical spreading loss.

TABLE 4.9. Time periods used for SSC analysis of drilling activities at Sivulliq.

| Activity | Analysis Period (UTC) |
|---|---|
| Drilling pilot hole (no ancillary vessels present) | 4 Oct 03:30 – 05:00 |
| | 4 Oct 19:30 – 21:00 |
| | 5 Oct 01:00 – 03:30 |
| Drilling with *Sisuaq* on DP alongside | 05 Oct 20:30 – 06 Oct 02:30 |
| Excavation of MLC | 15 Oct 09:00 – 15 Oct 14:30 |
| | 15 Oct 15:30 – 16 Oct 01:30 |
| | 16 Oct 02:30 – 16 Oct 04:30 |
| | 16 Oct 05:00 – 16 Oct 14:30 |
| | 16 Oct 20:00 – 17 Oct 16:30 |
| | 17 Oct 17:30 – 18 Oct 07:00 |
| *Tor Viking II* setting *Kulluk* anchor 10 | 22 Aug 13:00 – 22 Aug 18:00 |

TABLE 4.10. Sound level threshold distances for drilling activities at the Sivulliq drill site. Distances were obtained from the best-fit lines to averaged sound level versus range for the respective activity (Appendix E).

| Drill Site Activity | rms SPL Threshold Radii (m) | | | |
|---|---|---|---|---|
| | 190 dB re 1 µPa | 180 dB re 1 µPa | 160 dB re 1 µPa | 120 dB re 1 µPa |
| Anchor setting* | <10 | <12 | 63–120 | 12,000–29,000 |
| Drilling of pilot hole (no ancillary vessels present) | <10 | <10 | <10 | 660 |
| Drilling with Sisuaq on DP alongside** | <10 | <10 | <10 | 840 |
| Excavation of MLC | <10 | 20 | 140 | 6200 |

*Estimated from a single measurement point
**New analysis following 90-day report.

TABLE 4.11. Sound level threshold distances for vessels operating near the Sivulliq drill site in the Beaufort Sea from measurements made from 28 September to 2 October 2012. Distances were obtained from the 90th percentile fits to sound level versus range for the respective vessels.

| Vessel Name | Source Level (dB re 1 µPa) | rms SPL Threshold Radii (m) | | | |
|---|---|---|---|---|---|
| | | 190 dB re 1 µPa | 180 dB re 1 µPa | 160 dB re 1 µPa | 120 dB re 1 µPa |
| *Affinity* | 181 | 0 | <10 | <10 | 3000 |
| *Aiviq* | 193 | 0 | <10 | 67 | 11,000 |
| *Arctic Seal* | 173 | 0 | 0 | <10 | 510 |
| *Lauren Foss* (towing the *Tuuq*) | 173 | 0 | <10 | <10 | 1500 |
| *Nordica* | 178 | <10 | <10 | 24 | 4200 |
| *Pt Oliktok* | 175 | 0 | <10 | <10 | 830 |
| *Sisuaq* | 184 | <10 | <10 | 25 | 3000 |
| *Tor Viking II* | 188 | 0 | <10 | 30 | 12,000 |
| *Warrior* | 183 | <10 | <10 | 42 | 4400 |

### *Overview of SSC Results*

Seismic surveys and geotechnical surveys were the primary oil and gas industry activities at the lease areas in the Chukchi and Beaufort seas during open-water seasons of 2006 to 2011. Of the SSV measurements for the sound sources used during those surveys, the largest sound threshold radii resulted from large airgun arrays operated for 2D and 3D seismic surveys. The radii from the smaller airgun arrays, used for shallow hazards surveys, and from high-frequency geophysical survey sources were

comparatively small. Vessels associated with offshore oil and gas activities included industry-funded scientific research vessels (one to two per year), survey source vessels (typically one per project per year), monitoring vessels (generally one to two per project per year), and supply vessels (generally one per project per year).

In 2012, the predominant oil and gas industry activities at the offshore lease areas were those associated with Shell's drilling programs. The prevalent noise sources were vessels and drilling machinery. Noise from activities from 2012 cannot really be put into context with noise from activities in previous years since it is not appropriate to compare directly the radii to sound level thresholds for impulsive sources, such as airguns, with those from vessels and drilling equipment that produce continuous-type noise. Different characteristics of the two sound types (impulsive versus continuous) lead to differences in the thresholds at which the sounds can potentially harm or disturb marine life.

In terms of vessel activity, 2012 saw the largest number of vessels concentrated near a specific lease area during a single program. Shell's 2012 drilling programs involved a fleet of support vessels (nine vessels operated in the Beaufort Sea and 10 vessels operated in the Chukchi Sea, with some vessels operating in both seas) providing supply services, anchor handling, ice management and spill response capabilities. Results from the SSC measurements of the transiting vessels showed that the anchor handling vessels generated the greatest amounts of noise, particularly while towing the drill rigs. The measured threshold radii for the remaining vessels were comparable to those measured for similar-sized industry vessels in previous years (Fig. 4.7, above).

Anchor handling and ice management activities required vessels using increased thruster power which resulted in longer measured distances to the 120 dB re 1 µPa threshold in comparison to the other activities at the drill sites. For example, the distance from Burger to the 120 dB re 1 µPa threshold was determined to be 14,000 m (45,932 ft) during anchor connection, 9600 m (31,496 ft) during ice management, and 2700 m (8858 ft) during drilling. However, these high-sound generating activities (anchor handling and ice management) included only intermittent bursts of noise at these elevated levels. The anchor handling vessels also required high thruster power to tow the drillships onto the drill sites, consequently resulting in the largest radii of the vessel SSC measurements with threshold distances that were comparable to those produced during anchor handling activities. For example, the distance to the 120 dB re 1 µPa threshold from the *Aiviq* while towing the *Kulluk* was 19,000 m (62,336 ft) while that to the *Nanuq* transiting on its own at 11 kts was 6900 m (22,638 ft).

Excavation of the mud-line cellar was the third noisiest phase of the drilling operations. This noise is thought to result from the grinding of the large MLC drillbit into the seafloor since the sound signature lacks tonal characteristics that would be associated with rotating machinery on the drillship (Austin et al. 2013). This activity is a source of continuous noise that can be compared against vessel SSC measurements to put the sound levels in context. The ranges to 120 dB re 1 µPa for this activity (8159 m [26,768 ft] in the Chukchi Sea and 6200 m [20,341 ft] in the Beaufort Sea) were measured to be substantially larger than the corresponding average radii measured from noise of transiting vessels since 2007 (4399 m and 2256 m [14,432 ft and 7402 ft] in the Chukchi and Beaufort Seas, respectively). After completion of the MLC excavation, noise measurements from top-hole drilling yielded much shorter 120 dB radii, between 660 and 2700 m (2165 and 8858 ft).

### *Soundscape of 2012 Drilling Activities*

An intentional aim of Sound Source Characterization (SSC) is to exclude noise interference from ancillary activities in the analysis. Consequently, SSC results give a focused characterization of specific activities but do not provide a full understanding of the overall noise footprint created by a distributed fleet of project assets. For example, SSC analysis of drilling noise intentionally excluded periods of time

when support vessels were operating nearby to the SSC recorders. This provides a quantitative measure of drilling sounds but does not consider the larger-scale, composite footprint that includes support vessel noise. Data from the large-scale arrays of acoustic recorders in the Chukchi and Beaufort Seas provide a more holistic view of the distribution of industrial noise from a broader spatial context.

Since an SSC analysis also focuses temporally on a specific activity, attempting to capture the most intense sound generation, the resulting radii provide a conservative sound characterization when applied to the full period of time when that activity took place. Sound levels generated during activities that extend over a long period will fluctuate with the rise and fall of the intensity of the activity. In such cases, it may be appropriate to consider sound levels averaged over a longer period. As an example, the above SSC analysis of anchor attachment activities considered sound levels received while an anchor-handling vessel connected a drillship to a single anchor at a location closest to a single line of SSC sound recorders. In this section, we consider anchor connection as a complete period, which covered the first anchor connection until the last anchor connection, as received over an array of sound recorders. The aim of this section is to show broad-scale, median sound levels for complete activity windows. This analysis, jointly considered with the SSC radii from the previous section, provides a comprehensive look at the sound distribution and propagation during different phases of the drilling operations.

For this analysis, the following major activities associated with the drilling operation were selected for soundscape characterization: no activity, anchor handling, ice management, dynamic positioning, drilling, and mud-line cellar excavation. We identified times for which acoustic data were available that bounded complete activity windows for each sea (Table 4.12 for the Chukchi Sea, and Table 4.13 for the Beaufort Sea) and then generated contour maps of the median received sound levels at each sound recorder location for these times. We refer to these maps as soundscapes. A representative soundscape was generated for each activity window.

TABLE 4.12. Activity windows used to generate soundscape maps for activities at the Burger drill site in the Chukchi Sea, ordered chronologically.

| Activity | Start (AKDT) | End (AKDT) |
|---|---|---|
| No activity | 14 Aug 23:08 | 18 Aug 11:02 |
| Connecting drillship (*Discoverer*) to anchors | 6 Sep 00:00 | 9 Sep 04:35 |
| Ice management at Burger | 11 Sep 16:54 | 14 Sep 12:21 |
| Vessels on dynamic positioning (DP) near Burger, no drilling | 14 Sep 12:21 | 19 Sep 15:09 |
| Drilling pilot hole at Burger | 23 Sep 02:59 | 26 Sep 00:00 |
| Excavating mud-line cellar at Burger | 2 Oct 04:00 | 5 Oct 16:00 |

TABLE 4.13. Activity windows used to generate soundscape maps for activities at the Sivulliq drill site in the Beaufort Sea, ordered chronologically.

| Activity | Start (AKDT) | End (AKDT) |
|---|---|---|
| Anchor setting | 18 Aug 21:30 | 22 Aug 23:57 |
| No activity | 24 Aug 09:27 | 20 Sep 12:00 |
| Connecting drillship (*Kulluk*) to anchors | 21 Sep 12:34 | 27 Sep 17:27 |
| Vessels on DP | 27 Sep 17:27 | 2 Oct 09:57 |
| Drilling at Sivulliq | 3 Oct 15:55 | 8 Oct 18:29 |

Soundscapes were generated using a contouring routine that applies ordinary Kriging interpolation to estimate sound levels between recorder locations (Delarue et al. 2013). Kriging interpolation uses the data points and their spatial variance to determine trends that are then applied to grid points. Because there can be large distances between recorders, these soundscapes only approximate the large-scale sound distribution, possibly overlooking acoustic "hotspots" between recorders.

As a caveat, the recording bandwidth of the acoustic recorders deployed in the Beaufort Sea is narrower than that of the recorders deployed in the Chukchi Sea, which means that the received sound levels are not directly comparable between seas. Data from the recorders in the Beaufort (DASARs, Greeneridge Sciences) have a bandwidth of 10–450 Hz; while data from the recorders in the Chukchi Sea (AMARs, JASCO Applied Sciences) have a bandwidth of 10–8000 Hz. Both sets of recorders have bandwidths appropriate to capture most of the dominant frequencies of interest for noise from vessels and drilling machinery in their respective areas.

The same color scale is used on each map for each sea to allow a visual comparison between activities, but it must be kept in mind that sound levels are also affected by environmental conditions like wind speed and sea state. Although relative sound levels on each map highlight acoustic "hotspots", differences between maps may be due to differences in the background conditions and ambient sound levels for the respective maps.

It also must be kept in mind that the soundscapes show the median recorded sound levels around which the sound levels may fluctuate significantly for short times. Figure 4.10 helps put the median levels used in the soundscapes in perspective. It compares broadband levels at DASAR location 4H, near Sivulliq, with levels at DASAR location 2B (see Fig. 3.21 for DASAR locations), about 109 km (68 mi) east-northeast of Sivulliq. Mean hourly wind speed, as recorded at the Camden Bay meteorological buoy, is also shown since variations in background levels depend strongly on wind speed when anthropogenic activities are not present. Over its entire deployment duration, the median broadband level at 2B was 95.1 dB re 1 µPa, but the levels varied from 76.5 to 123.3 dB re 1 µPa, nearly a 47 dB range. From 6–8 September 2012, there was a period of bad weather in the Beaufort Sea where wind speeds reached ~14 m/s (31 mph). The Shell fleet was absent from the entire DASAR study area at that time so most of the sound sources were presumably natural. Broadband levels at DASAR location 2B over those two days varied by 32 dB, from 80.7 to 112.7 dB re 1 µPa with a median value of 101 dB re 1 µPa. Similarly, median sound levels from the entire summer deployment of recorders in the Chukchi Sea ranged from 98 dB re 1 µPa for offshore recorders distant from the Burger location to 109.9 dB re 1 µPa for recorders near Burger. Median sound levels that fluctuated between 86.0 dB and 112.9 dB re 1 µPa were measured throughout the Chukchi Sea on a day with low ambient noise levels on 19 August 2012 (Delarue et al. 2013).

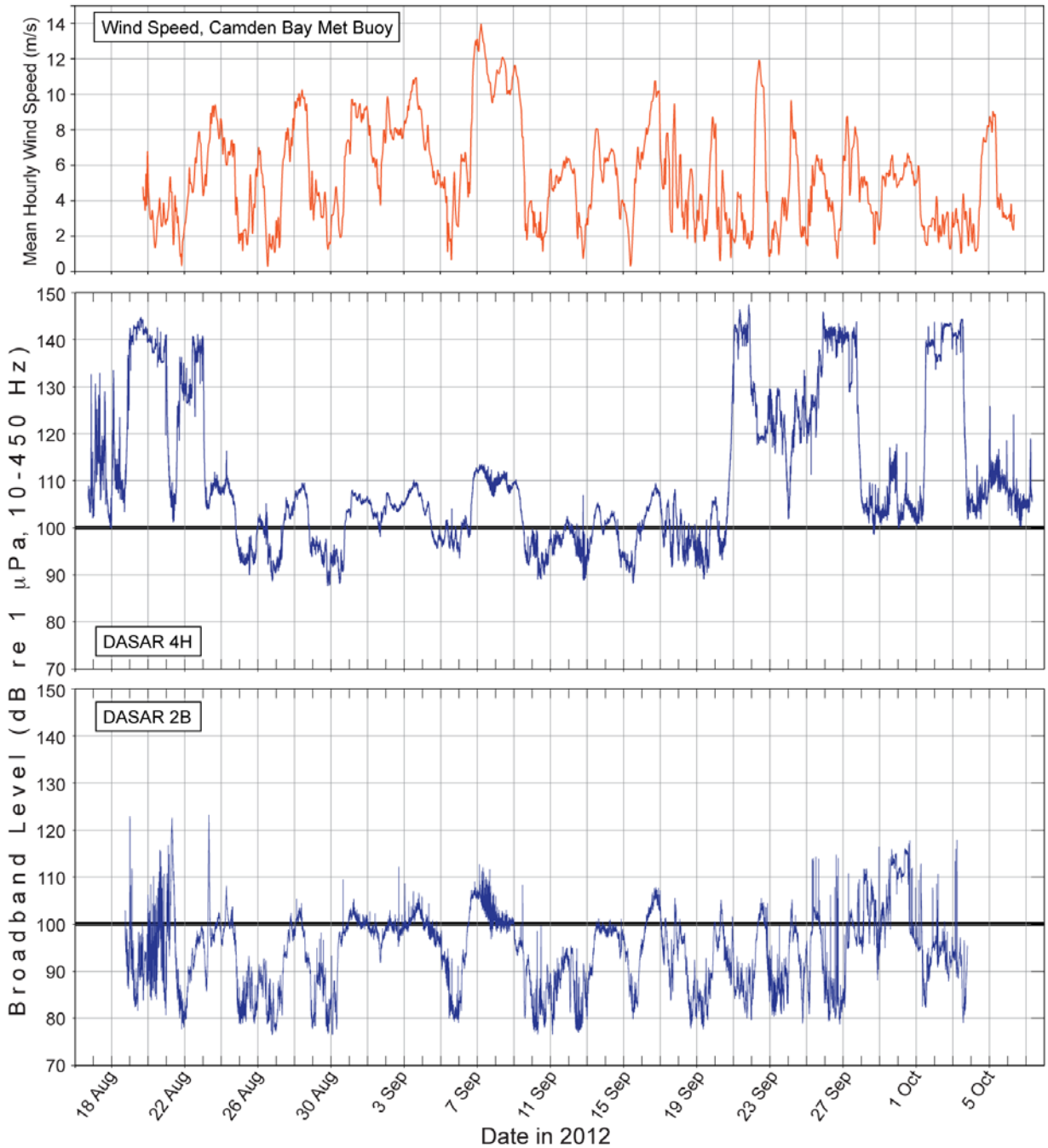


FIGURE 4.10. Broadband (10–450 Hz) sound levels during the entire 2012 deployments for a DASAR near (4H, 4.1 km [2.5 mi]) and far (2B, 109 km [68 mi]) from the Sivulliq drilling location. Mean hourly wind speed (Camden Bay met buoy, ~24 km [15 mi] NW of Sivulliq) is shown in the top plot. A black line at 100 dB has been added to the broadband level plots to facilitate comparisons.

### *Chukchi Sea Activity Soundscapes*

Figures 4.11 to 4.16 are maps of the soundscapes for the chosen activity windows in the Chukchi Sea from Table 4.12. The soundscapes include symbols depicting locations of Shell vessels for each hour of the activity window shown. Pockets of elevated received sound levels occur where recorder locations overlap with regions of concentrated vessel presence, for example at the recorder 56 km (35 mi) offshore of Wainwright in Figure 4.11. Here the SPL exceeds that at surrounding AMAR locations by approximately 5 dB. Acoustic hotspots, with median SPLs greater than 120 dB re 1 µPa, are concentrated at Burger during anchor connection (Fig. 4.12), ice management (Fig. 4.13), mud-line cellar excavation (Fig. 4.16), and pilot hole drilling (Fig. 4.15).

A vessel noise detector was run on the AMAR data from the Chukchi Sea (Delarue et al. 2013) to study the influence of vessel noise in the soundscapes. Figure 4.17 shows the difference between the median sound level from all data in which vessels were detected and the median sound level in the absence of vessels, over the entire summer 2012 deployment in the Chukchi Sea (Delarue et al. 2013). This plot shows that throughout the summer of 2012 median vessel sound levels were 10–19 dB above ambient sound levels in two key locations: at the Burger drill site and approximately 56 km (35 mi) offshore from Wainwright. These locations also correlate with the areas of highest vessel-based observation efforts, as reported by the PSO teams (Fig. 4.18) reflecting that they were areas of concentrated vessel presence during the drilling program.

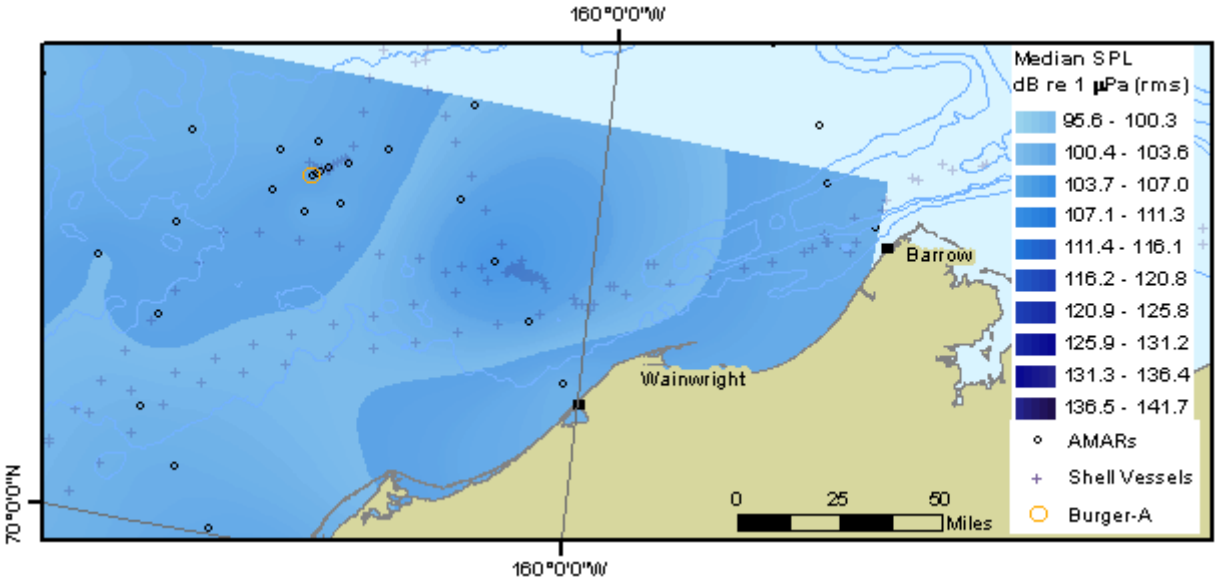


FIGURE 4.11. Soundscape for the Chukchi Sea from available AMAR data during a window of no activity at Burger, 14 August 23:08 to 18 August 11:02 (AKDT).

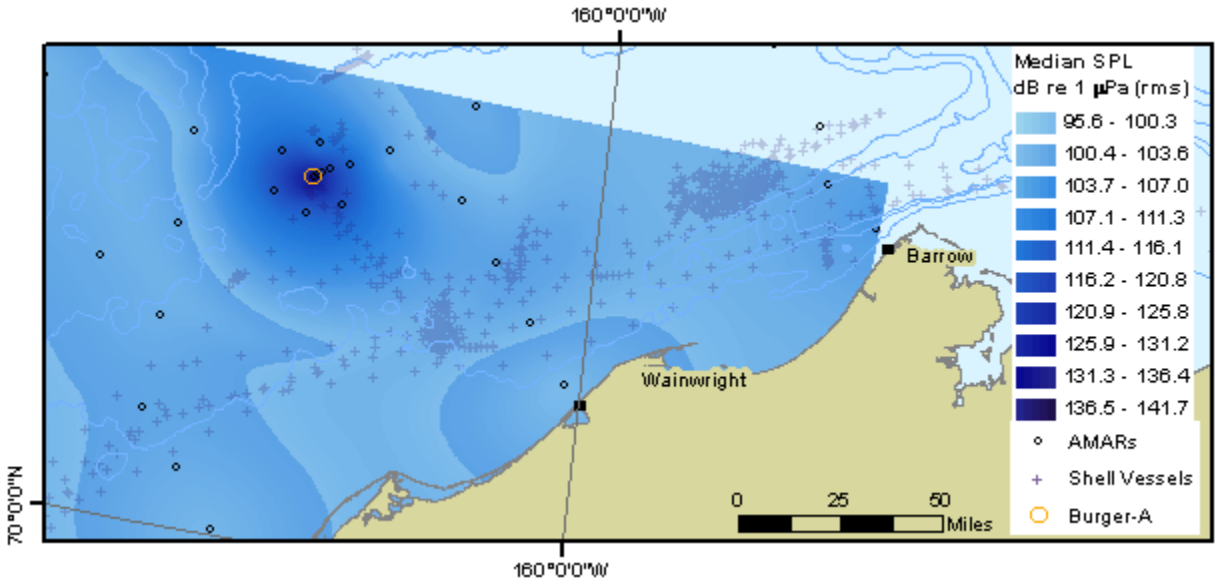


FIGURE 4.12. Soundscape for the Chukchi Sea from available AMAR data during anchor connection activities at Burger, 6 September 00:00 to 9 September 04:35 (AKDT).

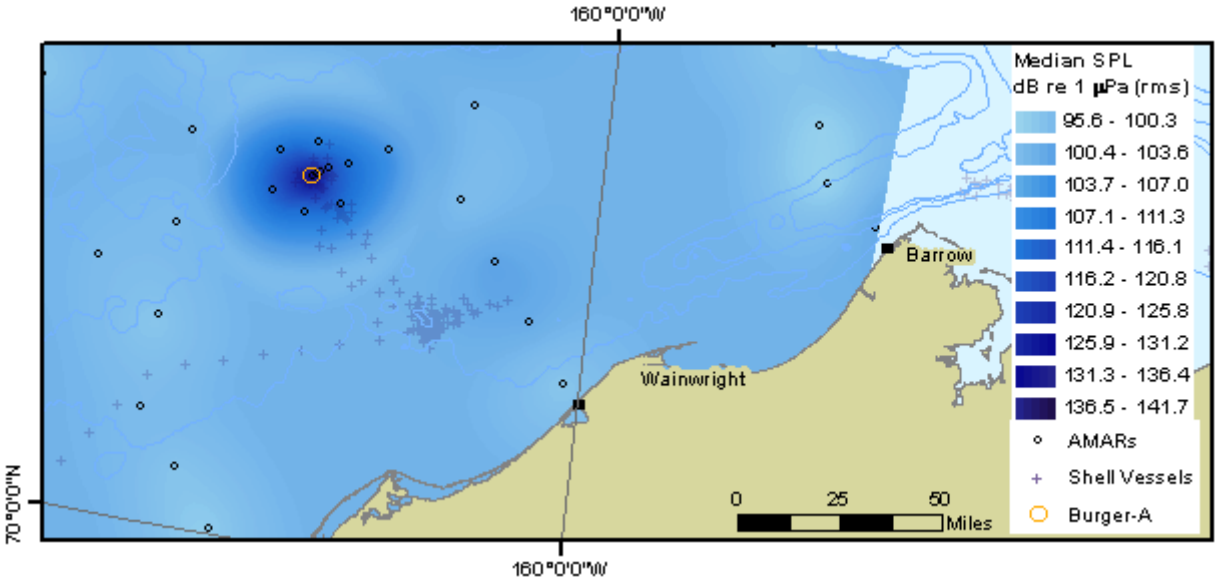


FIGURE 4.13. Soundscape for the Chukchi Sea from available AMAR data during a window of ice management activities at Burger, 11 September 16:54 to 14 September 12:21 (AKDT).

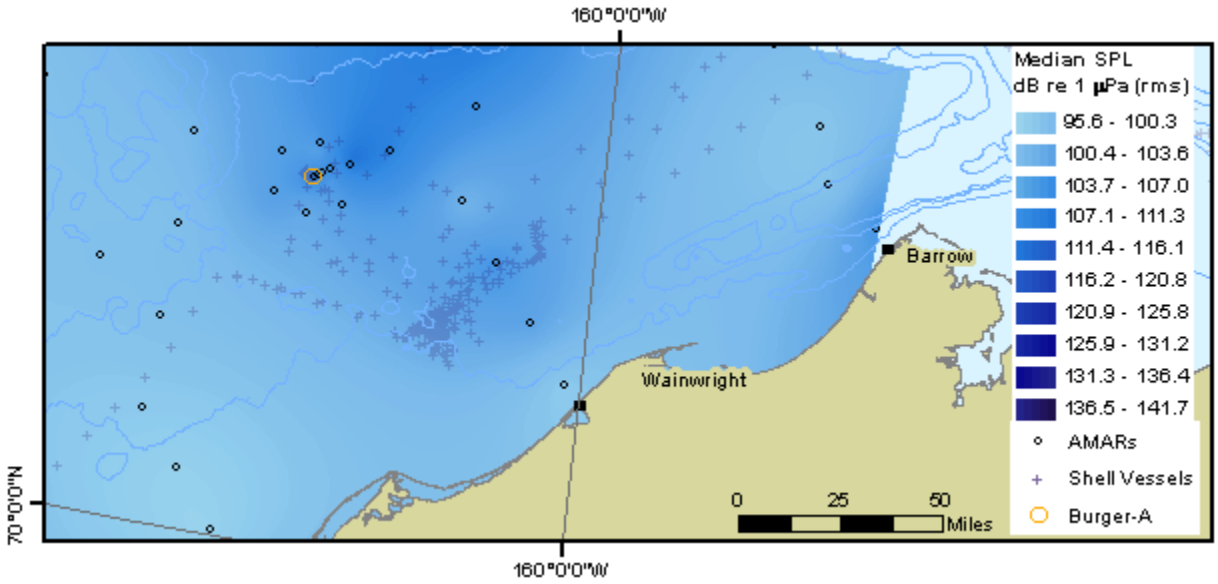


FIGURE 4.14. Soundscape for the Chukchi Sea from available AMAR data during a window while vessels were on DP near Burger but no drilling occurred, 14 September 12:21 to 19 September 15:09 (AKDT).

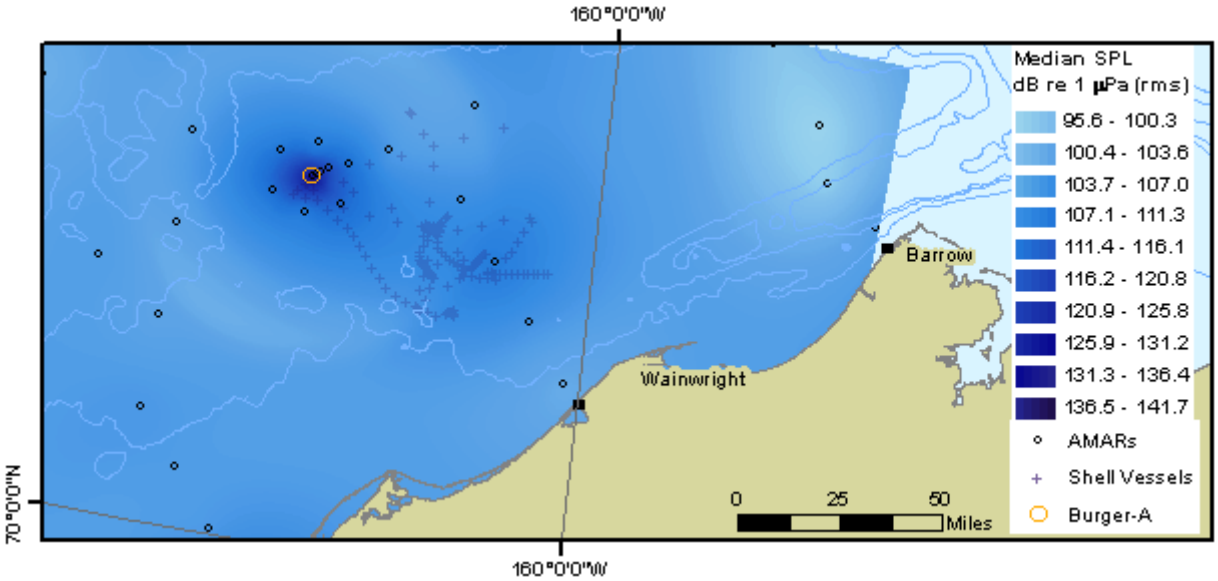


FIGURE 4.15. Soundscape for the Chukchi Sea from available AMAR data during pilot hole drilling at Burger, 23 September 02:59 to 26 September 00:00 (AKDT).

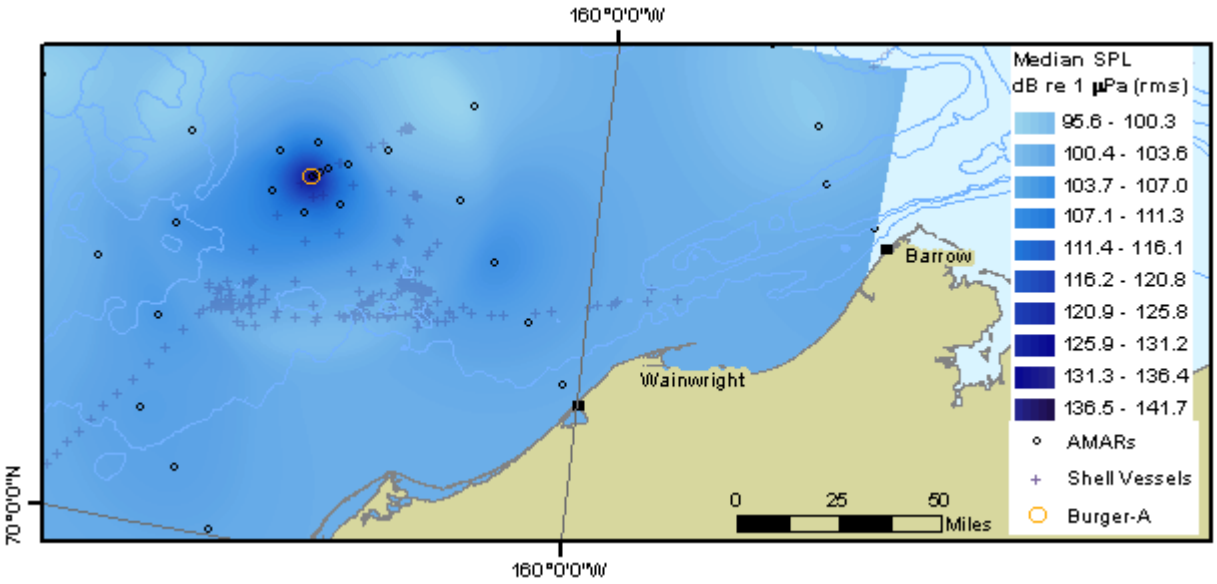


FIGURE 4.16. Soundscape for the Chukchi Sea from available AMAR data during mud-line cellar excavation at Burger, 2 October 04:00 to 5 October 16:00 (AKDT).

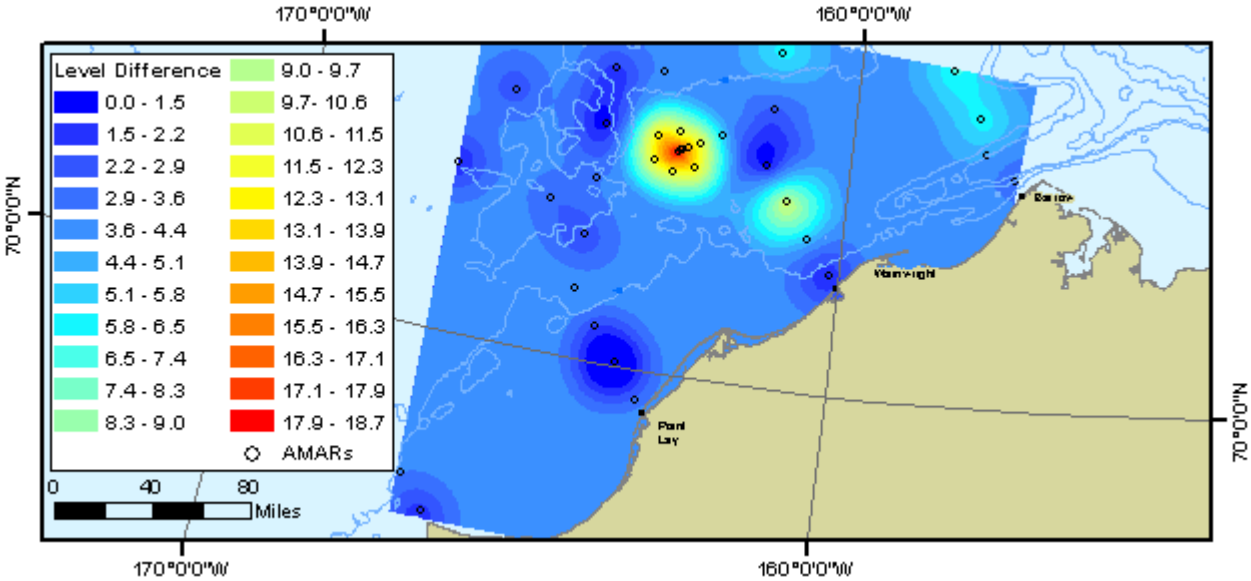


FIGURE 4.17. Difference between the median of vessel and ambient noise levels (Kriging-interpolated) throughout the Chukchi Sea, summer 2012.

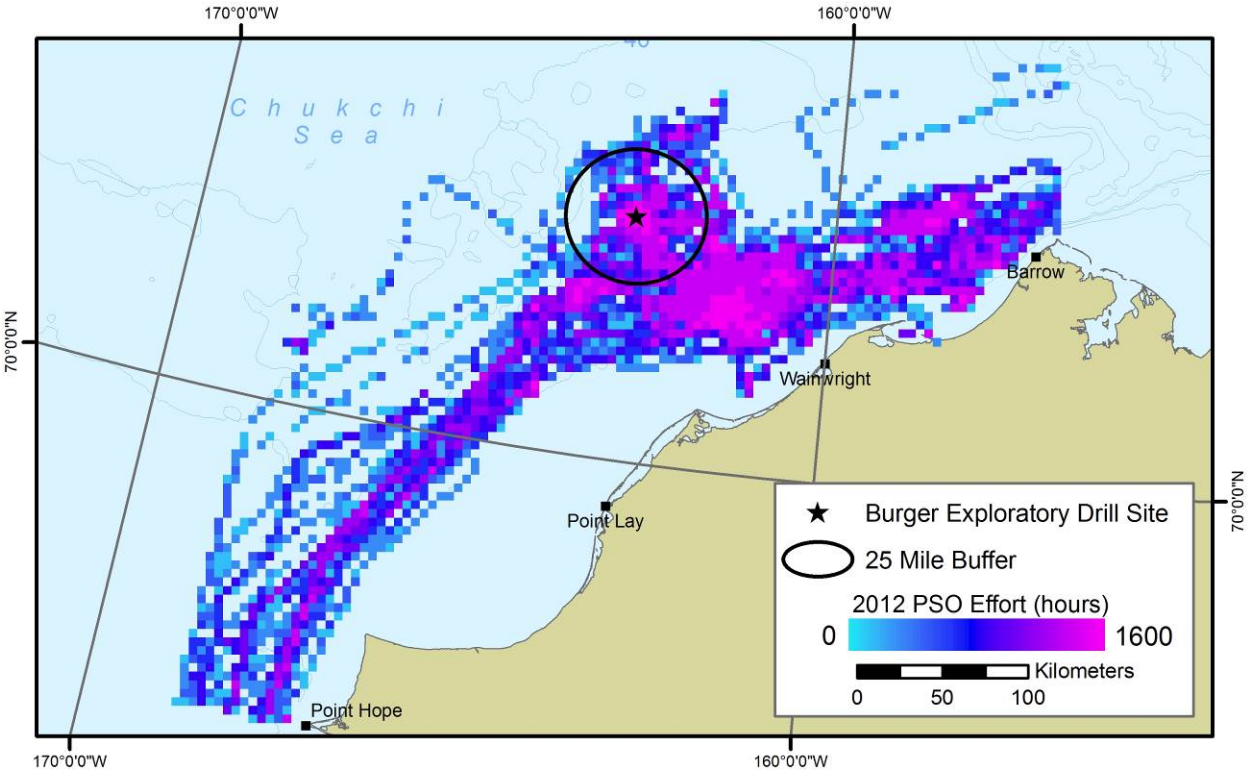


FIGURE 4.18. PSO effort hours in the Chukchi Sea during the Burger drilling program.

### *Beaufort Sea Activity Soundscapes*

Figures 4.19 to 4.23 are maps of the soundscapes for the chosen activity windows in the Beaufort Sea from Table 4.13. The soundscapes include symbols depicting locations of Shell vessels for each hour of the activity window shown. Acoustic hotspots with median SPLs exceeding 120 dB re 1 μPa are notably concentrated at Sivulliq during anchor setting (Fig. 4.19) and anchor connection (Fig. 4.21). Sound levels at Sivulliq did not obviously exceed those at surrounding DASAR locations during the drilling activity window from 3–8 October 2012 (Fig. 4.23). During this time the median sound levels at Sivulliq were comparable to those received at DASARs 25–30 km (16–19 mi) west of Sivulliq, with median SPLs within the range of variability of natural background noise (e.g., Fig. 4.20).

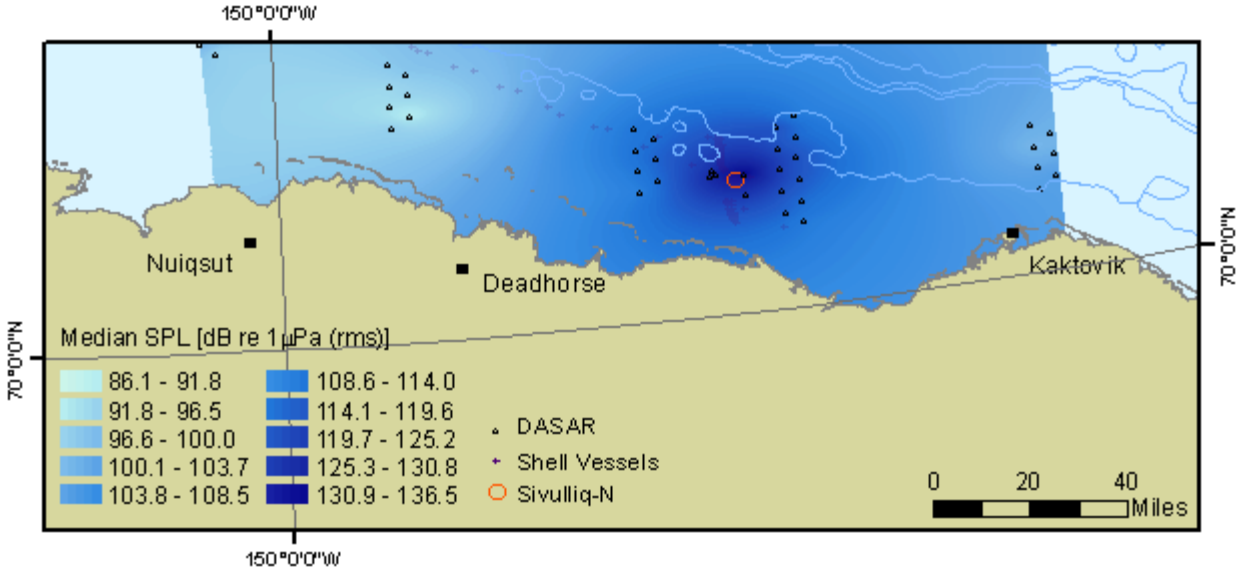


FIGURE 4.19. Soundscape for the Beaufort Sea from available DASAR data during a window of anchor setting activities at Sivulliq, 18 August 21:30 to 22 August 23:57 (AKDT).

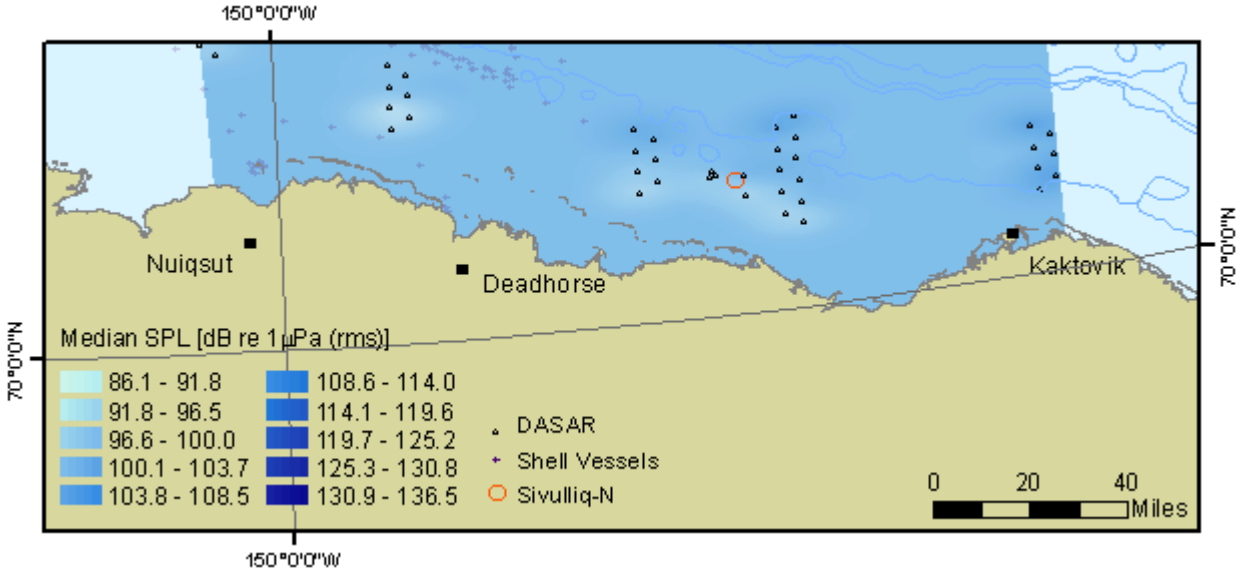


FIGURE 4.20. Soundscape for the Beaufort Sea from available DASAR data during a window of no activity at Sivulliq, 24 August 09:27 to 20 September 12:00 (AKDT).

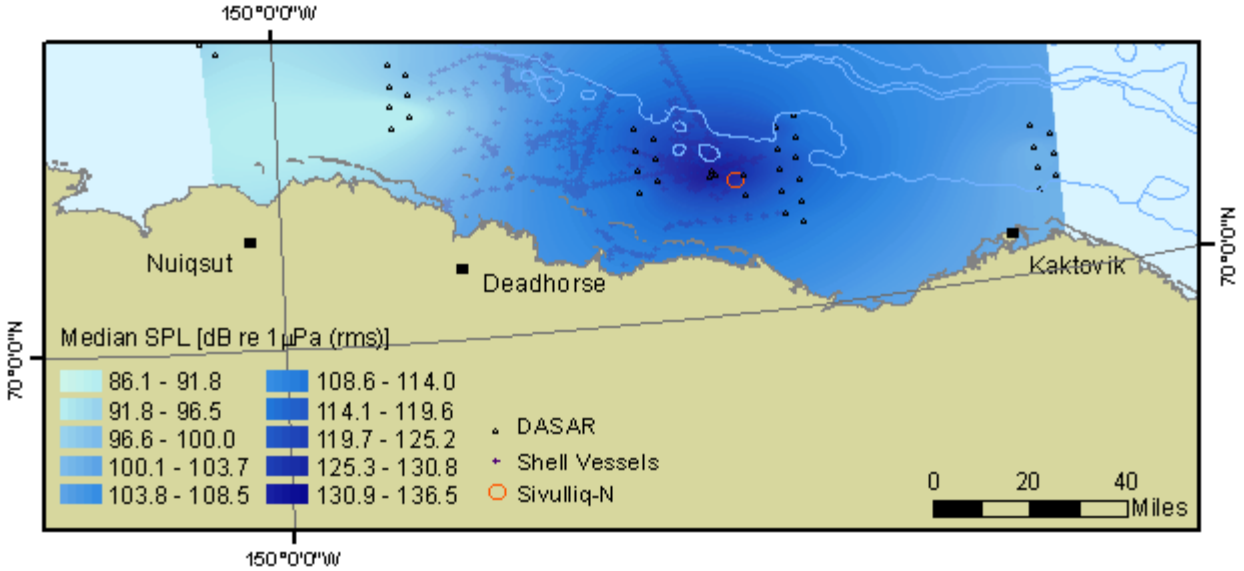


FIGURE 4.21. Soundscape for the Beaufort Sea from available DASAR data during a window of anchor connection activities at Sivulliq, 21 September 12:34 to 27 September 17:27 (AKDT).

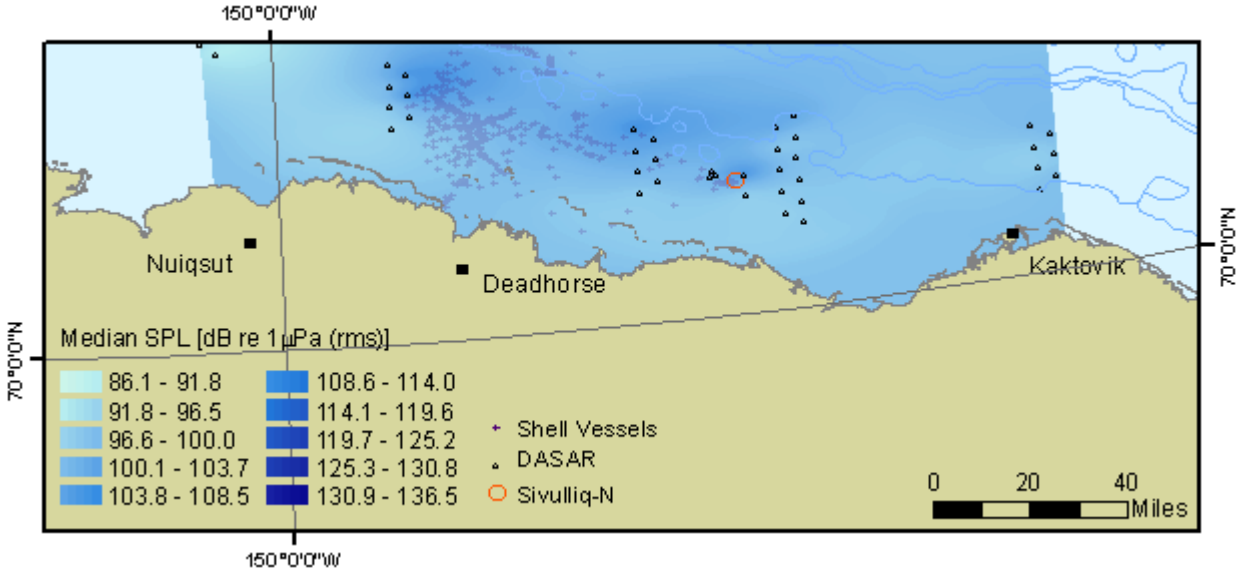


FIGURE 4.22. Soundscape for the Beaufort Sea from available DASAR data during a window while vessels were on DP near Sivulliq with no drilling occurring, 27 September 17:27 to 2 October 09:57 (AKDT).

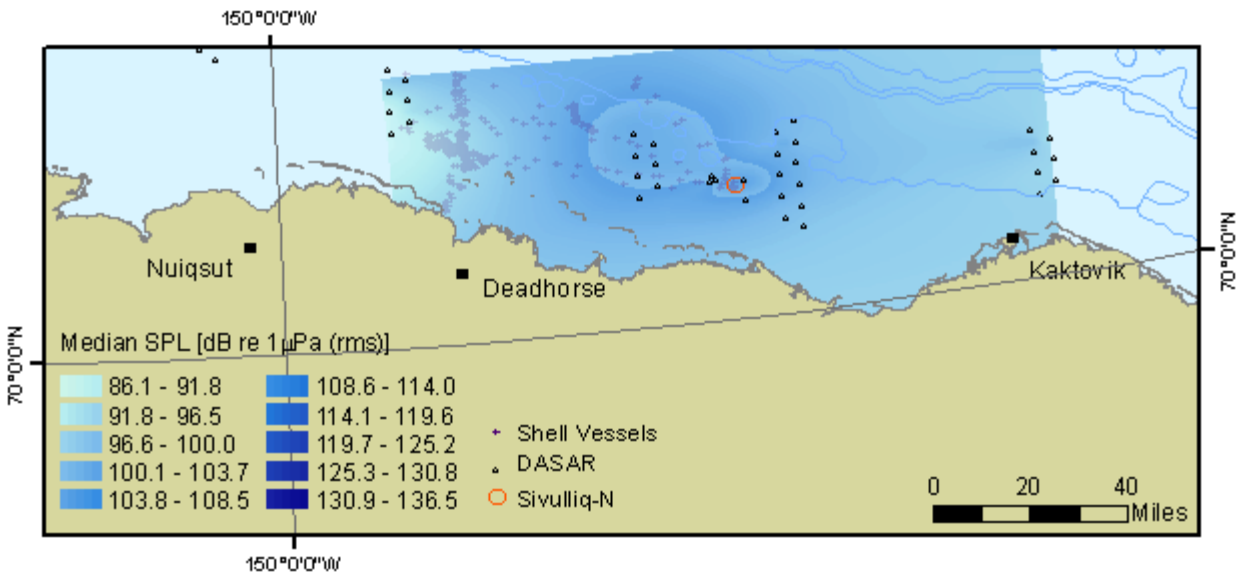


FIGURE 4.23. Soundscape for the Beaufort Sea from available DASAR data during a window of drilling activities at Sivulliq, 3 October 15:55 to 8 October 18:29 (AKDT).

The information in these soundscape maps can be combined with other information sources, such as visual sighting data, to attempt to identify marine mammal distribution patterns relative to noise footprints. Where possible, and meaningful, these maps are utilized in later chapters of this report looking at species-specific responses to industrial activities. Please see *Appendix E: Supplementary Results to Acoustic Monitoring of Oil and Gas Industry Noise Sources* for further methodology and results on sound source characterization of activities associated with drilling operations in 2012.

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# 5. MARINE MAMMAL SIGHTINGS BY ANALYSTS OF DIGITAL IMAGERY VS. AERIAL SURVEYORS

## *Introduction*

During past aerial surveys of marine mammals, people (PSOs or Protected Species Observers) have been considered superior sensors for collecting information on numbers and distribution of animals. PSOs have been able to monitor larger areas than other types of sensors and they are thought to be able to incorporate detection and identification cues for sightings that typically cannot be seen in imagery. Unmanned aerial systems (UAS) have been shown to be suitable platforms for monitoring animals in small study areas (Jones et al. 2006; Watts et al. 2010; Hodgson et al. 2011; Chabot and Bird 2012), but to date UAS have not been used during surveys of large study areas primarily because the area they could monitor has been small in comparison to PSOs (Koski et al. 2010). With the rapid improvement in sensors in recent years, UAS can now monitor areas of similar size to those monitored effectively by PSOs. Further, the resolution in the imagery has improved enough to document objects that PSOs cannot consistently see in real time. Although digital imagery does not incorporate cues such as movement into detection and identification, it nonetheless may provide opportunities to detect and identify animals that give results comparable to those of PSOs. This study was designed to directly test high-definition (HD) video and digital single lens reflex (DSLR) cameras as alternative methods of collecting data on distribution and numbers of cetaceans by comparing data from the digital images to those collected simultaneously by PSOs. If this imagery provides comparable or better data than do PSOs, these systems could be deployed in unmanned aerial systems (UAS) or manned aircraft without PSOs.

The specific objectives of this study were

1. To compare numbers and species of cetaceans within the same swath detected by PSOs with those obtained from HD video collected concurrently with the PSO observations,
2. To compare numbers and species of cetaceans within the same swath detected by PSOs with those obtained during a quick review of the DSLR imagery that simulated the view and timing a PSO would experience looking out the window of an airplane, and
3. To compare numbers and species of cetaceans within the same swath detected by PSOs with those detected during a detailed review of DSLR imagery collected concurrently with the PSO observations.

## *Results*

Aerial photographic surveys were conducted in northern Alaska in the Chukchi and Beaufort seas during summer and autumn of 2012 as part of the monitoring associated with drilling by Shell Offshore Inc (see *Aerial Survey Procedures*, Chapter 3). Sensor data collection and review are described in detail in the Appendix A.

### *Video Review vs. PSO*

The video was reviewed for eight surveys that covered 4483 km (2786 mi); this included 2790 km (1734 mi) flown at 305 m (1001 ft) ASL and 1693 km (1052 mi) flown at 457 m (1499 ft) ASL. PSOs recorded (during the survey) six cetacean sightings within the swath covered by the video, and four were detected during the video review (Fig. 5.1). PSOs saw 98 pinnipeds within the swath covered by the video and review of the video detected only 20 pinnipeds; this difference is highly significant ($\chi^2$

= 51.6, p <0.001). Ninety-three percent of PSO sightings and 95% of image reviewer sightings were during surveys conducted at 305 m ASL (Table 5.1). The sighting rates of pinnipeds during surveys at 305 m (1001 ft) were significantly higher than those at 457 m (1499 ft) both for PSOs ($\chi^2$ = 39.1, p <0.001) and image reviewers ($\chi^2$ = 9.1, p = 0.003). Although PSOs were able to identify slightly more than one third of the pinnipeds to species, none were identified to species during the review of the video (Fig. 5.2). Lastly, three polar bears were seen by PSOs within the video swath, and none were detected during review of the video.

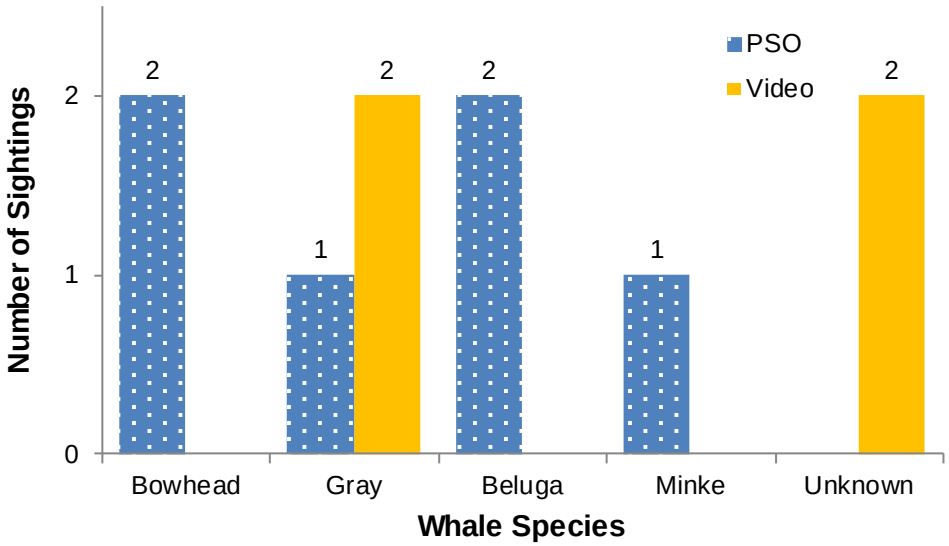


FIGURE 5.1. Cetacean sightings by PSOs and during review of the video.

TABLE 5.1. Effort and number of sightings of marine mammals during video, quick review, and detailed reviews of imagery collected by a Twin Otter flying at 305 m and 457 m (1001 ft and 1499 ft) above sea level.

| | Effort | Cetaceans | | | Pinnipeds[a] | | | Polar Bears | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (km) | PSO | Imagery | Total | PSO | Imagery | Total | PSO | Imagery | Total |
| Video 305 m | 2790 | 5 | 4 | 5 | 91 | 19 | ND | 3 | 0 | 3 |
| Video 457 m | 1693 | 1 | 0 | 1 | 7 | 1 | ND | 0 | 0 | 0 |
| Total video | 4483 | 6 | 4 | 6 | 98 | 20 | ND | 3 | 0 | 3 |
| Quick review 305 m | 4018 | 20 | 12 | 20 | 156 | 79 | ND | 6 | 0 | 6 |
| Quick review 457 m | 4445 | 17 | 13 | 17 | 54 | 39 | ND | 1 | 0 | 1 |
| Total quick review | 8463 | 37 | 25 | 37 | 210 | 118 | ND | 7 | 0 | 7 |
| Detailed review 305 m | 1964 | 17[b] | 19 | 20 | 97 | 105 | ND | 2[c] | 4 | 6 |
| Detailed review 457 m | 1163 | 8 | 7 | 8 | 10 | 33 | ND | 0 | 0 | 0 |
| Total detailed review | 3127 | 25[b] | 26 | 28 | 107 | 138 | ND | 2[c] | 4 | 6 |

[a] Pinniped sighting distances and times were not compared to determine which were likely the same animal.

[b] PSOs recorded one sighting that was not found in the imagery and either dove before it was photographed or its distance from the centerline was farther than estimated.

[c] A third sighting by the PSOs appears to have been a kill site identified by blood on the ice and the bear did not appear to be present.

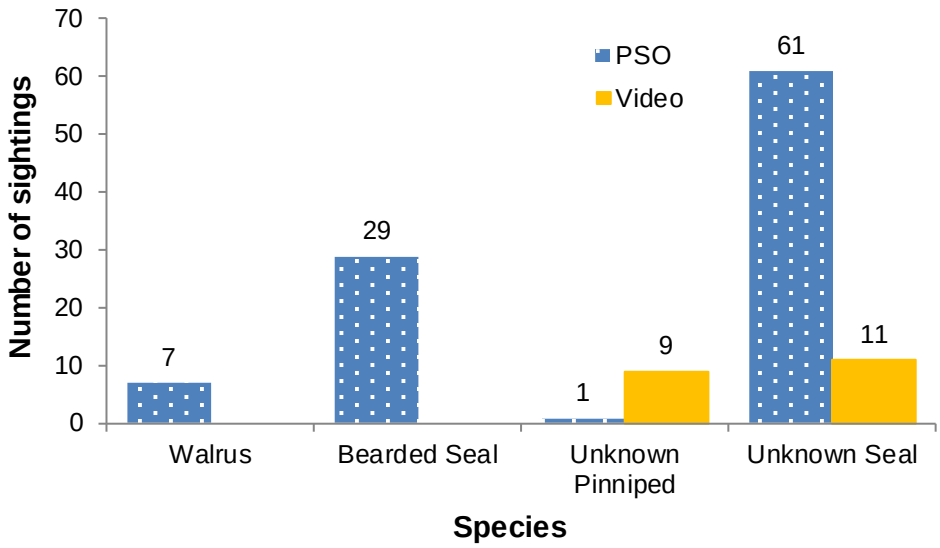


FIGURE 5.2. Pinniped sightings by PSOs and during review of the video.

### *Quick Review vs. PSO*

A quick review was conducted for 16 surveys that covered 8463 km (5259 mi) of transect and included 85,724 DSLR images. Slightly more than half (4445 km [2762 mi]) of the survey effort was conducted at 457 m (1499 ft). Four of these surveys were flown in the Chukchi Sea and 12 were flown in the central Beaufort Sea. Most survey effort was conducted during Beaufort wind force conditions 1–4 (Fig. 5.3), which is considered acceptable for conducting visual observations of large and medium-sized cetaceans from an aircraft (Forney et al. 1995; Heide-Jørgensen et al. 2010a). Sea conditions were slightly more favorable during surveys conducted at 305 m (1001 ft) ASL than during surveys at 457 m (1499 ft).

PSOs recorded 37 cetaceans within the area photographed by the DSLR cameras during the surveys examined and image reviewers saw 25 cetaceans (Fig. 5.4). The sighting rates for cetaceans were not significantly different between surveys at 305 m and 457 m (1001 ft and 1499 ft) for PSOs ($\chi^2 = 0.64$, $p = 0.42$) or for image reviewers ($\chi^2 = 0.003$, $p = 0.96$) and although PSOs saw more cetaceans than the image reviewers, the differences were not significant at either altitude (305 m [1001 ft], $\chi^2 = 2.00$, $p = 0.16$; 457 m, $\chi^2 = 0.53$, $p = 0.47$). PSOs and image reviewers were both able to identify almost all cetacean sightings to species, in contrast to reviewers of video who often could not. PSOs recorded 210 pinnipeds and identified about one third of them to species, whereas image reviewers detected significantly fewer pinnipeds (118, $\chi^2 = 25.8$, $p < 0.001$) and identified only four percent of them to species (Fig. 5.5). PSOs recorded seven polar bears but image reviewers did not record any polar bears.

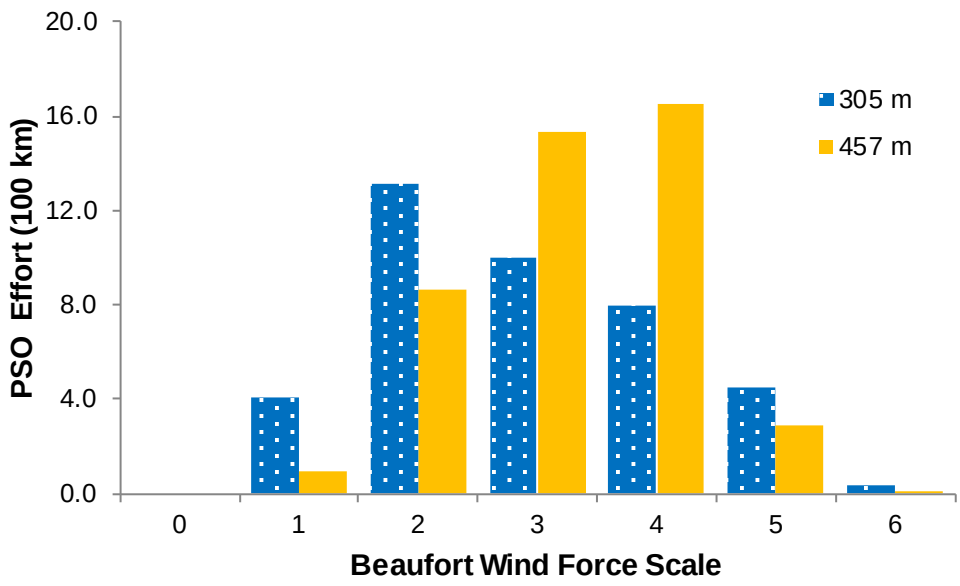


FIGURE 5.3. Sea conditions (Beaufort wind force scale) recorded by the protected species observers (PSOs) during 2-min survey segments included in the comparison between PSO sightings and the quick review of digital single reflex camera imagery.

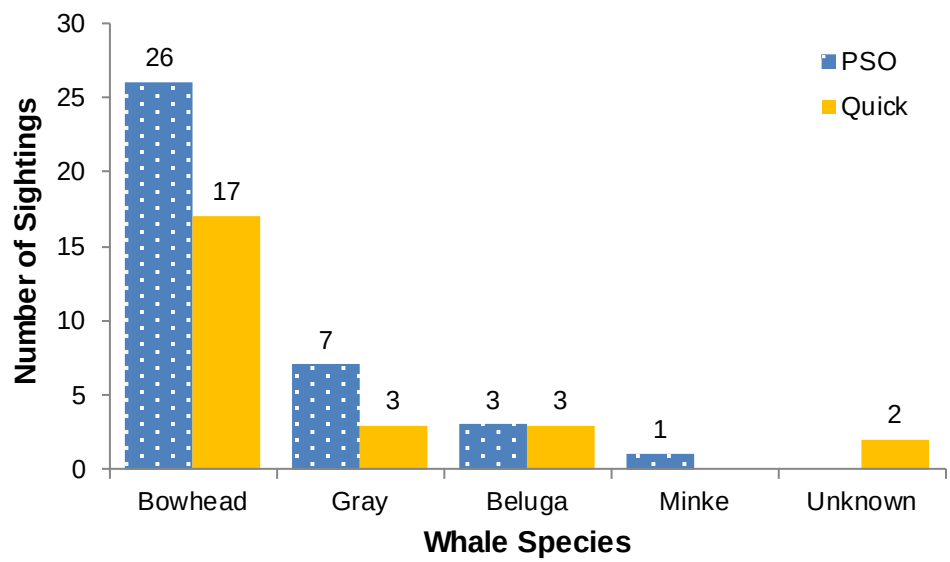


FIGURE 5.4. Cetacean sightings by PSOs and during the quick review of digital single reflex camera imagery.

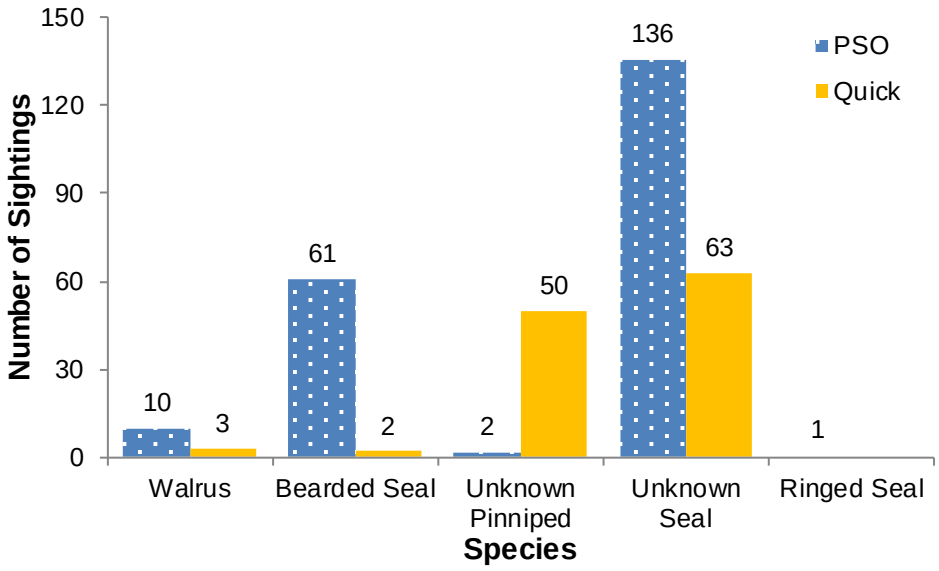


FIGURE 5.5. Pinniped sightings by PSOs and during the quick review of digital single reflex camera imagery. An unknown pinniped is most likely a walrus *Odobenus rosmarus* or bearded seal *Erignathus barbatus*.

### *Detailed Review vs. PSO*

Examples of imagery as seen during detailed review of the DSLR imagery are shown in Figure 5.6. The horizontal size of each image is cropped to 736 pixels or 1/10th of the horizontal dimension of the digital imagery to provide relative size in the imagery for each of the species shown. Each pair shows animals near the trackline and in the outer 1/3 of the image.

FIGURE 5.6. Examples of marine mammals in DSLR imagery from near the trackline (left) and about two thirds of the way between the trackline and outer edge of the frame (right). Shown are bowhead whales (top row), gray whales *Eschrichtius robustus* (second row), walrus (third row) and pinnipeds (bottom row).

### *Sightings and Species Identification*

The detailed review was conducted on six surveys that covered 3127 km (1943 mi) of transect and included 31,223 DSLR images. A total of 1964 km (1220 mi) were flown at 305 m (1001 ft) altitude and 1163 km (723 mi) at 457 m (1499 ft). Two of these surveys were conducted in the Chukchi Sea and the other four were in the Beaufort Sea. Sea conditions were more favorable during surveys at 305 m (1001 ft) altitude, but most effort at both altitudes was Beaufort wind force 0–4 (Fig. 5.7).

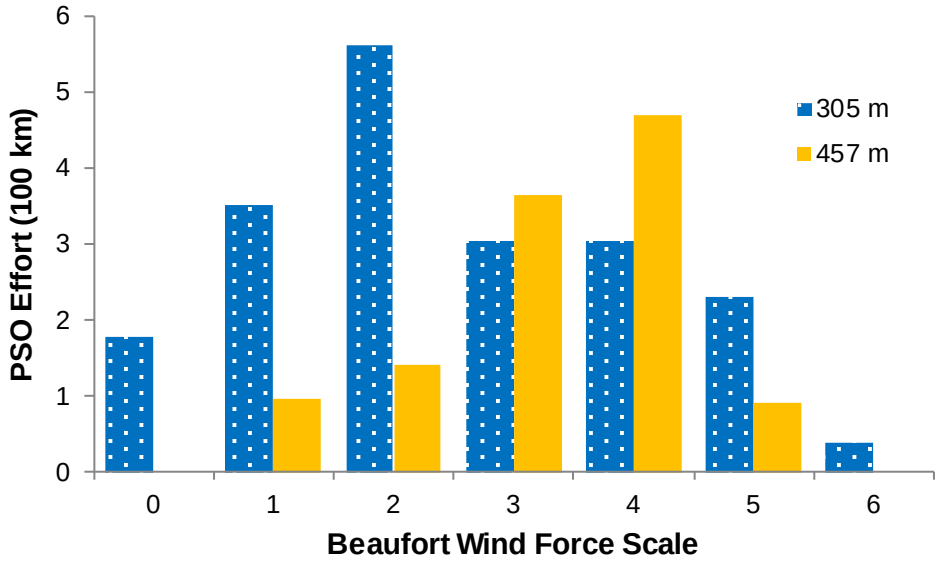


FIGURE 5.7. Sea conditions (Beaufort wind force scale) recorded by the protected species observers (PSOs) during 2-min survey segments included in the comparison between PSO sightings and the detailed review of digital single reflex camera imagery.

There were no significant differences among sighting rates of cetaceans by either PSOs or image reviewers for surveys conducted at 305 m versus 457 m (1001 ft versus 1499 ft; PSOs, $\chi^2 = 0.29$, $p = 0.59$; reviewers, $\chi^2 = 1.17$, $p = 0.28$; Table 5.1) or between PSOs and reviewers at each altitude (305 m [1001 ft], $\chi^2 = 0.11$, $p = 0.74$; 457, $\chi^2 = 0.07$, $p = 0.80$). PSOs and image reviewers both recorded 26 cetacean sightings (Fig. 5.8; Table 5.1) but two sightings by the PSOs were not found in the imagery; one sighting identified as two belugas by the PSOs was confirmed to be two bearded seals and the other sighting could not be found in the imagery. The animal may have been submerged when the photographs were taken, and so was not visible in the imagery, or the PSO's estimate of the animal's distance from the trackline may have been underestimated and it may actually have been outside of the area covered by the photographs. The two cetaceans recorded by the PSOs but missed by the image reviewers were confirmed to be present in the imagery during subsequent review of the imagery. Thus, the total number of cetaceans in the area covered by the imagery was at least 28; additional cetaceans may have been present that were missed by both the PSOs and image reviewers. PSOs identified slightly more of their sightings to species than did image reviewers, but they incorrectly identified a group of two bearded seals as belugas so not all of their species identifications were correct. There were no other discrepancies in cetacean identification between PSOs and image analysts.

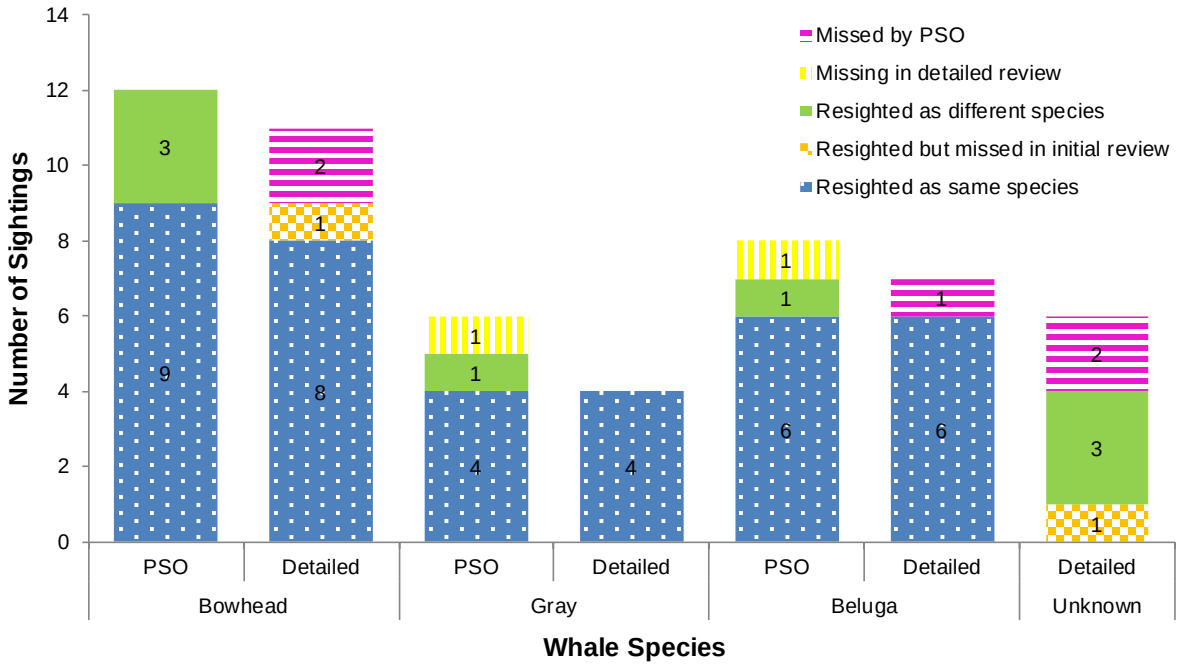


FIGURE 5.8. Cetacean sightings by PSOs and during the detailed review of digital single lens reflex camera imagery.

PSOs recorded significantly fewer pinnipeds (107) than image reviewers (138, $\chi^2$ = 3.92, $p$ = 0.047; Table 5.1; Fig. 5.9). Sighting rates were significantly higher for both PSOs ($\chi^2$ = 35.52, $p$ <0.001) and image reviewers ($\chi^2$ = 10.42, $p$ = 0.001) at altitude 305 m (1001 ft) ASL than at 457 m (1499 ft). At 305 m (1001 ft), sighting rates were not significantly different between PSOs and image reviewers ($\chi^2$ = 0.32, $p$ = 0.57), but at 457 m (1499 ft), sighting rates for image reviewers were significantly higher than PSOs ($\chi^2$ = 12.30, $p$ <0.001). Most pinnipeds recorded by both PSOs (95.3%) and image reviewers (90.6%) were seen in the water because the majority of the surveys were conducted during the open water period when little ice was present. The difference between the numbers of pinnipeds recorded hauled out on ice versus in the water by PSOs and image reviewers was not significantly different ($\chi^2$ = 2.00, $p$ = 0.16).

PSOs identified more of their sightings to species but it is unknown whether these additional identifications by PSOs were correct because the resolution of the imagery was not good enough to verify or refute the majority of identifications. PSOs identified almost half of the pinnipeds to species while reviewers were able to identify only a quarter of sightings to species. Neither PSOs nor image reviewers were able to identify small pinnipeds (Phoca seals) to species. No pinnipeds were found during the detailed review near the outer edges of the images and numbers of pinnipeds detected declined as the lateral distance from the trackline increased (Fig. 5.10), similar to what has been obtained for surveys conducted by PSOs (see Thomas et al. 2010; Heide-Jørgensen et al. 2010a, b; Hobbs and Waite 2010).

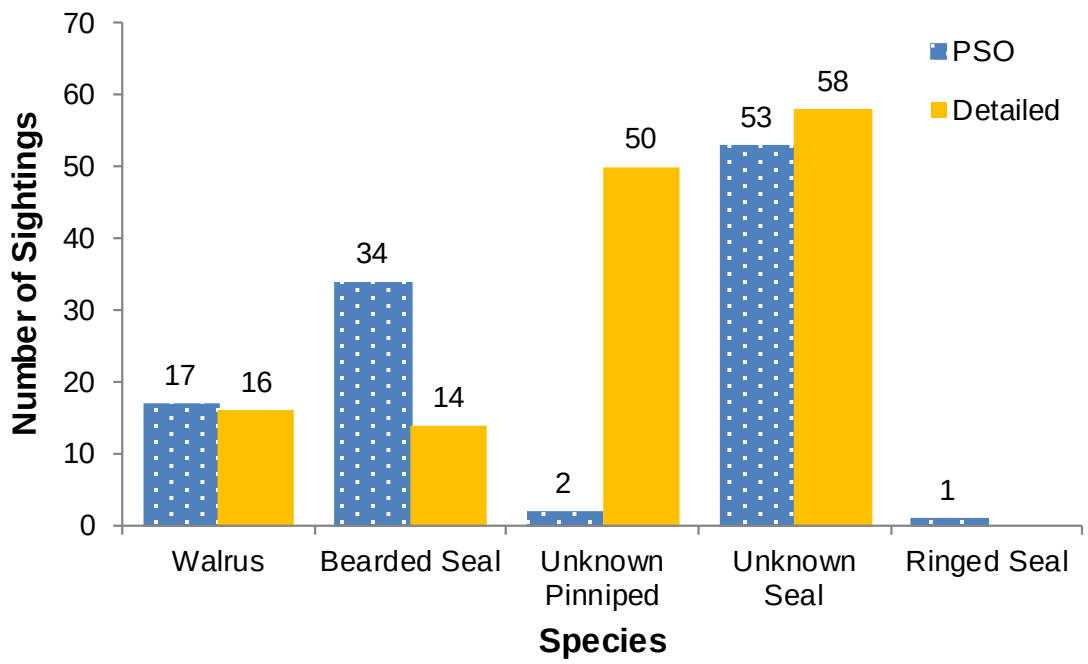


FIGURE 5.9. Pinniped sightings by PSOs and during the detailed review of DSLR imagery. Unknown pinnipeds are most likely walrus or bearded seals.

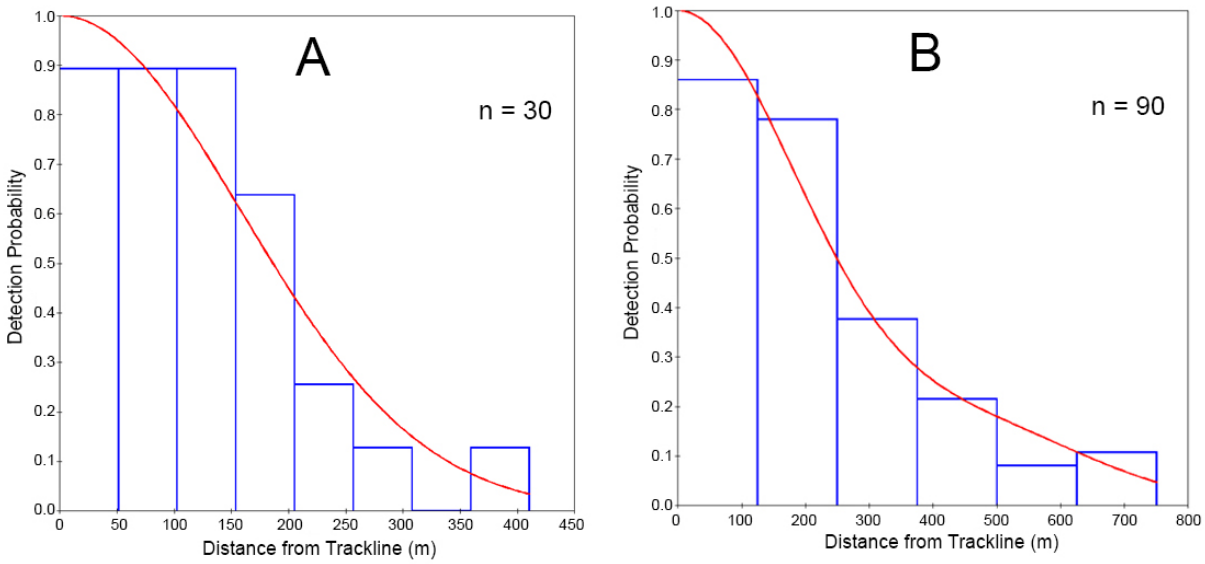


FIGURE 5.10. Probability detection functions for pinnipeds detected during detailed review of digital single reflex camera imagery covering (A) from the trackline to 670 m (2198 ft) and (B) from the trackline to 1000 m (3281 ft). A includes surveys flown at 305 m (1001 ft) with cameras pointed 25 degrees to the side and B includes surveys flown at 305 m (1001 ft) above sea level with cameras pointed 33 degrees to the side or 457 m (1499 ft) with cameras pointed 25 degrees to the side. Note, there were no detections toward the outer edge of the imagery because resolution was not good enough to distinguish pinnipeds from debris.

There were at least six polar bear sightings in the area covered by the DSLR imagery. Three polar bears were recorded by PSOs and two of these sightings were missed by the image reviewers. Two of the sightings missed by reviewers were confirmed to be present during subsequent review of the imagery. The other polar bear sighting by PSOs was not found in the imagery, but a blood spot visible on the ice suggested that the PSOs may have assumed a bear was present because of the presence of blood. On the other hand, four polar bears sightings were found during the detailed review that were missed by the PSOs. There may have been additional polar bears that were not detected.

### *Accuracy of Estimates of Distance from Trackline*

Estimates of the distances of sightings from the trackline by PSOs are rough estimates made with the aid of inclinometers which are not stable in a moving platform like an aircraft. The distance from the trackline in the digital imagery, however, can be measured directly with minor error related to whether the aircraft is level in the roll dimension. There was no significant difference between the measured distances and the PSO estimated distances (paired t test; $t = 0.69$, $p = 0.49$, df = 37) and there was a strong positive correlation between them ($r = 0.85$, $p = <0.001$, df = 36; Fig. 5.11). The slope of the regression was 0.99 indicating that the PSO estimates, while not precise, were unbiased; that is, on average they did not tend to over- or under-estimate the true distance.

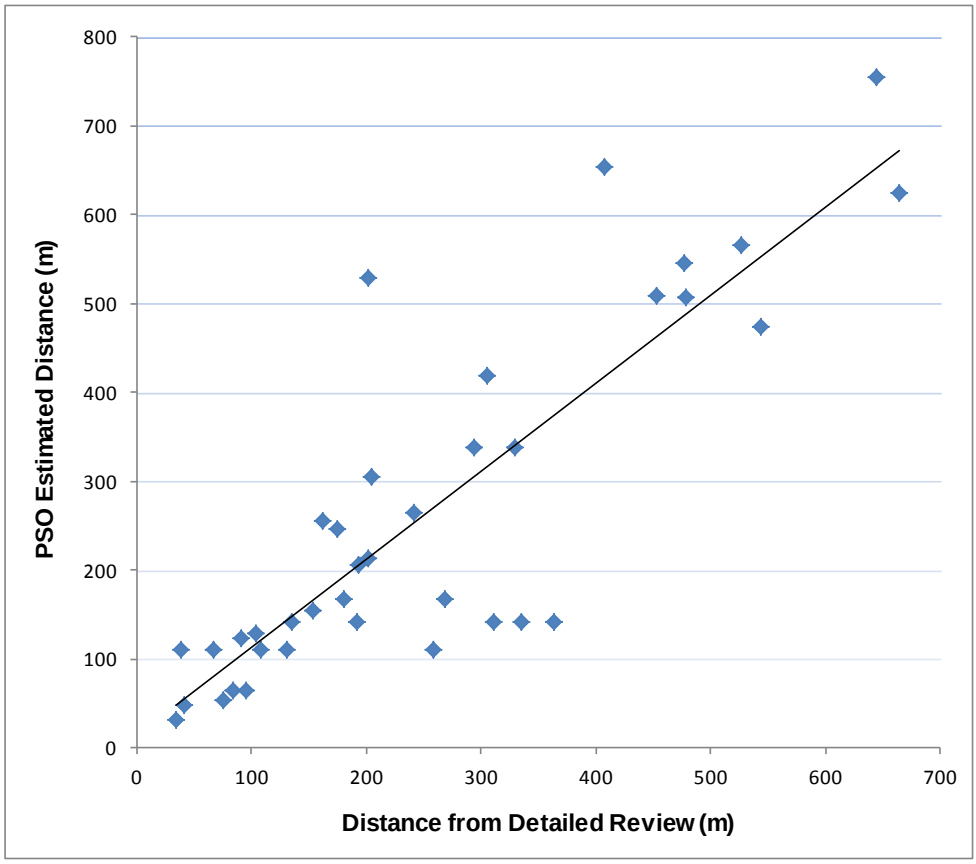


FIGURE 5.11. Comparison of cetacean, pinniped, and polar bear distances from the trackline estimated by PSOs versus the actual distances measured from the digital single lens reflex camera imagery.

## *Discussion*

### *Video vs. PSO*

Reviewers of imagery did not detect as many marine mammals in the video imagery as PSOs detected in real time within the same swath during manned aerial surveys and they were not able to identify as many of the sightings to species. The sample sizes for this evaluation, however, were very small and require confirmation by additional studies. This study tentatively concludes that current HD video is not a suitable option to replace human observers in manned aircraft for conducting aerial surveys because the search area is narrower and detection and identification rates appear to be lower. The next generation of higher-definition video may correct these shortcomings. The resolution of the HD video that was tested was one pixel per 31 × 31 cm (12 × 12 in) square on the water. The video was fixed to record a 600 m (1969 ft) swath along the aircraft trackline and did not scan back and forth as during earlier studies by Koski et al. (2009). While HD video with higher surface resolution, and hence covering a narrower swath, may provide imagery that could be used to detect and identify the species of interest during this study, the swath covered by two video cameras would be too narrow to collect sufficient data to be a replacement for PSOs. A fixed video camera was used here because coverage using scanning video is not uniform across the scan area and the area being scanned is in view only for a brief time, making sighting and identification of animals difficult (Buck et al. 2007). The purpose of testing HD video was to determine whether animal movement while in the video field of view, the ability to view sightings from different angles, and other sighting cues used to detect and identify large marine mammals that are available in the video but are not available in still images could compensate for lower resolution in video when compared to still imagery. Our tests suggest that these potential advantages of video imagery, at least at the resolution that was tested, did not compensate for the higher resolution of DSLR imagery. These tests, however, are based on a relatively small sample size of animals identified from either platform and require additional study.

### *Quick Review*

There is sometimes a need to obtain near-real time information on animals detected during surveys for regulatory purposes associated with many industrial activities. Image reviewers were not able to detect as many cetaceans or pinnipeds during the quick review as PSOs did during the surveys. Several factors contributed to the poorer performance during the quick review. The first is related to the resolution of the computer monitors. The best resolution available in off-the-shelf monitors was 2560 × 1600 pixels, whereas the camera resolution was 7360 × 4912. Thus the reviewers examined imagery at only 1/9th of the available resolution. Second, the images were reviewed with approximately the same time in view as PSOs have during aerial surveys, but the lack of motion in the imagery, an important sighting cue, made it more difficult to locate and identify marine mammals. Third, PSOs search ahead of the aircraft for marine mammals, and so have sightings in view for a longer period of time allowing them to more accurately identify or reject sightings. Also, the extended view available to PSOs provides greater likelihood of detecting animals that surface or dive as the aircraft is passing. If quick reviews are required during future studies, we recommend that higher resolution monitors be used, the length of time that each image is viewed should be increased, and the slide show should be stopped whenever a sighting is made to better identify the number and species of animal sighted. This procedure would increase the number of sightings and allow better identification and collection of more detailed supplementary information for each sighting while still providing relatively fast turnaround for the survey results.

### *Detailed Review*

The results of the detailed review suggest that there were no major differences between the numbers of cetaceans and polar bears sighted by PSOs during surveys as compared with image reviewers during a single review of high-resolution digital imagery. PSOs did, however, identify slightly more sightings to species and missed slightly more sightings of small animals than reviewers. PSOs misidentified at least one putative whale sighting, which could be clearly identified during the detailed review as two bearded seals. The ability to review sightings within imagery to confirm species identification, group size, and activity is a benefit not available with real-time PSO sightings. This analysis suggests that high-definition digital imagery provides similar data to PSOs for monitoring distribution and abundance of large cetaceans within a common swath, but the sample sizes were small and additional studies are recommended to confirm these results. PSOs recorded 11 cetacean sightings beyond the area being monitored by the cameras. In some situations, such as monitoring for mitigation, the higher number of sightings obtainable by PSOs scanning a larger swath is beneficial. However, when estimating densities of animals in an area, digital imagery has the potential to minimize or better account for detection biases. The images can be examined more than once to quantify biases and to provide more precise estimates of abundance (see Ferguson and Angliss 2010).

The detailed review of the DSLR imagery found slightly more pinniped sightings than detected by PSOs, but a lower proportion were identified to species during the imagery review. Rapidly diminishing numbers of pinnipeds were detected as lateral distance (Fig. 5.10) and altitude increased, indicating that the resolution of the oblique and higher altitude imagery was too poor to detect most pinnipeds (probably small pinnipeds or phocid seals, Phoca sp.) beyond a few hundred meters from the centerline or above altitudes of ~305 m (1001 ft). This is similar to the fall-off in sighting rates for PSOs during open-water pinniped surveys (Harwood and Stirling 1992). Future surveys for pinnipeds should monitor narrower swaths with higher resolution imagery (i.e., using longer lenses) on one set of cameras to better evaluate use of the DSLR imagery for surveying pinnipeds while maintaining similar resolution as used here for detection of large cetaceans.

### *Other Considerations*

The above analyses of samples of the 2012 photographic data show that post-survey detailed analysis of high-resolution still imagery was able to detect and identify large cetaceans as accurately as PSOs could in real time, at least in some situations. The analyses of the digital images are ongoing and labor intensive and there were too few sightings in the current dataset to quantify the effect of sea conditions and distance from the trackline on sighting numbers and species identifications. Additional analyses of more images are needed to determine whether photographic versus PSO detections are similar across varying survey conditions.

Manned aerial surveys optimized for cetaceans are conducted at altitudes that do not permit reliable identification and counting of pinnipeds. Our camera systems were optimized to collect data on large cetaceans and slightly more pinnipeds were present in the digital images than were seen by PSOs. However, many additional small objects were identified during the detailed review of images that may have been pinnipeds, birds or other objects such as pieces of wood or debris. These were excluded from analysis but many may have been pinnipeds. Higher resolution imagery may permit identification of these sightings and use of cameras with different lenses would permit concurrent collection of quantitative data on both cetaceans and pinnipeds. Reliable pinniped data cannot be obtained by PSOs during open-water periods because of altitude restrictions that prevent flying low enough to see and identify many of them.

The current analysis includes only periods when sightings were infrequent. We have started analysis of a survey conducted in an area with high concentrations of animals. In such situations, or with large groups of animals, the digital imagery provides much better information than PSOs. When large numbers of animals are encountered, PSOs miss sightings and often do not get an accurate count of the animals present; in addition, many studies have shown that ground and aerial observers tend to underestimate the size of large groups (Norton-Griffiths 1974; Mathews 1995; Lowry 1999; Scott et al. 1985; Stewart et al. 2013).

In many situations the DSLR cameras tested during this study could provide as much or more (and often better) information on the distribution, movements, and densities of marine mammals in a large area than manned aerial surveys. The major negative to the DSLR imagery over PSO data collection is the large amount of analysis time required to obtain maximum information from the imagery. While quick reviews of the imagery may provide data similar to those from PSOs if the procedures used here were modified as suggested above, the more precise information available in the imagery can only be obtained in near-real time if analysis software is developed to assist in the detection and recognition of marine mammals. Good programs exist to detect and recognize objects in terrestrial systems where the background is stationary and object shapes are relatively constant (see Bajzak and Piatt 1990; Abd-Elrahman et al. 2005); however, these systems do not work well when animals are present in natural settings where they blend in with the background (Wichmann et al. 2010) or in offshore areas. In offshore areas, the background clutter (waves) and widely varying amount of an object clearly visible in the imagery (because waves often obscure part of an animal) provide additional challenges to software development. Development and validation of software to detect and identify marine mammals in imagery from offshore areas is urgently needed.

One final benefit of the current study, and similar future studies comparing PSO and imagery data, is that corrections can be developed to account for animals missed by one or both systems using double independent observer methods as described by Manley et al. (1996) and Borchers et al. (2006). In particular, poor overlap in sightings of polar bears by PSOs and imagery analysts indicates that neither detected most of the bears present and the double independent observer analysis could be used to estimate the actual number of bears that were present with larger sample sizes. Even without PSO data, the imagery provides an opportunity for repeated analysis of the same survey to quantify detection rates for each of the marine mammal species or species groups present in the imagery.

### *Potential for UAS to Replace Manned Surveys*

The results of this study suggest that two DSLR cameras pointed obliquely to either side of the trackline in an UAS or fixed wing aircraft can collect imagery that is good enough to detect and identify cetacean sightings to monitor distribution and density in large study areas. These types of surveys have traditionally been conducted by people flying in aircraft. UAS would fly slower than the Twin Otter used during this study, so UAS would not cover as large an area in a given period of time as a manned aircraft. However, some UAS can fly for much longer than manned aircraft without refueling. This would enable UAS to cover the same area, or in some cases a larger area, on any given day. Rotating pilots to extend flight duration is simplified with UAS because aircraft control can be passed from one pilot to another without returning to base and landing. Thus there are no pilot restrictions on individual flights or on total daily flight duration for UAS as there are for manned aerial surveys, which are often limited by pilot flight time and pilot duty day. Also, multiple UAS can be flown in the same area without risk to human life, enabling more complete coverage while weather conditions are favorable to fly.

Another major advantage is that UAS are much smaller and quieter than manned aircraft used for current surveys. The potential for disturbance of the species being studied is avoided, or at least greatly reduced, with use of UAS. Surveys for cetaceans are typically required to be conducted at altitudes of 152 to 457 m (499 to 1499 ft) or higher to avoid disturbance to the species being studied, to other sensitive species in the survey area, or to animals that are being hunted by subsistence users. Because UAS are less likely to disturb wildlife, low-altitude UAS surveys could be flown when cloud ceilings are lower than minimum altitudes required for manned surveys. Higher resolution imagery could be collected by flying lower, or by using longer lenses. This would improve detection and identification, but the tradeoff would be coverage of a narrower strip width. One additional benefit of UAS over manned aircraft is their greatly reduced fuel consumption and smaller environmental footprint. A Twin Otter uses 65 gallons per hour at survey speed whereas a small long-endurance UAS such as the Boeing Insitu ScanEagle® or Brican TD100 can fly for approximately 12 hours on one gallon of fuel.

A major impetus for this study was the desire to reduce the risk to people conducting marine mammal and bird surveys in offshore waters where accidents have led to loss of human life. The sensor packages tested here were selected because they were small enough to install in UAS and were not the highest quality sensors available. Despite the size and weight limitations for sensors that can be used in small to medium UAS, this study suggests that some of these sensors have potential to be used in UAS to replace manned aerial surveys without risk to human life.

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# 6. BOWHEAD WHALE MONITORING RESULTS

## *Introduction*

The Bering-Chukchi-Beaufort Seas (BCB) population of bowhead whales is arguably the principle marine mammal stock of concern with respect to offshore oil and gas activities in the Alaskan Arctic. This population of bowhead whales has been hunted by indigenous whalers in the region for approximately two thousand years (e.g., Marquette and Bockstoce 1980) and remains an integral component of Alaskan Eskimo subsistence culture to this day. Despite a remarkable observed recovery in abundance following commercial over-exploitation during the 19th century (e.g., Brandon and Wade 2006; George et al. 2004a; Givens et al. 2013), BCB bowhead whales remain listed as endangered under the United States Federal Endangered Species Act (Shelden et al. 2001; Taylor 2003; Shelden et al. 2003).

A potential concern about offshore oil and gas activities is that they could affect the native subsistence hunts by changing bowhead whale distribution or behavior, such that availability of the whales to the hunters is decreased. One of the goals of industry monitoring efforts since 2006 has thus been to provide answers to this concern. Therefore, this chapter presents a synthesis of past and present analyses for monitoring interactions between offshore industry activities and bowhead whale distribution and behavior.

Disturbances to distribution and behavior could, if severe enough, ultimately lead to population level effects (e.g., National Research Council 2005). Hence, potential population level responses to anthropogenic disturbance are also considered in this chapter. The review of this information is timely given the recently updated time series of abundance estimates from independent spring ice-based surveys (Givens et al. 2013).

## *Objectives*

The goals of this chapter are:

- Document the extent, duration, and location of any changes in bowhead whale distribution and behavior in response to Shell's offshore activities;
- Present integrative studies of the data collections funded by Shell and other industry parties, that have not been presented in previous regulatory reports;
- Provide a unified investigation, with respect to Shell's drilling activities, of the three data sets (aerial, acoustic, and vessel) collected during 2012 in the Alaskan Beaufort and Chukchi Seas, and;
- Review information relevant to potential population level responses to anthropogenic disturbance.

The emphasis of this chapter is primarily on the various recent industry-sponsored data collections around Shell's offshore exploration activities, and throughout the reader may encounter phrases such as, 'the data'. That generalization by default implies a data set collected as part of the monitoring studies focused on offshore activities primarily by Shell, but also ConocoPhillips, Statoil and ION (i.e., Funk et al. 2007; Ireland et al. 2009; Funk et al. 2010; Funk et al. 2011a; Funk et al. 2011b; Bisson et al. 2013; Beland et al. 2013). We recognize, however, that any comprehensive investigation cannot be based on one related family of data alone. Therefore ongoing independent studies are also considered, notably satellite tagging (e.g., Quakenbush et al. 2012), federal agency aerial surveys (e.g., Clarke et al. 2013),

industry joint studies (e.g., Aerts et al. 2012; McDonald et al. 2012), reports on subsistence hunts (e.g., Galginaitis 2013; Suydam et al. 2013), and documented traditional knowledge (Noongwook et al. 2007; Huntington and Quakenbush 2009; Quakenbush and Huntington 2010). These studies provide valuable information for understanding bowhead whale distribution and behavior.

This chapter begins with an examination of observations pertaining to the possibility of large-scale spatial shifts in distribution during recent years in the Alaskan Beaufort and Chukchi Seas. That section also provides some background on the strengths and limits of inference based on acoustic call detection data. The theme of inference from acoustic data is expanded in the second section, which covers acoustic behavior of bowhead whales in relation to seismic sound. This has been a topic of study that has proven to be particularly informative during the course of these monitoring efforts.

Under the topic of acoustic behavior, a time series of all detected seismic pulses (including many of unknown origin) in the Beaufort Sea acoustic data is then presented. The results of this investigation show that although all the monitoring attention in 2012 was focused on Shell's drilling activities, the number of airgun pulses detected at the DASAR[1] array in 2012 exceeded each of the previous monitoring years (2007–2011). Compared to three of these years (2007, 2009, and 2011), the number of airgun pulses detected in 2012 had more than doubled.

The third section deals with the topic of deflection around sounds from airguns and smaller scale observations of distribution and behavior based on visual observations. This section also includes a discussion of the effects of ice coverage on bowhead distribution.

In the fourth section, the 2012 aerial, vessel, and acoustic data are presented with maps overlaying bowhead detections (visual and acoustic) and vessel tracks during various periods of Shell's offshore activities that season. These maps are one-step toward better understanding the relationships between offshore vessel activities and observed patterns in bowhead whale distribution and behavior.

Finally, the chapter concludes with consideration of potential population level effects and reviews the status of the BCB bowhead whale population as measured by trends in abundance.

## *Observations of Large-Scale Patterns of Distribution*

### *Alaskan Beaufort Sea: Large-Scale Patterns*

The most spatially and temporally complete industry-sponsored time series of data on bowhead distribution during recent years is the acoustic dataset in the Alaskan Beaufort Sea. These data have been collected annually since 2007 and provide estimates of bowhead call locations. Federal agency aerial surveys (e.g., BWASP[2]) started collecting systematic data in 1982, hence those data are also of note here; the federal agency aerial sightings data have proven useful in the design of the industry-sponsored acoustic study area, and, as illustrated below, they continue to provide a baseline for comparison over large scales.

Information obtained from the DASAR arrays (see Chapter 3 for deployment locations) is particularly useful for monitoring potential large-scale shifts in bowhead distribution. There are three main reasons for this. First, the arrays are spread over a wide area, ~280 km (174 mi), between Harrison Bay and Barter Island. Second, the arrays have continuous 24-hr sampling during deployment. Third, the fairly well defined migration corridor in the Beaufort Sea (Moore and Reeves 1993; Quakenbush et al. 2012) is suitable for detecting potential (latitudinal) shifts in calling bowhead locations in response to

[1] Directional Autonomous Seafloor Acoustic Recorder
[2] Bowhead Whale Aerial Survey Project

offshore activities. In the Chukchi Sea, migrating bowheads fan out over a wide area west of Barrow, making it difficult to predict what route animals will take or what constitutes a "normal" migration path.

There are, however, limitations to inference from acoustic data in general, and certain complications regarding interpreting call location estimates from the DASARs in particular. The main three limitations are explained below. First, the detectability of a sound on a recorder is affected by ambient sound levels, which are strongly correlated with wind speed. Therefore, statistical analyses have been limited in range, to areas within which detectability does not vary as a function of weather or other sound-producing activities. Second, the accuracy of whale localizations (obtained by triangulation, see Greene et al. 2004) decreases with distance from the recorders. Distant localizations therefore have lower positional accuracy in addition to a lower probability of detection (see McDonald et al. 2012). Third, only calling animals are detectable. If an animal stops calling, for whatever reason, then that animal no longer exists from the perspective of a passive acoustic recorder. Several recent studies have shown effects of industrial sounds on calling behavior (e.g., Di Iorio and Clark 2010; Risch et al. 2012; Blackwell et al. 2013). This means that acoustic data alone cannot address deflection if bowhead whales stop vocalizing before changing course. Hence, independent visual observations (e.g., aerial surveys) have been incorporated in monitoring programs and are also useful in verifying patterns in estimated call detection locations that are distant from the arrays.

Figure 6.1 shows maps of all localized calls in each year starting in 2007. These "satellite viewpoints" of the call distributions are only useful for detecting broad, qualitative changes in the distribution of calling whales. The paucity of calls much beyond the northern limit of the arrays is mostly due to the fact that calling whales tend to migrate within the bounds of the DASAR arrays. The placement of the DASAR arrays was designed to capture the majority of the whales that migrate westward in the fall by consulting data sets such as those collected by Clarke et al. (2013) since the early 1980s. Figure 6.2 illustrates this by showing BWASP sightings from nine low-ice years (1998–2008, excluding 2005 and 2006), superimposed on the DASAR call localizations from 2008. The BWASP sightings were used to compute the $10^{th}$ and $90^{th}$ quantiles of the distance from shore, showing the area containing 80% of all sightings in those years (for more details see Blackwell et al. 2010). As shown in Figure 6.2, the vast majority of the DASAR localizations in 2008 and other years (not shown) are located between the $10^{th}$ and $90^{th}$ quantiles, with one exception: 2011.

Due to the presence of sea ice in the study area in July, DASAR deployments normally did not take place before mid-August. In 2011, however, all DASARs were in the water and recording by 31 July. The turquoise oval in Figure 6.1 shows calls that were detected in the first two weeks of August 2011, in an area north of and between sites 3 and 4 where large numbers of calls had not been detected in the past.

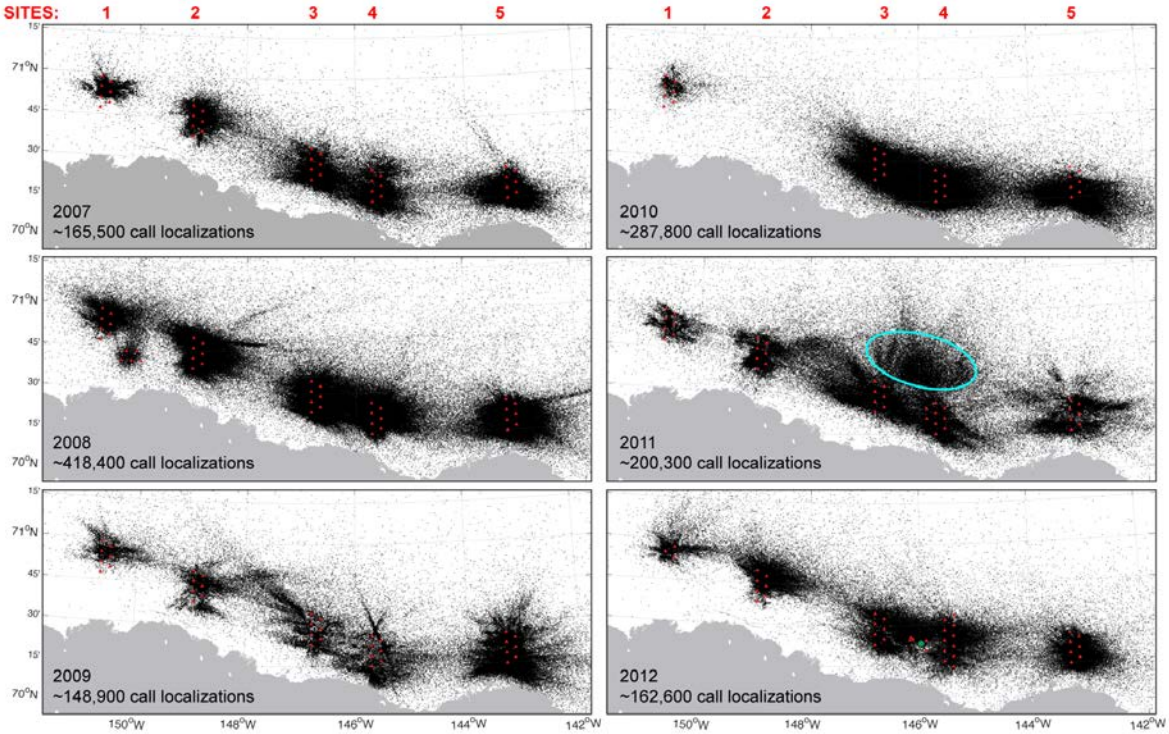


FIGURE 6.1. Localized bowhead whale calls as detected in each deployment season, 2007–2012, by five arrays (sites) of DASARs (red triangles; sites numbered 1–5 from west to east). The number of DASARs deployed each year varied between 35 and 40. All localized calls are shown, regardless of their accuracy or probability of detection. Site 2 was not deployed in 2010 because of ice. The distance from the center of site 1 to the center of site 5 is ~280 km (174 mi).

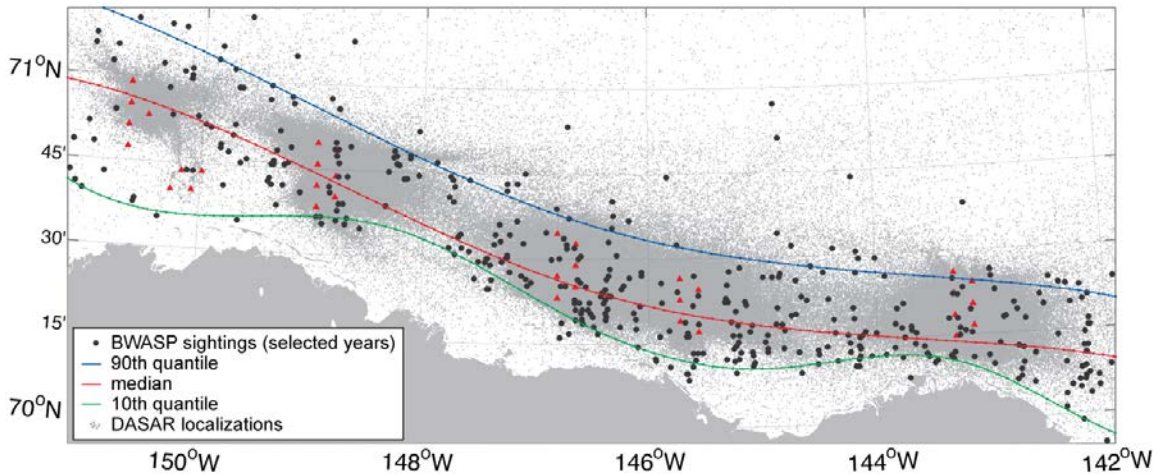


FIGURE 6.2. Comparison between DASAR localizations in 2008 (grey dots) and BWASP sightings during nine low-ice years (1998–2004, 2007, 2008, black dots). The red (middle) line shows the median distance from shore for BWASP whale sightings during these years, the green (inshore) line is the 10th percentile and the blue (offshore) line is the 90th percentile. Functional DASAR locations are shown as red triangles.

The general location of these offshore 2011 call detections overlapped with that of a satellite-tagged whale that had moved west from the Canadian Beaufort in late June (as described by Clarke et al. 2012). The tagged whale then stayed offshore, north of the Camden Bay area for about four weeks before returning to the Canadian Beaufort. In mid-July, an ASAMM[3] aerial survey team made a directed flight over the offshore area and sighted 14 bowhead whales[4] in the immediate vicinity of the tagged whale location (Clarke et al. 2012).

These visual observations are especially relevant in assessing the ability of the DASAR arrays to detect large concentrations of offshore calls. Without independent verification, inference from apparent patterns of call detections farther offshore is uncertain, because the precision and probability of call localizations is decreased. This example indicates that, on a broad scale, the DASAR arrays are able to identify large concentrations of calls north of where most of the calling whales have been localized later in the fall.

Based on DASAR data (Fig. 6.1), it does not appear that the various anthropogenic activities taking place near the DASAR arrays in 2007, 2008, and 2012, and to a lesser extent in 2010, resulted in large[5] offshore or onshore displacement in the distribution of calling bowhead whales during the periods of DASAR deployment. Further, based on the detection of bowhead calls offshore of the arrays during summer 2011, it does not appear that large numbers of calling bowheads are present much north of the arrays during the mid-August to early October period of deployment during 2007–2012. These statements are not based on a quantitative assessment, but rather on a broad-scale qualitative view of the distributions of whale calls such as those shown in Figure 6.1.

The most recent quantitative assessment of large-scale bowhead distribution in the Alaskan Beaufort during the fall migration period (September–October) was by Clarke et al. (2013). Their analysis ("Bowhead whale central tendency - analysis II") fits a spatial model to on-transect ASAMM encounter rates (i.e., standardized for effort, and taking into account group size estimates) across the Alaskan Beaufort, from the Canadian border to Point Barrow. Statistics such as the model-predicted median distance from shore during 2012 were compared with estimates based on encounter rate data during recent light ice years (2007–2012). The results of the Clarke et al. (2013) analysis suggest that the fall distribution of bowhead whales was farther from shore during 2012 than during the previous six years (including, for example, to the east of Kaktovik and to the east of Point Barrow).

The explanation for the apparent difference in distribution during the fall 2012 migration period in the Alaskan Beaufort is not immediately obvious. Treacy et al. (2006) also observed variation in the offshore distribution during previous federally funded aerial surveys. While Treacy et al. (2006) concluded that sea ice was the primary factor influencing the distance-from-shore movements of bowheads, they noted that in light ice years other factors such as bathymetry, ocean currents, transport and food likely played an important role in influencing the migration corridor. Such naturally dynamic factors might explain the results of the spatial modeling by Clarke et al. (2013).

It is interesting to note that the acoustic and aerial data collected as part of Shell's monitoring efforts do not provide clear evidence of a more northerly distribution of bowheads during 2012 compared to recent years in the Central Alaskan Beaufort Sea. The most prominent pattern observed by the 2012 aerial surveys funded by Shell was one of a nearshore shift as the fall migration progressed (see

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[3] Aerial Survey for Arctic Marine Mammals, carried out the National Marine Fisheries Science Service under funding by the Bureau of Ocean Energy Management.

[4] Two possible repeat sightings were noted by Clarke et al. (2012).

[5] Each DASAR array stretches approximately 21 km (13 mi) north to south. A large-scale shift in this context would be one where the fall migration corridor had minimal or no overlap with the arrays.

*Observations around the 2012 Offshore Industry Activities*). This apparent inconsistency between data sets might have to do with the different longitudinal ranges (scales) covered by the two studies. For example, it would not necessarily be inconsistent that the distribution of bowhead whales over a restricted longitudinal range was not farther offshore than average, while the overall average offshore distance, taken over a much larger longitudinal range, was greater than recent years.

### *Alaskan Chukchi Sea: Large-Scale Patterns*

Bowhead whale distribution in the Alaskan Chukchi Sea during summer and fall is less well defined than in the Alaskan Beaufort Sea. The majority of the BCB bowhead whale population is known to summer in the eastern Beaufort Sea (e.g., Moore and Reeves 1993). Recent observations of satellite-tagged whales have expanded this understanding, by documenting the movements of bowhead whales between the eastern Beaufort and the Chukchi Sea during the summer (Quakenbush et al. 2010). The observations from satellite-tagged animals suggest that, in general, bowhead whales are more wide-ranging during the summer than previously believed. During the fall migration period, as mentioned above, bowhead whales are found over a wide spatial area as the migration corridor fans out west of Barrow (Moore and Reeves 1993; Quakenbush et al. 2012). Hence, the naturally more scattered spatial distribution in the Alaskan Chukchi complicates interpretation of observed patterns relative to the Alaskan Beaufort Sea.

As in the Alaskan Beaufort Sea, the acoustic data from the Chukchi Sea (e.g., Delarue et al. 2013) are the most spatially complete data set collected as part of industry-sponsored monitoring efforts. Deployments of acoustic recorders[6] have occurred at the same or similar locations each year, since 2007, in the Alaskan Chukchi Sea (Fig. 6.3 shows the "summer" recorder locations since 2009). The recorders were distributed along four lines spread between Cape Lisburne and Barrow and extending up to 100 nautical miles from shore. Since 2009, clusters of recorders were added in summer to survey specific lease blocks particularly with regards to fall migrating bowhead whales. The acoustic recorders were typically deployed each year between 25 July and 10 August, which provided limited or no recording effort in July. Some winter recorders were, in some years, still active in July, providing some data mainly in offshore areas. The discussion around summer distribution in this section is restricted to July–August. This allows for comparison with the federal agency aerial surveys (e.g., ASAMM).

[6] AURALS (Autonomous Underwater Recorder for Acoustic Listening) in summer 2007 and for all winter deployments (October to July), AMARs (Autonomous Multi-channel Acoustic Recorder) for all summer deployments (late July or early August until mid-October) since 2008.

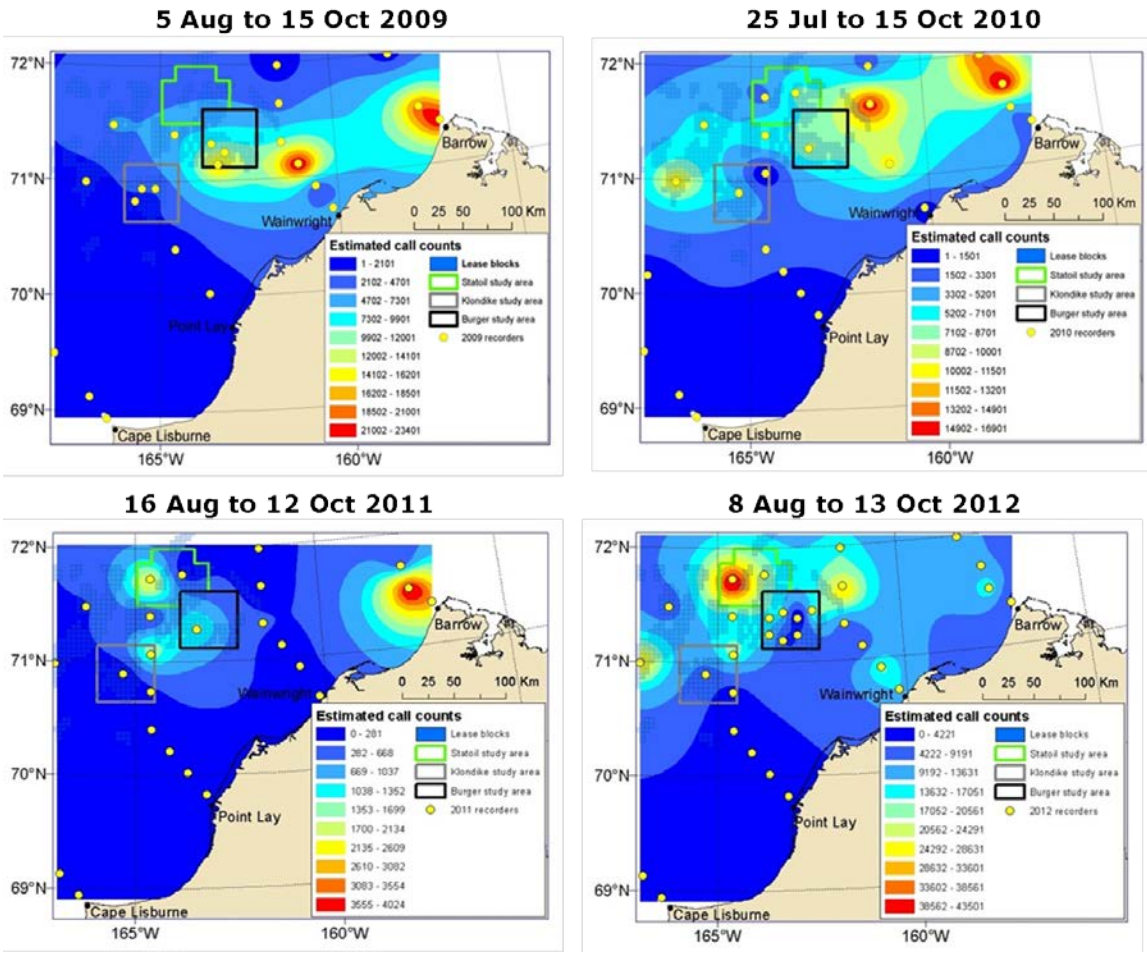


FIGURE 6.3. Bowhead whale call counts in the Chukchi Sea during the summer and early fall. Interpolated call counts are based on the sum of automated call detections in all files with manual detections at all recording stations in the northeastern Chukchi Sea during the time periods shown (from Delarue et al. 2013).

The second lowest number was observed during **July–August 2009** (Delarue et al. 2011a). Call detections occurred sporadically in August 2009, specifically on 9 August at Klondike, on 14 August 20 nmi off Wainwright and on 19 August 50 nmi off Barrow. In comparison, there were only two bowhead whale sightings recorded by federal agency aerial surveys during August 2009 (Clarke et al. 2011). Each sighting was estimated to be a single animal. In contrast, there were multiple agency aerial sightings during July 2009, and these were around the Peard Bay area (between Point Franklin and Barrow; Clarke et al. 2011). Summer recorders were not deployed until 7–10 August but of the four winter recorders still active in July 2009, only one detected bowhead calls on 5 July, 50 nmi from Wainwright. It is worth noting, however, that these winter recorders did not cover the inshore part of the Alaskan Chukchi Sea. This fact likely explains the discrepancy with the aerial survey sightings.

In **July–August 2011**, bowhead detections increased compared to previous years. Between 27 July and 9 August, bowhead calls were concentrated for the most part in an area located between the Burger prospect and a station 50 nmi northwest of Point Lay. Detections lasted an average of five detection-days per station (range: 1–12 detection-days). The relative persistence of these detections suggests that bowheads were foraging and not simply transiting near the recorders. There were no detections in the

second half of August. The relative increase in call detections from the acoustic data during early August 2011 is consistent with observations from CSESP. Aerts et al. (2012) reported sightings of bowhead whales in the Burger and Klondike lease areas throughout the month of August 2011 (Aerts et al. 2012). This was a first for the CSESP survey, which has been ongoing since 2008 (Aerts et al. 2012). In contrast, there was only one bowhead whale sighted in August 2011 during agency aerial surveys in the Chukchi (Clarke et al. 2012). The discrepancy between both visual surveys may come from the apparently non-uniform distribution of bowhead whales combined with different levels of effort, particularly near the Klondike and Burger leases where the sightings were concentrated. With respect to nearshore distribution, the 2011 ASAMM data do not indicate there were as many bowhead whales near Peard Bay during July–August 2011 as compared to July–August 2009. Hence, the ASAMM observations provide evidence of variability in bowhead summer distribution in the Peard Bay area, both within and between years.

In **2012**, there were no active winter recorders left in July and the summer recorders were not deployed until 10 August. As in 2011, a short period of detections occurred in August. Calls were detected between 11 and 16 August off Cape Lisburne and Wainwright and between the Klondike and Burger prospect areas. In August, the CSESP surveys report fewer sightings than in 2011, but more than in 2008–2010 (Aerts et al. 2012). There were no ASAMM bowhead whale sightings in the Chukchi during August 2012 (Clarke et al. 2013). Overall, acoustic and visual (boat-based and aerial) survey data all indicate that bowhead abundance is generally low in July and August, with some inter-annual variability in their spatial and temporal occurrence. Acoustic detections and boat-based sightings both suggest an increased presence in the central part of the Lease Sale Area in August 2011 and 2012 compared to 2009 and 2010. The factors behind this apparent increase are not clear considering that ice concentrations and the level of human activities, among other factors, varied annually.

Despite some sightings in July and August likely associated with early migrants or foraging whales, the bulk of bowhead observations in the Chukchi Sea remains linked to the spring and fall migrations. During the late summer and early fall, the AMAR data indicate that the Burger prospect area has been near the center of the distribution of vocalizing bowhead whales during recent years, whereas the Klondike area has been on the southern edge (Fig. 6.3; Delarue et al. 2013). Some questions remain, however, regarding interpretation of the 2012 call count data near the Burger prospect, due to the possibility of masking by elevated sound levels from vessels on standby southeast of the drill site (Delarue et al. 2013). Nevertheless, Shell-sponsored aerial surveys also sighted more bowheads on the northwestern side of the drill site, which coincides with the observed distribution in acoustic detections (see *Observations around the 2012 Offshore Industry Activities*). The migration corridor derived from the location of acoustic detections has been relatively consistent across years. The observed large-scale patterns in the acoustic data indicate that bowhead whale distribution during the early fall migration period in recent years has been concentrated north of 71°N. Some migrating bowheads follow the coast south to Wainwright, although this does not appear to be true every year. The scarcity of detections at the inshore Point Lay and Cape Lisburne stations indicates that most bowheads head offshore towards the Chukotka coast once off Wainwright (Delarue et al. 2013).

Contrary to the Beaufort Sea acoustic arrays, which are located so as to capture the vast majority of migrating bowheads, the tagging data to date (Quakenbush et al. 2012) suggest that the Chukchi Sea array does not monitor the entire migration path. For example, whales that migrate towards Wrangel Island along the shelf break (the “northern route”; Moore and Reeves 1993) are unlikely to be detected by the recorders. In 2012 recorders were added to the north of the summer monitoring area to evaluate whether migrating bowheads are present north of Hanna Shoal. The decrease in call counts at the northern stations relative to those south of 72°N indicates that most individuals traveling the “southwestern route” across the Lease areas are captured by the summer recorders and indeed concentrate north of 71°N. This general

broadscale pattern of distribution is also consistent with the results of ASAMM aerial surveys (e.g., Clarke et al. 2013) and movements of satellite-tagged whales (Quakenbush et al. 2012). The timing of the migration is generally similar between years. Nevertheless, a delay in the first fall detections in 2007 and lower call counts in 2011, two years with record-low ice conditions, both suggest that the migration through the Chukchi Sea proceeded later than in other years. This observation is consistent with local traditional knowledge (Huntington and Quakenbush 2009).

The northeastern Chukchi Sea has seen increasing—though variable—amounts of anthropogenic activities in recent years. Shallow-hazard surveys were conducted in active lease blocks in 2009 and 2011. A full 3D survey was performed in 2010, and 2012 saw the first drilling attempt in the Burger prospect area in recent years. The 2009–2011 acoustic detections do not provide evidence for a change in distribution or occurrence caused by these activities, possibly because of their limited temporal overlap with bowheads' occurrence in the Chukchi Sea. In 2012, we observed a non-uniform distribution in call counts at the recorders surrounding the Burger drill site. Investigations are ongoing to see whether this is caused by call masking associated with the noise generated by vessels on standby southeast of the drilling area, or whether bowheads diverted their course north of the drill site. Bowhead whales have been shown to react to noise at lower threshold when migrating compared to feeding (e.g., Koski et al. 2009).

## *Acoustic Behavior of Bowhead Whales in Relation to Seismic Sound*

### *Observed Vocal Changes in Relation to Industry*

Subtle effects of anthropogenic sounds on bowhead behavior are known to occur, such as effects on calling behavior (Blackwell et al. 2013) and surfacing, respiration, and dive behavior (Richardson and Malme 1993; Robertson et al. 2013). Moreover, if not properly interpreted, these effects can easily lead to misinterpretations of the data—an example is given below.

Examination of DASAR data collected during the four years of 2007–2010 showed that 2009, which was the year of lowest industry activity, was the year of lowest recorded call detections. Conversely, 2008, which was the year of highest nearby activity, was the year of highest call detections (see Fig. 6.1). Recent analyses (Blackwell et al. *In Prep*) have shown that as soon as airgun pulses are detectable above background, whale calling rates increase over calling rates measured in the absence of airgun pulses, and level off at roughly twice the non-seismic calling rate. At still higher received levels from airgun pulses, calling rates drop and the whales become virtually silent (see below for more information on these results). So, despite the fact that calling was depressed near the seismic vessel (Blackwell et al. 2013), at the other arrays the received levels of sound from airgun pulses (from Shell and other operators) were at doses corresponding to increased calling in the whales.

To quantify this relationship, we summed the number of whale calls localized inside well-defined areas around each array ("racetracks" as presented in Blackwell et al. 2013) during the period 27 August–29 September each year. We also counted the number of airgun pulses detected at a central DASAR, 3G (see Chapter 3 for DASAR deployment locations). Compared to 2007, 2008 had 2.0 times the number of whale calls and 2.1 times the number of detected airgun pulses. These values were 0.6 and 0.9 for 2009, and 1.2 and 1.3 for 2010. These relationships may be improved by also taking into account the received levels of the airgun pulses, which are important in predicting changes in bowhead calling behavior.

Table 6.1 summarizes the number of localized calls across six years of data collection, within racetrack-shaped areas around each array, and for the same date range each year: 27 August–29 September. These racetracks represent the area within which call detectability does not vary much as a function of background levels (see Blackwell et al. 2013). In other words, within these areas we expect to

detect about the same number of calls regardless of wind speed. The exception to this is 2012, when the number of large vessels likely caused masking of calls at some of the DASARs.

Table 6.1 shows that site 5 often had the highest call counts (in three out of six years) and site 1 the lowest (in four out of five years). The largest overall totals were in 2008, when Shell had by far the highest level of activities (seismic exploration) within our study area. The lowest overall totals were in 2009 and 2011, the two years with the lowest levels of activity near the arrays. Despite the likely masking of some calls at site 4 in 2012 when drilling-related activities were taking place at Sivulliq, totals at site 4 in 2012 exceeded those in both 2009 and 2011. The overall impression given by these numbers is not one of depressed calling in the presence of industrial activities, rather to the contrary, and some of the evidence presented below supports this hypothesis.

There has long been interest in gathering information on the reactions of whales to anthropogenic activities, and sounds in particular (e.g., Watkins 1986). With passive acoustics we are limited to studying the reactions of vocalizing animals, but the ability to localize calls from a DASAR array means the animals' responses can be studied in both time and space. Starting in 2000, an array of DASARs was used northeast of an oil-production island (Northstar) on the western side of Prudhoe Bay, to study the effects of fluctuating sounds from the island operation on the southern edge of the bowhead whale migration corridor. McDonald et al. (2012) reported specifically on the 2003 season, when ~25,200 calls from migrating bowhead whales were localized during the month of September. Weighted quantile regression was used to relate the average distance from shore of each call with both natural and anthropogenic covariates. The study showed that when tones from machinery were present at the island during the 15 min preceding each call, the southern edge of the migration corridor as represented by "calling whales" (5th quantile) shifted offshore by on average 0.67 km (0.42 mi). It is unknown whether some whales closer to shore stopped calling or whether they actually moved offshore.

As part of the Shell-sponsored studies in the Beaufort Sea, six summers (2007–2012) of DASAR deployments have provided a huge dataset of localized bowhead calls. Meanwhile, various activities have taken place inside our study area, from very little activity (2009) to substantial amounts of seismic exploration (2007 and 2008) or activities linked with drilling, including vessel traffic (2012). By judiciously combining the information on whale calls with that on anthropogenic activities, we can examine the effects of specific sound-producing activities on the acoustic behavior of bowhead whales.

Airgun pulses are produced during surveys of the seafloor to search for oil-bearing strata or simply to map the bottom topography. Airgun pulses are relatively easy to identify and distinguish from other man-made sounds. Therefore they are also relatively easy to quantify, with little contamination from other noise sources. Using DASAR data collected in 2007, we have shown that bowhead calling rates (as indicated by call detection rates at the DASARs) drop significantly when airgun operations are near the whales (median distance 41–45 km [25–28 mi]) and the estimated median received level of airgun sound (SPL) at the animals is 116–129 dB re 1 μPa (10–450 Hz, Blackwell et al. 2013).

Taking this a step further, we sought to determine the threshold of received airgun sound at which this behavioral change (cessation of calling) starts to occur. Several re-analyses of the data collected in 2007–2010 have consistently given the same results: when the received cumulative sound exposure level (CSEL) at the whale exceeds ~127 dB re 1 $\mu Pa^2$-s (as calculated over 10 minutes), calling rates start to decrease. At received CSELs close to 160 dB, the animals are nearly silent. Interestingly, before this drop in calling rates there is an increase: as soon as airgun pulses become detectable, bowhead whales start calling more often, until the calling rate is about double that seen when no airgun pulses are present.

TABLE 6.1. Number of localized bowhead calls in each year of DASAR deployments, by site, and restricted to a racetrack-shaped area (of width 8 km [5 mi]) around each site (see Blackwell et al. 2013). Only standard 7-DASAR sites were considered (see Chapter 3); data from DASARs 4H and 4I (only deployed in 2010–2012), or 4J, 4K, 4L, and 4M (only deployed in 2012) were not included. Site 2 was not deployed in 2010 because of ice, and site 1 was omitted from these calculations in 2012 because the site only included three of the seven original DASARs. The calls were detected using an automated call detection algorithm (see Thode et al. 2012). Two different totals are shown: one for all sites combined and another limited to the sites that were deployed every year: sites 3, 4, and 5.

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|
| Site 1 | 2881 | 6971 | 1783 | 1959 | 2829 | N.A. |
| Site 2 | 5728 | 23,622 | 2307 | N.A. | 5137 | 6356 |
| Site 3 | 7031 | 12,968 | 3329 | 11,732 | 4063 | 7062 |
| Site 4 | 8800 | 15,767 | 2587 | 21,457 | 5001 | 6637 |
| Site 5 | 11,843 | 13,374 | 12,156 | 8647 | 1113 | 7985 |
| Totals – all sites | 36,283 | 72,702 | 22,162 | 43,795 | 18,143 | 28,040 |
| Totals – sites 3, 4, 5 | 27,674 | 42,109 | 18,072 | 41,836 | 10,177 | 21,684 |

In 2012, Shell started drilling in both the Beaufort and Chukchi seas. This resulted in a number of new activities (within the framework of this study) as well as increased vessel traffic, notably in the Beaufort study area, compared to previous years. DASAR data collected in 2012 are currently being analyzed to identify the effects on bowhead whale calling behavior of the industrial sounds produced during drilling activities at Sivulliq.

Figure 6.4 offers an early glimpse into the type of trends that the data may reveal. The figure shows the mean number of localized bowhead calls per cell-time interval for different bins of a tone index. A cell-time interval is a 10-min period within a circle of radius 2 km (1 mi) centered on a functional DASAR. For each 10-min period at each DASAR, calls localized inside this circle were counted. Samples collected when background levels were above ~118 dB re 1 μPa (rms) were excluded, as masking of whale calls will occur when background levels are elevated, and inclusion of such samples could bias the results. The tone index used in Figure 6.4 is a measure of tonal sounds, which are typically produced by machinery. (For details on the calculation of the tone index, see McDonald et al. 2012.) Identifying tones and measuring their amplitude can serve as an indicator of anthropogenic activities. 213,751 observations (cell-time intervals) were included in the leftmost bin, and ~3323 observations were included in each of the other 10 bins. The number shown under each bin is the midpoint value of the tone index for that bin; increasing numbers are indicative of greater amounts of anthropogenic sound. Figure 6.4 suggests that the number of bowhead calls decreases as the number and amplitude of tones increase.

The data in Figure 6.4 have not undergone any statistical analyses, but they suggest that as the number and amplitude of tones from machinery increases (and the value of the tone index increases), calling rates gradually decrease. Whether the initial increase in calling rate (between median tone index values of 62.9 and 76.8 dB) is real or an artifact remains to be shown.

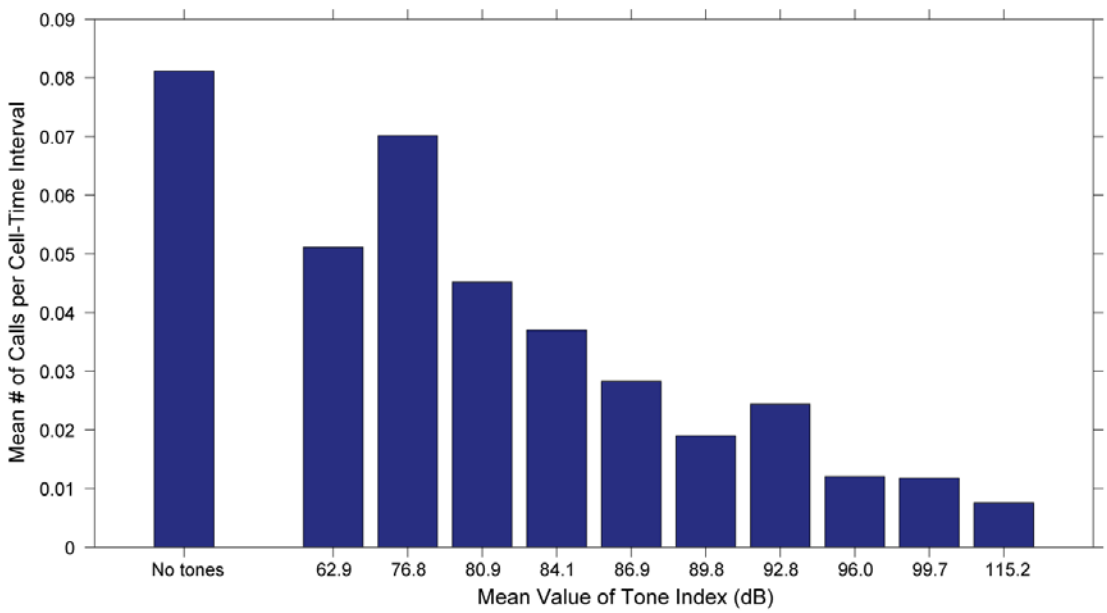


FIGURE 6.4. Mean number of calls per cell-time interval (10-min period at one DASAR) as a function of received sound from industrial tones. The leftmost bar shows samples in which no tones were detected. See text for more information.

### *Presence and Sound Levels in the Central Beaufort Sea Associated with Seismic*

Seismic exploration by Shell in the Central Alaskan Beaufort acoustic study area (the roughly 300 km wide [186 mi] swath of continental shelf that includes all five DASAR sites) took place in 2007, 2008 and 2010. In the first two years, the *Gilavar* performed 3D surveys using a 3147 $in^3$ array in areas between sites 3 and 4 and near site 1 (see Fig. 6.5). The *Henry Christoffersen* (40 $in^3$) also performed shallow-hazard surveys. In 2010, the *Mt Mitchell* used a 40 $in^3$ array for shallow-hazard surveys. Every year an automated airgun pulse detection routine (see Thode et al. 2012) was used on the data collected by each DASAR. This provided the numbers of airgun pulses detected, their bearing (direction from which they originated), the inter-pulse intervals (time between successive pulses) and sound parameters for each airgun pulse. These included the received sound pressure level (SPL) and sound exposure level (SEL), pulse duration, and frequency composition.

Over the six years of the study (2007–2012), up to ~950,000 airgun pulses were detected at the DASARs located in deeper water[7]. The vast majority of these pulses were not produced by Shell's seismic exploration activities, but rather by other distant surveys, mostly to the north or to the east. To compare these pulses across years we focused on DASAR location 5G (see Chapter 3 for deployment locations) for several reasons: it is at one of the deepest deployment depths (52.3 m [172 ft]) and it is closer than any other DASAR to the shelf break and even deeper water, which is favorable for long-distance propagation of airgun pulses across ocean basins. It is also closest to the Canadian Beaufort, where several of the non-Shell seismic exploration activities took place. Finally, received sound at site 5 is relevant to assessing sound levels in areas where subsistence whaling is occurring.

[7] Most of the sound energy included in airgun pulses is at low frequencies, which do not propagate well in shallow water. Therefore, recorders located in the shallowest water depth will generally detect the fewest pulses at the lowest received levels.

Figures 6.5 and 6.6 show bearings and received SELs, respectively, to all detected airgun pulses at location 5G as a function of date in 2007–2012. The total number of airgun pulses detected each year is given in each plot. The highest number (264,128) was in 2012 and the lowest (81,483) in 2011. Since deployment durations varied between years, the average number of pulses per day of deployment is shown in Figure 6.7. Even so, 2012 remained the year with the highest number of detected airgun pulses, with over 5700 per day.

One interesting aspect shown by Figure 6.6 is the fact that with the exception of 2011, in all other years the majority of airgun pulses had received sound exposure levels in the range 100–120 re 1 $\mu Pa^2$-s. In other words, received levels at site 5 in the years in which the *Gilavar* (using a relatively large airgun array at 3147 $in^3$) was operating within our study area, between sites 3 and 4, are not much different from received levels from some of the operations that were roughly 300–1400 km (186–870 mi) away. (When the *Gilavar* was operating near site 1 in 2008 the pulses did not propagate far because of the shallow water depths, ~15–22 m [49–72 ft].) This can be explained by the logarithmic nature of sound propagation. For example, a spreading loss term of 20 dB means that received levels will decrease by 20 dB for every tenfold change in distance, whether that is 2 m to 20 m (7 ft to 66 ft), 500 m to 5 km (1640 ft to 3 mi), or 50 km to 500 km (31 mi to 311 mi). Site 5 is about 90 km (56 mi) from site 4, where much of the airgun use took place in 2007 and 2008. This is a distance where received levels at a DASAR, all else being equal, will change very slowly with increasing range. In other words, the 20 dB range in received SELs could result from seismic operations at a huge range of distances, for example 70–700 km (43–435 mi; again, all else being equal).

During DASAR retrievals in October 2012, five AURAL recorders were deployed within and between DASAR array locations to collect data during the winter 2012–2013. In particular, these recorders were to collect data on the late-season seismic survey conducted by ION in autumn 2012. This joint project between Shell and ION was preceded by an overwintering deployment by Shell of six AURALs in October 2011, the results of which are presented in Appendix C. In addition to information on sound levels during the winter and the presence and amplitude of airgun pulses, these deployments will provide information on the presence and density of various marine mammals during the ice-covered season.

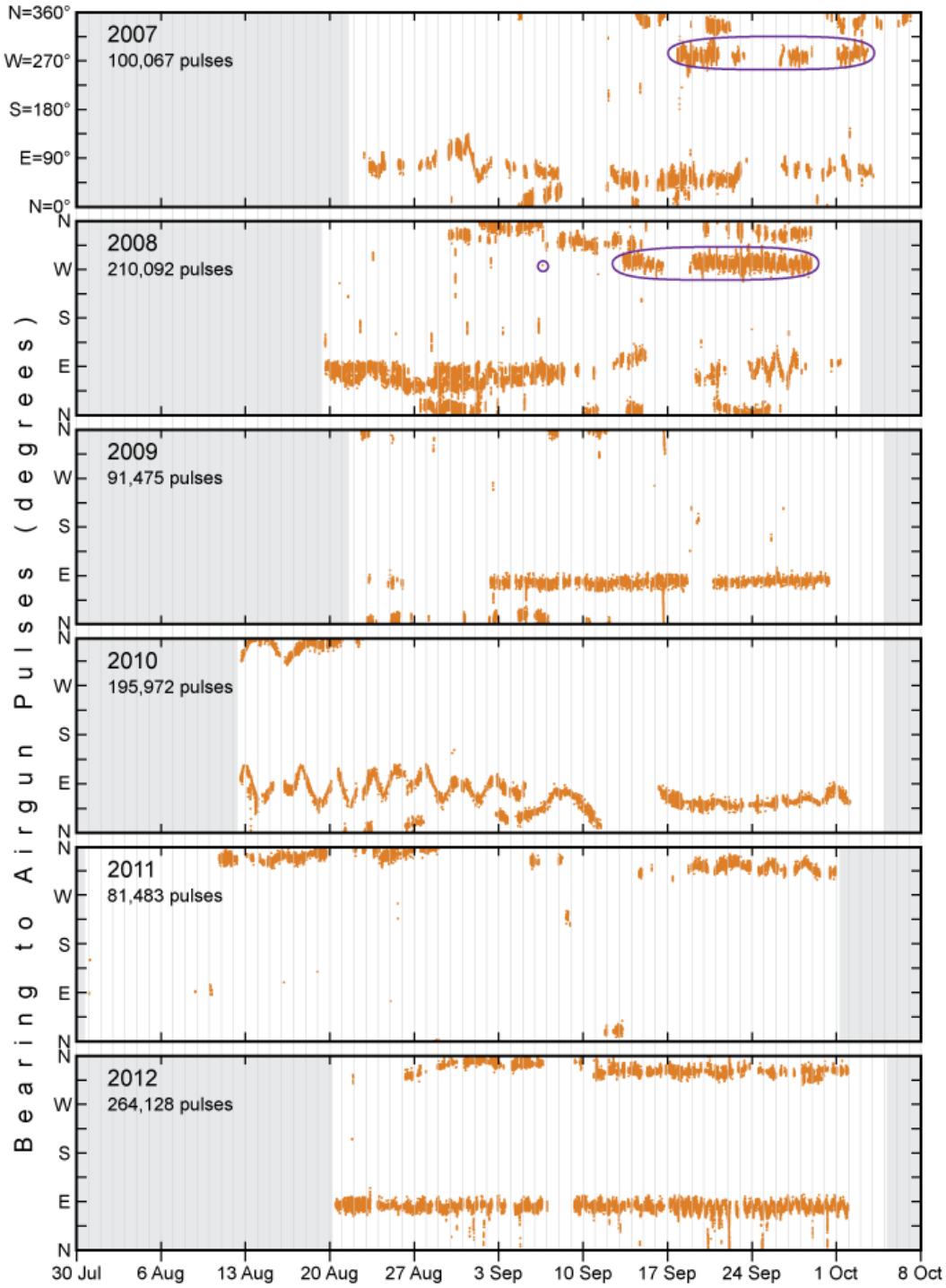


FIGURE 6.5. Bearings to airgun pulses detected at DASAR 5G in 2007–2012. North is shown by both 0° and 360°, 90° corresponds to pulses from the east, 180° pulses from the south, and 270° pulses from the west. Shaded areas indicate times when the DASAR was not deployed. The two large purple ovals show pulses produced by Shell's activities near sites 3 and 4 in 2007 and 2008. The small purple circle in 2008 shows the only pulses within the correct bearing range while the *Gilavar* was working at site 1, ~250 km (155 mi) away.

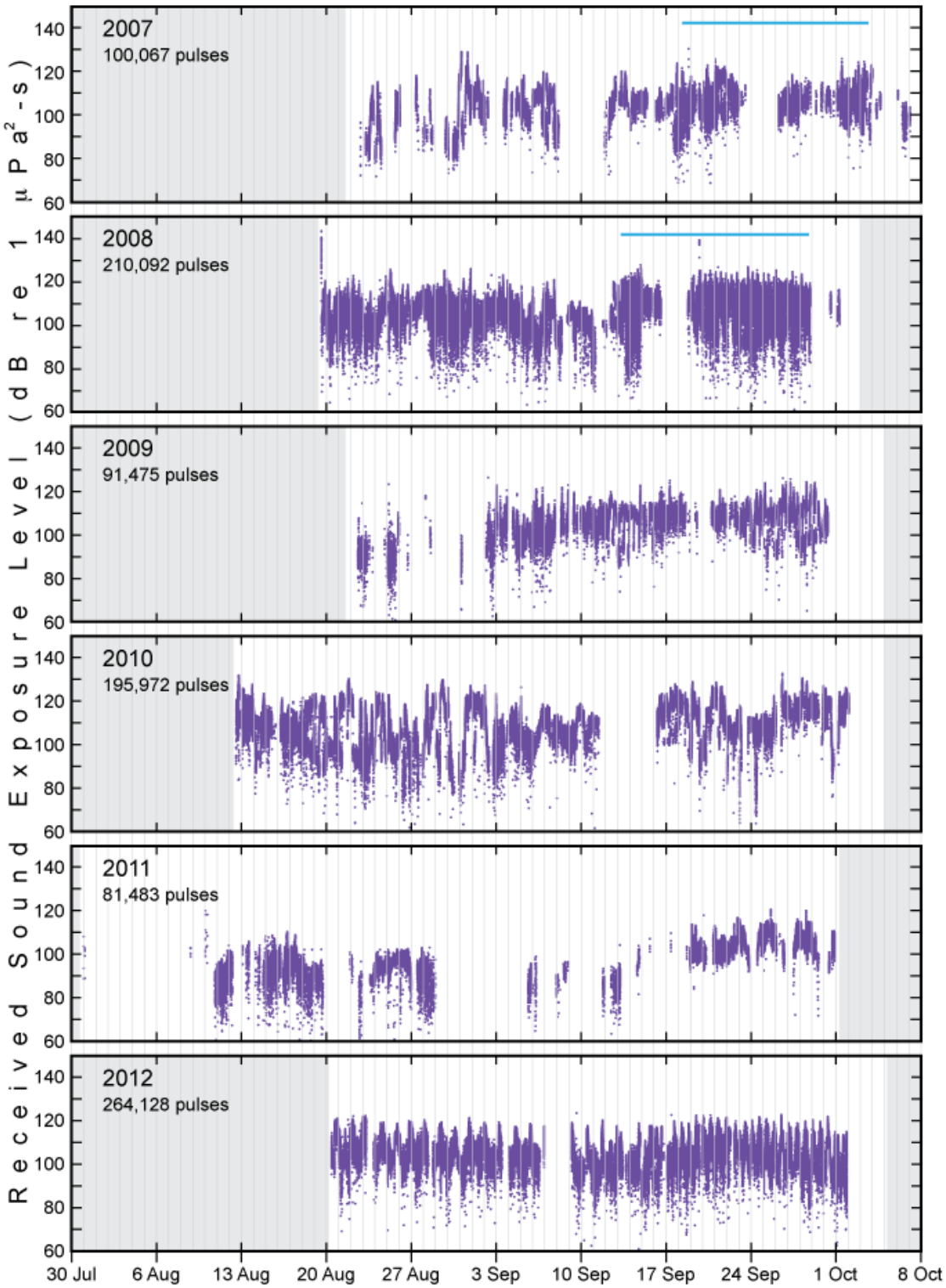


FIGURE 6.6. Received sound exposure levels (SELs) to airgun pulses detected at DASAR 5G in 2007–2012. Blue lines (in 2007 and 2008) show times when at least some of the pulses detected (see Fig. 6.5) originated during Shell's 3D surveys between sites 3 and 4. Shaded areas indicate times when the DASAR was not deployed.

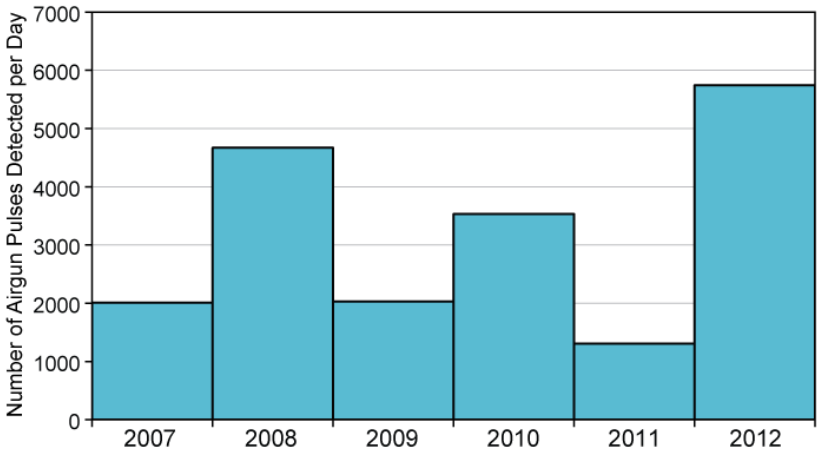


FIGURE 6.7. Number of airgun pulses detected per day of deployment for DASAR 5G in 2007–2012.

## *Observations of Small to Medium-Scale Patterns of Distribution*

### *Observed Patterns of Distribution and Ice Conditions in the Central Beaufort Sea*

Light and moderate ice cover do not appear to impede bowhead whale movements (George et al. 1989; Moore and Reeves 1993; Ferguson et al. 2010), but heavy nearshore ice cover in the fall has been shown to result in a westward migration corridor that is farther from the coast, over deeper water (Moore 2000; Treacy 2002; Treacy et al. 2006).

Documented traditional knowledge (e.g., Quakenbush and Huntington 2010; Huntington and Quakenbush 2009) also provides important information on observed effects of sea ice and bowhead whale distribution. For example, traditional knowledge indicates that whales migrate on both sides (nearshore and offshore) and also among the ice floes when ice is present around Kaktovik. In general, during years with ice, the observed distribution of bowhead whales around Kaktovik has been closer to shore (Huntington and Quakenbush 2009). This last observation seems to be inconsistent with the scientific studies cited above, but it may also be an illustrative example of how apparent differences can exist in observed patterns depending on the spatial scale of observation. During the period 2007–2012, 2010 was the only year during which there existed persistently high concentrations of ice in the coastal Central Alaskan Beaufort Sea. In addition to high concentrations, the ice cover was also characterized by substantial areas containing first-year thick and multi-year floes. Figure 6.8, showing overlays of call distributions on ice maps for two representative periods during August 2010, illustrates the relationship between sea ice and call localizations through the study area during the early 2010 fall migration period. The distribution of calling bowheads during this period was consistent with previous observations of heavy nearshore ice cover (70–100%) resulting in the migration route being farther offshore (Blackwell et al. 2011).

Galginaitis (2011) reported on the results of the 2010 whaling season (29 August–1 September, 2010) at Cross Island. Although the 2010 whaling season was considered favorable, the whalers did not hunt in the ice for various reasons. Galginaitis (2011) noted that the whalers agreed that whales were harder to spot in the ice. He also noted that striking a whale is risky because the whale can more easily escape by diving under the ice. Given these factors, and favorable sea states in the open water north of the ice during the whaling season, Galginaitis (2011) reported that whalers consciously decided to hunt in

the open water offshore, and that all of the whales were struck there. It is therefore not possible draw any conclusions about the locations of the strikes and the distribution of bowhead whales.

Brandon et al. (2011, 2012) investigated the 2010 distribution of industry-sponsored aerial sightings with respect to sea ice and seismic activity. The distribution of aerial sightings was found to be consistent with the observed pattern in acoustic call detections: bowhead whales were typically observed farther from shore when heavy concentrations of ice were present. This comparison suggests that the lower aerial encounter rate when surveying over ice was due to lower densities of whales.

During the latter half of the 2010 survey season (late September), stormy weather dissipated the tongue of ice shown in Figure 6.8. This resulted in the bulk of the seismic activity occurring during that stage in the season (mainly during the first week of October). The aerial survey data that were collected during this open-water period of seismic activity indicated that the distribution of bowhead whales (e.g., measured by the median distance of sightings from shore) shifted closer to the seismic survey area (nearshore) than it had been earlier in the season when there were high concentrations of sea ice, but little to no seismic activity. Based on this evidence, and the observed pattern in the acoustic data, Brandon et al. (2012) concluded that the extent of sea ice had a greater effect on bowhead distribution around Harrison Bay during 2010 than did Shell's shallow-hazard survey (performed using a relatively small 40 $in^3$ array).

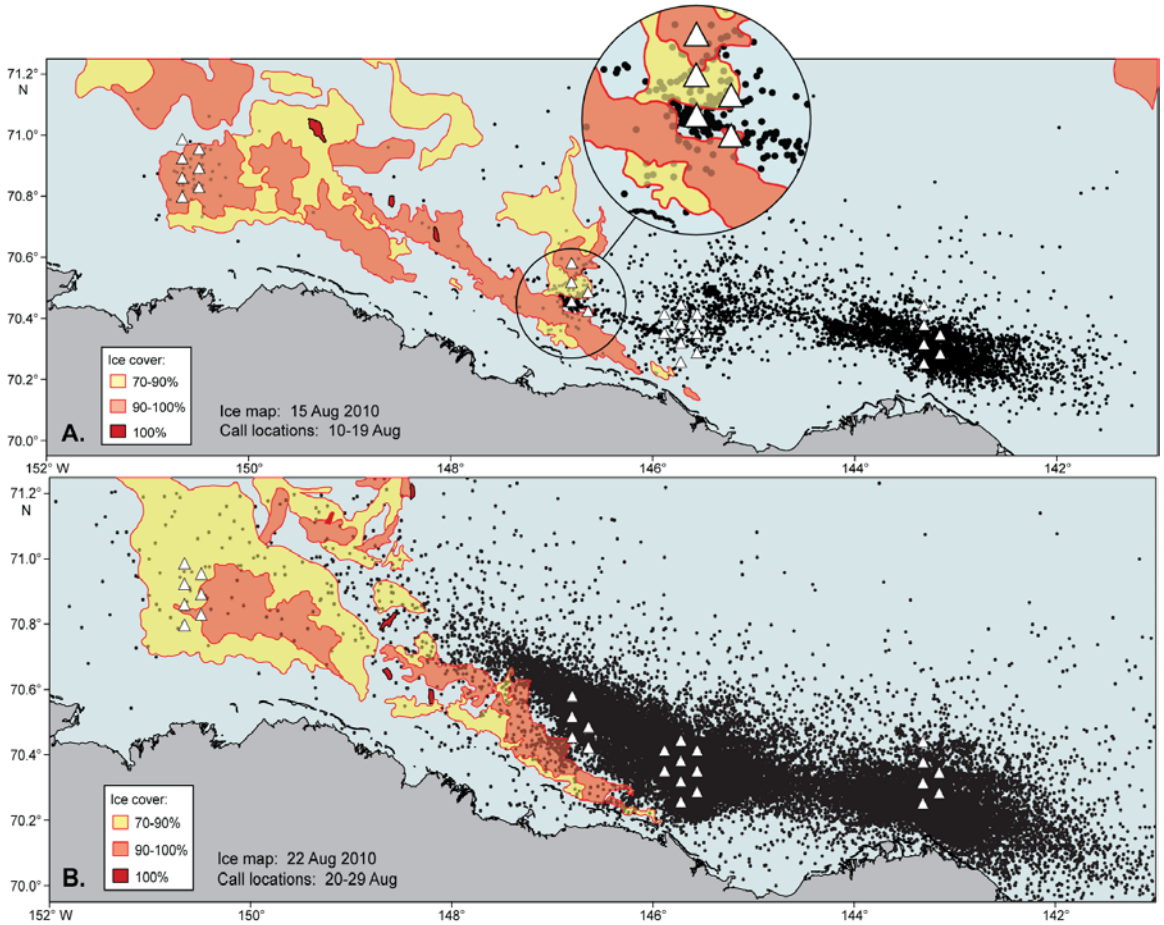


FIGURE 6.8. Two examples from the 2010 season illustrating the relationship between bowhead call distribution and the presence of ice. Colored areas showing the percentage ice cover are semi transparent to show the underlying call localizations. Plot A shows the calls localized during the period 10–19 August, superimposed on an ice map from 15 August 2010. Funneling of the calls from westward-migrating whales through a narrow passage between two ice fields is visible and is enlarged in the inset. Plot B shows how the presence of ice from Point Thomson to Harrison Bay results in a wedge-shaped distribution of calls over a distance of >100 km (62 mi).

### *Observed Patterns of Distribution in Relation to Received Sound Levels from Recent Seismic Surveys in the Alaskan Beaufort Sea*

The most informative scientific data available to address the question of bowhead whale deflection around Shell's seismic activities have been collected by industry-sponsored aerial surveys in the Central Alaskan Beaufort Sea. Acoustic data alone cannot be relied on to detect deflection because, as described above, calling behavior is affected by sounds from seismic activity (Di Iorio and Clark 2010; Blackwell et al. 2013). The satellite tagging data are informative in many respects. Nevertheless, during the fall migration period in the Beaufort Sea, the number of tagged individual animals has not been sufficient to document intra-annual shifts in distribution around seismic survey areas. The ASAMM aerial survey design covers a wide area, as discussed in the section *Observations of Large-Scale Patterns of Distribution* above. One or two aircraft are used, resulting in a survey effort that is sparse in any given area relative to that of the targeted effort near activities by industry-sponsored overflights.

The most in-depth quantitative analyses of the Central Alaskan Beaufort Sea aerial data were by Christie et al. (2010) based on the 2007–2008 data, and by Koski et al. (2009) for the 2006–2008 data. Both analyses fit the data using a multivariate negative-binomial regression, taking into account various temporal and environmental variables, and the estimated received sound levels along the aerial survey trackline based on sound source characterization studies[8] of Shell's seismic operations. Bowhead whale sighting counts during two-minute survey intervals (aerial observations covering ~8 km [5 mi] of trackline) were fit as the response variable.

During some of the 2007–2008 aerial surveys, large numbers of feeding bowhead whales were observed in the aerial study areas. Koski et al. (2009) found that during surveys when feeding whales were present ("feeding periods") the mean distance from the center of the seismic survey area was not significantly different between periods with (51.4 km [31.9 mi]) and without (49.6 km [30.8 mi]) seismic activity. But the mean distance was found to be significantly greater if seismic was occurring during "travelling periods" (51.5 vs. 27.3 km [32 vs. 17 mi], respectively). A gradation in the whales' reactions that is dependent on the animal's state, e.g., feeding versus traveling, has been noted in other studies, for example Miller et al. (2005).

During feeding periods, the highest sighting rates were recorded in areas where received airgun pulses were estimated to have been well over 120 dB re 1 μPa (rms SPL). During the travelling period on the other hand, sighting rates in the area that included the seismic operations declined as seismic exposure increased, suggesting localized avoidance of seismic operations (Koski et al. 2009). An additional factor to consider in terms of decreased sighting rates near seismic operations is that, in general, traveling whales respond to airgun use by altering the surfacing, respiration and dive behavior (e.g., Richardson and Malme 1993; Robertson et al. 2013). This behavioral reaction results in individuals being more difficult to detect from the air (Robertson et al. *In Prep*).

Figures 6.9 and 6.10 present the Beaufort aerial sightings data split by area (Camden Bay versus Harrison Bay) and by periods, i.e., with and without Shell's seismic activities. The locations of sightings were standardized in a Cartesian coordinate system relative to either the center of the seismic survey area (for sightings that occurred during periods when Shell's seismic surveys were not active) or to the location of the nearest active seismic vessel during periods when Shell's seismic surveys were active. The sightings data in these figures have not been split by feeding and traveling periods, as per Koski et al. (2009). There are also two context-specific patterns that are worth noting. First, the distribution of whales was more nearshore in Camden Bay in 2008 while airguns were active (Fig. 6.9). This distribution was associated with animals feeding in nearshore waters. That is not to say that nearshore deflection did not occur at some level, but rather to highlight the importance of taking into account the observations of bowhead whale activity states when interpreting these data (as per Koski et al. 2009). Second, sea ice was present for much of the non-seismic period during the 2010 season in Harrison Bay (Fig. 6.10). Sea ice had a relatively large effect on bowhead whale distribution, as discussed in more detail in *Observed Patterns of Distribution and Ice Conditions in the Central Beaufort Sea*. Also of note during 2010, the SSC measurements were not considered reliable, due to difficulties with data collected in

[8] Note that using sound source characterization (SSC) equations for estimating received levels at locations other than where the SSC was performed—and particularly at large ranges—can lead to substantial errors. Blackwell (per. comm.) calculated received levels of airgun pulses using an SSC equation (for the *Gilavar* in 2008, 3147 $in^3$ array) at a range of distances (~20–120 km [12–75 mi]), and then compared the values to those measured concurrently at 40 DASARs. At distances of <40 km (25 mi) from the seismic ship, SSC-based estimates were within a few dB of the values recorded at some DASAR locations. At other DASAR locations the values differed by up to ±8 dB, as a function of the DASAR deployment depth (higher values for deeper DASARs). At long ranges (≥100 km [62 mi]), all values calculated using the SSC equation were underestimated, by up to 20 dB or more.

the shallow waters of the seismic survey area that year. Hence, two radii are presented in Figure 6.10. The operational 120 dB radius was based on previous years' measurements from similar seismic surveys, and adopted for mitigation purposes. The smaller 120 dB radius—which was the one obtained in 2010—was not used for mitigation, but is shown for reference.

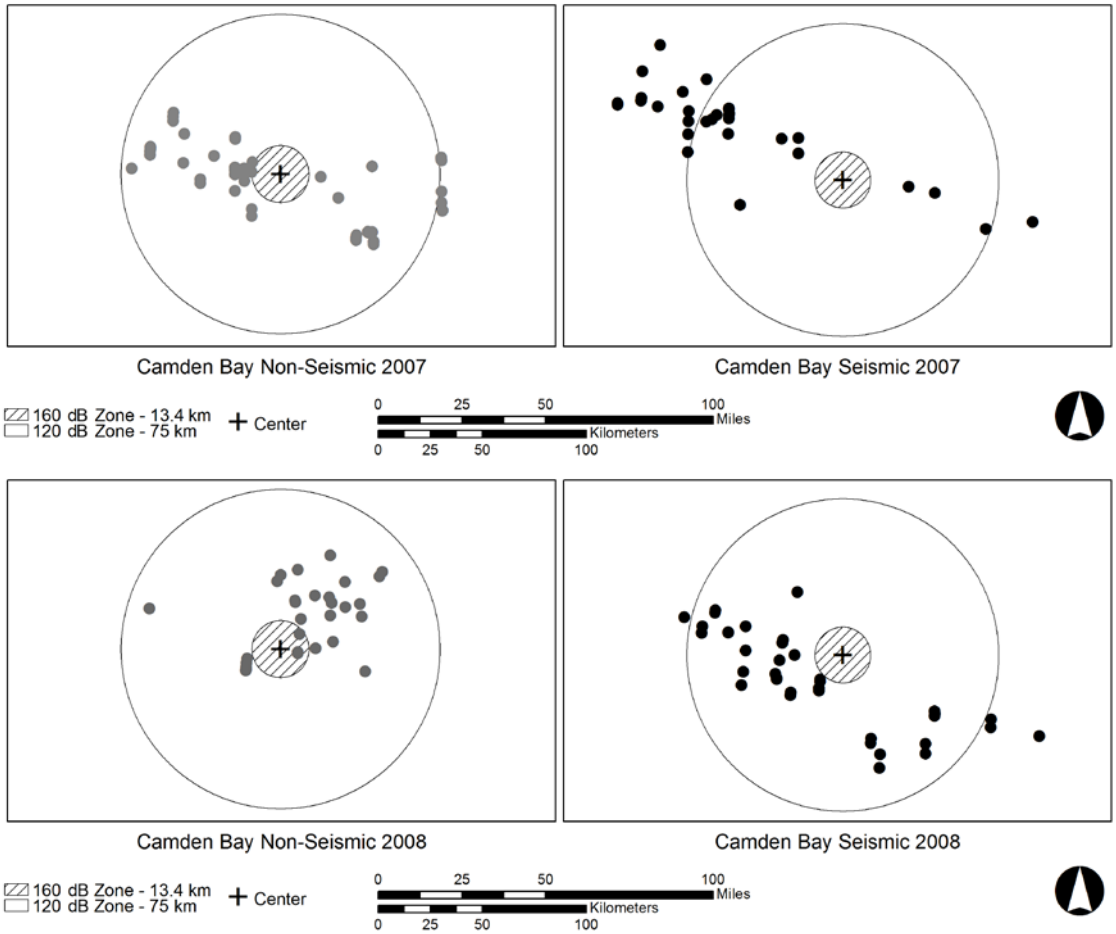


FIGURE 6.9. Aerial sightings of bowhead whales, standardized in a Cartesian coordinate system relative to the center of the seismic survey area during periods when the seismic vessel was not shooting seismic pulses (left panels) or the nearest active seismic vessel (right panels). The sound pressure level radii estimated from sound source characterization studies are shown at 120 dB re 1 μPa (rms; outer circle) and 160 dB (inner dashed circle), for Camden Bay during 2007 (upper panels) and 2008 (lower panels).

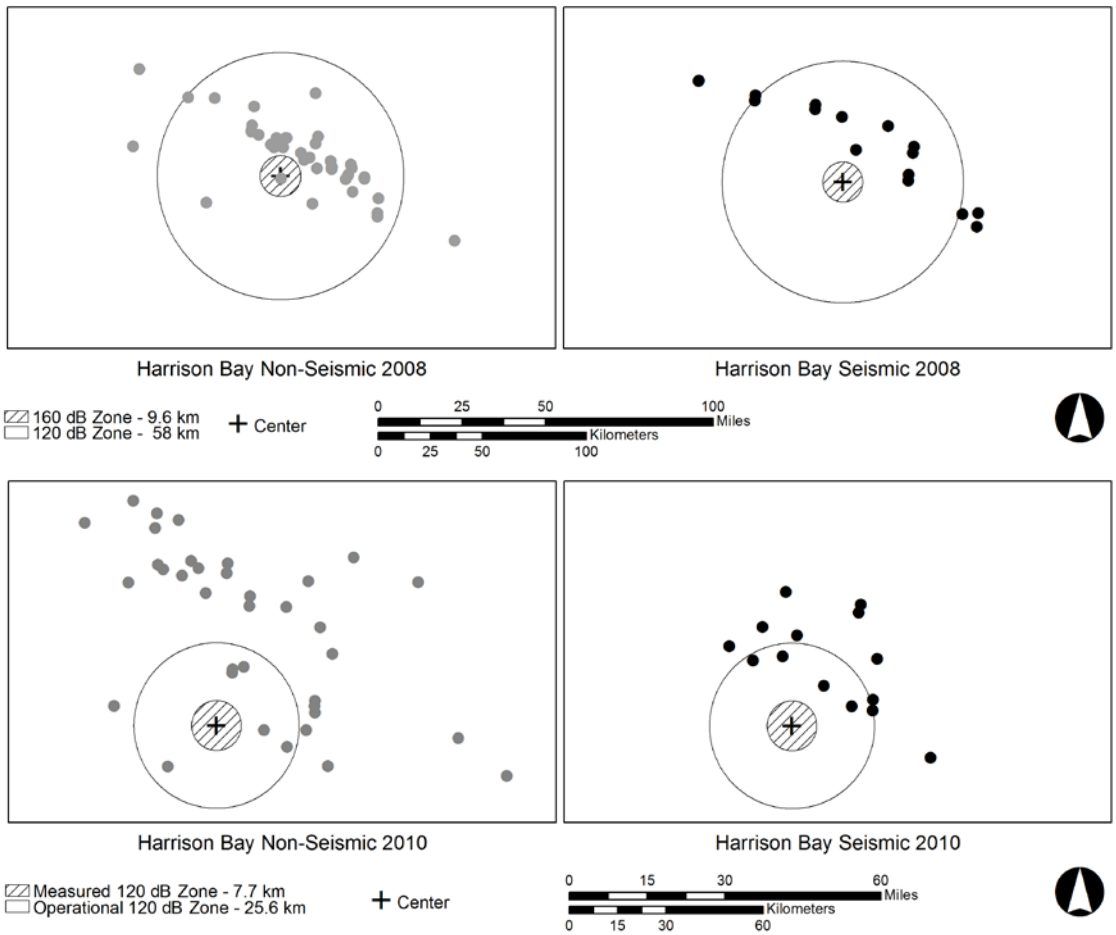


FIGURE 6.10. As per Figure 6.9, but showing sightings data relative to seismic activity in Harrison Bay during 2008 (upper panels) and 2010 (lower panels).

Figures 6.9 and 6.10 do, however, provide a general visual appraisal of the fact that any deflection around Shell's seismic activities was not driven by an avoidance by the whales to received levels as low as 120 dB re 1 μPa (rms SPL). For example, Figure 6.9 shows a 120 dB circle 75 km (47 mi) from the seismic ship. This is the estimated 120 dB radius obtained for the *Gilavar* (3147 $in^3$ array) in 2007, and is used instead of the smaller 2008 value (58 km [36 mi]) for the sake of precaution. If the received levels measured at the DASARs in 2008 are taken into account (explained in the footnote on the previous page), the received level at 75 km (47 mi) would be closer to 125 dB and the 120 dB circle would be placed about 100 km (62 mi) from the seismic ship. All of the whale sightings during seismic in 2008 (bottom right in Fig. 6.9) and all but 5 or 6 in 2007 (top right in Fig. 6.9) would be inside the empirical 120 dB radius measured at the DASARs. These figures therefore offer no evidence for a uniform offshore deflection around the 120 dB radius of estimated received levels.

Based on the more detailed analysis of aerial sightings, feeding bowheads appeared to tolerate seismic sounds until levels approached the estimated value of 150 dB (Koski et al. 2009); the authors did not have sufficient survey effort to evaluate tolerance to higher exposure levels. Further, given observations from the active vessels, some feeding whales appear to have tolerated even higher levels. One group of three whales tolerated received levels of seismic sounds which could have been near ~180 dB re 1 μPa (rms SPL) and eight groups (12 individuals) tolerated levels likely >170 dB. The latter levels

are much higher than the 120–130 dB threshold for avoidance by migrating bowhead whales observed during seismic operations near the same location in 1996–98 (Miller et al. 1999). Koski et al. (2009) concluded that bowhead whales will tolerate higher levels of airgun sounds when feeding than when travelling. Similar tolerance to seismic exploration has been seen in the summer feeding areas in Canadian waters (Miller et al. 2005; Richardson et al. 1987).

## *Observations around the 2012 Offshore Industry Activities*

The presentation of the 2012 observations and various offshore activities are organized into a series of maps. Most maps cover a period of nine days. The time periods covered at the beginning and end of the season were allowed to be slightly longer though, because observational effort (e.g., acoustic instrument deployment) and offshore activities were not as uniform during the tails of the season.

The nine-day length for each of these snap-shots is somewhat arbitrary, but consideration was given to several important factors, including the desire to isolate key offshore activities. Examination of vessel activity logs and soundscapes showed that using longer time periods would result in several major offshore activities getting included in the same time period. This would complicate the interpretation of patterns in bowhead distribution around different activities. Likewise, it is important that the periods all be of the same length, particularly while the acoustic recorders were deployed, to allow for comparisons of call counts between periods.

### *Alaskan Beaufort Sea: 2012 Observations*

*15 August–24 August, 2012:*

The first period of the Beaufort survey season, shown in Figure 6.11, involved the deployment of the DASAR recorders (16 August–21 August) and two days of aerial survey effort (15–16 August). Ice was mostly gone from the area delimited by the DASAR arrays, with a few remaining patches at 10–30% ice coverage. During this period the *Norseman II* (tracks not shown in Fig. 6.11) was active throughout the area deploying the DASARs. There was also other vessel activity, notably: the *Nordica*, *Aiviq* and *Kulluk* transited to and from the area and installed the buoyed anchors (used to moor the drillship) on 18–22 August. Anchor handling generated some of the highest received levels of the season at nearby DASARs. Figure 6.12, originally presented in Chapter 4, shows a soundscape for the Beaufort Sea study area during anchor handling. This soundscape is produced by modeling sound level data collected at all the DASARs during the period of interest. It shows relatively high received levels of sound (130 dB re 1 μPa and higher) several km from Sivulliq. Calls from bowhead whales in that area, if present, would likely have been masked by the high background levels and not been detected on nearby DASARs. Nevertheless, at DASARs farther from Sivulliq, such as those at site 2, masking should not have been a problem. Bowhead calls were detected near site 2, but not nearly as many as were localized at site 5 (Fig. 6.11). Recently documented traditional knowledge and previous scientific studies indicate a feeding area to the east of Kaktovik (Richardson and Thomson 2002; Huntington and Quakenbush 2009). It is unknown whether the call detections near site 5 shown in Figure 6.11 might have been associated with feeding whales east of Kaktovik, late-summer or early-fall migrants, or some combination.

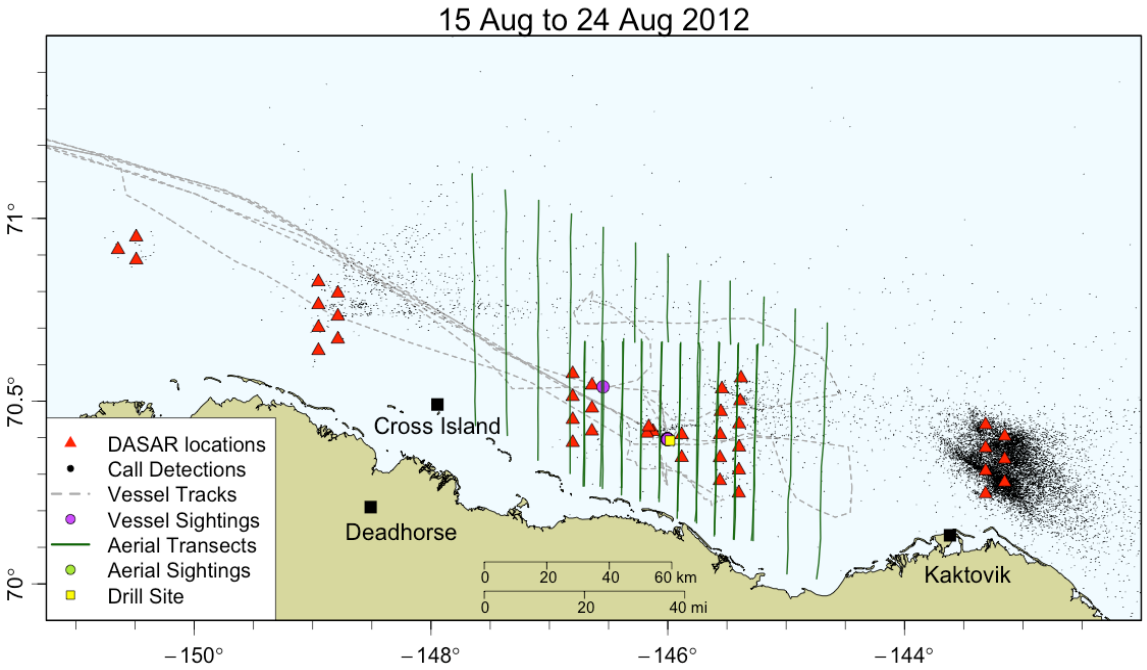


FIGURE 6.11. The vessel, aerial, and acoustic data for 15–24 August 2012.

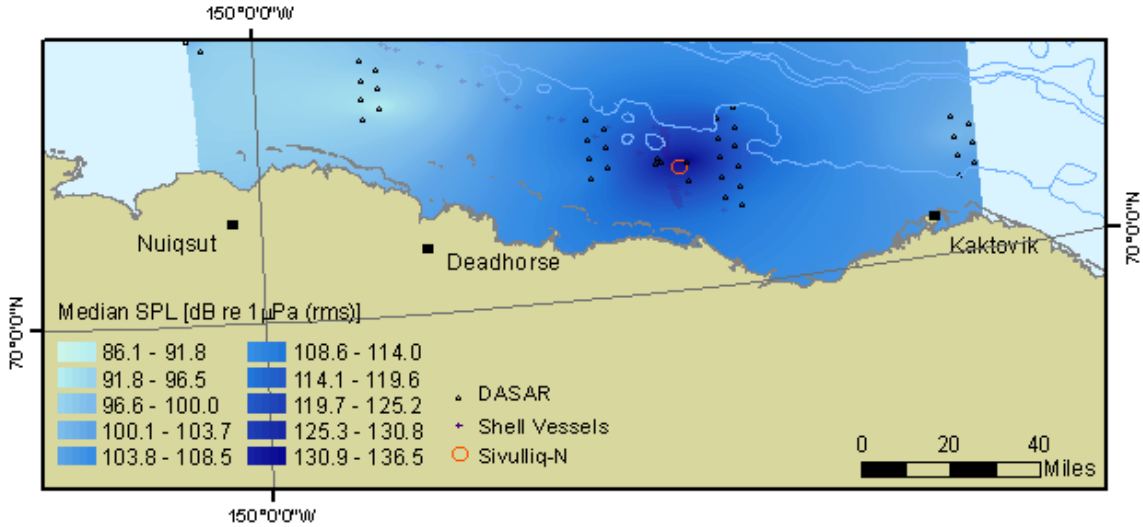


FIGURE 6.12. Soundscape for the Beaufort Sea from available DASAR data during a window of anchor setting activities at Sivulliq-N, 18 August 21:30 to 22 August 23:57 (AKDT).

There were two vessel sightings of bowhead whales (Fig. 6.11), one in the immediate vicinity of where the drill site would be located later in the season. Aerial survey coverage was good[9], but there were no bowhead whale sightings, suggesting bowhead densities were low prior to anchor handling. The call detections shown in Figure 6.11 need to be interpreted with some caution, because the DASARs at different sites were deployed on different dates. Site 4 was deployed first (16–17 August), followed by site 2 (18 August), site 3 (19 August), site 5 (20 August), and site 1 (21 August). Despite being deployed next to last, site 5 had a large number of call detections compared to any of the other sites. Neither the aerial, vessel, or call location data suggest that there were high densities of bowhead whales in the study area west of Kaktovik during 15–24 August. This is consistent with the majority of the population being located east of the study area during the summer.

*25 August–2 September, 2012:*

This period covers the start of the 'whaling blackout' and whaling effort at Cross Island. There was no vessel activity associated with Shell's drilling operations in the study area, as shown by the lack of vessel tracks in Figure 6.13. Based on recorded GPS tracks from where the Cross Island whalers have typically scouted (Galginaitis 2013 and references therein), the operational decision was made that the aerial survey would not fly the two westernmost track-lines during the blackout, in order to avoid potential disruption of whaling activities by industry-sponsored aerial surveys. Scouting at Cross Island started on 1 September (in poor sea state conditions; Galginaitis 2013). Except for a few small remnant chunks in southeastern Camden Bay, the study area was ice-free and remained so until new ice started to form in October. Aerial surveys were conducted on 25 and 29 August. Sightings were made in the eastern part of the survey area on 25 August (weather was uniformly poor on 29 August). Poor weather conditions (low clouds and high sea states) farther offshore during those flights precluded any useable aerial effort in the offshore area north of the drill site. Compared to the previous period, the numbers of localized whale calls were higher at all sites except site 5. This matches expectations based on the timing of the westward migration of bowhead whales, which generally picks up in late August and early September (Moore and Reeves 1993).

In contrast to the soundscape shown for 15–24 August (Fig. 6.12), which included some of the highest sound levels of the season, the soundscape for 25 August–2 September, shown in Figure 6.14, includes some of the quietest times of the season. Received levels were generally below 105 dB re 1 μPa (rms).

[9] Aerial survey effort is only possible during periods of favorable weather. During periods of poor weather or low ceilings, aerial surveys are not flown, or daily survey effort is limited.

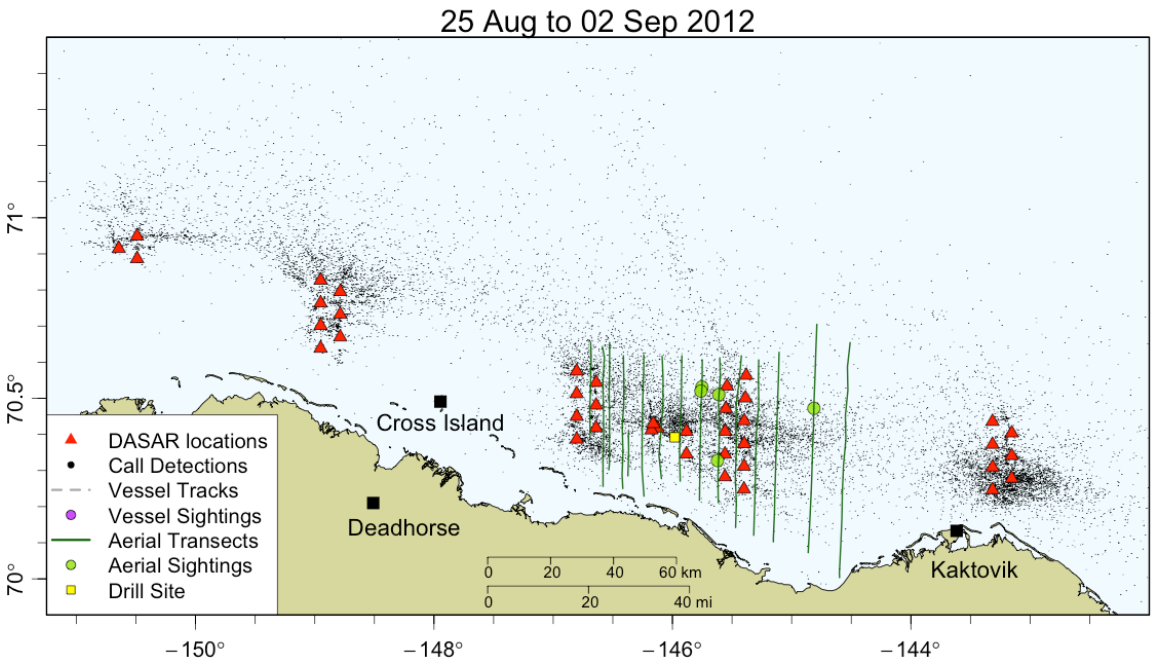


FIGURE 6.13. The vessel, aerial, and acoustic data for 25 August–2 September 2012.

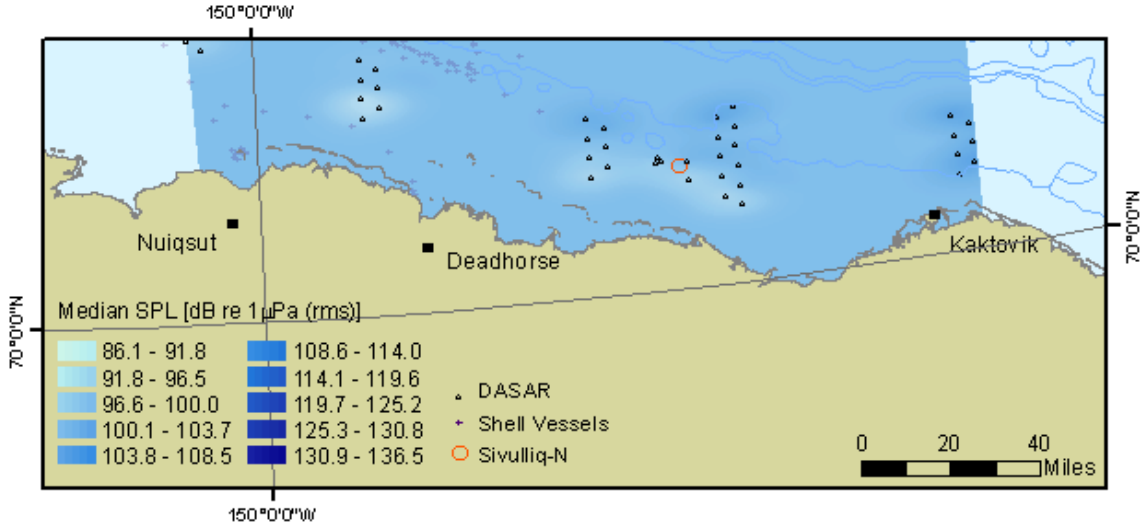


FIGURE 6.14. Soundscape for the Beaufort Sea from available DASAR data during a window of no activity at Sivulliq-N, 24 August 09:27 to 20 September 12:00 (AKDT).

*3 September–11 September, 2012:*

This period coincides with the bulk of the Cross Island whaling season. Whales were landed on 5 September, 10 September (two whales), and 12 September. The whalers stated that they had been successful in finding whales because Shell was not working during the hunt, emphasizing that the potential for vessel traffic to disrupt Cross Island whaling remains a key concern for Nuiqsut whalers (Galginaitis 2013). Some vessels were on standby during this period to the north of DASAR site 1, as shown by the vessel tracks in the northwestern part of the study area in Figure 6.15. Numbers of call localizations further increased during this time period. Note that there were relatively fewer calls localized offshore of the arrays (and higher densities of calls within the arrays) despite the lack of industry activity east of Harrison Bay.

Aerial surveys occurred over three days (9–11 September) and sightings matched the location of the main axis of acoustic call detections (Fig. 6.15). Unfortunately, the aerial effort was again curtailed by low ceilings and higher sea states in the offshore portion of the survey area. Likewise, as mentioned above, there was no aerial effort over the westernmost two transect lines, out of deference to Cross Island whaling. Kaktovik landed the first whale of its season on 5 September. Thereafter, a death in the community and windy weather resulted in the season being extended longer than usual, with a period of nearly three weeks when no hunting effort took place (Suydam et al. 2013).

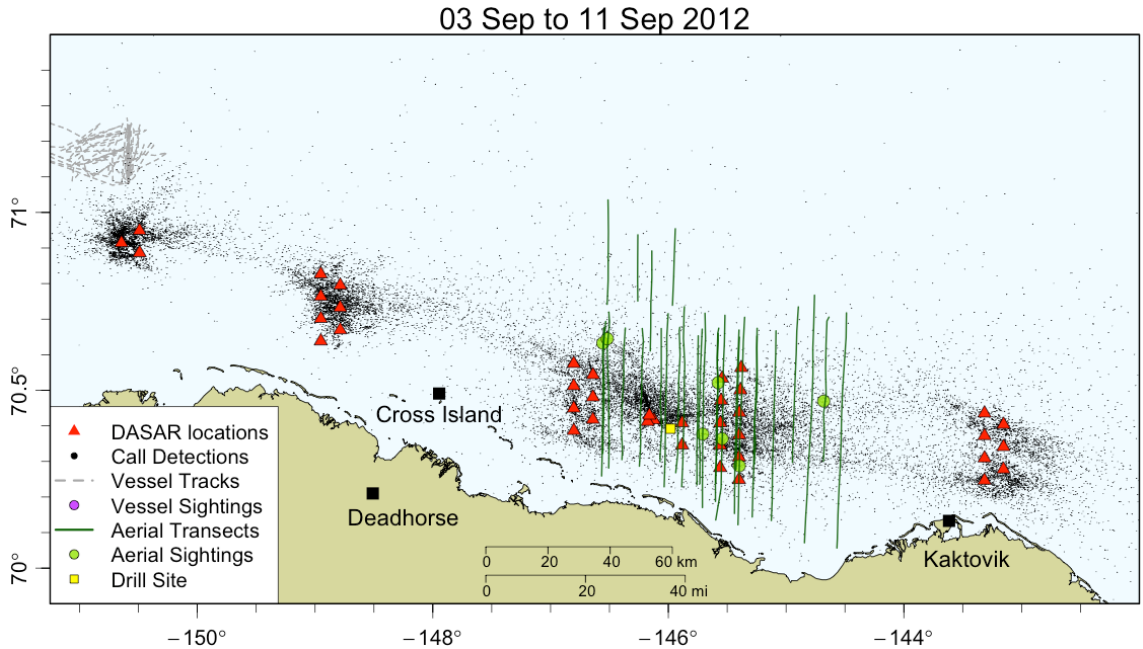


FIGURE 6.15. The vessel, aerial, and acoustic data for 3–11 September 2012.

*12 September–20 September, 2012:*

This period marked the bulk of the observed westward fall migration through the study area, based both on acoustic localizations and aerial sightings (Fig. 6.16). On the first day of this period the fourth and final whale was landed at Cross Island. Shell's vessel tracks while on standby can again be seen in the northwestern corner of Figure 6.16. There was essentially no other vessel activity associated with Shell's drilling fleet in the study area prior to 20 September. On that day, the *Aiviq*, *Warrior*, and *Nanuq* were involved in towing the *Kulluk* to the drill site. During that transit, several bowhead whale sightings

were made by PSOs onboard the vessels. The vessel tracks approaching the drill site from the north in Figure 6.16 correspond to the *Sisuaq's* approach to the drill site area on 20 September. Sighting rates for the aerial surveys (15 and 18–20 September) were high during this period (Brandon and Koski 2013) and overlapped with the highest densities of localized calls in the center of the study area, near the DASARs. No aerial sightings were made on the more offshore transect lines. A second whale was landed at Kaktovik on 20 September.

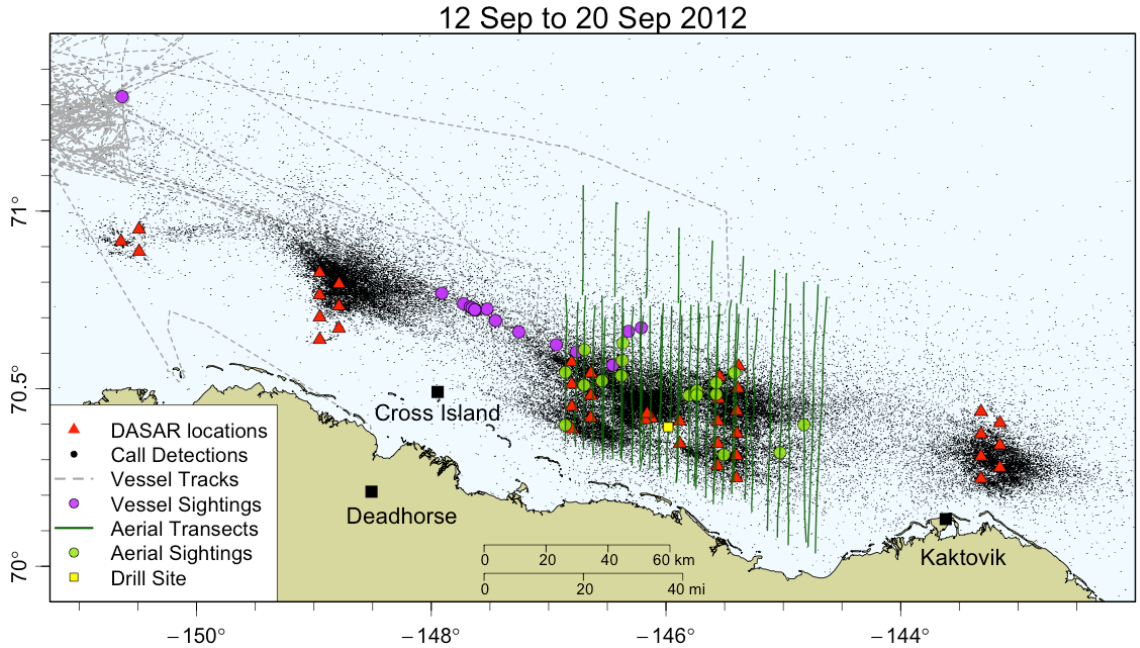


FIGURE 6.16. The vessel, aerial, and acoustic data for 12–20 September 2012.

*21 September–29 September, 2012:*

The observations from this period, shown in Figure 6.17, are particularly interesting for several reasons. First, this period includes anchor handling (21–27 September). The soundscape corresponding to that activity, also presented in Chapter 4, is shown in Figure 6.18. Received levels of sound were similar to those recorded during anchor handling on 18–22 August (Fig. 6.12, above). The peak of the bowhead migration past Prudhoe Bay is often close to 20 September (Blackwell et al. 2007). Based on the call localization maps for this and the previous period, it appears the peak in 2012 was right before rather than right after 20 September. The decline in call rates was most notable at and between DASAR sites 2 and 4 (Figs. 6.16 and 6.17). Nevertheless, because of the anchor handling activities taking place during 21–27 September, it is possible that some of the potential calls near Sivulliq (between sites 3 and 4) were not detected because of masking.

Aerial surveys occurred during 25 and 29 September. While the more offshore lines could not be surveyed because of weather and low ceilings, there appeared to be a nearshore shift in distribution at this stage in the season (Brandon and Koski 2013). When presented jointly, the aerial, vessel, and acoustic data offer some support for the possibility that the distribution of bowhead whales during this time period was more nearshore—perhaps as far east as Kaktovik (or farther), continuing nearshore across Camden Bay and then moving away from the coast again towards DASAR site 2. At present, there is no quantitative analysis, based on jointly analyzing these data sets. Brandon and Koski (2013) examined the

median distance from shore for aerial sightings, and found statistical evidence consistent with a nearshore shift later in the season. Based on aerial observations of behavior nearshore, Brandon and Koski (2013) presented a hypothesis that an increase in nearshore prey availability and foraging might have occurred during the second half of the fall migration period.

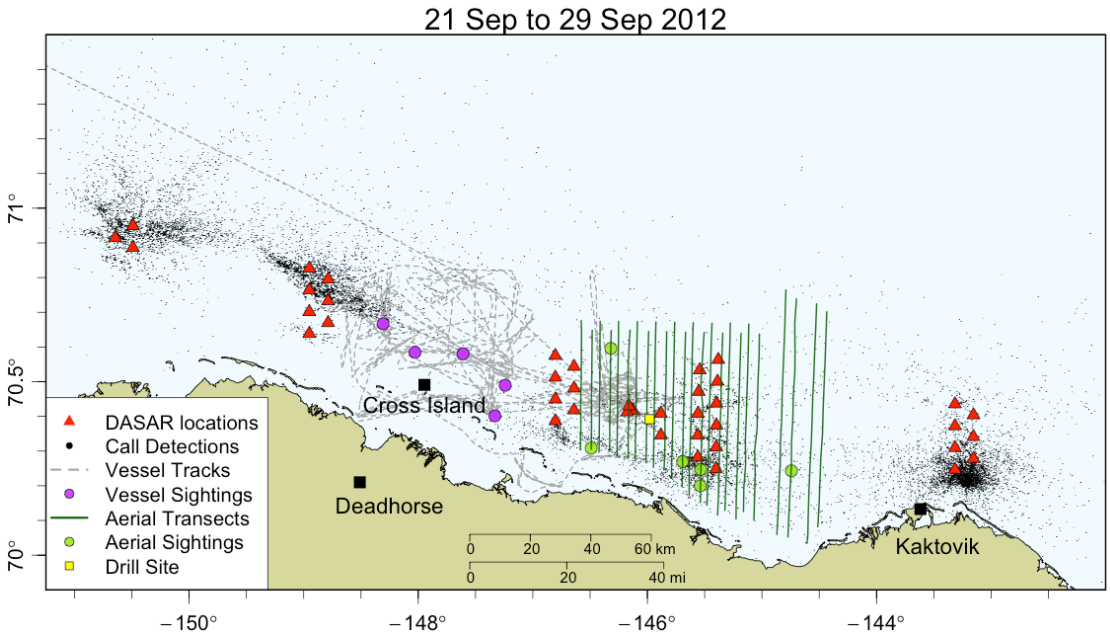


FIGURE 6.17. The vessel, aerial, and acoustic data for 21–29 September 2012.

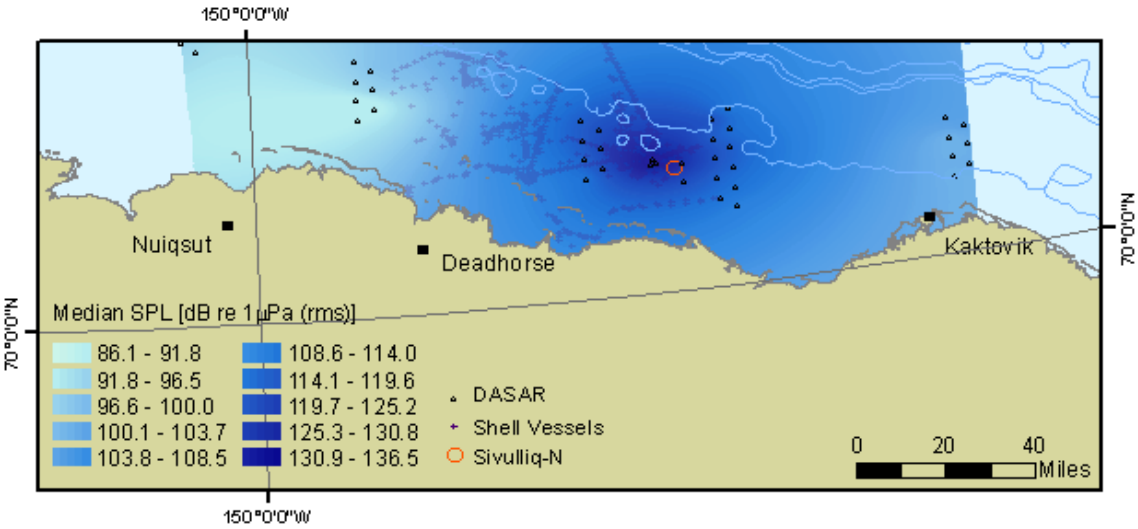


FIGURE 6.18. Soundscape for the Beaufort Sea from available DASAR data during a window of anchor connection activities at Sivulliq-N, 21 September 12:34 to 27 September 17:27 (AKDT).

The low densities of localized calls at sites 3 and 4 could result from a behavioral response to vessel or anchor handling activities, or could be due to masking of the calls by these anthropogenic sounds. Analyses aiming to answer these questions are ongoing.

*30 September–8 October, 2012:*

This period, shown in Figure 6.19, is notable for including the onset of active drilling operations, which occurred during 3–8 October. Aerial survey coverage was good, with surveys on 30 September, 2–4 and 6 October. Sightings rates were relatively low, indicating that the peak of the migration had passed and/or that this period coincided with a lull in the bowhead whales' pulsive migration pattern (e.g., Blackwell et al. 2007). The majority of aerial sightings occurred in the southern (nearshore) half of the survey area. The animals sighted nearshore did not appear to be engaged in directed travel, but were instead generally observed to have been swimming slowly while turning at the surface. This is consistent with the observed pattern of distribution and behavior from aerial observations during the previous time period, 21–29 September.

Based on the aerial observations, Brandon and Koski (2013) could not rule out the hypothesis that nearshore deflection around drilling was occurring. Behavioral observations during playback experiments to drilling noise (Richardson et al. 1995), indicate that bowhead whales would be expected to exhibit some of the same behaviors (slower swim speeds and turning at the surface) as would be expected when they are foraging. These observations confound inference from the aerial survey observations in this case.

During the first week of October the DASARs were being retrieved, which needs to be kept in mind when making comparisons: Site 1 was retrieved on 3 October, Site 2 on 4 October, Site 5 on 5 October, and Sites 3 and 4 on 6–7 October. DASARs need to be calibrated and retrieved before the ocean starts freezing, or they risk being abandoned and overwintering. This happened in 2007 for four DASARs, which could only be retrieved in August of the following year (Blackwell et al. 2009). Nevertheless, clouds of calls were still localized at the southern ends of sites 3, 4, and 5. The third and final whale of the season was landed at Kaktovik on 2 October (Suydam et al. 2013).

Concurrent with DASAR retrievals in October, five overwintering AURAL recorders were deployed at locations 3D, 4D, and 5D, north of site 2, and between and north of sites 2 and 3 (see Appendix C for 2011 deployment locations). These recorders collected acoustic information during the remainder of Shell's operations in October as well as ION's seismic survey in October and November 2012. As of the writing of this report (summer 2013) the recorders have been retrieved and data analyses have begun.

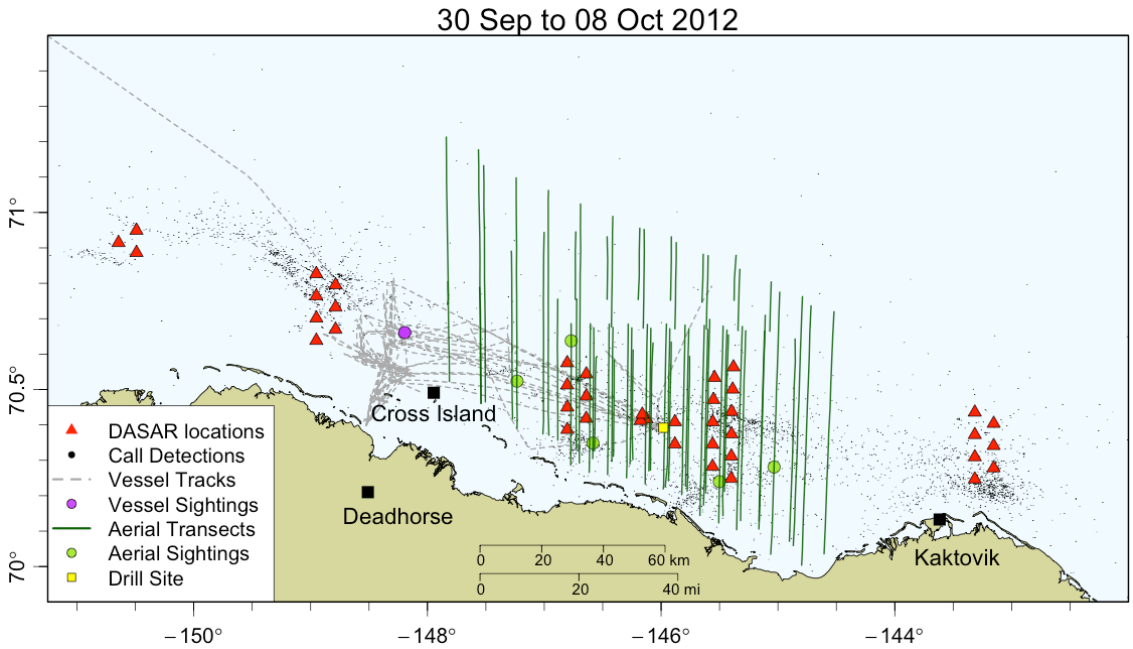


FIGURE 6.19. The vessel, aerial and acoustic data for 30 September–8 October 2012.

*9 October–22 October, 2012:*

Drilling activities continued through this time period, shown in Figure 6.20: vessel activity logs recorded drilling activities during 13–18 October and then again during 21–25 October. DASARs had been retrieved during the prior period, so there are no call localizations for comparison (also note that the 14-day duration of time considered here is longer than the previous default presentation periods of nine days). New ice was forming along the coastline and barrier islands during this time period. Aerial coverage was reasonable, with flights occurring on 14 and 21–22 October (Fig. 6.20). Aerial effort on individual flights was curtailed, however (i.e., <400 km [<249 mi] on any given flight), and effort continued to decline as the season progressed because of weather moving through the area in combination with shortening hours of daylight. The last two flights of the season (25 October and 3 November) were terminated early because of weather. It is noteworthy, though, that the aerial sighting rates were quite high on 21 October, suggesting that a substantial number of bowhead whales were still in the area at that time (Brandon and Koski 2013). That observation is also consistent with ASAMM data, which were collected in the same general area on 21 October (Clarke et al. 2013). Further, the data from this time period suggest that the distribution of bowhead whales in the study area continued to be predominantly nearshore until the end of effective aerial observations.

As drilling operations at Sivulliq were coming to an end, ION conducted SSV measurements of their 4380 in$^3$ airgun array at shallow (~35 m [115 ft]) and deep (~500 m [1640 ft]) water sites near the US-Canada maritime border on 20–23 October. ION used two vessels during their survey; the *Geo Arctic* towed the seismic airgun array while the *Polar Prince* functioned as an escort icebreaker whenever newly forming sea ice was encountered.

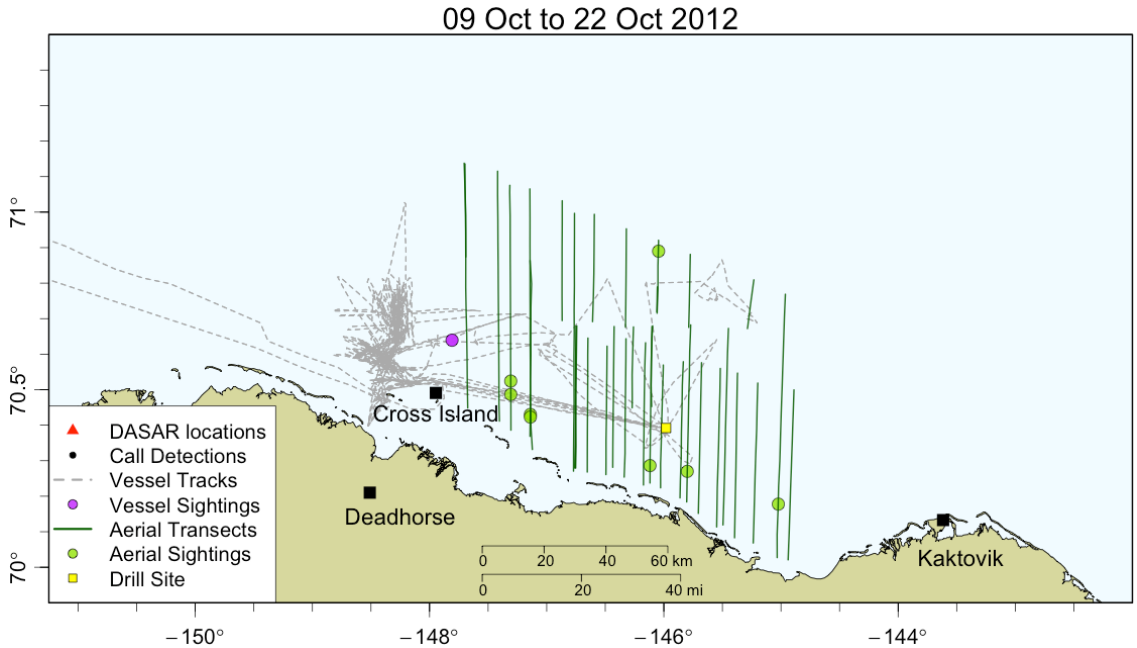


FIGURE 6.20. The vessel, aerial, and acoustic data for 9–22 October 2012.

*23 October–11 November, 2012:*

After concluding the SSV measurements on 23 October, ION began collecting 2D seismic data on 24 October. Seismic survey operations continued in the Alaskan Beaufort Sea until 9 November, during which time there were no bowhead sightings from the vessels (Fig. 6.21). Aerial survey results summarized in the previous section were the last of the season, so there are no additional data from aerial surveys during this time period. Over-winter recorders deployed in early October, when the DASAR arrays were retrieved, collected acoustic data during IONs survey and throughout the rest of the winter and spring of 2013. Those recorders have only recently been retrieved and the data are currently being analyzed.

### *Alaskan Chukchi Sea: 2012 Observations*

*27 July–7 August, and 8–16 August, 2012:*

The beginning of the first period, 27 July, corresponds to the start of vessel operations in the area of interest. Figure 6.22 shows maps for these two time-periods with activities limited to vessel traffic and anchor handling on 8–10 August. There were no aerial surveys during either time period, and the AMAR deployments occurred between 9 and 14 August. Available observations, including vessel tracks, three vessel sightings west of Barrow and the first recorded acoustic calls counts are shown here for completeness, but observational data were generally limited at this stage relative to subsequent time periods.

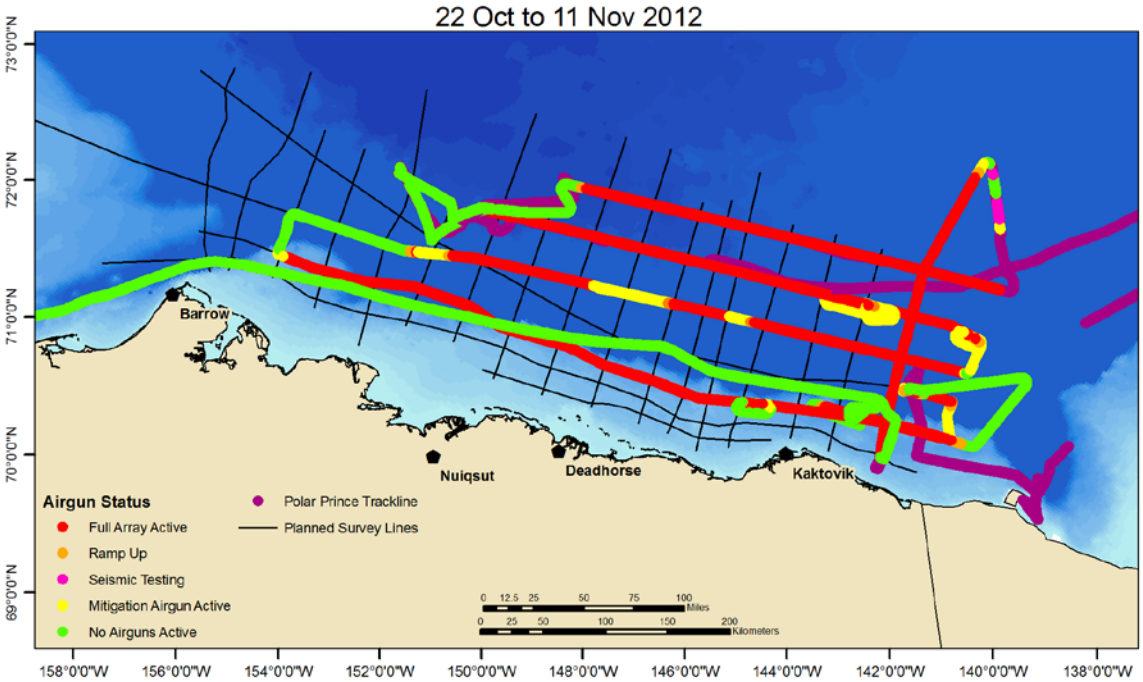


FIGURE 6.21. ION 2D seismic survey activities for 22 October–11 November 2012.

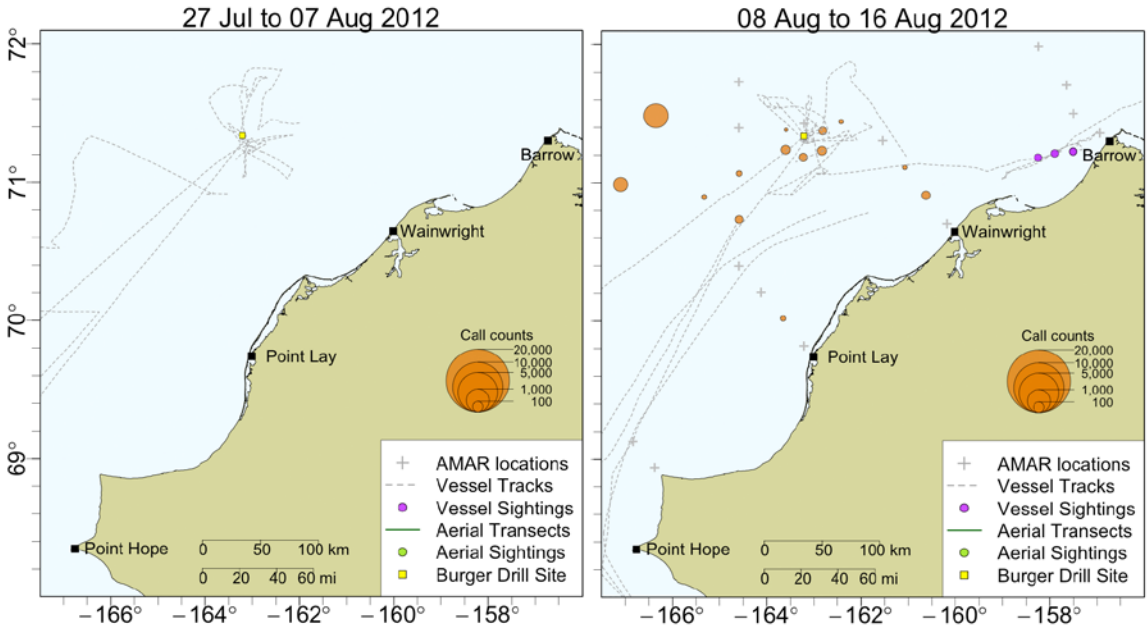


FIGURE 6.22. The vessel, aerial, and acoustic data for 27 July–7 August 2012 (left panel) and 8–16 August (right panel).

*17 August–3 September, 2012:*

The first aerial surveys of the season occurred during this period, shown in Figure 6.23. Three offshore surveys (19, 21 and 28 August) and one nearshore sawtooth survey on 23 August were completed without bowhead whale sightings (Thomas and Bourdon 2013). The lack of aerial sightings during this period is consistent with the ASAMM aerial survey data, which also did not have any sightings during the month of August (Clarke et al. 2013).

It should be noted that the offshore surveys were performed using camera systems on the aircraft. While the preliminary results of those efforts are promising, the effective strip width (area covered) is less than that for PSOs. So, the raw encounter rates implicit in this presentation will be lower than the flights conducted by PSOs (although density estimates from the camera systems are comparable with those from PSO sightings data; Koski et al. *In Prep*).

There were three vessel sightings of bowhead whales north of Wainwright (Fig. 6.23, left panel). These sightings are not unusual, but bear repeating given the increased numbers of bowhead whales detected in the survey area during 2011–2012 compared to 2009–2010, as discussed in the section *Alaskan Chukchi Sea: Large-Scale Patterns*. In addition to the lack of aerial sightings, there were only three isolated acoustic detections at Burger during this period, which suggests the vessel sightings were not indicative of a widespread distribution of bowhead whales in the Chukchi Sea, even at low densities.

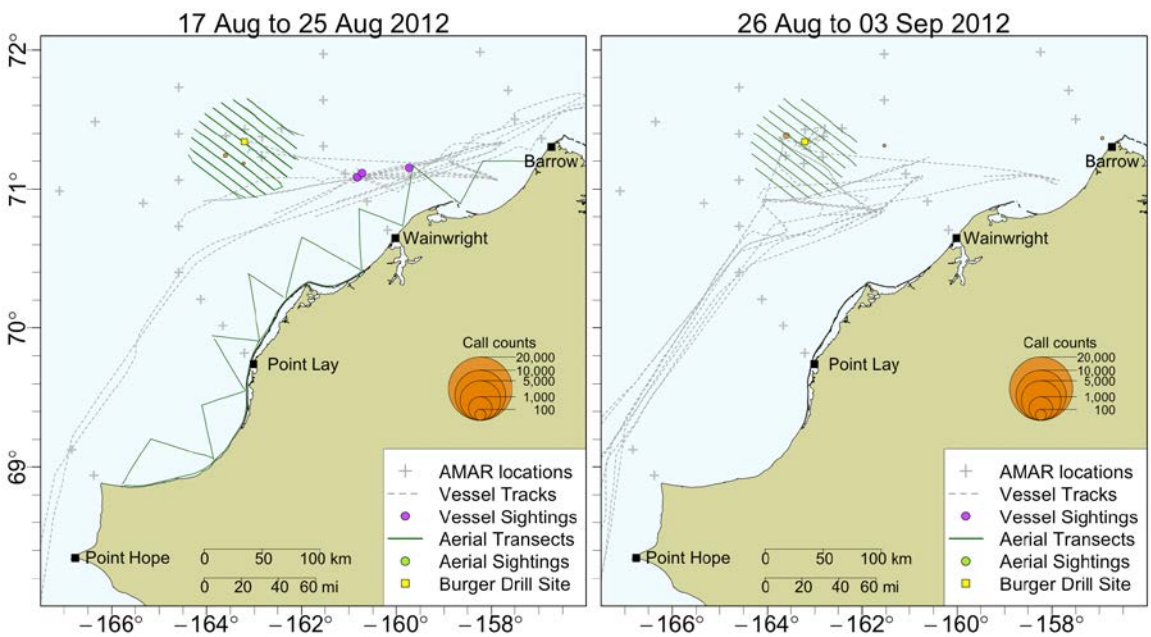


FIGURE 6.23. The vessel, aerial, and acoustic data for 17–25 August (left panel) and 26 August–3 September 2012 (right panel).

*4 September–21 September, 2012:*

During this period, shown in Figure 6.24, two notable offshore activities occurred: anchor handling (6–9 September) and ice management (11–14 September; see the northern vessel tracks in Fig. 6.24, right panel). Because these activities produced some of the highest anthropogenic sound levels of the season, soundscapes for both activities are presented in Figures 6.25 and 6.26, which were introduced in Chapter 4.

Acoustic detections through this part of September were characterized by relatively high call counts off the coast of Wainwright following five days of moderate detections 5 nmi off Barrow. Detections then receded off Wainwright and increased off Barrow and to a lesser extent throughout the rest of the study area, mainly offshore (Fig. 6.24). These offshore detections coincide with an increase in vessel sightings farther offshore during 13–21 September (Fig. 6.24 right panel). Numerous vessels supporting Shell's drilling operations were on standby to the southeast of the Burger drill site, which Delarue et al. (2013) note resulted in higher noise levels at nearby recorders for much of this time period. It does not appear, however, that bowhead whales were actively avoiding that area, given the relatively high number of vessel-based sightings and acoustic detections there (e.g., Fig. 6.24 right panel).

Offshore aerial survey coverage was good during the first half of this time period, with surveys occurring daily during 7–10 September; however, no bowhead sightings were recorded for those surveys during a "slide show review" of the imagery (Thomas and Bourdon [2013] provide details on the image review methodology). This is consistent with the lack of acoustic call detections farther offshore during 4–12 September (Fig. 6.24 left panel). One nearshore aerial survey was flown on 15 September, and the single bowhead sighting from that survey was in the same area north of Wainwright where bowhead whales were detected acoustically and by vessel PSOs (Fig. 6.24 right panel).

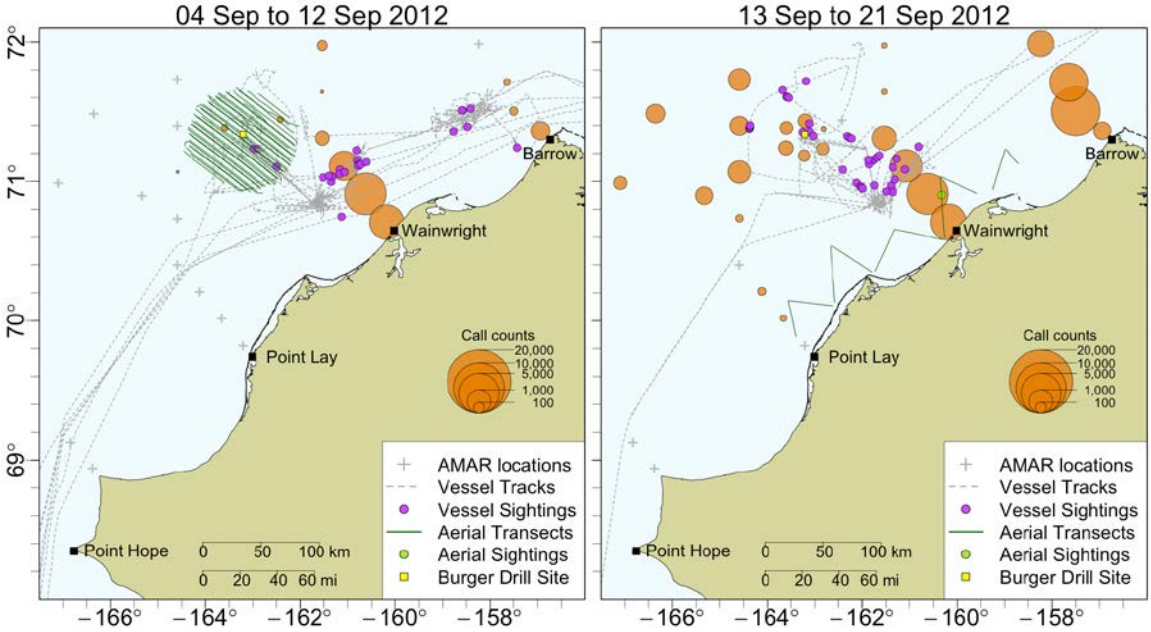


FIGURE 6.24. The vessel, aerial, and acoustic data for 4–12 September (left panel) and 13–21 September (right panel).

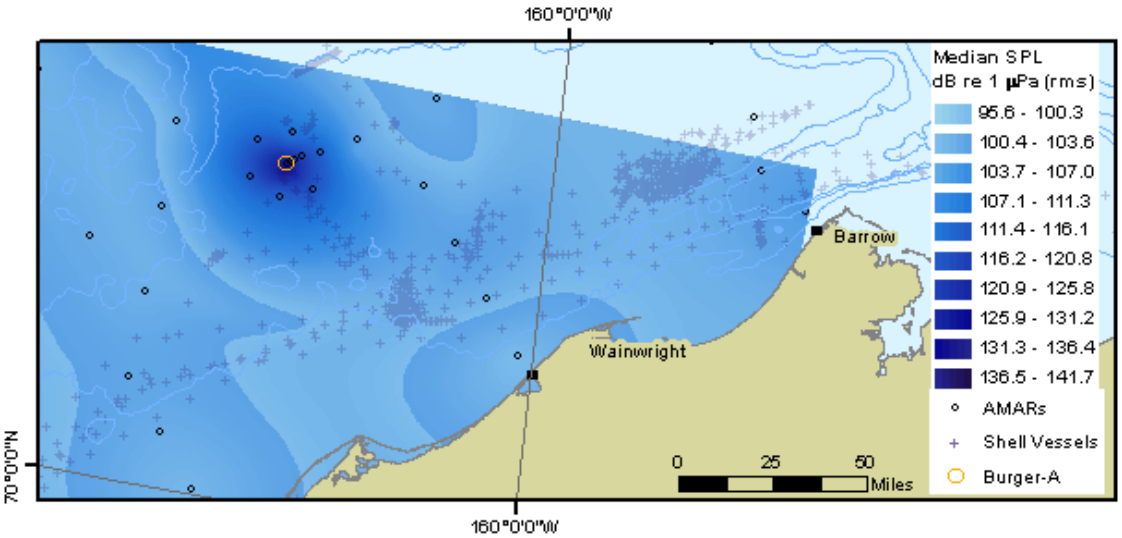


FIGURE 6.25. Soundscape for the Chukchi Sea from available AMAR data during anchor connection activities at Burger-A, 6 September 00:00 to 9 September 04:35 (AKDT).

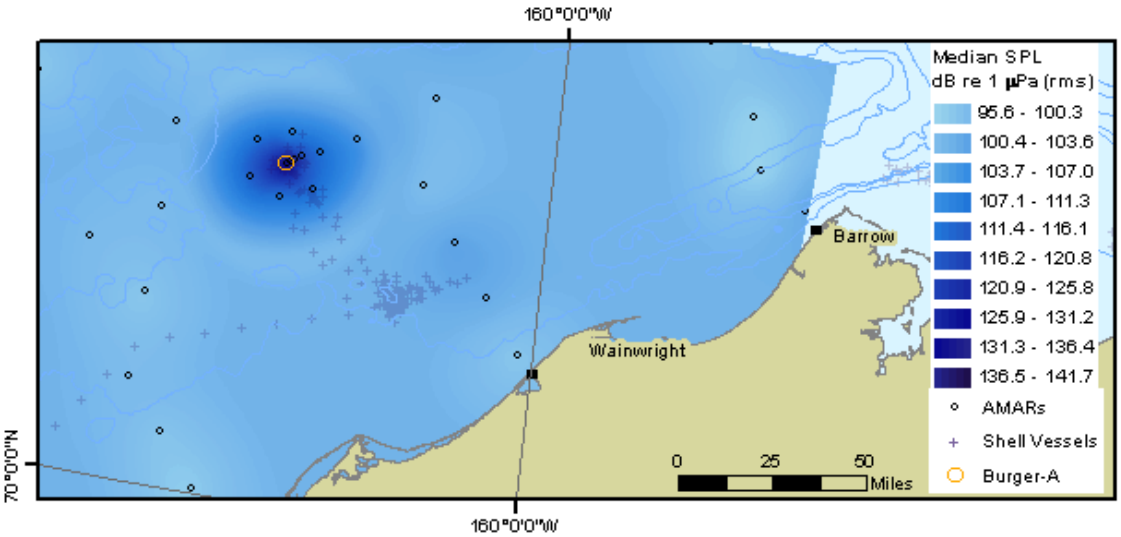


FIGURE 6.26. Soundscape for the Chukchi Sea from available AMAR data during a period of ice management activities at Burger-A, 11 September 16:54 to 14 September 12:21 (AKDT).

*22 September–9 October, 2012:*

This period, shown in Figure 6.27, includes the first successful drilling activities in the Chukchi Sea during 2012 by Shell. An earlier attempt to drill on 9 September was aborted, when the pack ice started shifting south and the drillship *Discoverer* was moved off site. Drilling occurred during 23–26 September. One of the soundscapes from Chapter 4 for drilling activities (mud-line cellar drilling) is shown in Figure 6.28. Received levels near Burger-A were considerably lower than during anchor connecting or ice management shown in Figures 6.25 and 6.26, above.

During late September and early October offshore call counts started to increase, presumably marking the first pulse of calling bowhead whales during the fall migration through the Chukchi. Three

offshore aerial photographic surveys were also completed (26, 29 and 30 September) and the first observed bowhead sightings during the slide show review were recorded on 29 September (Fig. 6.27 left panel). Nearshore aerial sightings of bowhead whales indicate that during the time period 22–30 September, bowhead whales were distributed between Wainwright and Barrow. This is consistent with sightings in that area by ASAMM during the second half of September (Clarke et al. 2013).

The second half of this period is interesting because the 1–9 October period marked the peak of offshore call counts, with the highest counts north of 71°N and almost no detections south of 71°N, except off Wainwright (Fig. 6.27 right panel). It is important to note, however, that retrieval of the AMARs started on 5 October and continued through 14 October. The one offshore aerial survey that occurred, on 6 October, also recorded a peak number of sightings (*n*=5), and all of them were in the northern half of the survey area.

Nine bowheads were landed at Barrow between 1–6 October (the other was landed on 19 October), and as reported by Suydam et al. (2013), whalers noted the whales were further offshore than usual. This is consistent with the results of Clarke et al. (2013) and there also appears to be some indication of this pattern in the call count data (Fig. 6.27 right panel).

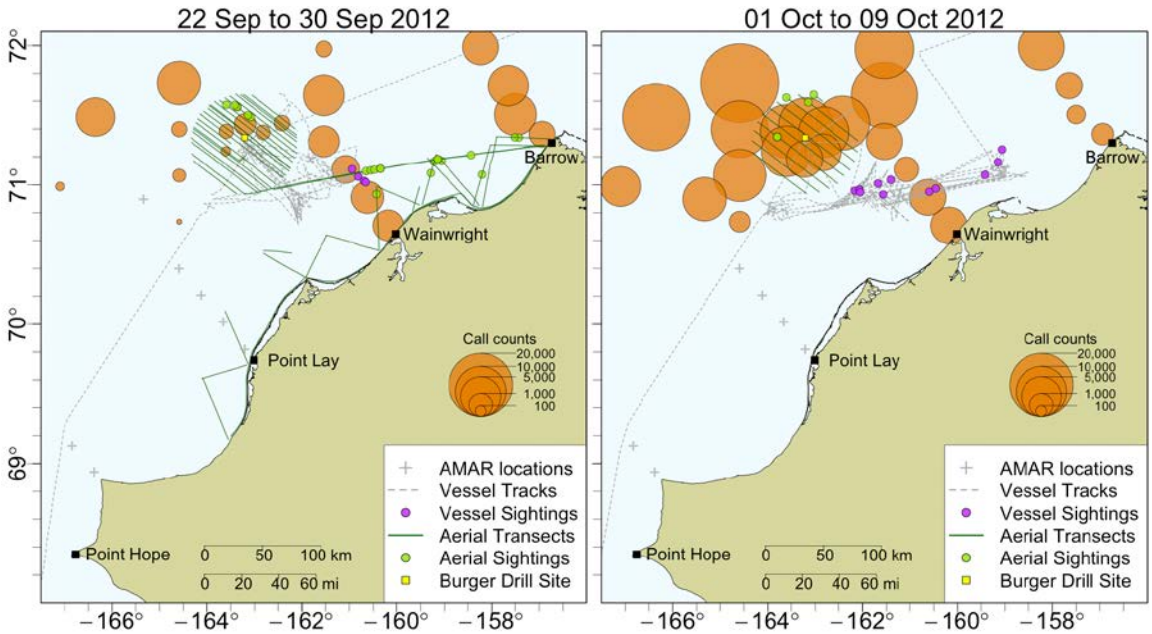


FIGURE 6.27. The vessel, aerial, and acoustic data for 22–30 September (left panel) and 1–9 October (right panel).

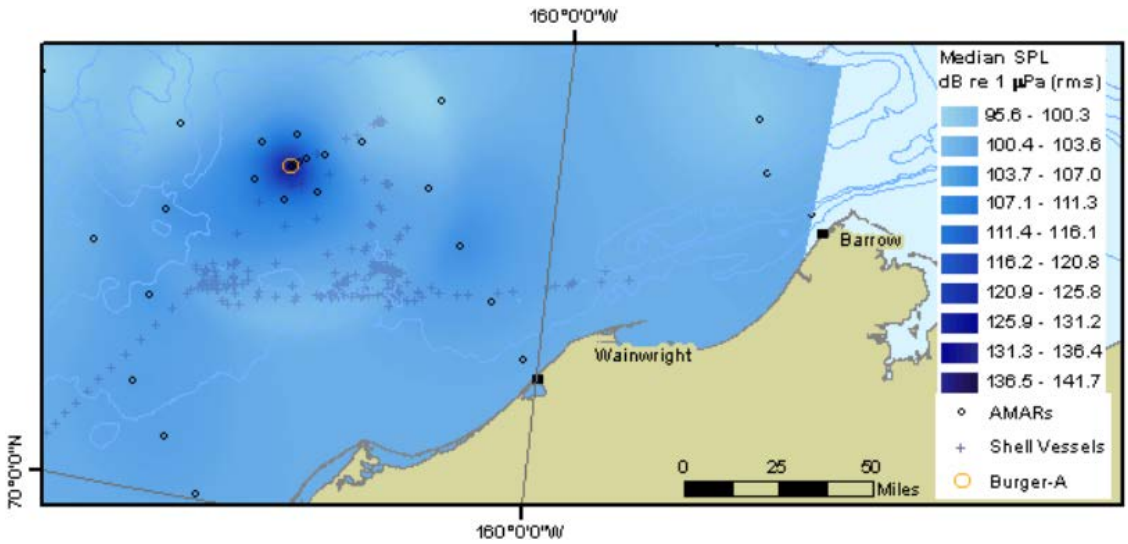


FIGURE 6.28. Soundscape for the Chukchi Sea from available AMAR data during mud-line cellar drilling at Burger-A, 2 October 04:00 to 5 October 16:00 (AKDT).

*10 October–10 November, 2012:*

Retrieval of the AMARs was completed during the first part of this time period, so there are only call count data through 14 October. Hence, it is not possible to make a comparison between call count totals from the previous time periods. Vessel sightings indicate that bowheads were still distributed northwest of Wainwright during 10–18 October (Fig. 6.29 upper left panel). Drilling was recorded in the vessel activity logs as occurring during 16–19 October. During that time, there were two offshore aerial surveys (18–19 October), and bowheads were sighted on both days (Fig. 6.29 both upper panels). Additional offshore survey effort on 22–23 October did not result in any bowhead sightings, but there was one sighting during the last offshore survey of the season on 27 October. Nearshore survey effort during 24–26 October did not result in any bowhead whale sightings (Fig. 6.29 upper right panel). Nevertheless, vessel sightings indicate that there were bowhead whales still present between Barrow and Wainwright into early November (Fig. 6.29 upper right panel and lower left panel).

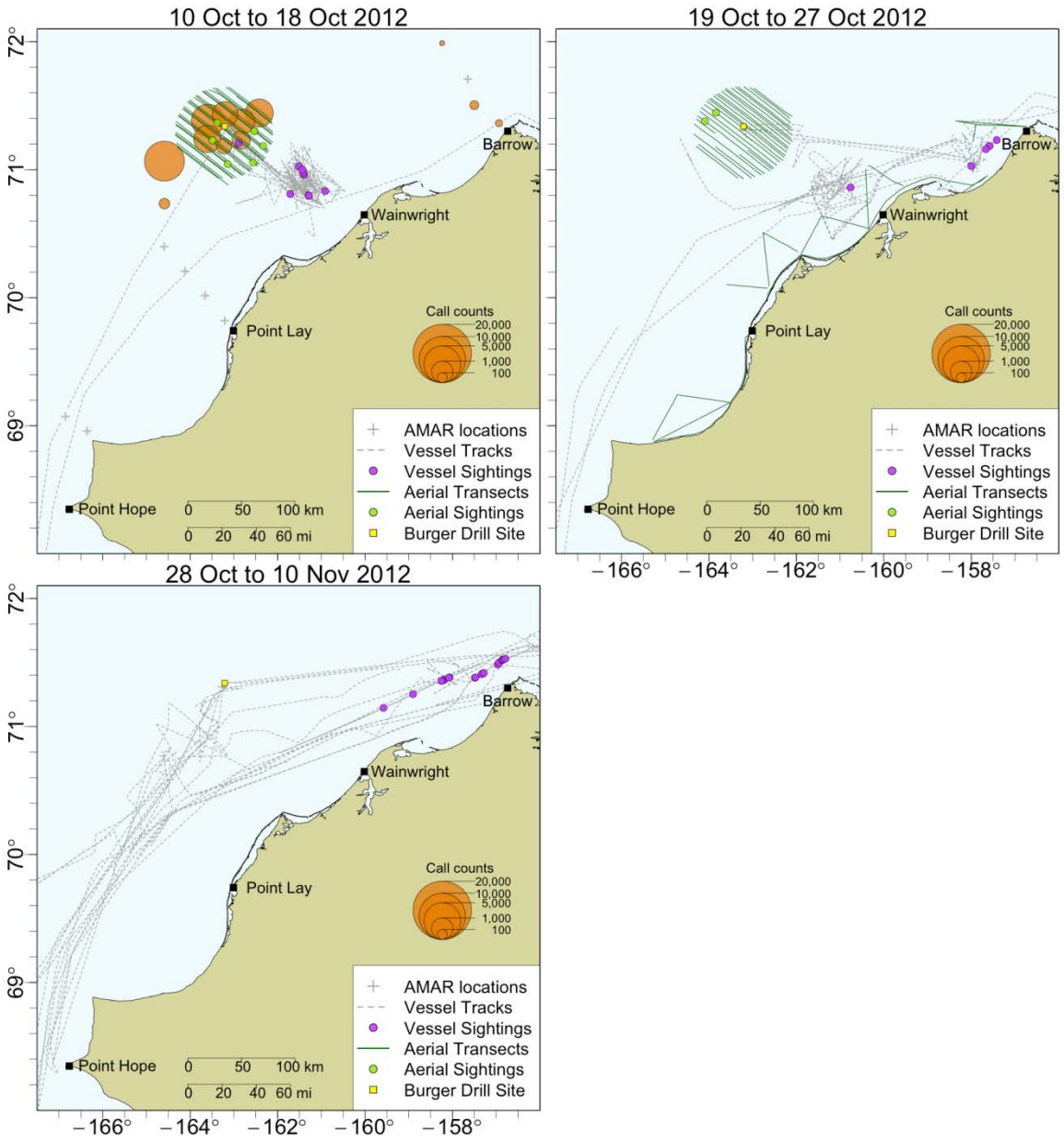


FIGURE 6.29. The vessel, aerial, and acoustic data for 10–18 October (upper left panel), 19–27 October (upper right panel) and 28 October–10 November (lower left panel).

*12 November–16 November, 2012:*

ION's survey vessels entered the Chukchi Sea on 12 November and transited to a short survey line in the north-central Chukchi Sea near the maritime border with Russia (Fig. 6.30). Seismic survey operations were only conducted on 14 and 15 November, after which the vessels began transiting south towards the Bering Sea. PSOs aboard the two vessels recorded 38 bowhead sightings of 80 individual whales on the 14 and 15 November, with one additional sighting on 16 November, just south of Point Hope. Ice conditions in the area included pans of newly forming sea ice mixed with patches of open-water and total ice cover from 40–80%. These sightings, in conjunction with observations from Shell vessels earlier in November between Barrow and Wainwright, as well as the 21–22 October aerial

sightings in the Beaufort Sea (Clarke et al. 2013), suggest that a pulse of migrating bowheads may have occurred quite late in 2012. Alternatively, this portion of the north-central Chukchi Sea may have continued to be a potential feeding "hotspot" as suggested by the persistent presence of satellite-tagged bowheads in the area through October and early November (ADFG 2012).

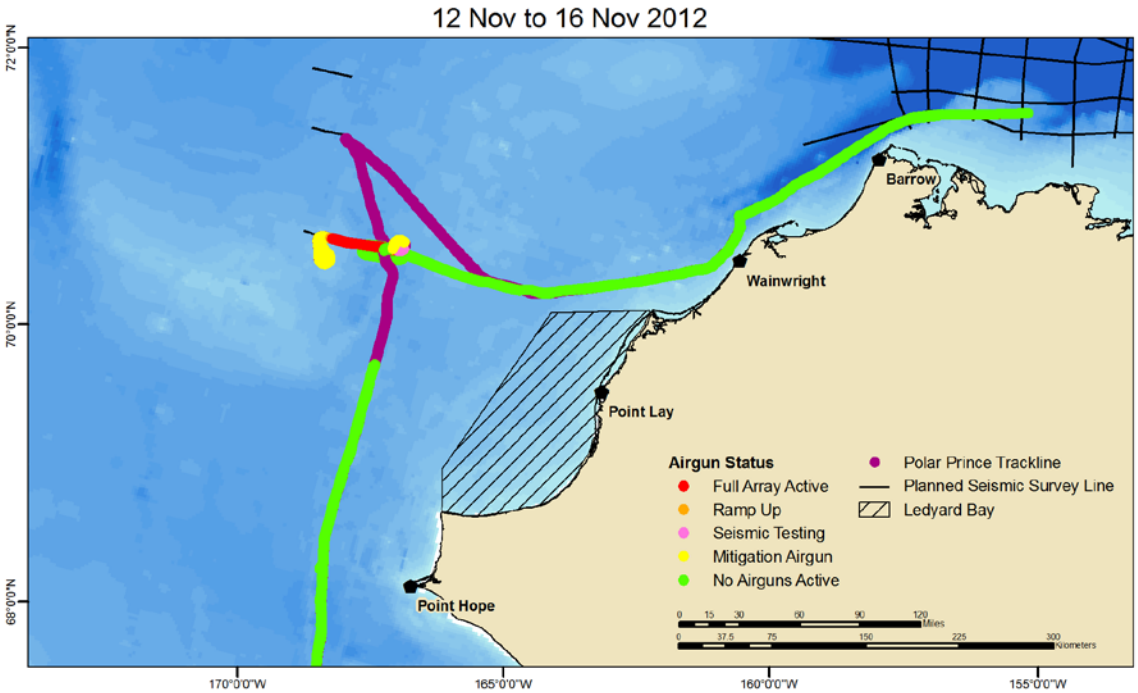


FIGURE 6.30. ION 2D seismic survey activities for 12–16 November 2012.

## *Population Level Observations: Abundance and Trends*

The most recent abundance estimate (Givens et al. 2013) indicates that this population of bowheads has been experiencing an annual increase rate of 3.7% (95% confidence intervals: 2.8%, 4.7%) during a period of exponential[10] growth that has been ongoing since at least the late 1970s. The 2011 estimated abundance 16,892 (95% confidence intervals: 15,704; 18,928), is up from 10,545 in 2001 (95% confidence intervals: 7,100; 9,400; Zeh and Punt 2005). The time series of abundance estimates indicates an approximate 50% increase in total abundance during the last ten years, and a doubling in abundance from the early 1990s.

Given the latest abundance estimate, and taking into account the results of the most recent stock assessments that integrated various sources of independent information on population dynamics and historical catches (e.g., Brandon and Wade 2006; Punt 2006; Brandon and Punt 2009), it appears plausible that there are currently as many or more bowheads in Alaskan waters than there were before the start of commercial Yankee whaling in 1848. Moreover, the trend in abundance has shown no signs that the increase rate has slowed in recent years.

[10] The annual increase rate has been estimated by fitting a linear regression to the logarithms of the abundance estimates (e.g., George et al. 2004a; Givens et al. 2013).

George et al. (2009) have found some evidence that the body condition of animals killed in the subsistence hunt is related to sea ice conditions in the eastern Beaufort Sea during the summer and fall. Those findings are consistent with the conceptual model of Moore and Laidre (2006) that more open water may have a beneficial effect on body condition of bowhead whales, presumably through increases in prey availability and/or abundance. Thus, one hypothesis for the continued increase in BCB bowhead whale abundance is that decreases in sea ice have resulted in an increased carrying capacity of the environment for this population.

Given the life history of bowhead whales and gestational constraints on minimum calving intervals (e.g., Reese et al. 2001), and assuming that adult survival rates based on aerial photo-ID data (Zeh et al. 2002; Schweder et al. 2010) and age-at-maturity have remained stable, the trend in abundance implies that the population has been experiencing relatively high annual calf and juvenile survival rates. This is consistent with documented observations of native whalers around St. Lawrence Island, who have reported not only catching more pregnant females but also seeing more young whales than during earlier decades (Noongwook et al. 2007). It is also interesting to note, with the caveat that sample size was small, that the pregnancy rate from the 2012 Alaskan harvest data indicate that 2013 calf production could be higher than average (George et al. 2004b; George et al. 2011; Suydam et al. 2013).

A change in either calf production or survival rates (or age-at-sexual maturation) of young whales in the future could be indicative of a population level response to anthropogenic stressors, or alternatively, a signal of the seemingly inevitable event that this population approaches the carrying capacity of its environment (Eberhardt 1977). Since the late 1970s and the initiation of surveys for abundance, however, the estimates of population size do not indicate that either anthropogenic (e.g., offshore oil and gas activities, subsistence whaling catch quotas, etc.) or natural factors (e.g., prey availability) have resulted in any negative influence on the BCB bowhead whale trend in abundance.

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# 7. BELUGA WHALES, GRAY WHALES, AND OTHER CETACEANS

## *Beluga Whale in the Chukchi and Beaufort Seas*

The beluga whale (Sisuaq, *Delphinapterus leucas*) has a circumpolar distribution in the Northern Hemisphere, occurring in the arctic and subarctic waters between 50º and 80ºN latitude (Reeves et al. 2002). Five geographically distinct stocks of beluga whales are recognized in Alaska: Beaufort Sea, eastern Chukchi Sea, eastern Bering Sea, Bristol Bay, and Cook Inlet (O'Corry-Crowe et al. 1997). The first two of these stocks regularly occur in the Chukchi and Beaufort seas. The most recent estimate of the eastern Chukchi Sea population is 3710 animals (Allen and Angliss 2012). The Beaufort Sea population was estimated to contain 39,257 individuals as of 1992 (Allen and Angliss 2012 based on surveys by Harwood et al. 1996), but that estimate is negatively biased because it covered only a fraction of the known range.

Most Beaufort Sea beluga whales winter in the Bering Sea and migrate north through the Chukchi Sea in the spring to summer feeding grounds in the Canadian Beaufort Sea before returning to the Chukchi Sea in the fall. Braham et al. (1984) and 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 pack ice and east into the Canadian Beaufort Sea (Suydam et al. 2001, 2005). Based on the late-summer and early-fall distributions, there appears to be overlap between the Chukchi and Beaufort seas beluga whale stocks at that time of year (Allen and Angliss 2013).

### *Chukchi Sea*

Few beluga whales were recorded by vessel-based observers during the 2006–2012 industry monitoring programs in the Chukchi Sea (Table 7.1). Beluga whales are one of the most commonly sighted species in the Chukchi Sea during aerial surveys, however there are relatively few belugas sighted by vessel-based observers. The low number of beluga whale sightings by vessel-based observers may be due to a combination of generally lower numbers of belugas in the Chukchi Sea during July–October when vessels are present, and of beluga avoidance of vessels and industry activities as reported in other locations (Richardson et al. 1995; Miller et al. 2005).

TABLE 7.1. Beluga sightings from industry vessels and industry aerial surveys in the Chukchi and Beaufort seas, 2006-2012. See Chapter 3, Table 3.3 for a summary of observer effort from 2006–2012.

| Beluga Whale | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| **Vessel Sightings** | | | | | | | |
| Chukchi Sea | 4 (42) | 0 | 1 (2) | 0 | 0 | 0 | 1 (2) |
| Beaufort Sea | 0 | 0 | 5 (6) | 0 | 0 | -- -- | 2 (138) |
| **Aerial Survey Sightings** | | | | | | | |
| Chukchi Sea | 55 (409) | 91 (598) | 17 (152) | -- -- | 5 (6) | -- -- | 10 (54) |
| Beaufort Sea | 29 (70) | 48 (125) | 268 (604) | -- -- | 49 (80) | -- -- | 17 (96) |
| ***Total*** | ***88 (521)*** | ***139 (723)*** | ***291 (764)*** | ***0*** | ***54 (86)*** | ***0*** | ***30 (290)*** |

Figure 7.1 shows visual detections of belugas during industry-sponsored monitoring from 2006–2012 and acoustic detections from 2012. Results from aerial surveys indicate that belugas are one of the

most abundant cetaceans in the Chukchi Sea, although their distribution varies substantially by season. When 2006–08, 2010, and 2012 data from the combined Chukchi Sea industry-sponsored aerial surveys were considered, the higher sighting rates for beluga whales in the Chukchi Sea during July and October–November were relatively consistent with beluga migratory patterns identified in earlier studies (Suydam et al. 2001, 2005). This is further supported by the detection of large numbers of beluga whales in relatively nearshore areas of the Chukchi Sea in late-June and early-July 2012 during aerial surveys flown by the National Marine Mammal Laboratory (NMML) as part of the Aerial Survey of Arctic Marine Mammals program (ASAMM; Clarke et al. 2013). Swim direction was analyzed for all "swimming" belugas observed during NMML surveys for July–August and was significantly clustered around a mean of 67°, suggesting spring migration movement to the north and east (Clarke et al. 2013). In 2012, there were no aerial sightings of beluga whales in September from industry or NMML surveys. There were 11 beluga sightings during aerial photographic surveys over the Burger prospect in early October 2012, the first year that an offshore survey in the Chukchi Sea was flown by industry since recent monitoring efforts began in 2006. Clarke et al. (2013) also reported few sightings of belugas in the Chukchi Sea during the summer months of 2012. Sightings from industry-operated vessels indicated that at least a few belugas were in the vicinity of exploration activities in the open-water season. No beluga sightings were reported in the five years of dedicated vessel surveys conducted on the lease prospect areas (Aerts et al. 2012). Future offshore aerial surveys in the Chukchi Sea may indicate higher fall migratory spatial dispersal than what has been seen during the spring migration along the coast (Clarke et al. 2013).

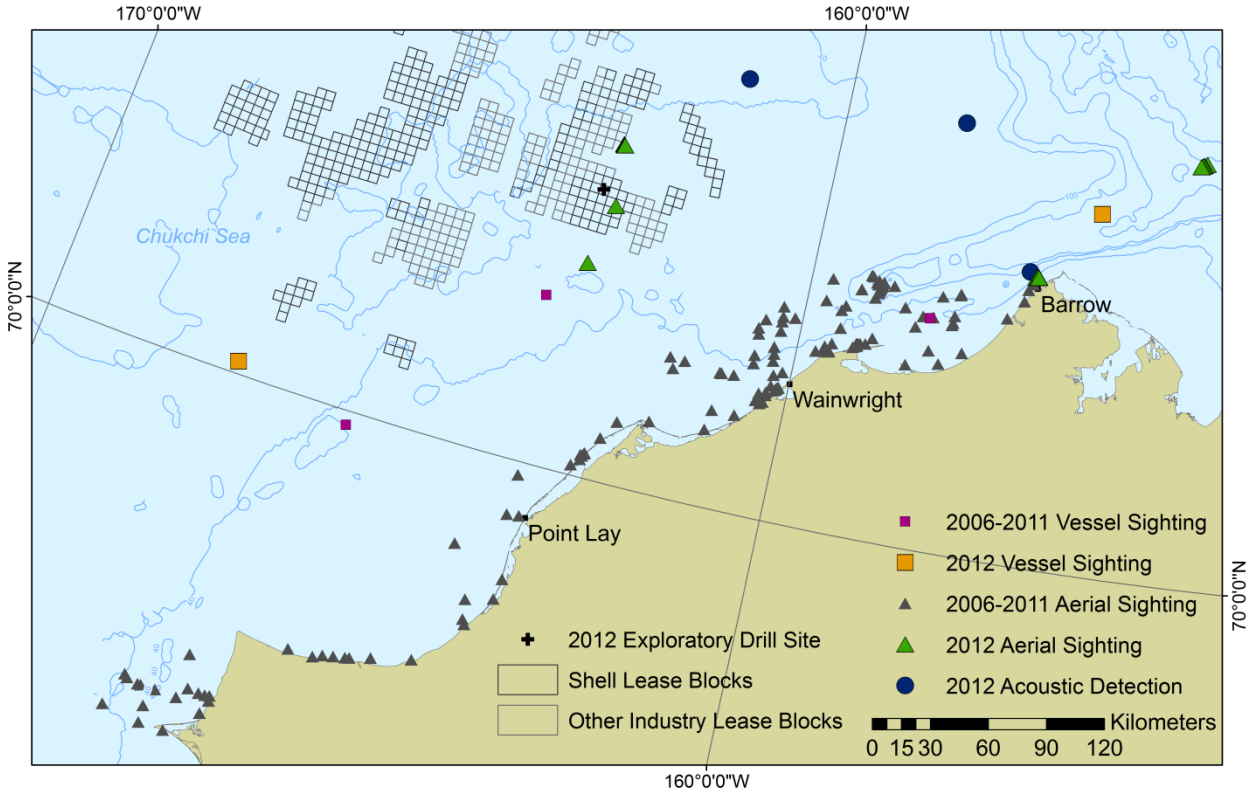


FIGURE 7.1. Beluga sightings from industry vessels and industry aerial surveys in 2012 compared to previous years and stations with confirmed beluga acoustic detections in 2012, Chukchi Sea.

Group size in 2012 was greater in July-August than in October (5.4 individuals per group in July–August and 1.5 individuals per group in October), which may be an indicator of a more dispersed beluga whale migration pattern during the fall. NMML aerial surveys of the Chukchi Sea in 2012 also recorded larger group sizes earlier in the year when groups of over 100 whales were observed on four different days in late-June and the first half of July compared to fewer sightings of smaller groups in summer and fall (Clarke et al. 2013). Average group size over all years surveyed by industry shows a similar trend (Fig. 7.2). Group size was highest among all years in the band 26–35 km (16–22 mi) offshore. However, the largest single groups were sighted at locations in the band within 5 km (3 mi) of the shoreline. Average group size was largest for animals "milling", but there was no difference in group size between "travelling", "feeding", or "resting" in 2012, or among all years.

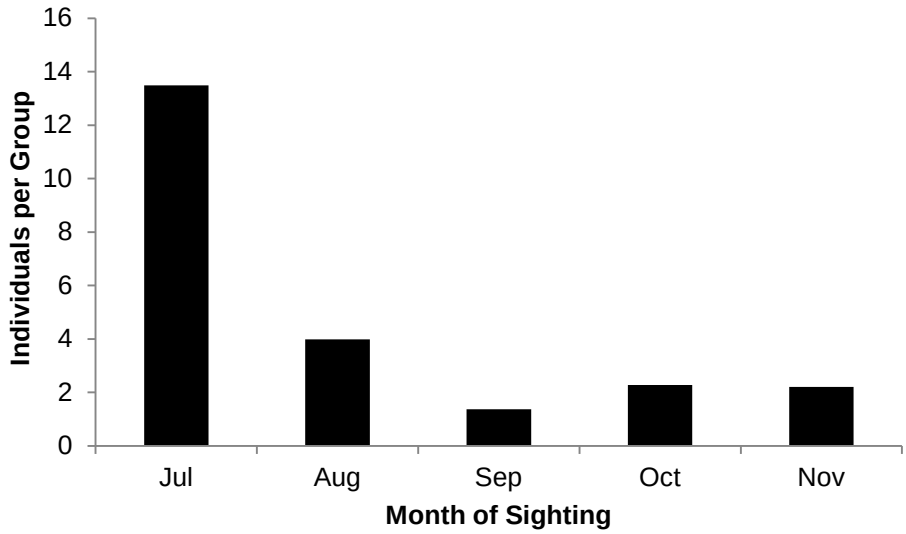


FIGURE 7.2. Average number of individual beluga whales in groups per sighting during 2006–2012 aerial surveys.

Beluga vocalizations were captured on recorder stations in the fall and spring of 2011 and 2012, respectively. The earliest beluga acoustic detections in the fall of 2011 occurred on 7 October at the northernmost stations (see Chapter 3 for acoustic recorder stations in the Chukchi Sea). During the fall, the station just offshore from Barrow had the largest number of detection days ($n$=12). Most detections occurred between mid-October and the first week of November; after this time only three more detections occurred with 8 December having the last acoustic detection of the 2011 program. At the other stations, acoustic detections of belugas were few and sporadic, although a more concentrated area-wide wave of detections occurred in the second half of November. These detections were concentrated around 16–17 November in the northern half of the study area. In the southern half of the study area, detections began at the same time as in the north, but were spread over a longer period.

In spring (2012), detections started on 13 April off of Point Lay and on 15 April at Barrow. The Barrow detections proceeded in three distinct pulses from mid-April to early May, followed by a three-week gap with few to no detections. Detections resumed strongly on 20 May and continued regularly until the beginning of June when they ceased abruptly. A few sporadic detections occurred between late June and late July. The station at Barrow consistently had the highest call counts in spring 2012 (Fig.

7.3). Detections at the three northernmost stations started days after the initial detections closer to shore, indicating the movement of belugas offshore into the northeastern Chukchi Sea at or beyond the shelf break.

The winter 2011–2012 detections confirmed the trend observed in previous years in the main part of the study area. The station at Barrow usually had the most consistent and predictable detections, and as whales migrated across the Chukchi Sea detections at the other stations become more sporadic (Fig. 7.4). The slight increase in the number of detection days with decreasing distance to shore along with the proliferation of aerial survey sightings of belugas along the coast suggests that a larger proportion of the migrating population may follow the coast, thereby being undetectable acoustically with the existing array geography.

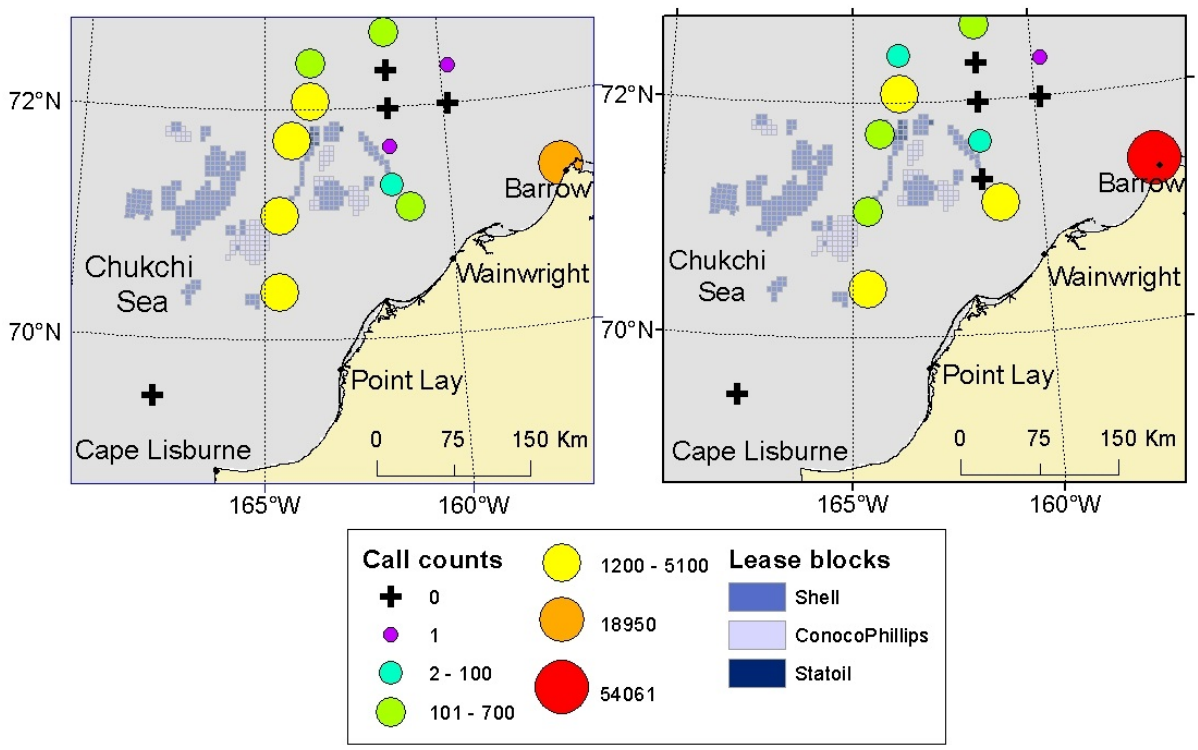


FIGURE 7.3. Beluga whale call count estimates* in the Chukchi Sea at all operational winter 2011–2012 recording stations. (Left) 13–30 April 2012; (right) May 2012. Areas of complete ice coverage on the mean detection date are shown in gray for (left) 22 April 2012 and (right) 15 May 2012 (NOAA 2012). *Corrected sum of automated call detections in all files with manual detections. See Appendix B for details.

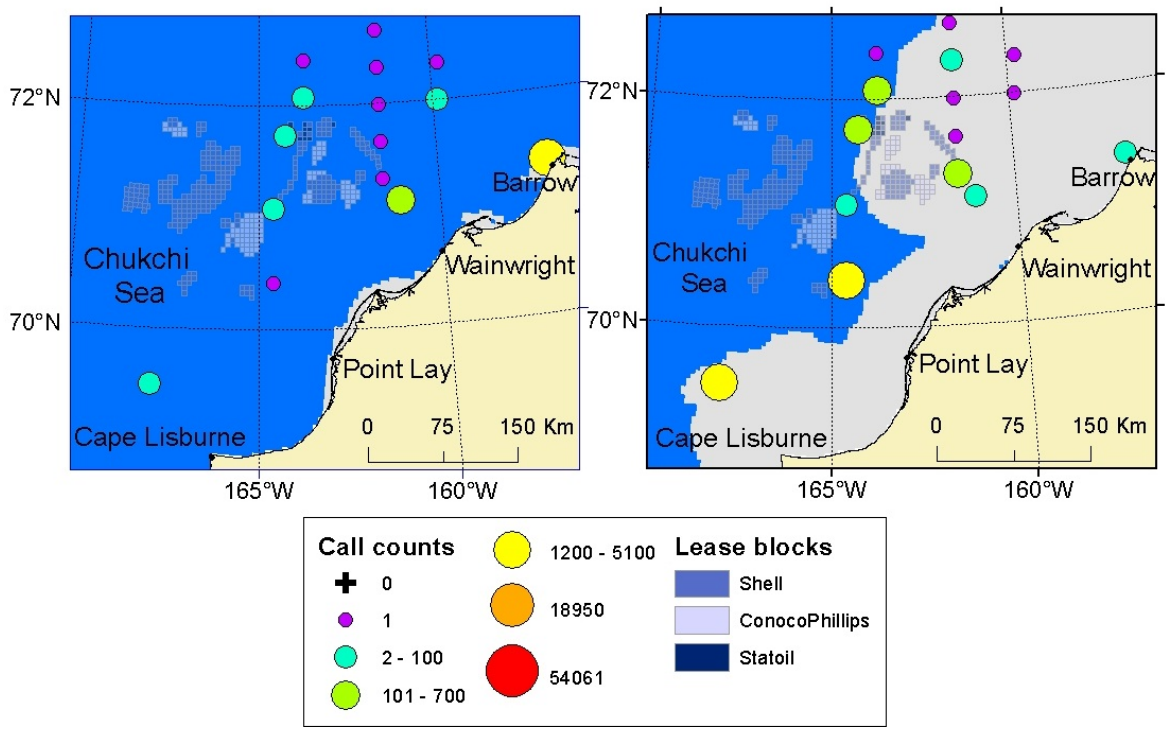


FIGURE 7.4. Beluga whale call count estimates* in the Chukchi Sea at all winter 2011–2012 recording stations. (Left) from 15 October–7 November 2011; (right) 8 November–1 December 2011. Areas of complete ice coverage on the mean detection date are shown in gray for (left) 27 October 2011 and (right) 20 November 2011 (NOAA 2012). The blue background indicates open water. *Corrected sum of automated call detections in all files with manual detections.

The 2012 summer acoustic data confirm the limited occurrence of belugas in the northeastern Chukchi Sea in summer. Over the last 5 years, detections have been concentrated in/near Barrow canyon in August as eastern Chukchi Sea belugas forage locally. These acoustic detections correspond with locations of 2012 vessel and aerial sightings (Fig. 7.1). Sporadic detections have frequently occurred in late September and early October during the early part of the fall migration. These detection patterns are consistent with results from aerial surveys and vessel sightings; observers on industry vessels only sighted belugas in early August and late October–November. Fall acoustic recordings yield far fewer beluga detections than spring recordings, which suggest that some animals transiting through the Chukchi Sea in the spring may migrate outside of the study area in the fall.

In 2006–2012, there were no sightings of belugas in areas where industrial sounds were ≥120 dB rms. The analyses of beluga sighting rates and behavior with respect to anthropogenic sound were therefore not considered appropriate with the current dataset. Belugas were not detected in the Chukchi Sea during much of 2012 operations; however two beluga whales were photographed from aerial surveys near the Burger prospect during drilling operations (Fig. 7.5). Since sampling effort was not consistent across the study area between years, interpretation is limited to relative comparisons among years.

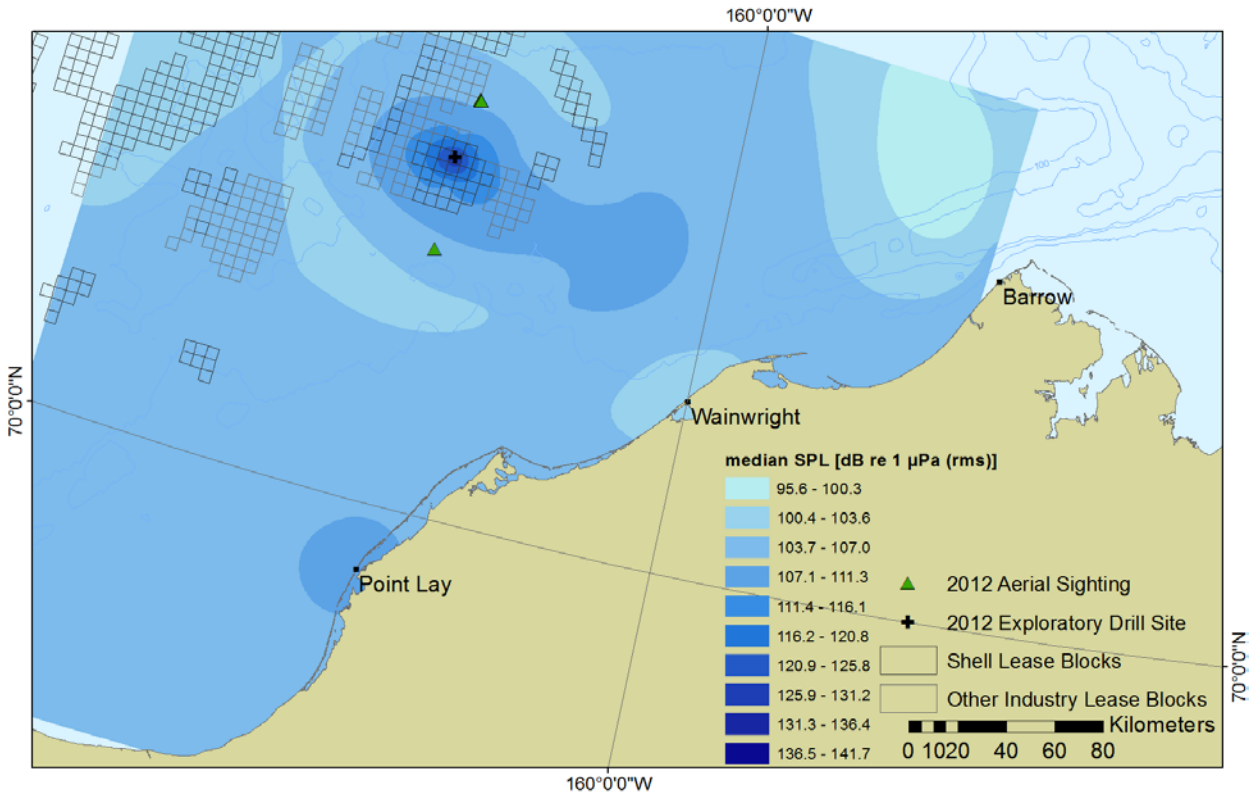


FIGURE 7.5. Beluga sightings from offshore aerial surveys on 18 October 2012, with a median SPL soundscape from 23–26 September 2012 during which drilling activities were taking place.

### *Beaufort Sea*

Beluga whales are common in the Alaskan Beaufort Sea during summer periods; however few belugas were recorded during 2006–2012 Beaufort Sea vessel-based operations (Table 7.1). Belugas may occur nearshore but generally migrate and feed farther offshore than bowhead whales (*Balaena mysticetus*) remaining primarily in deeper outer-shelf and slope waters (Moore and DeMaster 1998; Moore 2000; Moore et al. 2000; Christie et al. 2010; Clarke et al. 2011, 2013). Industry aerial surveys terminated at or south of the shelf break. As expected, the majority of beluga sightings during aerial surveys in previous years were at or near the shelf break toward the north end of the survey transects (Fig. 7.6). However, in 2012 the majority of beluga sightings during industry aerial surveys were sighted on the shelf (e.g., sightings were observed in depths between 25–50 m [82–164 ft]). This pattern might be explained by the presence of sea ice in the survey area through late August, and an association between beluga whales and sea ice when the majority of sightings were made (Fig. 7.6). NMML aerial surveys in the Beaufort Sea during 2012 detected belugas in offshore areas at or beyond the shelf break, a distribution very similar to what has been observed in previous agency and industry-sponsored aerial surveys (Fig. 7.7; Clarke et al. 2013).

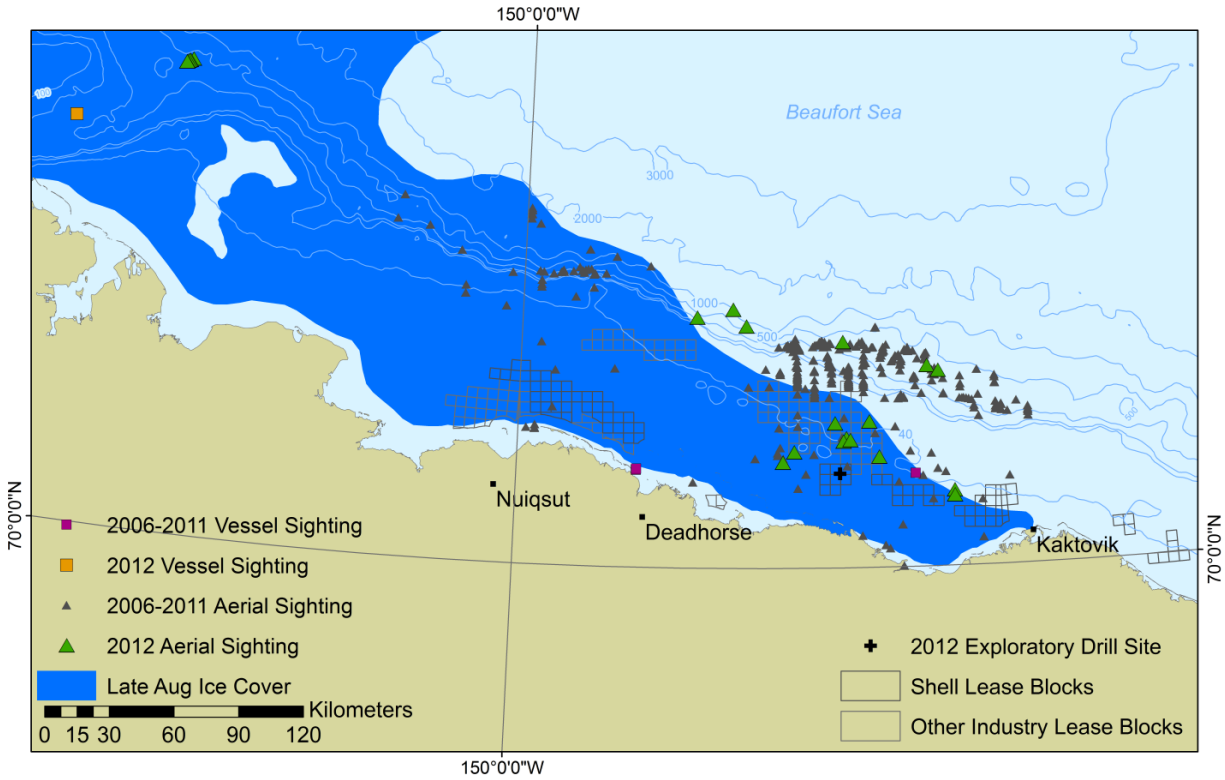


FIGURE 7.6. Beluga sightings from industry vessels and aerial surveys in 2012 in the Beaufort Sea compared to previous years. Late August Ice Cover indicates >10% ice on 25 August 2012 and is associated with beluga sightings on the shelf on 25 August 2012.

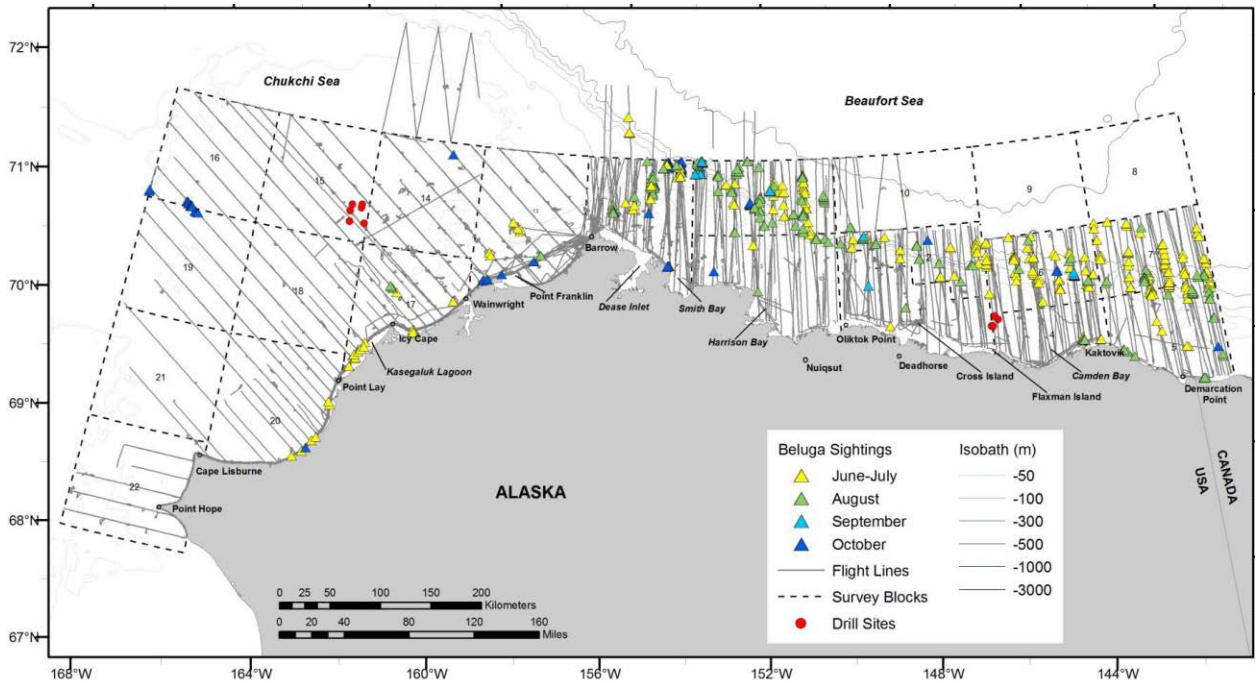


FIGURE 7.7. ASAMM beluga sightings plotted by month, with transect, search, and circling effort, 2012. Deadhead flight tracks are not shown. Source: Clarke et al. 2013

Acoustic detections of beluga whales in the Beaufort Sea in late summer 2011 were infrequent and of short duration. All receiver locations had a few beluga detections in October or November 2011 before the onset of ice and most of the detections were weak, suggesting they were probably farther offshore. Belugas were detected again in the spring (beginning in March), but then only at the deepest and most northerly site (see Appendix C). This is consistent with the current understanding of the distribution of beluga whales in the Beaufort Sea (Moore et al. 2000; Christie et al. 2010; Clarke et al. 2011, 2013).

Exploration activities in the Beaufort Sea occurred on the continental shelf where belugas are typically less abundant. In 2012, beluga sightings were recorded from aerial surveys during anchor handling activities and during drilling, but the sighting during drilling was recorded off the shelf break and just outside of the soundscape created for acoustic analysis (Fig. 7.8). Had the soundscape been calculated out to the location of the sighting, the beluga sighting would have been exposed to between 100 and 103.7 median SPL [dB re 1 µPa (rms)]. This is the same median SPL for beluga sightings during periods with no industrial activity in the area (Fig. 7.9). Thus, during periods of drilling activity in the Beaufort Sea, beluga whales along the shelf break were probably exposed to industrial sound levels similar to typical ambient sound levels in the Beaufort Sea.

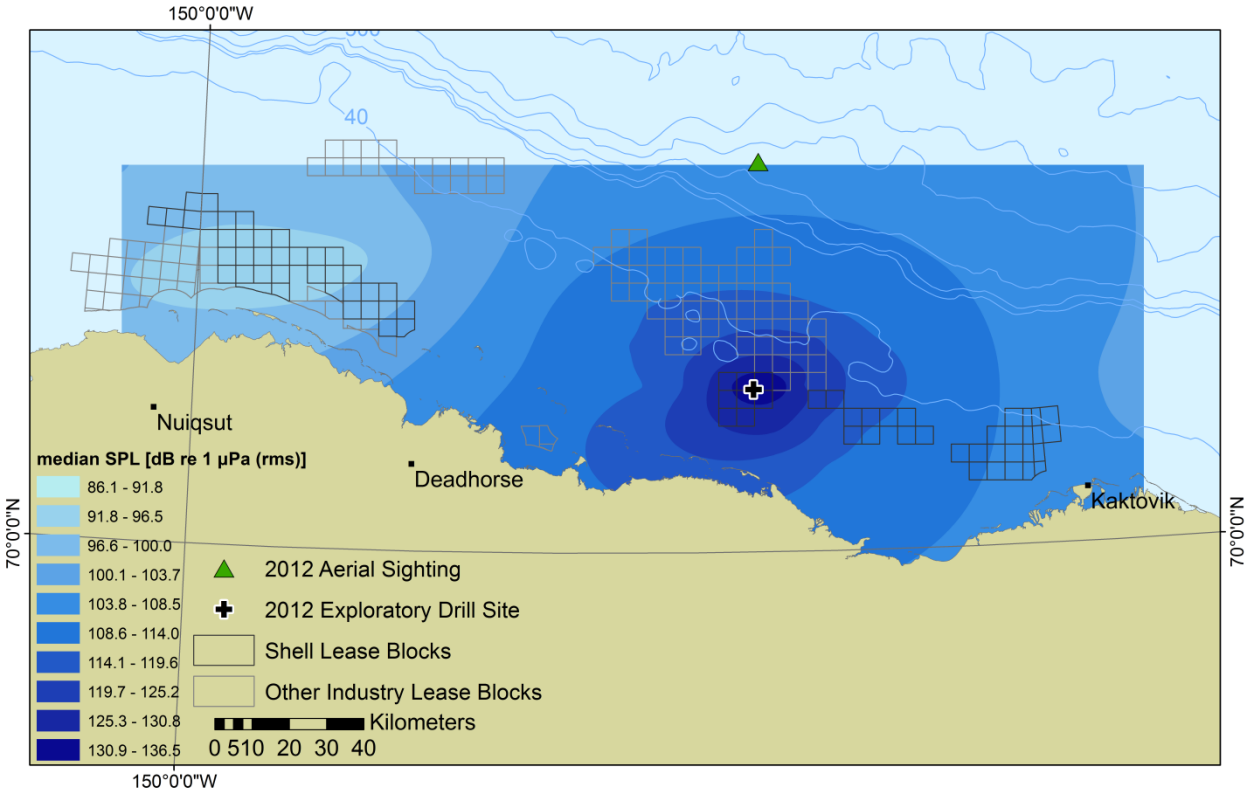


FIGURE 7.8. A beluga sighting during an aerial survey on 4 October 2012, with a median SPL soundscape from 3–8 October 2012 during which drilling activities were taking place.

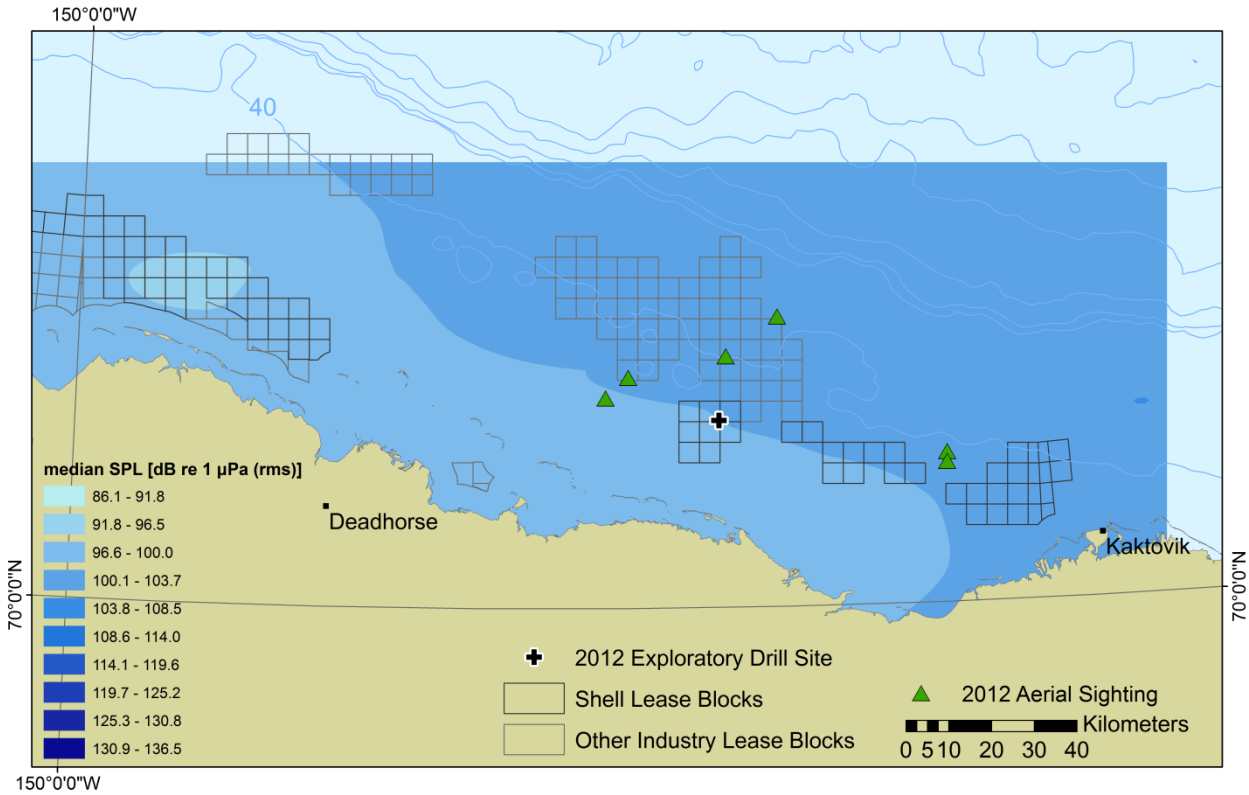


FIGURE 7.9. Beluga sightings from industry vessels and aerial surveys on 25 and 29 August and 10 September 2012, with a median SPL soundscape from 24 August to 14 September 2012 during which no activities were taking place.

Belugas were slightly closer to shore in 2012 than in previous years, likely due to the lingering presence of >10% ice over the shelf. After the ice retreated, the beluga sighting distribution was similar to previous years (Brandon et al. 2013). Median sound pressure levels at the location of beluga sightings in 2012 were nearly the same during drilling as when there was no activity in the area; thus, the effect of anthropogenic sound on belugas during the open-water season in the Beaufort Sea was likely minimal. Belugas may be present over the shelf closer to the exploration area during times when ice is present; however most operations are not possible in the presence of ice. The exception would be for activities such as ice management or in-ice seismic.

## *Gray Whale in the Chukchi and Beaufort Seas*

Gray whales (Aqviqluaq, *Eschrichtius robustus*) are present in the Chukchi Sea and to a lesser extent the Beaufort Sea during the summer months. The Chukchi Sea is a key feeding area for a portion of the gray whale population (Moore et al. 1986, 2000). Moore et al. (2000) reported that during the summer, gray whales in the Chukchi Sea were clustered along the shore primarily between Cape Lisburne and Point Barrow and were associated with shallow, coastal shoal habitat. Gray whales occur fairly frequently near Point Barrow, but historically only a small number of gray whales have been sighted in the Beaufort Sea east of Point Barrow (Rugh and Fraker 1981; Miller et al. 1999; Christie et al. 2010). Although they are most common in portions of the Chukchi Sea close to shore, gray whales may also occur in offshore areas of the Chukchi Sea, particularly over offshore shoals.

Gray whale was by far the most frequently sighted and most numerous cetacean species recorded during the vessel-based industry monitoring studies in the Chukchi Sea from 2006–2012. Other researchers have also reported gray whales in the Chukchi Sea during summer and fall (Moore 2000; Moore and DeMaster 1998; Moore et al. 1986) and gray whale was the most abundant cetacean species recorded during aerial surveys of nearshore areas of the eastern Chukchi Sea in all years aerial surveys were flown.

Gray whale sightings from industry vessels were similar in 2012 to previous years with one exception (Table 7.2; Fig. 7.10); in 2012 there was an increase in gray whale sightings farther offshore from Wainwright than occurred in previous years. This location was a staging area for vessels related to the Shell exploration project in 2012, and demonstrates that sampling effort was not uniformly distributed across the sampling area. Interpretation of the data is limited to relative comparisons among years. Similarly, gray whales were reported in this same general area by Aerts et al. (2012). They reported more gray whales in 2012 than in previous study years but had only a few sightings farther offshore in 2012. Gray whale sightings from industry-sponsored vessels continued past Barrow into the Beaufort Sea as far as Smith Bay in 2012 (Figure 7.10). A similar distribution of gray whales in the western Beaufort Sea in 2012 was observed during ASAMM aerial surveys (Clarke et al. 2013).

TABLE 7.2. Gray whale sightings from industry vessels and aerial surveys in the Chukchi and Beaufort seas, 2006–2012. See Chapter 3, Table 3.3 for a summary of observer effort from 2006–2012.

| Gray Whale | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| **Vessel Sightings** | | | | | | | |
| Chukchi Sea | 37 (92) | 39 (75) | 103 (226) | 3 (3) | 33 (103) | 8 (33) | 128 (256) |
| Beaufort Sea | 8 (14) | 1 (1) | 7 (9) | 0 | 0 | -- -- | 6 (7) |
| **Aerial Survey Sightings** | | | | | | | |
| Chukchi Sea | 46 (58) | 221 (280) | 200 (243) | -- -- | 113 (135) | -- -- | 28 (35) |
| Beaufort Sea | 3 (3) | 1 (1) | 0 | -- -- | 1 (1) | -- -- | 0 |
| ***Total*** | ***94 (167)*** | ***262 (357)*** | ***310 (478)*** | ***3 (3)*** | ***147 (239)*** | ***8 (33)*** | ***162 (298)*** |

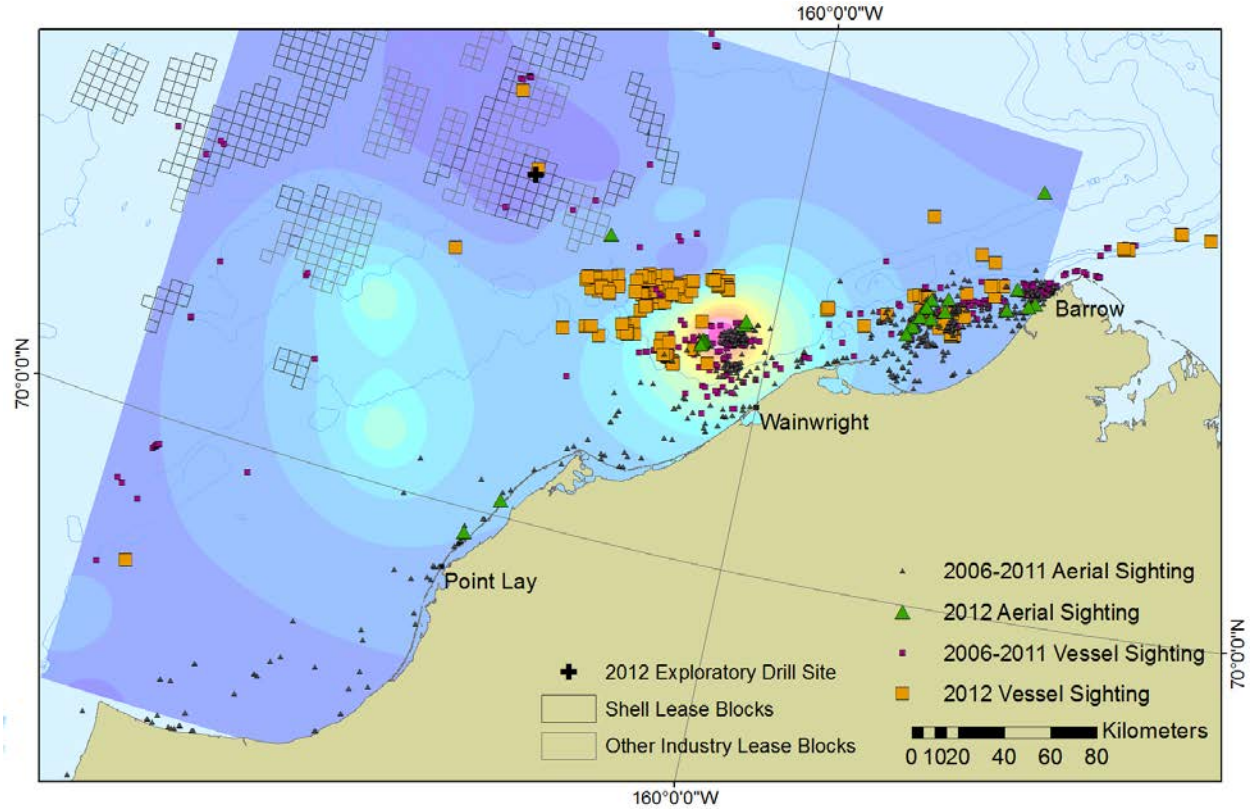


FIGURE 7.10. Gray whale sightings from industry vessels and aerial surveys in 2012 in the Chukchi and Beaufort seas compared to previous years and an interpolation of gray whale distribution from acoustic detections in 2012 showing gray whale calls most frequently detected offshore of Wainwright.

Gray whale distribution in 2012 was consistent with previous aerial survey results reported by Moore (2000), who found that gray whales in the Chukchi Sea were seen most often in coastal or shoal habitats (Fig. 7.10). The distribution of gray whales from aerial surveys by NMML in 2012 was very consistent with results from industry-sponsored monitoring (Fig. 7.11; Clarke et al. 2013). Gray whales historically used Hanna Shoal for feeding in the 1980s and early 1990s (Moore 2000). Neither industry nor agency-sponsored aerial surveys in 2012 detected feeding gray whales near Hanna Shoal in 2012 (Clarke et al. 2013), and it does not appear that gray whales have utilized this offshore region in the Chukchi Sea with any consistency since 2008 (Clarke et al. 2012).

Gray whales were more abundant in nearshore waters of the eastern Chukchi Sea during 2007, 2008, 2010, and 2012 than during 2006. In 2007, 2008, 2010, and 2012 they were most abundant in the northern part of the survey area from about Wainwright to Barrow (Fig. 7.12). In all years, gray whale numbers increased from July to August, then declined in September with few observations after mid-September. This decrease in gray whale detection rates later in the open-water season was also noted in results from NMML's 2012 aerial survey program (Clarke et al. 2013). No gray whales were observed during industry-sponsored aerial surveys after 21 September 2007, but in 2008 gray whales were observed until 9 October and in 2010 gray whales were seen during the last survey of the season on 11 October. In 2012, gray whale numbers were high in August and declined in September, and the last gray whale sighting was on 28 September. This shorter sighting season compared to previous years is likely due to the truncated aerial survey effort in 2012 due to weather and other issues.

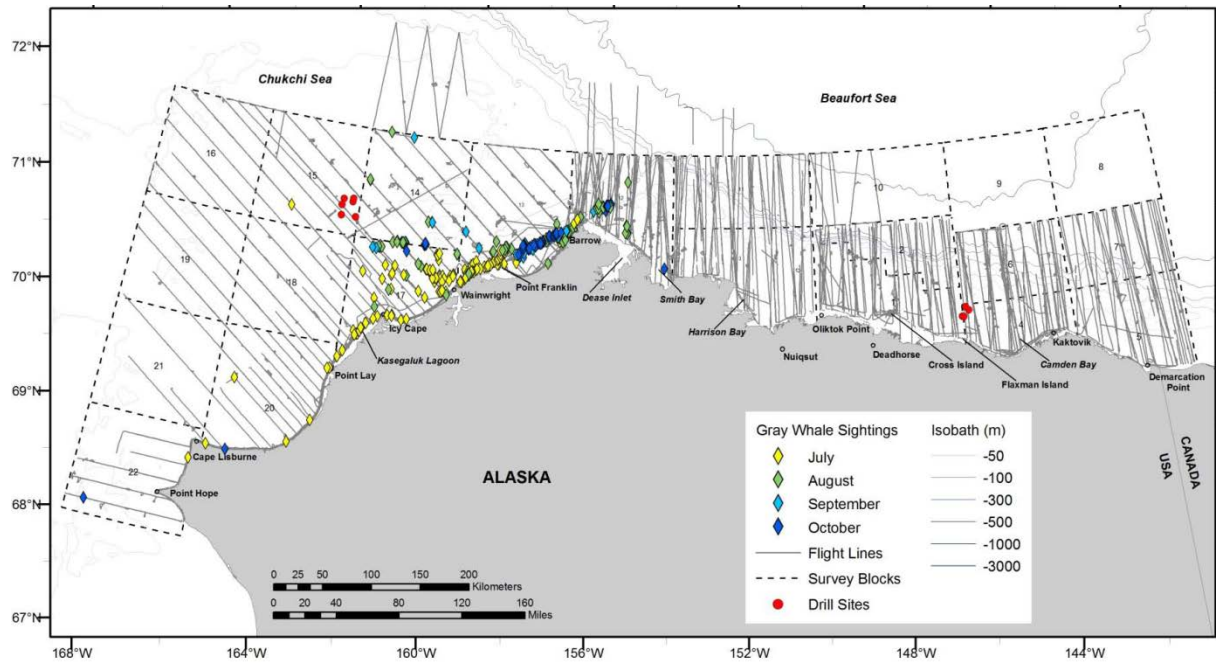


FIGURE 7.11. ASAMM gray whale sightings plotted by month, with transect, search and circling effort, 2012. Gray whales were not seen during a survey on 30 June. Deadhead flight tracks are not shown. Source: Clarke et al. 2013.

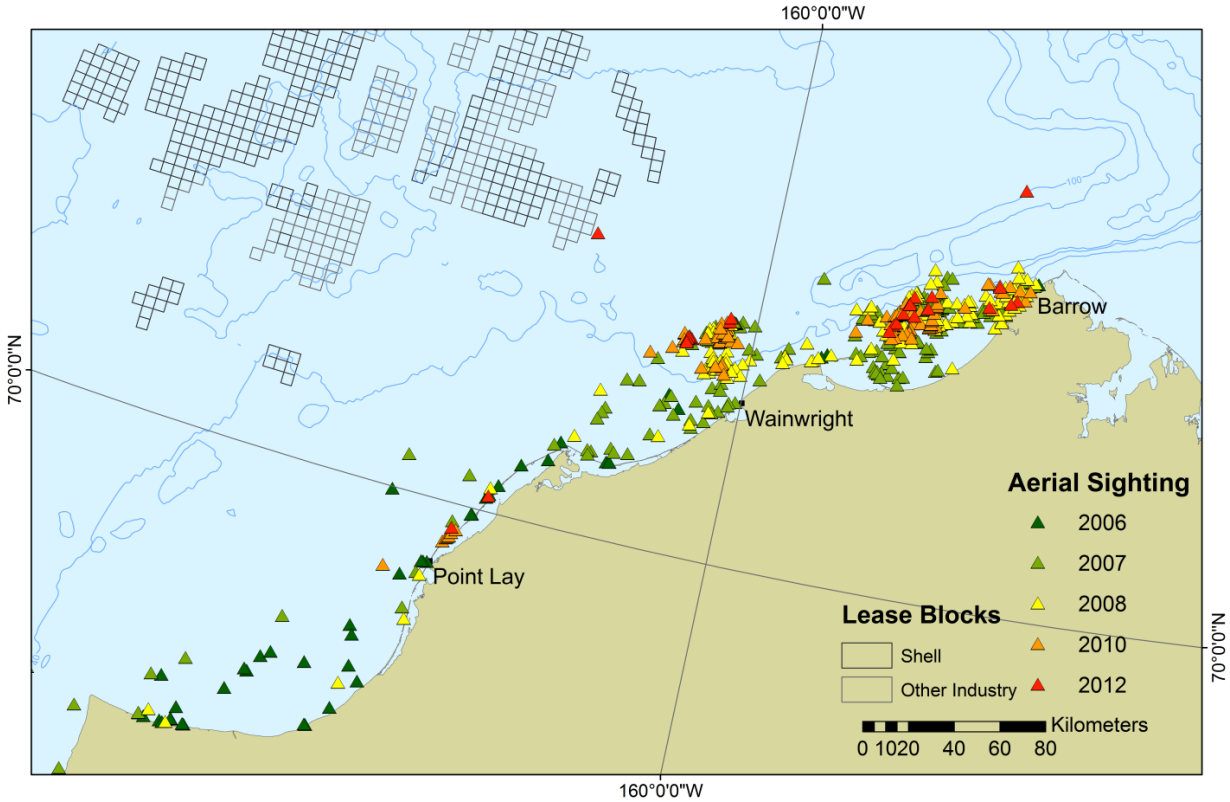


FIGURE 7.12. Gray whale sightings from all years of industry sponsored aerial surveys indicating a more southerly distribution in 2006 as compared to all later years.

Sighting rates were significantly higher in the 0–5 km-from-shore band in 2006 and in the 25–35 band in all following years; this was most likely due to differences in food availability and ice cover. Gray whale use of foraging grounds are temporally and spatially variable (Moore 2000; Moore et al. 2003), so it may be that food was more abundant closer to shore in 2006 than in the subsequent six years.

Acoustic detections of gray whale vocalizations occurred between 12 August and 11 October 2012. The 2012 detection distribution was similar to 2011, although improvements to recorders and analyses resulted in a large increase in number of gray whale detections in 2012. The prominent feature of gray whale detections, i.e., their concentration off Wainwright, coincides with the latest information on gray whale distribution based on aerial surveys (Fig. 7.10; Clarke and Ferguson 2010). However, many vessel and aerial sightings of gray whales indicate that Peard Bay is an important feeding location for gray whales. The lack of acoustic detections in the vicinity of Peard Bay implies that there are no gray whales present, but no acoustic recorders have been deployed there. The addition of recorders in the vicinity of Peard Bay would almost certainly alter the gray whale distribution indicated by acoustic data.

Gray whales are one of the easiest cetaceans for which to document feeding due to the presence of large mud plumes that often accompany feeding activity. Observers on board industry vessels and during aerial surveys recorded the vast majority of feeding activity off of Wainwright and in Peard Bay, although aerial observers noted isolated instances of feeding along the shore down to Cape Lisburne (Fig. 7.13). Two sightings of feeding gray whales in 2007 were recorded from vessels far offshore (>145 km [90 mi]) near Hanna Shoal, which historically has been a feeding location for gray whales, but now appears to be used infrequently. Bluhm et al. (2007) suggest that frontal systems play an important role in food availability at gray whale foraging grounds. With a 50% decline in ampeliscid biomass in the northern Bering Sea since the 1980s (Coyle et al. 2007), it may be that greater variability in gray whale distribution will be observed as the recovering gray whale population seeks adequate foraging opportunities.

During periods of drilling in the Chukchi Sea in 2012, seven gray whale sightings from vessels occurred where sound from drilling were ≤110 median SPL [dB re 1 μPa (rms)]. The soundscape at the time of these sightings indicates that these exposures were not from drilling activity but were from vessel sounds created by the staging of Shell vessels near the gray whale sightings (Fig. 7.14). Only two gray whales were sighted during aerial surveys at a time of active drilling, and both of these sightings were in locations where industrial sounds were ≤105 median SPL [dB re 1 μPa (rms)]. Two gray whale sightings were recorded from industry vessels during ice management activities in the Chukchi Sea in 2012 (Fig. 7.15). Both of these sightings were recorded from vessels in standby in the staging location, and both sightings were in locations where vessel sounds were <105 median SPL [dB re 1 μPa (rms)].

Generally, sound generating exploration activities occur farther offshore than the largest concentrations of gray whales that tend to be nearer to the coast (Fig. 7.10). Measurements indicate that sounds from exploration activities reached background levels before reaching these areas of higher gray whale concentration (Funk et al. 2011). Gray whales are unlikely to be impacted directly by sounds from exploration activities in Lease Sale 193; however they may be impacted by increased vessel traffic near the coast in areas where gray whales routinely feed during the open-water season (see Chapter 2: *Background and Context*).

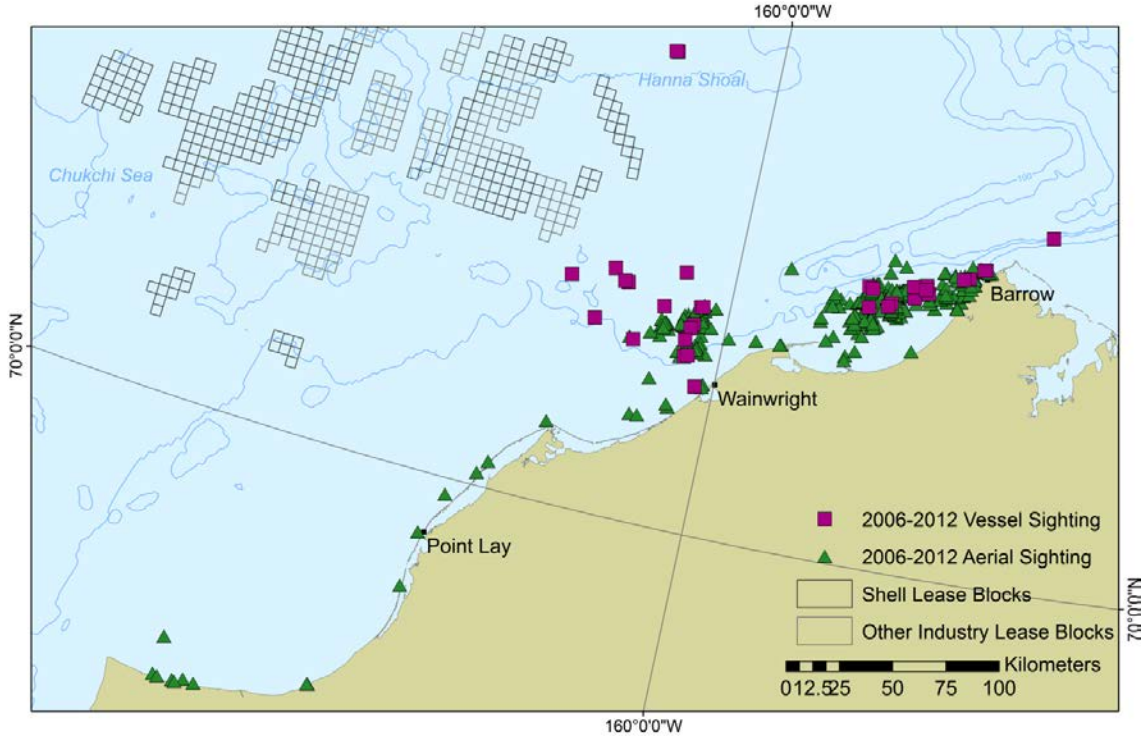


FIGURE 7.13. Gray whale sightings from industry vessels and aerial surveys in which "feeding" activity was recorded.

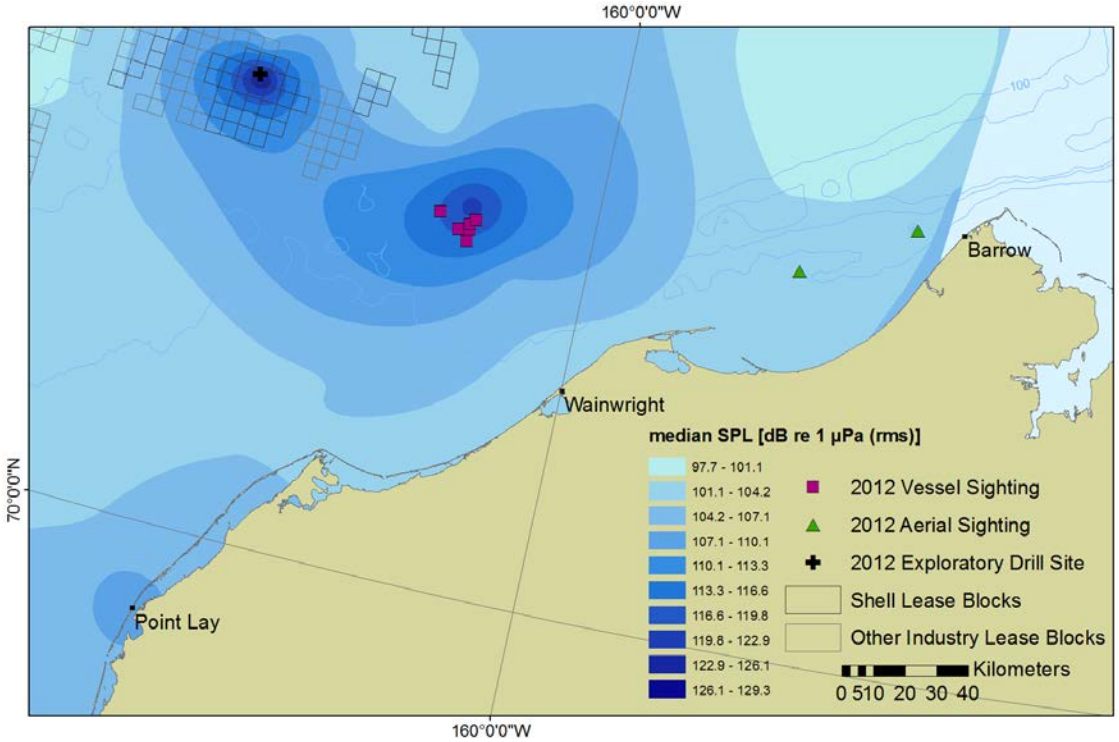


FIGURE 7.14. Gray whale sightings from industry vessels and aerial surveys on 25 September 2012, with a median SPL soundscape from 25 September 2012 during which drilling activities were taking place.

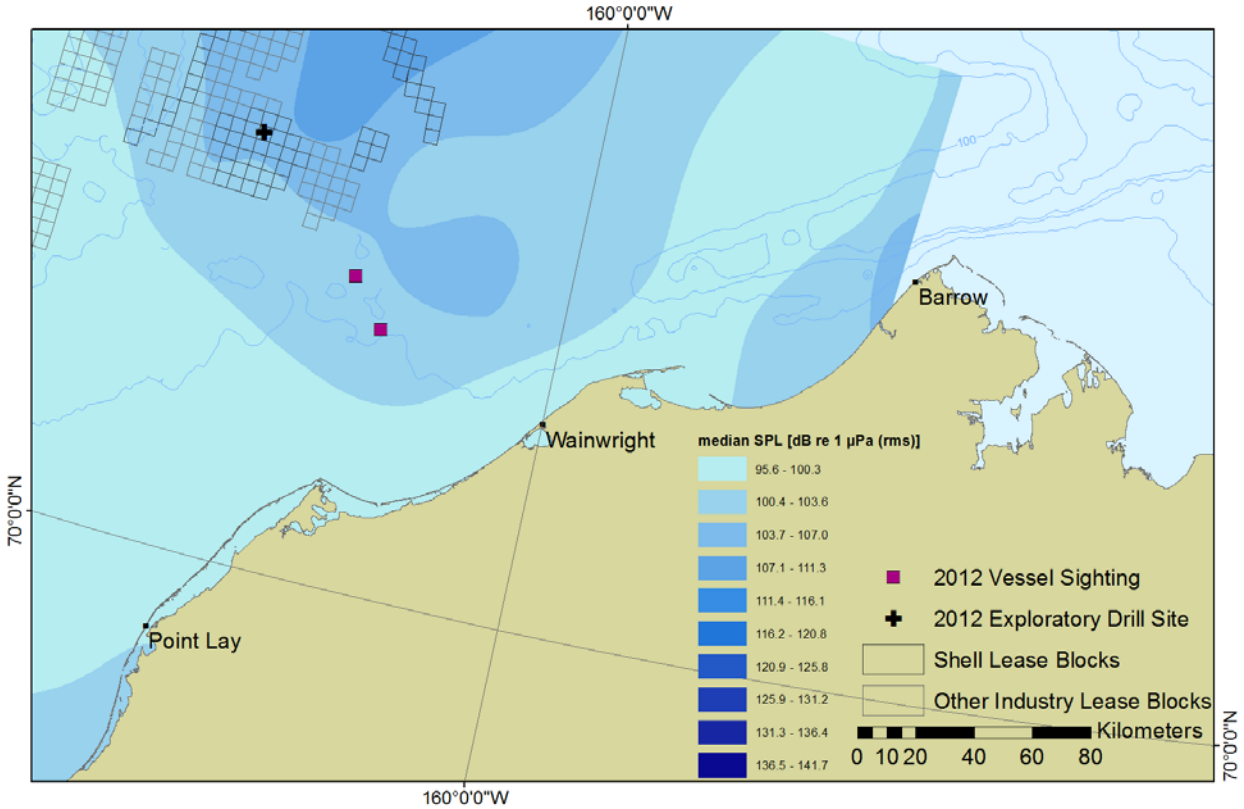


FIGURE 7.15. Gray whale sightings from industry vessels on 13 September 2012, with a median SPL soundscape from 13 September 2012 during which ice management activities were taking place.

## *Other Cetaceans in the Chukchi and Beaufort Seas*

Sightings and acoustic detections of some species which are considered to be uncommon in the Chukchi Sea appear to be increasing, suggesting the initial stages of future range expansion of these populations. Minke whales (*Balaenoptera acutorostrata*) were detected acoustically in the Chukchi Sea first in 2011 and again in 2012, and the first sighting of a minke whale during an industry aerial survey was in 2012 (Table 7.3). Minke whales have been sighted by vessel-based observers in 2006–2008, 2010, and 2012. Humpback (*Megaptera novaeangliae*) and fin (*Balaenoptera physalus*) whales, which are both considered to be rare in the Chukchi Sea, were recorded during the 2006–2010 industry monitoring programs and again in 2012. COMIDA's vessel-based program observed seven fin whales in the southern Chukchi Sea in 2010 (LGL unpublished data) and fin whale sightings were also recorded during NMML aerial surveys in 2008 and 2012 (Clarke et al. 2011, 2013).

Effects of anthropogenic activity in the Chukchi and Beaufort seas on these species (fin whale, humpback whale, minke whale, harbor porpoise (Aavisuaq, *Phocoena phocoena*), and killer whale (Aaglu, *Orcinus orca*) are likely minimal due to the low numbers of these species near areas of activity. However, if the ranges of these species continue to expand north, the likelihood of the animals encountering exploration activities in the Alaskan Arctic will increase. In the future, changes may need to be made to monitoring efforts such as sampling rate and frequency of acoustic recorders and design of aerial surveys to effectively monitor any potential effects to these species.

TABLE 7.3. Cetacean sightings from industry vessels and aerial surveys in the Chukchi and Beaufort seas, 2006–2012. See Chapter 3, Table 3.3 for a summary of observer effort from 2006–2012.

| Species | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| **Vessel Sightings** | | | | | | | |
| *Chukchi Sea* | | | | | | | |
| Fin Whale | 0 | 0 | 3 (6) | 0 | 0 | 0 | 1 (1) |
| Humpback Whale | 0 | 4 (6) | 2 (4) | 0 | 1 (1) | 0 | 2 (6) |
| Minke Whale | 8 (8) | 5 (6) | 26 (34) | 0 | 9 (11) | 0 | 10 (12) |
| Dall's Porpoise | 0 | 0 | 1 (5) | 0 | 0 | 0 | 1 (4) |
| Harbor Porpoise | 22 (38) | 11 (28) | 18 (30) | 3 (10) | 5 (13) | 0 | 1 (6) |
| Killer Whale | 2 (7) | 1 (1) | 2 (2) | 0 | 1 (2) | 0 | 2 (5) |
| *Beaufort Sea* | | | | | | | |
| Minke Whale | 0 | 1 (1) | 1 (2) | 0 | 0 | -- -- | 1 (1) |
| Harbor Porpoise | 1 (1) | 0 | 0 | 0 | 0 | -- -- | 0 |
| **Aerial Sightings** | | | | | | | |
| *Chukchi Sea* | | | | | | | |
| Humpback Whale | 0 | 0 | 1 (1) | -- -- | 0 | -- -- | 0 |
| Minke Whale | 0 | 0 | 0 | -- -- | 0 | -- -- | 1 (1) |
| Harbor Porpoise | 0 | 1 (1) | 0 | -- -- | 4 (4) | -- -- | 0 (0) |
| Killer Whale | 0 | 0 | 0 | -- -- | 0 | -- -- | 1 (3) |
| *Beaufort Sea* | | | | | | -- | |
| Harbor Porpoise | 0 | 2 (3) | 3 (7) | -- -- | 0 | -- -- | 0 |
| ***Total Cetaceans*** | ***33 (54)*** | ***25 (46)*** | ***57 (91)*** | ***3 (10)*** | ***20 (31)*** | ***0 (0)*** | ***20 (39)*** |

### *Harbor Porpoise*

The harbor porpoise is a small (~1.5 m or 5 ft) odontocete that inhabits shallow coastal waters in the temperate, subarctic, and Arctic regions of the Northern Hemisphere (Read 1999). Harbor porpoises occur mainly in shelf areas where they can dive to depths of at least 220 m (722 ft; Harwood and Wilson 2001). There are three geographically distinct subspecies of harbor porpoise; in Alaska, *Phocoena phocoena vomerina* is found in the Chukchi Sea, Pribilof Islands, Unimak Island, Bristol Bay, and southeast Alaska. Point Barrow, Alaska, is likely the northeastern extent of their regular range (Suydam and George 1992), though there are records of sightings as far east as the mouth of the Mackenzie River in the Northwest Territories, Canada. Harbor porpoises present in the Chukchi Sea belong to the Bering Sea stock, which includes animals from Unimak Pass northward. Suydam and George (1992) suggested that harbor porpoises occasionally occur in the Chukchi Sea and reported nine records of harbor porpoise in the Barrow area in 1985 to 1991.

Harbor porpoises may be one of the more abundant species of cetacean in the Chukchi Sea; however, they are difficult to detect from vessels and during aerial surveys for several reasons. Harbor porpoises typically occur in small groups of only a few individuals and tend to avoid vessels (Richardson et al. 1995). Also, harbor porpoises have small bodies, short surfacing times, and produce very little water disturbance while surfacing, which makes them difficult to detect from the air. Even with these difficulties, harbor porpoises are sighted frequently by PSOs onboard industry vessels in the Chukchi Sea and infrequently by PSOs onboard vessels in the Beaufort Sea. They are rarely recorded during aerial surveys in either the Chukchi or the Beaufort seas (Fig. 7.16). The location of these sightings indicates that, as expected, harbor porpoises are more common in the Chukchi Sea than the Beaufort Sea; but they

may have a larger range in the Beaufort Sea than previously thought. No acoustic information is available because the acoustic recorders used to date have had a sampling rate too low to capture the majority of harbor porpoise vocalizations.

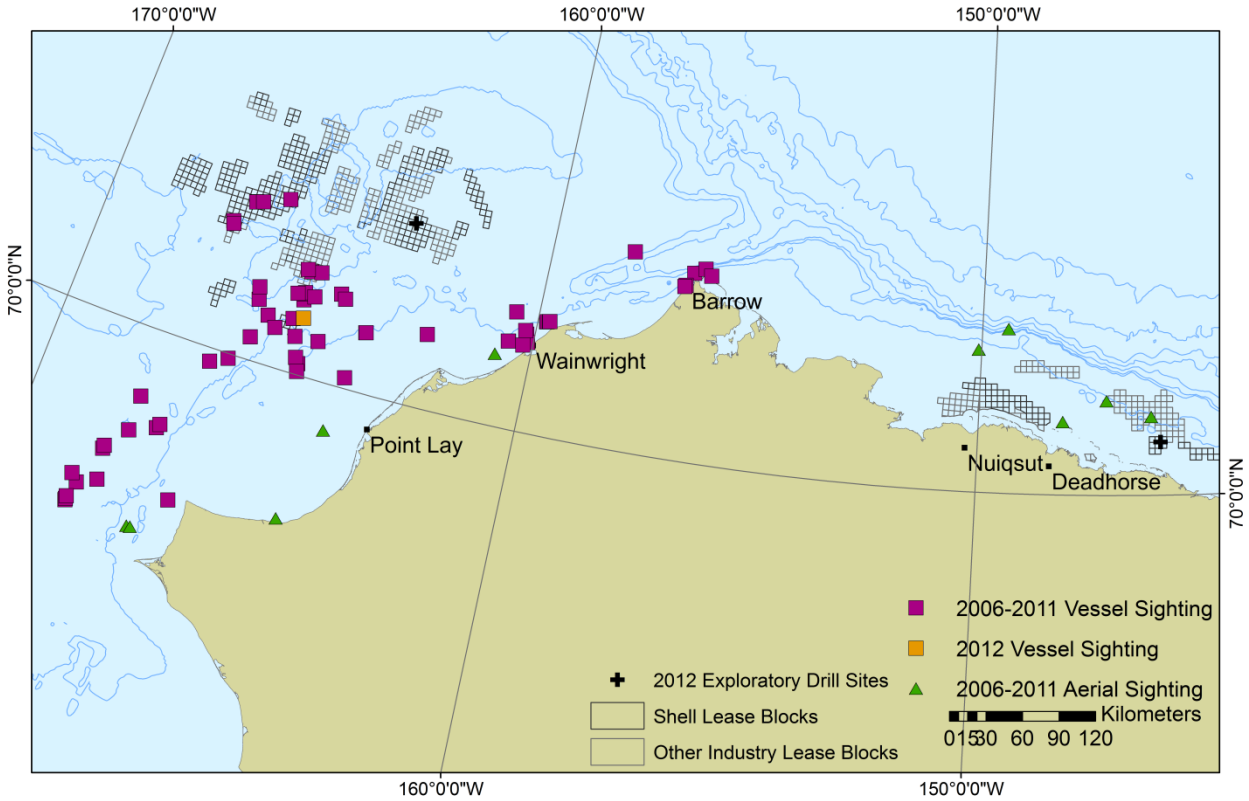


FIGURE 7.16. Harbor porpoise sightings in the Chukchi and Beaufort seas from industry vessels in 2012 compared to previous years, and sightings from aerial surveys 2006–2011. There were no sightings of harbor porpoise during aerial surveys in 2012.

### *Killer Whale*

Killer whales are known to inhabit almost all coastal waters of Alaska, extending from southeast Alaska through the Aleutian Islands to the Bering and Chukchi seas (Allen and Angliss 2012). PSOs onboard industry vessels in the Chukchi Sea recorded killer whales in 2006, 2007, 2008, 2010, and 2012 (Table 7.3). The first killer whale sighting from industry aerial surveys in the Chukchi Sea was in 2012 (Table 7.3). NMML aerial observers also recorded killer whales for the first time in the northeastern Chukchi Sea during ASAMM surveys in 2012 (Clarke et al. 2013). Clarke et al. (2013) reported 13 killer whales ~10 km (6.2 mi) northwest of Barrow on 20 August and another group of five individuals ~80 km (50 mi) northwest of Point Hope on 11 September.

Killer whales probably do not occur regularly in the Beaufort Sea although sightings have been reported (George and Suydam 1998). PSOs onboard industry vessels and conducting aerial surveys in the Beaufort Sea have not reported any confirmed killer whale sightings.

Killer whales were acoustically detected in 2007, 2009, 2010, 2011, and 2012 open-water seasons in the Chukchi Sea (Delarue et al. 2010a). Killer whales were detected predominantly off Cape Lisburne and Point Lay in all years with a few detections off Wainwright. Further analysis of the 2007 data

revealed that mammal-eating killer whales, called transients, were the source of the detected calls (Delarue et al. 2010b), the latter being consistent with observations of killer whale predation on marine mammals in the Chukchi Sea (George and Suydam 1998; Kryukova et al. 2012). Unique calls, detected in multiple years including 2012, indicate that the same pods or individuals belonging to the same community return to the northeastern Chukchi Sea each year.

In 2012, there was no clear spatial distribution pattern, although killer whale detections were typically recorded south of 71°N with the exception of detections near the Burger prospect and near Barrow (Fig. 7.17). There were no detections in the winter 2011–2012 dataset. Sightings from industry vessels 2006-2012 were >50 km (>31 mi) offshore, although the killer whale sighting during aerial surveys was <10 km (<6 mi) from shore (Fig. 7.17).

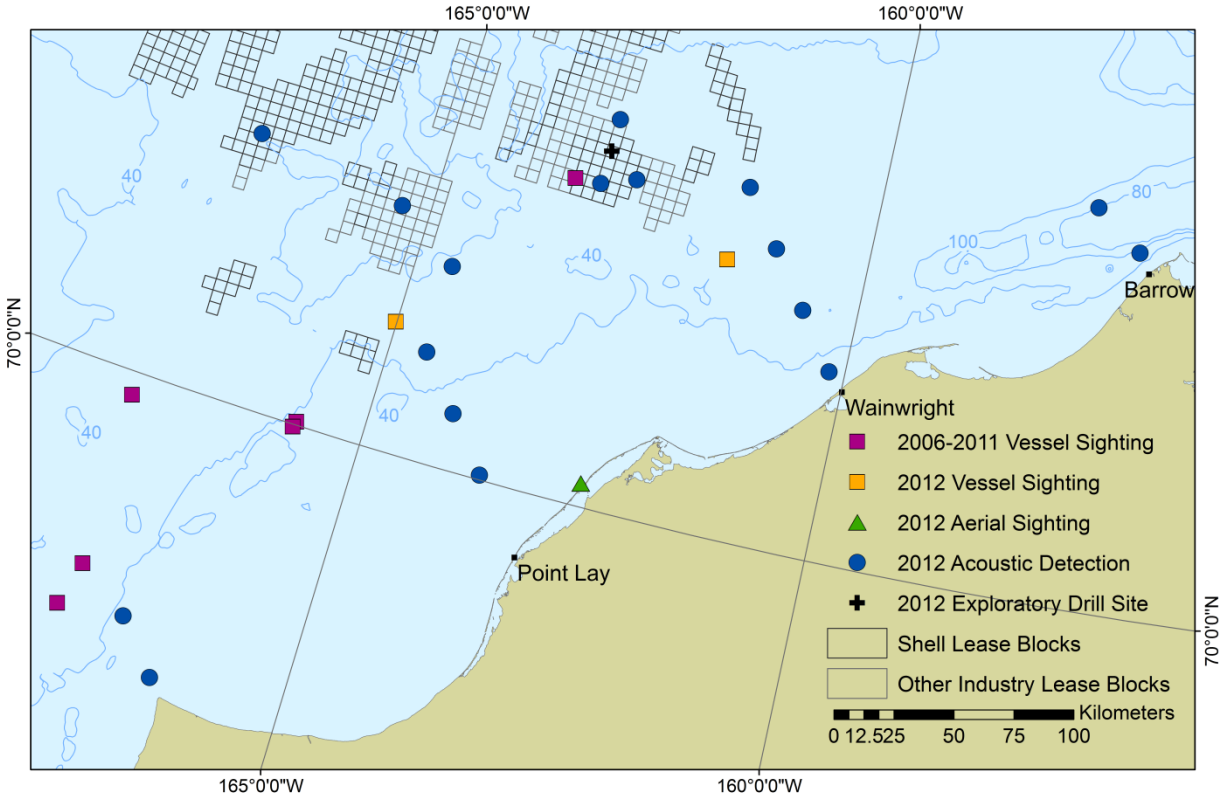


FIGURE 7.17. Killer whale sightings from industry vessels and aerial surveys in 2012 compared to previous years and stations with confirmed killer whale acoustic detections in 2012.

## *Minke Whale*

Minke whales have a cosmopolitan distribution at ice-free latitudes (Stewart and Leatherwood 1985) and also occur in some marginal ice areas of both the Northern and Southern Hemispheres. The range of minke whales does extend into the Chukchi Sea, but the level of use of the Chukchi Sea is currently unknown. Minke whales have been sighted relatively consistently from vessels in the Chukchi Sea since 2006; however, the first confirmed minke whale sighting from industry-sponsored aerial surveys in the Chukchi Sea was in 2012 (Table 7.3). NMML observers reported six sightings of seven minke whales in 2012, which marked the second consecutive year that minke whales were recorded in the Chukchi Sea during ASAMM surveys (Clarke et al. 2013). Minke whales were first detected acoustically

in the Chukchi Sea in 2011 and again in 2012. In the Beaufort Sea, PSOs onboard industry vessels recorded one minke whale sighting in each of 2007, 2008, and 2012.

The majority (~81%) of minke whale sightings in the Chukchi Sea from both vessel and aerial surveys sponsored by industry occurred in mid-to-late August. Only two acoustic detections occurred in late August and one in late September while the majority of calls were recorded from 4–11 October 2012. In 2011, minke whales were also detected acoustically in October; however sightings from vessels again occurred in mid-late August. The prevalence of acoustic detections offshore from Ledyard Bay in 2012 is similar in distribution to minke whale sightings from vessels in all years prior to 2012 (Fig. 7.18). Very few minke whale sightings (<1%) were reported near Peard Bay in 2006–2011, while the majority of minke whale sightings (~70%) from vessels were reported in this location in 2012. Peard Bay, as well as Barrow Canyon to the north, is known to be a foraging hotspot for certain species of whales.

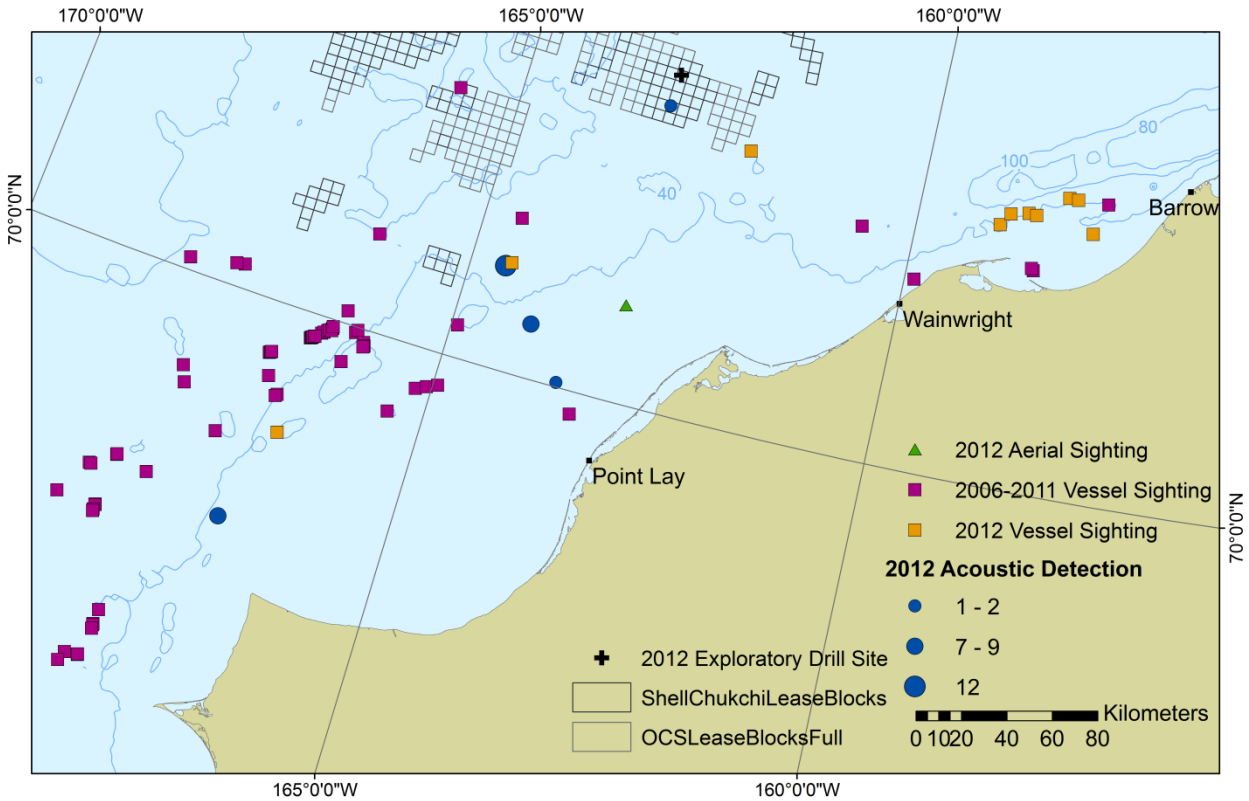


FIGURE 7.18. Minke whale sightings from industry vessels and aerial surveys in 2012 compared to previous years and confirmed minke whale acoustic detections in 2012.

## *Fin Whale*

Fin whales are widely distributed in all the world's oceans (Gambell 1985), but typically occur in temperate and polar regions. Recent data from recorders placed north of the Aleutians indicate the presence of aggregations of prey and fin whales during winter and early spring (Stafford et al. 2010); however, no estimates of fin whale abundance during the summer in the Chukchi Sea are available. The North Pacific fin whale population's summering grounds span from the Chukchi Sea to California (Gambell 1985).

Fin whales were first seen in the Chukchi Sea by industry vessels in 2006 (Patterson et al. 2006). Fin whale sightings were made in 2008 from NMML survey aircraft in the northeastern Chukchi Sea for the first time outside of Ledyard Bay, which was believed to be a potential indication that the range of fin whales was expanding (Clarke et al. 2011). As mentioned above, seven fin whales were seen by PSOs aboard the COMIDA vessel in 2010 (Table 7.3; LGL unpublished data). There have been no sightings of fin whales in the Chukchi Sea during industry aerial surveys and only one sighting was reported from industry vessels in 2012. There were, however, three sightings of five fin whales observed during NMML aerial surveys in 2012 in the Chukchi Sea, all of which were 25–30 km (16–19 mi) south-southwest of Point Hope on 11 September (Clarke et al. 2013).

Fin whales were first detected acoustically in 2007 in the Chukchi Sea, and subsequent acoustic detections in the 2009, 2010, and 2011 summer datasets have confirmed their seasonal presence in most years. There were no confirmed fin whale calls during summer 2012. The number of acoustic detections decreased sharply from 2007 to 2009 with detections remaining rare thereafter. Sporadic acoustic and visual detections of fin whales from 2006–2012 indicates that fin whales likely are irregular visitors the northeastern Chukchi Sea.

### *Humpback Whale*

Humpback whales are distributed in major oceans worldwide and are seasonal migrants to the North Pacific (Allen and Angliss 2012). In general, humpback whales spend the winter in tropical and sub-tropical waters where breeding and calving occur, and migrate to higher latitudes for feeding during the summer. Humpbacks are considered extralimital in the Arctic; however, sightings in the Bering Sea have been recorded frequently southwest of St. Lawrence Island, the southeastern Bering Sea, and north of the central Aleutian Islands (Moore et al. 2002; Allen and Angliss 2012). In the Chukchi Sea, PSOs onboard industry vessels have reported humpback whale sightings in 2007, 2008, 2010, and 2012, and a sighting during industry-sponsored aerial surveys was reported in 2008 (Table 7.3). Clarke et al. (2013) reported 20 sightings of 29 humpback whales in the northeastern Chukchi Sea during 2012 NMML aerial surveys, most of which were within 50 km (31 mi) south and west of Point Hope.

There have been no confirmed acoustic detections of humpback whales in the Chukchi Sea; however, some moan or scream-like sounds, which may be attributed to humpback whales, were detected. Sporadic visual and potential acoustic detections of humpback whales in the Chukchi Sea since 2007 indicate that this species is likely an irregular visitor to these waters.

Humpback whales have been sighted near and east of Barrow on two occasions: one whale was seen east of Barrow near Smith Bay on 1 August 2007 by Hashagen et al. (2009) and one was photographed just east of Barrow during the BOWFEST study.

## *Unidentified Cetaceans*

PSOs onboard industry vessels and conducting aerial surveys are encouraged to identify animals based only on observed characteristics. Many of cetacean sightings could not be identified to species, as diagnostic features for identifying cetaceans are oftentimes not observed from vessels or aircraft (Table 7.4). PSOs included detailed descriptions of observed characteristics for each sighting, and it is likely that the majority of unidentified whale and unidentified mysticete whale sightings were gray whales and bowhead whales. This is consistent with the idea that gray whales and bowhead whales are two of the most abundant cetaceans in the Alaskan Arctic and potentially more difficult to positively identify when compared to beluga whales or other, more conspicuous species.

TABLE 7.4. Unidentified cetacean sightings from industry vessels and aerial surveys in the Chukchi and Beaufort seas, 2006-2012.

| Species Type | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| **Vessel Sightings** | | | | | | | |
| *Chukchi Sea* | | | | | | | |
| Unidentified Mysticete Whale | 6 (6) | 11 (17) | 99 (150) | 11 (16) | 44 (80) | 7 (9) | 167 (295) |
| Unidentified Odontocete Whale | 4 (5) | 2 (2) | 0 | 1 (1) | 1 (3) | 0 | 0 |
| Unidentified Whale | 21 (25) | 16 (26) | 20 (40) | 0 | 5 (9) | 0 | 152 (275) |
| *Beaufort Sea* | | | | | | | |
| Unidentified Mysticete Whale | 0 | 32 (58) | 61 (91) | 0 | 34 (52) | -- -- | 64 (117) |
| Unidentified Whale | 3 (6) | 17 (28) | 16 (25) | 0 | 20 (28) | -- -- | 47 (76) |
| **Aerial Survey Sightings** | | | | | | | |
| *Chukchi Sea* | | | | | | | |
| Unidentified Mysticete Whale | 0 | 0 | 19 (22) | -- -- | 8 (9) | -- -- | 0 |
| Unidentified Odontocete Whale | 0 | 0 | 1 (10) | -- -- | 0 | -- -- | 0 |
| Unidentified Whale | 0 | 22 (34) | 12 (12) | -- -- | 6 (6) | -- -- | 2 (2) |
| *Beaufort Sea* | | | | | | | |
| Unidentified Mysticete Whale | 0 | 1 (1) | 9 (9) | -- -- | 4 (4) | -- -- | 0 |
| Unidentified Odontocete Whale | 0 | 0 | 4 (4) | -- -- | 1 (1) | -- -- | 0 |
| Unidentified Whale | 0 | 1 (1) | 1 (1) | -- -- | 0 | -- -- | 1 (1) |
| ***Total*** | ***34 (42)*** | ***102 (167)*** | ***242 (364)*** | ***12 (17)*** | ***123 (192)*** | ***7 (9)*** | ***433 (766)*** |

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# 8. ICE SEAL MONITORING

Bearded seal (Oogruk, *Erignathus barbatus*), ringed seal (Natchiq, *Phoca hispida*), spotted seal (Qasigiaq, *Phoca largha*), and ribbon seal (Qaiquliq, *Histriophoca fasciata*) inhabit both the Beaufort Sea and Chukchi Sea study areas. Together, these species are often referred to as "ice seals" since all or a portion of their life histories are dependent on sea ice. Of these species, the ribbon seal is relatively uncommon in the region having been sighted only a few times during industry programs since 2006. The other three species are commonly seen throughout the waters of both study areas. Ringed seals are the most common seal in the Arctic in general and remain in these waters throughout the year. Bearded seals are fewer in number than are ringed seals, but are also commonly seen. They tend to frequent ice floes in shallower water and move seasonally with the advance and retreat of sea ice. Spotted seals are more common in the Chukchi Sea than in the Beaufort Sea, though they are found in both locations. From July through September, spotted seals haul out on land part of the time, but also spend extended periods at sea. Haulouts occur regularly in Kasegaluk Lagoon and near Icy Cape in the Chukchi Sea (Lowry et al. 1998) and in the Coleville River Delta in the Beaufort Sea (Johnson et al. 1999). Most spotted seals move seasonally between the Bering Sea where they winter and the Chukchi and Beaufort seas where they spend the summer (Quakenbush 1988; Rugh et al. 1997).

This chapter describes results of visual monitoring conducted by protected species observers (PSOs) onboard vessels and fixed wing aircraft during Shell's drilling programs in the Chukchi and Beaufort seas in 2012 as well as industry seismic programs conducted from 2006 through 2012 in these areas. We also describe results of acoustic studies conducted in the region during these years.

The primary focus of monitoring by PSOs from industry vessels is the mitigation of potentially adverse effects on marine mammals from the activities being conducted. This focus, the relatively small size of seals when seen from large ships, and the short duration of a typical seal sighting often make species identification difficult resulting in large numbers of ice seals being classified as "unidentified." Similarly, aerial surveys flown at 305 m (1000 ft) or higher make detection and identification of seals difficult. Bearded seals, because of their larger size and more distinct head, are usually easier to identify to species than are ringed and spotted seals. Given what we know about the overall abundance of ringed seals when compared to spotted seals, the unidentified sightings are likely predominantly ringed seals. Interpretation of the results should therefore recognize the mixed-species nature of this "species" category.

Acoustic detections of bearded seals have generally been easier to distinguish because of their unique calls and periods where they dominate the sounds recorded in the Chukchi and Beaufort seas, particularly in spring. Ringed, spotted and ribbon seals have proven more difficult to detect with certainty though progress continues to be made with identifying the calls of these species.

## *Results*

### *Seal Sightings*

Seals were commonly seen from all vessels operating in both study areas. From 2006 through 2012, a total of 8252 sightings of 11,176 individuals and 7125 sightings of 11,625 individuals was observed by PSOs aboard vessels and aircraft operating in the Chukchi and Beaufort seas, respectively (Tables 8.1 and 8.2). Differences among years in the numbers of sightings are primarily related to the amount of vessel-based and aerial monitoring effort during each season. Note that there was no industry-

sponsored visual monitoring effort in the Beaufort Sea during the 2011 season. Details of monitoring effort in other years are discussed in Chapter 3 of this report.

TABLE 8.1. Numbers of seal sightings and individuals in the Chukchi Sea from vessel-based and aerial surveys during industry operations from 2006 through 2012. See Chapter 3, Table 3.3 for a summary of observer effort from 2006–2012.

| | Sightings (Individuals) by Year | | | | | | | *Total All Years* |
|---|---|---|---|---|---|---|---|---|
| | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | |
| **Species** | | | | | | | | |
| Bearded seal | 400 (457) | 151 (217) | 450 (528) | 17 (17) | 193 (199) | 59 (61) | 228 (293) | ***1498 (1772)*** |
| Ribbon seal | 2 (2) | 1 (1) | 3 (3) | 0 (0) | 3 (5) | 0 (0) | 0 (0) | ***9 (11)*** |
| Ringed seal | 874 (1083) | 150 (179) | 289 (345) | 38 (40) | 71 (75) | 20 (20) | 86 (96) | ***1528 (1838)*** |
| Spotted seal | 212 (351) | 32 (71) | 74 (293) | 2 (2) | 19 (324) | 1 (1) | 68 (79) | ***408 (1121)*** |
| Unidentified seal | 1594 (1931) | 594 (1100) | 1323 (1581) | 31 (31) | 515 (567) | 24 (24) | 728 (1200) | ***4809 (6434)*** |
| ***Total Seals*** | ***3082 (3824)*** | ***928 (1568)*** | ***2139 (2750)*** | ***88 (90)*** | ***801 (1170)*** | ***104 (106)*** | ***1110 (1668)*** | ***8252 (11,176)*** |

TABLE 8.2. Numbers of seal sightings and individuals in the Beaufort Sea from vessel-based and aerial surveys during industry operations from 2006 through 2012. See Chapter 3, Table 3.3 for a summary of observer effort from 2006–2012.

| | Sightings (Individuals) by Year | | | | | | | *Total All Years* |
|---|---|---|---|---|---|---|---|---|
| | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | |
| **Species** | | | | | | | | |
| Bearded seal | 28 (31) | 116 (148) | 260 (285) | 19 (21) | 336 (363) | - | 144 (149) | ***903 (997)*** |
| Ribbon seal | 0 (0) | 0 (0) | 3 (3) | 0 (0) | 0 (0) | - | 0 (0) | ***3 (3)*** |
| Ringed seal | 104 (119) | 302 (739) | 1047 (1609) | 100 (153) | 200 (438) | - | 172 (325) | ***1925 (3383)*** |
| Spotted seal | 67 (77) | 70 (103) | 121 (163) | 17 (18) | 35 (36) | - | 59 (63) | ***369 (460)*** |
| Unidentified seal | 276 (293) | 377 (1086) | 1467 (2369) | 65 (99) | 1036 (1892) | - | 704 (1043) | ***3925 (6782)*** |
| ***Total Seals*** | ***475 (520)*** | ***865 (2076)*** | ***2898 (4429)*** | ***201 (291)*** | ***1607 (2729)*** | ***-*** | ***1079 (1580)*** | ***7125 (11,625)*** |

## *Seal Distribution*

Visual sampling effort was not uniformly distributed across the study areas each year. Therefore, it is not appropriate to make definitive inferences about the overall distribution of ice seals in the Chukchi and Beaufort seas. It is possible, however, to make limited comparisons among the areas that were surveyed regularly and also to consider variables such as sea ice and sighting conditions. Seals were generally distributed widely across the survey areas in the Beaufort and Chukchi seas, with a notable exception during the 2012 season (see *An Anomalously Large Group of Seals Sighted in 2012* below).

Ringed, bearded, and spotted seals all have life histories that are influenced by sea ice. The presence and persistence of sea ice habitat in and around the study areas likely influenced the distribution of seals within the study areas. In 2012, sea ice remained in the study areas, particularly in the Chukchi Sea, despite it being the lowest annual sea ice minimum on record Arctic-wide (see Chapter 2: Background and Context). Ice presence directly affected the timing of drilling operations and the locations of vessels in both the Chukchi and Beaufort seas. Figure 8.1 shows seal sightings overlaid on

ice maps presented in Chapter 2: Background and Context. The numbers and locations of sightings largely reflect the location of operations and the amount of effort in those areas since vessel locations dictated the areas where this opportunistic monitoring effort occurred. Although vessels typically operated in areas away from ice, these data indicate that most of the seal sightings occurred where ice persisted for the longest periods of time.

Ice conditions have varied greatly in the study area each year since 2006. Figures 8.2 through 8.7 show the number of weeks ice was present throughout each open-water season (2006 through 2011) from 18 July through 10 October. In addition, these figures have the location of vessel-based and aerial-survey seal sightings overlaid to show the distribution of seal sightings in relation to ice persistence throughout the open-water season.

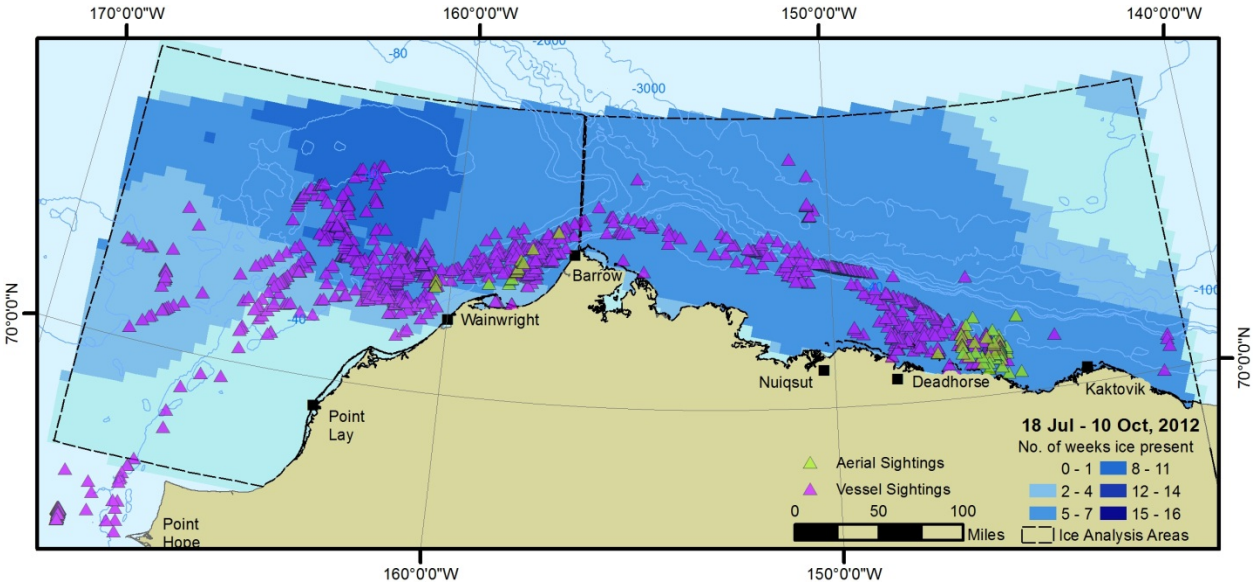


FIGURE 8.1. The number of weeks ice was present during the open-water season from 18 July–10 October, 2012 in the Chukchi and Beaufort seas. Seal sightings from vessels and aerial surveys are overlaid on the ice data.

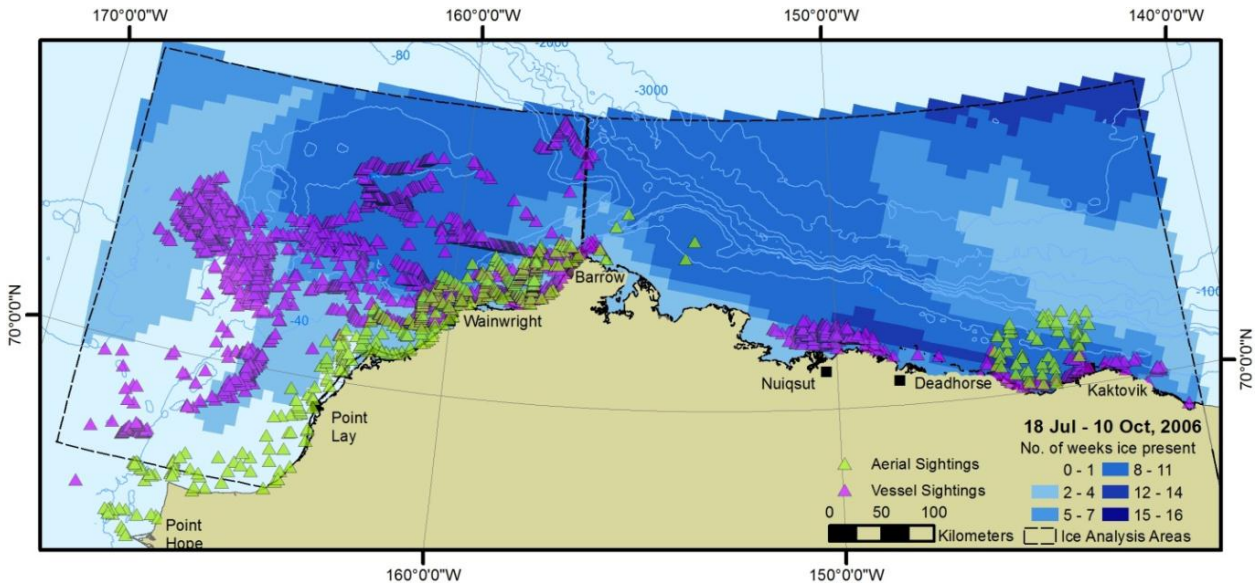


FIGURE 8.2. The number of weeks ice was present during the open-water season from 18 July–10 October, 2006 in the Chukchi and Beaufort seas. Seal sightings from vessels and aerial surveys are overlaid on the ice data.

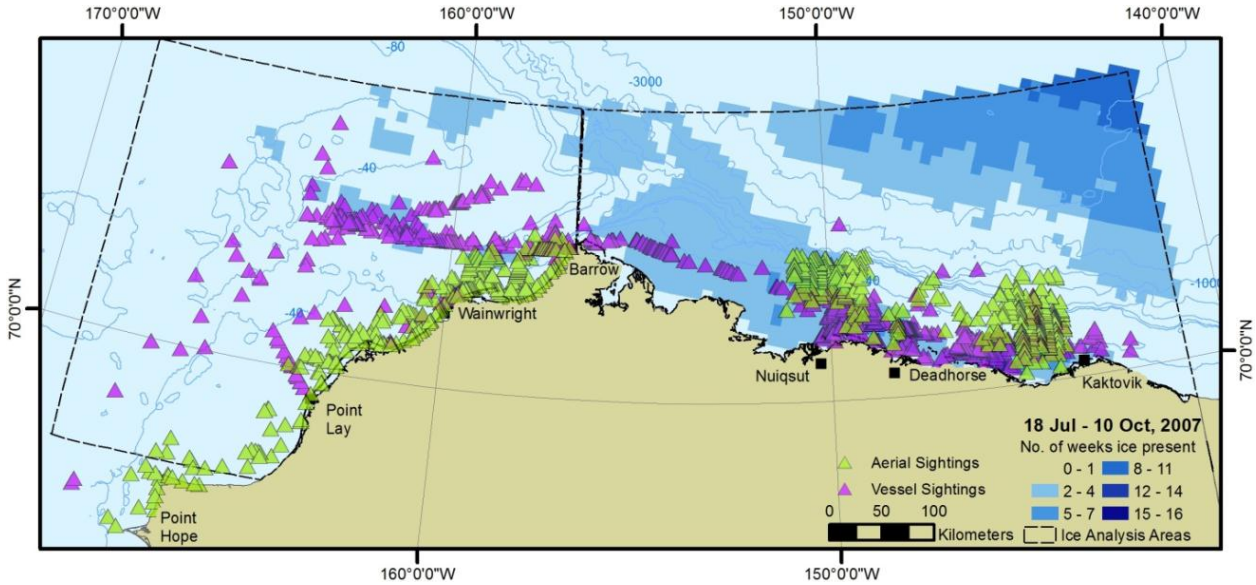


FIGURE 8.3. The number of weeks ice was present during the open-water season from 18 July–10 October, 2007 in the Chukchi and Beaufort seas. Seal sightings from vessels and aerial surveys are overlaid on the ice data.

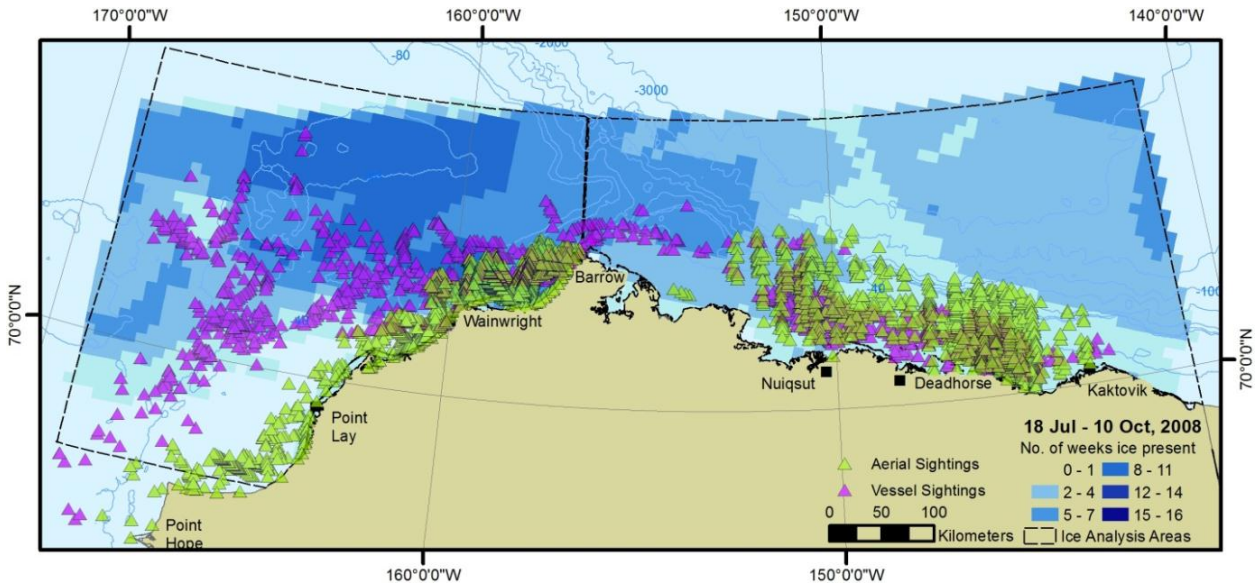


FIGURE 8.4. The number of weeks of ice was present during the open-water season from 18 July–10 October, 2008 in the Chukchi and Beaufort seas. Seal sightings from vessels and aerial surveys are overlaid on the ice data.

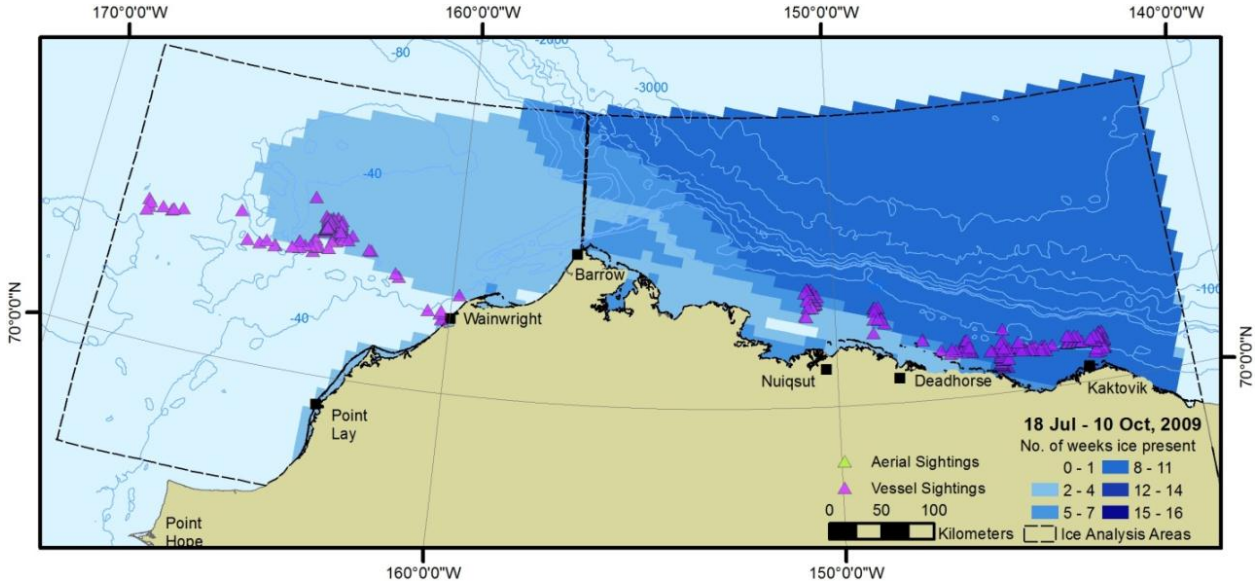


FIGURE 8.5. The number of weeks ice was present during the open-water season from 18 July–10 October, 2009 in the Chukchi and Beaufort seas. Seal sightings from vessels are overlaid on the ice data. No aerial surveys were conducted by Industry in 2009.

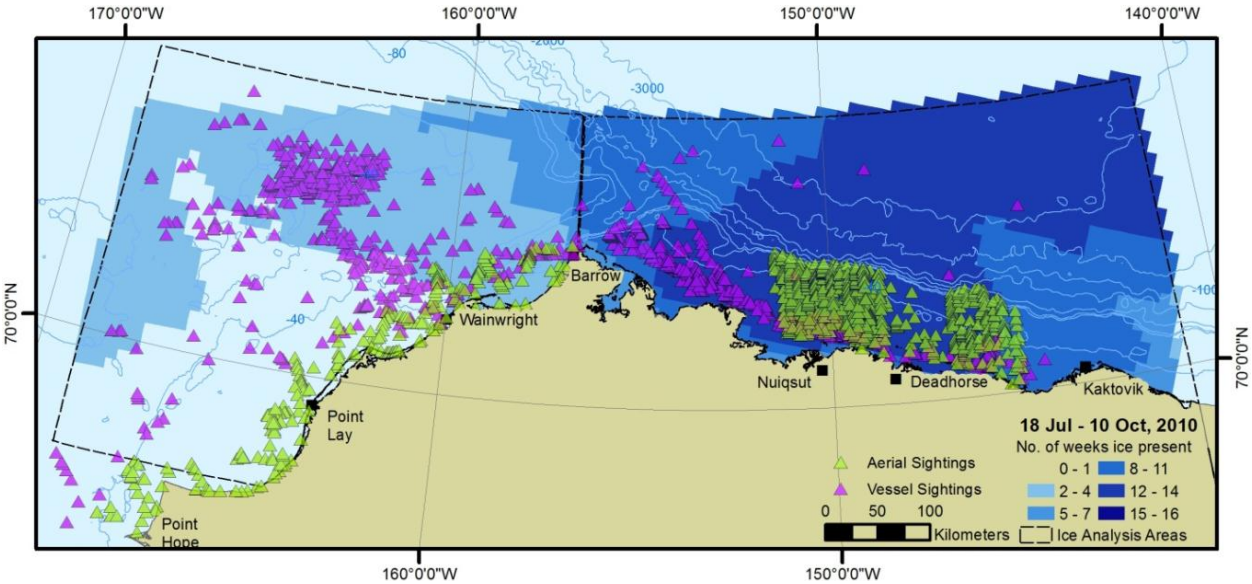


FIGURE 8.6. The number of weeks ice was present during the open-water season from 18 July–10 October, 2010 in the Chukchi and Beaufort seas. Seal sightings from vessels and aerial surveys are overlaid on the ice data.

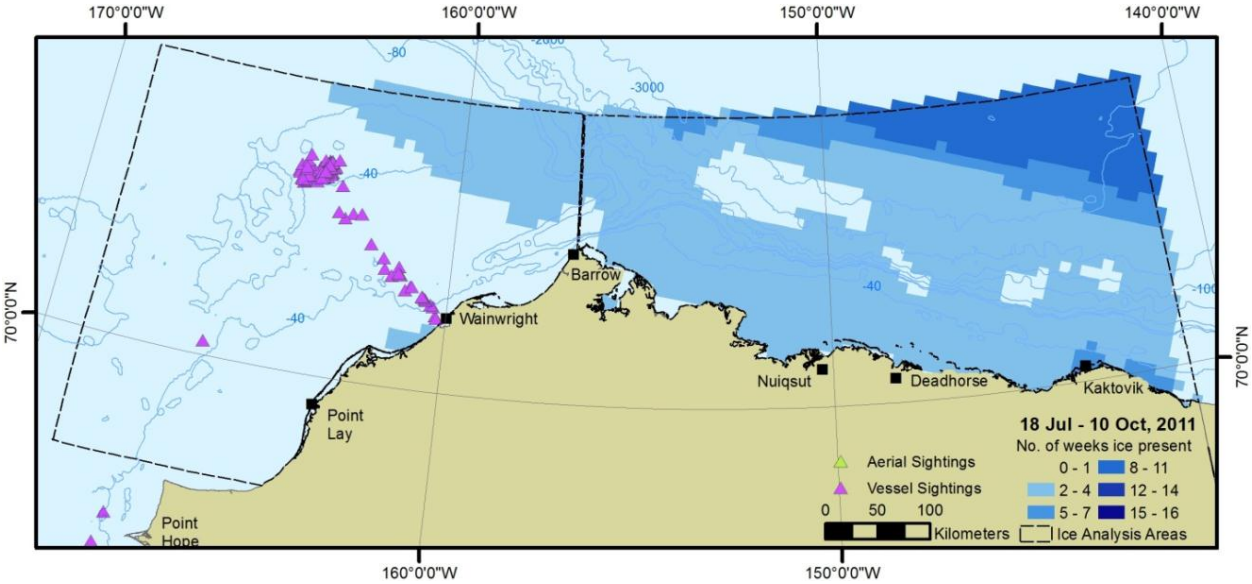


FIGURE 8.7. The number of weeks ice was present during the open-water season from 18 July–10 October, 2011 in the Chukchi and Beaufort seas. Seal sightings from vessels are overlaid on the ice data. No aerial surveys were conducted by industry in 2011.

Ice was present for the highest number of weeks in both the Chukchi and Beaufort seas in 2006, and was present for the lowest number of weeks in both seas during 2007 and 2011. In 2008, ice was more persistent in the Chukchi Sea than in the Beaufort Sea, and the opposite was true in 2009 and 2010. In all years there were numerous seal sightings across ice presence classifications, but in years when ice was persistent in the study areas there was a general trend of sightings occurring in areas with greater ice

persistence. This pattern is apparent despite the fact that vessel data are collected opportunistically from vessels that typically operate away from the ice edge, thereby biasing effort towards ice-free areas.

### *The Influence of Environmental Factors on Seal Sighting Rates*

Various environmental factors influence the sightings rates of seals from industry ships in Arctic waters. Sightings and effort data from 2006–2012 were combined to explore some of these relationships between seal sighting rates and key environmental conditions. We focus on two environmental factors: ice presence and cover and Beaufort Wind Force.

#### *Sea Ice Cover*

As described above, ice presence in and around areas where ships operate may influence the numbers of seals that are present. This means more animals are available for sighting and results in higher sighting rates in areas closer to pack ice and in waters with greater ice cover. Sightings and effort data were combined into bins based on the distance of the sighting from the ice edge. The data were also placed into two bins for ice concentration, >10% ice cover and <10% ice cover. More detailed descriptions of the methods used for these analyses are provided in Appendix A.

Sighting rates for each category are shown in Table 8.3. From both moving and stationary vessels in the Chukchi Sea, and from moving vessels in the Beaufort Sea, sighting rates of seals were significantly higher in and close to ice than were sighting rates of seals farther away from ice (moving vessels Chukchi: G=440.07; stationary vessels Chukchi: G=48.30; moving vessels Beaufort: G=116.53 respectively; df=6 and $p<0.001$ in all cases). Sighting rates from stationary vessels in the Beaufort Sea did not vary significantly by ice conditions (G=11.85, df=6, $p=0.07$), however this result should be interpreted with caution as the effort in one of the ice bins was below 70 hr and markedly lower than the effort in the other bins.

TABLE 8.3. Seal sighting rates by ice conditions in the Beaufort and Chukchi Seas during industry activities and marine surveys, 2006–2012.

| Ice Conditions & Proximity | Beaufort Sea | | Chukchi Sea | |
|---|---|---|---|---|
| | Moving Vessels [a] | Stationary Vessels [b] | Moving Vessels [a] | Stationary Vessels [b] |
| **Ice concentration >10%** | 63.6 | 1.4 | 61.0 | 0.5 |
| **Ice concentration <10%** | 32.8 | 1.7 | 21.6 | 1.7 |
| **0-5 km (0-3.1 mi) from Ice** | 78.9 | 1.2 | 37.7 | 1.4 |
| **5-10 km (3.1-6.3 mi) from Ice** | 32.5 | 1.2 | 48.3 | 0.6 |
| **10-15 km (6.3-9.4 mi) from Ice** | 38.5 | 0.8 | 38.4 | 1.1 |
| **15-20 km (9.4-12.6 mi) from Ice** | 45.8 | 1.7 | 31.1 | 1.2 |
| **>20 km (>12.6mi) from Ice** | 41.6 | 1.0 | 21.4 | 0.7 |
| ***Overall Sighting Rate*** | ***43.2*** | ***1.1*** | ***25.3*** | ***0.9*** |

[a] Sighting rates from moving vessels are expressed as number of sightings per 1000 km (621 mi) of sighting effort.
[b] Sighting rates from stationary vessels are expressed as number of sightings per 10 hr of sighting effort.

### *Beaufort Wind Force*

Unlike sea ice, Beaufort Wind Force is not expected to influence the number of seals present in a particular area. Rather, it affects water surface conditions and, therefore, the ability of an observer to see seals in the water and to identify them once they are seen. As wind force increases on the Beaufort scale, the less likely it is that observers will be able to locate and identify seals in the water around the ships. See Appendix D for definitions of Beaufort Wind Force categories.

Seal sightings and effort data for the 2006–2012 seasons were combined and used to calculated sighting rates within wind force categories zero through five (Table 8.4). In all cases, sighting rates were negatively associated with increasing wind force. For both moving and stationary vessels in the Beaufort and Chukchi seas, sighting rates varied significantly by wind force (G=2116.75, G=79.04, G=3547.67, G=123.26 respectively; df=5 and $p<0.001$ in all cases). The ability of PSOs to see seals in the water around ships decreased rapidly once wind force reached three on the Beaufort scale.

The distances at which seals were first detected also varied by wind force. Tables 8.5 through 8.8 show the descriptive statistics for the distances at which seals were first sighted by PSOs aboard vessels. For both moving and stationary vessels in the Beaufort and Chukchi seas, average detection distances are lower in higher Beaufort Wind Force categories with distances of first detection more than 2/3rds less in seas of Beaufort four or five. Results of paired Wilcoxon tests suggest that, for both moving and stationary vessels in the Beaufort and Chukchi seas, sighting distance is significantly shorter in conditions of Beaufort four and higher (W=330668.5, W=8398.0, W=3545885.0, W=8938.0; $p<0.001$ in all cases).

TABLE 8.4. Seal sighting rates by Beaufort Wind Force in the Beaufort and Chukchi Seas during industry activities and marine surveys, 2006–2012.

| Beaufort Wind Force | Beaufort Sea | | Chukchi Sea | |
|---|---|---|---|---|
| | Moving Vessels [a] | Stationary Vessels [b] | Moving Vessels [a] | Stationary Vessels [b] |
| **0** | 151.4 | 3.8 | 259.4 | 4.1 |
| **1** | 122.1 | 2.5 | 77.4 | 2.0 |
| **2** | 52.6 | 1.2 | 28.8 | 1.0 |
| **3** | 18.8 | 0.8 | 14.3 | 0.5 |
| **4** | 10.5 | 0.7 | 9.4 | 0.4 |
| **5** | 11.3 | 0.6 | 6.4 | 0.5 |
| ***Overall Sighting Rate*** | ***43.2*** | ***1.1*** | ***25.3*** | ***0.9*** |

[a] Sighting rates from moving vessels are expressed as number of sightings per 1000 km (621 mi) of sighting effort.

[b] Sighting rates from stationary vessels are expressed as number of sightings per 10 hr of sighting effort.

TABLE 8.5. Distances at which PSOs aboard moving vessels first detected seals by Beaufort Wind Force in the Chukchi Sea during industry activities and marine surveys, 2006–2012.

| Beaufort Wind Force | Mean Detection Distance (m) | s.d. | Range (m) | *n* |
|---|---|---|---|---|
| **0** | -- | -- | -- | ***--*** |
| **1** | 345 | 425 | 2-5031 | ***1182*** |
| **2** | 273 | 357 | 2-4000 | ***963*** |
| **3** | 196 | 237 | 1-2301 | ***609*** |
| **4** | 117 | 128 | 2-782 | ***297*** |
| **5** | 129 | 131 | 5-782 | ***132*** |
| ***Total*** | ***278*** | ***353*** | ***1-5301*** | ***3680*** |

TABLE 8.6. Distances at which PSOs aboard stationary vessels first detected seals by Beaufort Wind Force in the Chukchi Sea during industry activities and marine surveys, 2006–2012.

| Beaufort Wind Force | Mean Detection Distance (m) | s.d. | Range (m) | *n* |
|---|---|---|---|---|
| **0** | -- | -- | -- | ***--*** |
| **1** | 391 | 607 | 0-4500 | ***101*** |
| **2** | 321 | 362 | 10-2173 | ***88*** |
| **3** | 166 | 194 | 10-1000 | ***51*** |
| **4** | 126 | 126 | 5-628 | ***32*** |
| **5** | 79 | 63 | 10-300 | ***26*** |
| ***Total*** | ***286*** | ***435*** | ***0-4500*** | ***312*** |

TABLE 8.7. Distances at which PSOs aboard moving vessels first detected seals by Beaufort Wind Force in the Beaufort Sea during industry activities and marine surveys, 2006–2012.

| Beaufort Wind Force | Mean Detection Distance (m) | s.d. | Range (m) | *n* |
|---|---|---|---|---|
| **0** | 302 | 312 | 5-2000 | ***244*** |
| **1** | 302 | 323 | 1-339 | ***1099*** |
| **2** | 274 | 386 | 2-5419 | ***840*** |
| **3** | 172 | 213 | 5-1500 | ***320*** |
| **4** | 113 | 113 | 10-600 | ***128*** |
| **5** | 86 | 88 | 5-426 | ***77*** |
| ***Total*** | ***263*** | ***327*** | ***1-5419*** | ***2708*** |

TABLE 8.8. Distances at which PSOs aboard stationary vessels detected seals by Beaufort Wind Force in the Beaufort Sea during industry activities and marine surveys, 2006–2012.

| Beaufort Wind Force | Mean Detection Distance (m) | s.d. | Range (m) | *n* |
|---|---|---|---|---|
| **0** | 356 | 353 | 20-1110 | ***11*** |
| **1** | 346 | 347 | 5-1997 | ***81*** |
| **2** | 230 | 230 | 2-1122 | ***102*** |
| **3** | 249 | 249 | 4-1687 | ***75*** |
| **4** | 101 | 101 | 5-400 | ***35*** |
| **5** | 157 | 157 | 2-695 | ***18*** |
| ***Total*** | ***201*** | ***313*** | ***2-1997*** | ***322*** |

### *An Anomalously Large Group of Seals Sighted in 2012*

During the transit from the Beaufort Sea portion of the study area to the Chukchi Sea, the PSOs on the *Geo Arctic* and *Polar Prince* observed 92 seal sightings of 125 individual seals during a 5.5 hr period on 11 November 2012. These seal sightings accounted for approximately 88% of the total seal sightings observed during ION's 2012 operations in the Beaufort Sea. However, this observation period accounted for only a small percentage (~2%) of the total time the *Geo Arctic* and *Polar Prince* spent in the Beaufort Sea during the 2012 season. The large number of seals observed on 11 November can be at least partially attributed to the favorable observation conditions, as the Beaufort sea state was ≤2 throughout the day and the majority (76%) of observation effort occurred during visibility conditions ≥7 km (4.3 mi). Habitat factors like water depth and ice conditions also likely influenced the number of seals present. The water depth ranged from 40 to 206 m (131 to 676 ft) during observations on 11 November, with slightly more

than half (~56%) of the observational effort in water depths ≤100 m (328 ft). The area was also largely covered by new and small pancake ice (averaged 90% coverage) allowing animals to be hauled out and more visible to observers. In addition, there was no seismic activity occurring during the transit.

The seal sightings on 11 November ranged from 67 to 78 km (42 to 48 mi) offshore and were predominantly (83%; *n*=76) in water depths ≥50 m (164 ft). The high seal sighting rate (532.0 sightings/1000 km; 856 sightings/1000 mi) in water depths ≤200 m (656 ft) on 11 November is consistent with previous aerial surveys conducted during springtime in the central Alaskan Beaufort Sea, where estimated seal densities were higher in shallow areas than in deeper areas (Frost et al. 2004; Moulton et al. 2002; Moulton et al. 2005). In the eastern Canadian Beaufort Sea, ringed seal densities were also generally high in waters with similar depths (50–100 m or 50–150 m; 164–328 ft or 164–492 ft; Stirling et al. 1982; Kingsley 1990). During observations in the Beaufort Sea on 21 October 2012, when the *Geo Arctic's* airguns were off and there were similar visibility and Beaufort wind force conditions as on 11 November, the two vessels observed no seals while in open-water and in water depths ≥200 m (656 ft). The difference between the number of seal sightings during these two days suggest that certain habitat factors like water depth and ice conditions may have influenced the number of seals encountered on 11 November, although temporal and weather factors, and also distribution of food resources may have also played a role. However, with this limited dataset conclusions cannot be drawn regarding which factor(s) played the most influential role, but as future projects are conducted in the same area during a similar time period certain trends may become evident.

### *Seal Distribution and Behavior Relative to Industry Activities in 2012*

In addition to the large-scale influence of ice cover on seal distribution, industry operations may affect seal presence and behavior in localized areas where activities are occurring. Drilling operations that occurred in 2012 emitted continuous sound into the marine environment, disturbed a small and highly localized area of seafloor, and required vessel traffic in and around the drill site to support the activities. Polar plots of each drilling rig that show all seal sightings relative to the drilling vessels during stationary periods were used to visually test hypotheses regarding seal avoidance of the drilling operations. If seals actively avoided the drilling vessel while strong sounds were being produced, then polar plots would be expected to show a halo effect of the location of seal sightings around the rigs during periods of drilling and/or other noisy activities. Further, it might be expected that seals would generally approach the drilling vessel more closely during periods when drilling, or other sound producing activities, were not occurring. Mean closest points of approach (CPA) for seal sightings varied among drill rig activity categories (Bisson et al. 2013), but too few sightings occurred during the relatively short periods that drilling took place to allow meaningful statistical comparisons among these data.

Figures 8.8 and 8.9 indicate that most seals were sighted within several hundred meters of the drilling vessels in both the Chukchi and Beaufort seas. There appeared to be little, if any, avoidance of the drilling vessels during periods when actual drilling was occurring.

There was no significant difference between mean closest points of approach (CPAs) of seals to drill rigs during drilling compared to non-drilling periods in 2012 (*Discoverer*: W=87, *p*=0.26; *Kulluk*: W=259.5, *p*=0.54). Such comparisons require sightings meet various analysis criteria to avoid bias in results that occurs if data from periods of poor visibility are included in analyses (Appendix A). These statistical comparisons of CPA from drill rigs in 2012 are based on limited sample sizes from drilling periods and should be interpreted with caution (*n*=6 and 11 for the *Discoverer* and *Kulluk*, respectively). Figures 8.8 and 8.9, however, show all sightings recorded from the rigs regardless of conditions under which sightings were made. There were more sightings of seals during periods when the drill rigs were not active, but this was related to the much greater monitoring effort during non-drilling periods. Overall

drilling occurred for only a short period of time in each sea. Further, there appeared to be little difference between sighting distances and locations when comparing periods of active drilling to periods of all other activities.

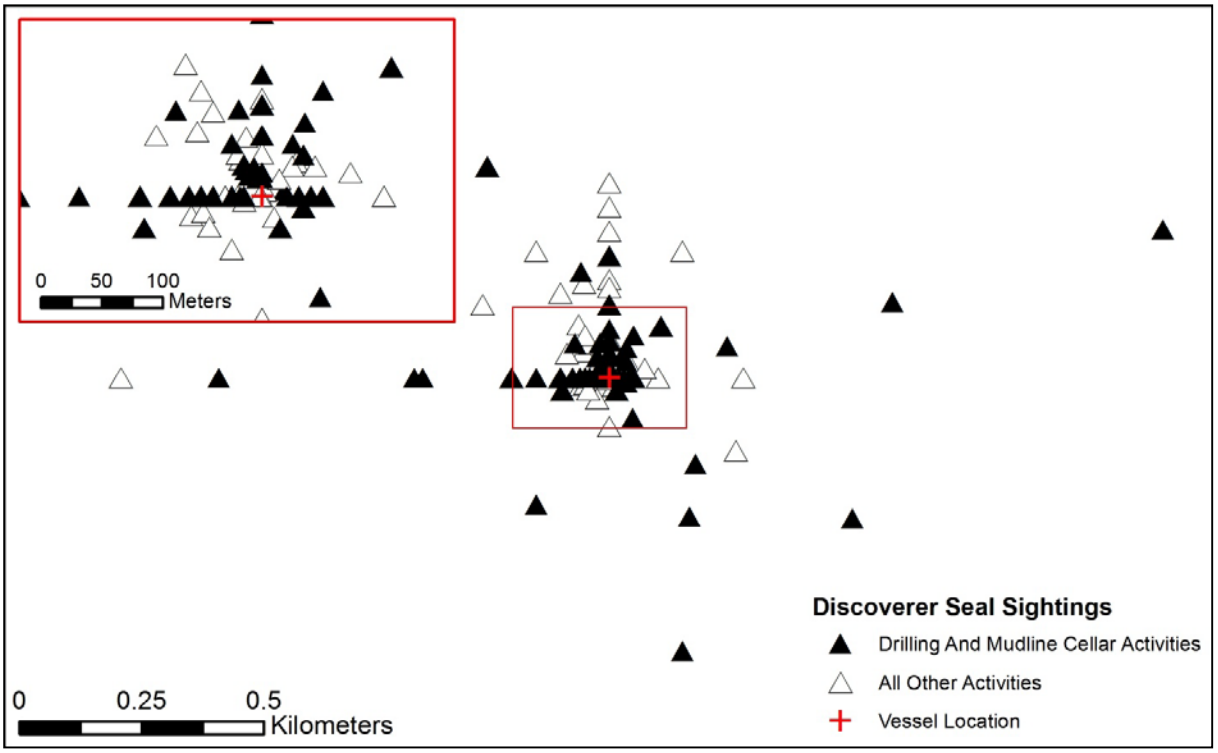


FIGURE 8.8. All seal sightings around the drill ship *Discoverer* during active drilling versus periods of other stationary activities in the Chukchi Sea during 2012.

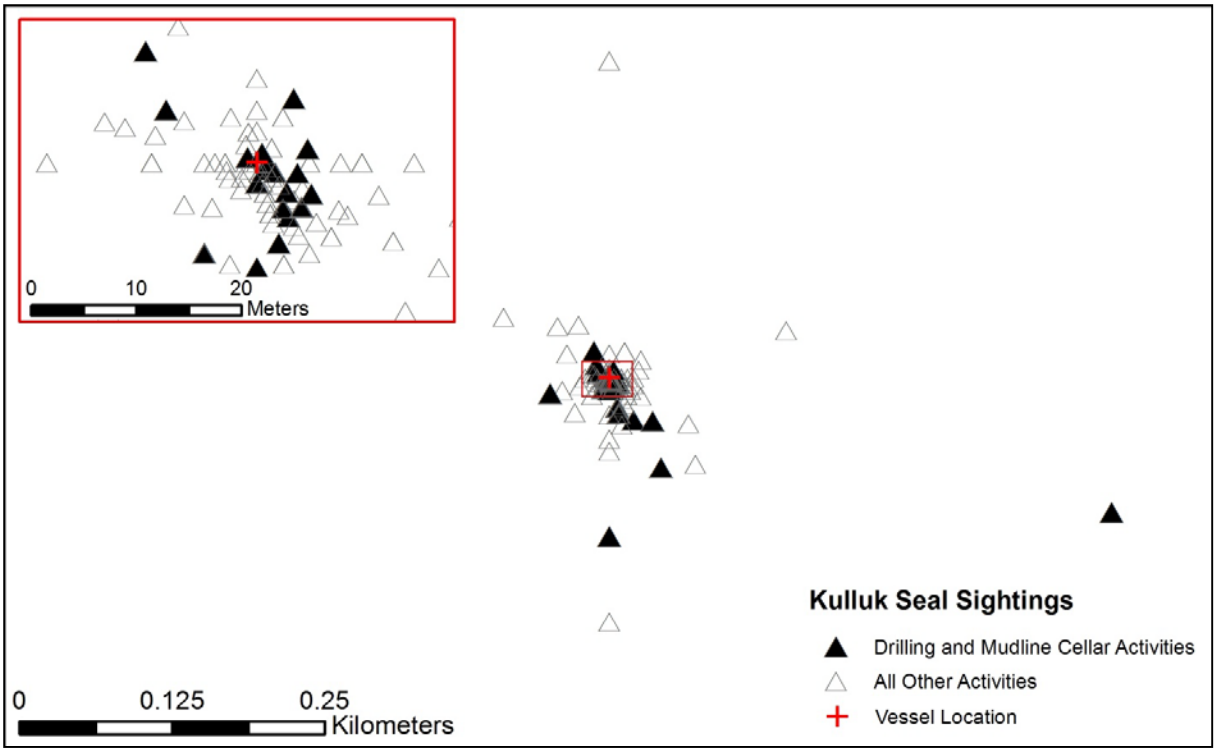


FIGURE 8.9. All seal sightings around the drilling platform *Kulluk* during active drilling versus periods of other stationary activities in the Chukchi Sea during 2012.

### *Sighting Duration and Behavior of Seals Sighted from the Kulluk in 2012*

An opportunity to better understand the behavior of both bearded and ringed seal individuals near the drilling platform *Kulluk* occurred when PSOs recognized and tracked individual seals that remained present near the drilling vessel. The *Kulluk* was anchored at the Sivulliq prospect in the Beaufort Sea from 25 September to 6 November, 2012. During this time, PSOs suspected that individual seals were being observed on multiple occasions over time. Digital photography was used to confirm that a total of seven individuals, three bearded and four ringed seals, were present in the waters around the *Kulluk* on multiple occasions during the drilling program. An additional eight ringed seals were also thought to be returning individuals and were identified during sightings by specific marks on their pelage such as color patches and patterns or scars. Although photographs of these additional eight ringed seals were not taken, PSOs felt confident in the identification of the individual seals. Two large groups of ringed seals (six to seven individuals, and 15–20 individuals) were also seen on multiple occasions. The summary of descriptive statistics of the sighting durations for each individual and group, and for sightings of seals that were not identified, are provided in Table 8.9.

Animals that were identified and photographed were given a code combining the species initials and a number (BS for bearded seal, RS for ringed seal, e.g., BS3 or RS2). Ringed seals observed repeatedly but not photographed, were assigned a letter after the abbreviation RS (e.g., RSA, RSK). Each of the codes corresponded to sightings of only one individual. Two large groups of ringed seals (six to seven animals, and 15–20 animals) were also sighted on multiple occasions, and were coded as RSG1 and RSG2. These resightings were thought to be of the same groups of individuals and may have indicated some social affiliation among individuals, though the composition of the groups could not be verified at the level of the individual. The numbers of animals in each group was consistent across the multiple

sightings as were the appearances and behaviors of members of the groups. The dates of occurrence for each identified animal or group of seals near the *Kulluk* is shown in Figure 8.10.

*Kulluk* PSOs recorded a total of 163 seal sightings in 2012. Each of these sightings, including initial detections and resightings of previously-recorded individuals, was considered in the following results. Each record provided information pertaining to behavior, reaction, etc. over a wide range of operational activities, which may have changed over the course of a sighting event. Of the 163 sightings of seals recorded by the *Kulluk* PSOs in 2012, 94 were of uniquely-identified animals and 69 sightings were of seals that were not recognizable (Table 8.9). The number of resightings of identified seals ranged from two to 11. If PSOs were not able to confirm the identity of a particular seal, the sighting was included among the unidentified animals. Table 8.9 also shows the total length of time that individual seals were present in the waters visible around the *Kulluk* drilling platform, the mean duration of each sighting and the range of durations for each individual.

These data further support the idea that seals did not avoid the drilling rigs. At least in the Beaufort Sea, seals frequented the rig over periods of days to weeks. PSOs onboard the *Discoverer* in the Chukchi Sea also reported that seals often appeared to be the same individuals that had been sighted previously that day or over periods of several days, but specific efforts to identify the seals, as was done on the *Kulluk*, were not undertaken.

The behavior and reaction of the animals to the *Kulluk* during various operations from general maintenance to drilling of the top hole and mud-line cellar also provide some insight into the potential effects of these operations on seals and seal behavior. The initial behavior observed for each recorded sighting is presented in Table 8.10.

Regardless of vessel activity, the most commonly observed behavior of seals near the Kulluk was “look,” followed closely by “dive,” “swim on back,” and other “swim” behaviors (Table 8.10). “Look” as a behavior indicates the seal was looking around but not in a manner that was focused on the rig. The “other” behavior category included “feed” and “log.”

While in proximity to the *Kulluk*, the majority of both identified and non-identified seals displayed no discernible reaction to the vessel (Table 8.11). The most frequently observed reaction was an animal “looking” at the vessel. Two seals were observed “interacting with gear,” both of which were observed making contact with the vessel’s hull as opposed to actually interacting with drilling equipment or related gear.

TABLE 8.9. Total duration, mean duration, and range of duration of sightings (in hrs) of seals observed from the *Kulluk* during the 2012 season.

| Seal ID | Total Duration (hrs) | Mean Duration (hrs) | Range (hrs) | *n* |
|---|---|---|---|---|
| **BS3** | 147.90 | 13.45 | < 0.01 - 41.11 | 11 |
| **BS6** | 3.29 | 0.82 | 0.11 - 2.17 | 4 |
| **BS7** | 16.89 | 3.38 | 0.21 - 8.55 | 5 |
| **RS1** | 123.66 | 12.37 | 0.20 - 26.93 | 10 |
| **RS2** | 74.23 | 7.42 | 0.05 - 19.67 | 10 |
| **RS4** | 34.46 | 6.89 | 0.01 - 14.63 | 5 |
| **RS5** | 58.24 | 9.71 | 1.37 - 19.30 | 6 |
| **RSA** | 6.20 | 2.07 | 0.85 - 3.64 | 3 |
| **RSB** | 49.77 | 24.88 | 24.88 - 24.88 | 2 |
| **RSC** | 47.05 | 15.68 | 9.90 - 18.73 | 3 |
| **RSD** | 12.70 | 6.35 | 6.35 - 6.35 | 2 |
| **RSE** | 4.98 | 2.49 | 1.12 - 3.87 | 2 |
| **RSF** | 0.27 | 0.13 | 0.01 - 0.25 | 2 |
| **RSH** | 80.60 | 13.43 | 3.70 - 27.65 | 6 |
| **RSK** | 102.04 | 9.28 | 0.03 - 30.98 | 11 |
| **RSG1** | 28.41 | 4.06 | 0.01 - 8.67 | 7 |
| **RSG2** | 83.56 | 16.71 | 01.66 - 26.40 | 5 |
| **Total of IDd** | **874.25** | **9.30** | **< 0.01 - 41.11** | **94** |
| **No ID** | 147.96 | 2.14 | 0.01 - 31.11 | 69 |
| ***Total*** | ***1022.20*** | ***6.27*** | ***< 0.01 - 41.11*** | ***163*** |

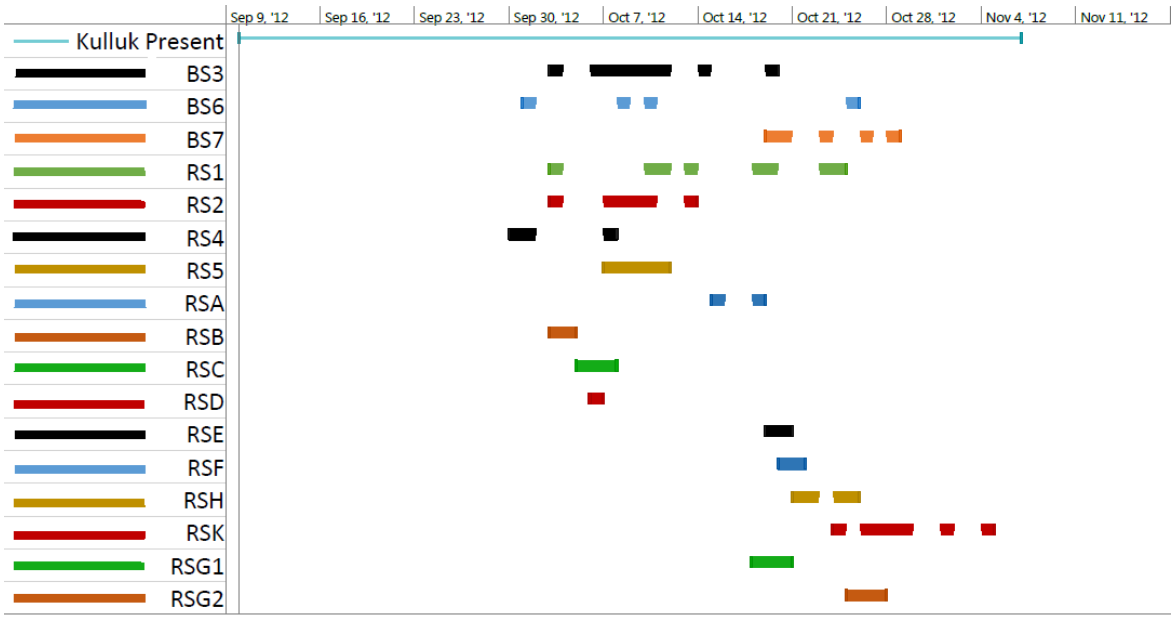


FIGURE 8.10. Dates of presence for each seal individual or group identified and resighted by PSOs from the drilling platform *Kulluk* in the Alaskan Beaufort Sea, 2012. Animals with a number (BS6, RS3) were photo-identified, whereas animals with a letter (RSA, RSB) were resighted and identified with confidence, but no photographs were acquired.

TABLE 8.10. Initial behaviors of seals observed from the *Kulluk* during the 2012 season.

| Seal ID | Initial Behavior | | | | | | |
|---|---|---|---|---|---|---|---|
| | Dive | Look | Swim on Back | Mill | Swim | Other | *Totals* |
| **BS3** | 4 | 5 | - | - | 1 | 1 | ***11*** |
| **BS6** | - | 4 | - | - | - | - | ***4*** |
| **BS7** | - | 4 | - | - | - | 1 | ***5*** |
| **RS1** | - | 2 | 8 | - | - | - | ***10*** |
| **RS2** | 4 | 1 | 1 | - | 4 | - | ***10*** |
| **RS4** | 3 | 1 | 1 | - | - | - | ***5*** |
| **RS5** | - | 1 | 4 | - | 1 | - | ***6*** |
| **RSA** | - | 2 | 1 | - | - | - | ***3*** |
| **RSB** | - | 2 | - | - | - | - | ***2*** |
| **RSC** | - | - | 3 | - | - | - | ***3*** |
| **RSD** | 1 | - | - | - | - | 1 | ***2*** |
| **RSE** | - | 1 | 1 | - | - | - | ***2*** |
| **RSF** | - | - | 1 | 1 | - | - | ***2*** |
| **RSH** | 1 | - | 4 | 1 | - | - | ***6*** |
| **RSK** | - | 2 | 1 | 4 | 4 | - | ***11*** |
| **RSG1** | - | - | - | 5 | 2 | - | ***7*** |
| **RSG2** | - | - | 2 | 2 | 1 | - | ***5*** |
| **Total of IDd** | **13** | **25** | **27** | **13** | **13** | **3** | **94** |
| **No ID** | 23 | 22 | 6 | - | 14 | 4 | ***69*** |
| ***Total*** | ***36*** | ***47*** | ***33*** | ***13*** | ***27*** | ***7*** | ***163*** |

TABLE 8.11. Reaction behaviors of seals observed from the *Kulluk* during the 2012 season.

| Seal ID | Reaction Behavior | | | | | |
|---|---|---|---|---|---|---|
| | Change Direction | Look | Splash | Interaction With Gear | None | *Totals* |
| **BS3** | - | 5 | 1 | - | 5 | ***11*** |
| **BS6** | - | 4 | - | - | - | ***4*** |
| **BS7** | - | 5 | - | - | - | ***5*** |
| **RS1** | - | 2 | - | - | 8 | ***10*** |
| **RS2** | - | 1 | - | - | 9 | ***10*** |
| **RS4** | - | 1 | - | - | 4 | ***5*** |
| **RS5** | - | 2 | - | - | 4 | ***6*** |
| **RSA** | - | 3 | - | - | - | ***3*** |
| **RSB** | - | 2 | - | - | - | ***2*** |
| **RSC** | - | - | - | - | 3 | ***3*** |
| **RSD** | - | 1 | - | - | 1 | ***2*** |
| **RSE** | - | 1 | - | - | 1 | ***2*** |
| **RSF** | - | 1 | - | - | 1 | ***2*** |
| **RSH** | - | - | - | 1 | 5 | ***6*** |
| **RSK** | 1 | 3 | - | - | 7 | ***11*** |
| **RSG1** | - | 3 | - | - | 4 | ***7*** |
| **RSG2** | - | 1 | - | - | 4 | ***5*** |
| **Total of IDd** | **1** | **35** | **1** | **1** | **56** | **94** |
| **No ID** | 1 | 17 | - | 1 | 50 | ***69*** |
| ***Total*** | ***2*** | ***52*** | ***1*** | ***2*** | ***106*** | ***163*** |

When the reactions of seals sighted from the *Kulluk* are grouped based on the activity occurring on or around the drilling platform, a higher proportion of most species of seals were seen to react in some manner when there was no drilling compared to periods when the rig was actively drilling (Table 8.12). For bearded seals, 45% of animals sighted during drilling did not show a visible reaction, whereas only 36% of animals sighted during non-drilling periods showed no visible reaction. For ringed seals, the comparable percentages of seals that reacted during drilling compared to non-drilling periods were 68% and 71%, respectively, and for unidentified seals the percentages were 100% and 78%, respectively. When all seals are considered, 66% of seals observed during drilling activities showed no reaction to the *Kulluk*, and no reaction was observed in 64% of sightings during non-drilling activities.

The most commonly observed reaction was "looking" at the *Kulluk* as opposed to more significant reactions typically associated with distress or avoidance such as rapidly swimming away or splashing. There were a greater number of sightings during periods in which drilling was not active due to the relatively small proportion of the season in which drilling occurred and, hence, a much lower proportion of the 2012 monitoring effort was conducted when compared to non-drilling periods. Monitoring effort during drilling activities was not high enough to support statistical comparisons of behaviors and reactions between drilling and non-drilling activities.

TABLE 8.12. Reaction behaviors of seals observed from the *Kulluk* during the 2012 season. MLC = Mud-line Cellar drilling, DY = vessel nearby in dynamic positioning.

| Species / Vessel Activity | Reaction | | | | | |
|---|---|---|---|---|---|---|
| | Change Direction | Look | Splash | Interaction With Gear | None | *Totals* |
| **Bearded Seal** | | | | | | |
| **Drilling** | 1 | 4 | 0 | 0 | 4 | ***9*** |
| **No Drilling** | 0 | 17 | 1 | 0 | 10 | ***28*** |
| **MLC** | 0 | 1 | 0 | 0 | 2 | ***3*** |
| **No MLC** | 1 | 20 | 1 | 0 | 12 | ***34*** |
| **MLC + DY** | 0 | 3 | 0 | 0 | 2 | ***5*** |
| **No MLC + DY** | 1 | 18 | 1 | 0 | 12 | ***32*** |
| **Total Bearded Seal** | ***1*** | ***21*** | ***1*** | ***0*** | ***14*** | ***37*** |
| **Ringed Seal** | | | | | | |
| **Drilling** | 0 | 6 | 0 | 1 | 15 | ***22*** |
| **No Drilling** | 1 | 20 | 0 | 1 | 56 | ***78*** |
| **MLC** | 0 | 0 | 0 | 0 | 3 | ***3*** |
| **No MLC** | 1 | 26 | 0 | 2 | 68 | ***97*** |
| **MLC + DY** | 0 | 0 | 0 | 1 | 6 | ***7*** |
| **No MLC + DY** | 1 | 26 | 0 | 1 | 65 | ***93*** |
| **Total Ringed Seal** | ***1*** | ***26*** | ***0*** | ***2*** | ***71*** | ***100*** |
| **Unidentified Seal** | | | | | | |
| **Drilling** | 0 | 0 | 0 | 0 | 4 | ***4*** |
| **No Drilling** | 0 | 5 | 0 | 0 | 17 | ***22*** |
| **MLC** | 0 | 0 | 0 | 0 | 2 | ***2*** |
| **No MLC** | 0 | 5 | 0 | 0 | 19 | ***24*** |
| **MLC + DY** | 0 | 0 | 0 | 0 | 1 | ***1*** |
| **No MLC + DY** | 0 | 5 | 0 | 0 | 20 | ***25*** |
| **Total Unidentified Seal** | ***0*** | ***5*** | ***0*** | ***0*** | ***21*** | ***26*** |
| **All Seals** | | | | | | |
| **Drilling** | 1 | 10 | 0 | 1 | 23 | ***35*** |
| **No Drilling** | 1 | 42 | 1 | 1 | 83 | ***128*** |
| **MLC** | 0 | 1 | 0 | 0 | 7 | ***8*** |
| **No MLC** | 2 | 51 | 1 | 2 | 99 | ***155*** |
| **MLC + DY** | 0 | 3 | 0 | 1 | 9 | ***13*** |
| **No MLC + DY** | 2 | 49 | 1 | 1 | 97 | ***150*** |
| ***Total All Seals*** | ***2*** | ***52*** | ***1*** | ***2*** | ***106*** | ***163*** |

These data suggest that, in general, seals did not show overt reaction to the 2012 drilling programs in the Chukchi or the Beaufort seas. Reactions were typical of seals when they encounter vessels operating in these areas as reported in previous JMP reports that described monitoring of seismic and shallow hazards programs from 2006–2011 (Funk et al. 2007, 2010a,b, 2011; Ireland et al. 2009). Seals often approached the drilling vessels while they were stationary and remained in the general vicinity of the drilling operations for days. Some individuals were seen each day for weeks at a time.

Acoustic measurements taken during the drilling season suggested that in at least some circumstances sound levels around the rig could be elevated considerably by vessels that were nearby and using dynamic positioning (DP) to maintain a stationary position relative to a drilling rig or at vessel standby locations away from the well site. No dedicated measurements of ships using DP were made during the 2012 season so it was not possible to use sound measurements from ships in DP to compare seal sightings during such operations. PSOs did, however, record periods when ships were using DP as part of their daily logs of vessel activity. We prepared polar plots of seal sightings from ships using DP to maintain their positions and compared them to sightings for ships operating when they were not using DP. Figure 8.11 shows these data.

Similar to the data presented earlier for seal sightings from the *Kulluk* and the *Discoverer* during periods when they were and were not actively drilling, there were few differences in the positions of seals relative to vessels when they were operating in DP compared to periods when vessels were not using DP. Seals approached vessels operating in both modes and did not appear to be affected to any greater extent by vessels using DP despite the likely higher sound levels in the water caused by the use of the DP system. Future measurements will provide greater insight to questions regarding the sound levels in the water caused by DP systems on ships.

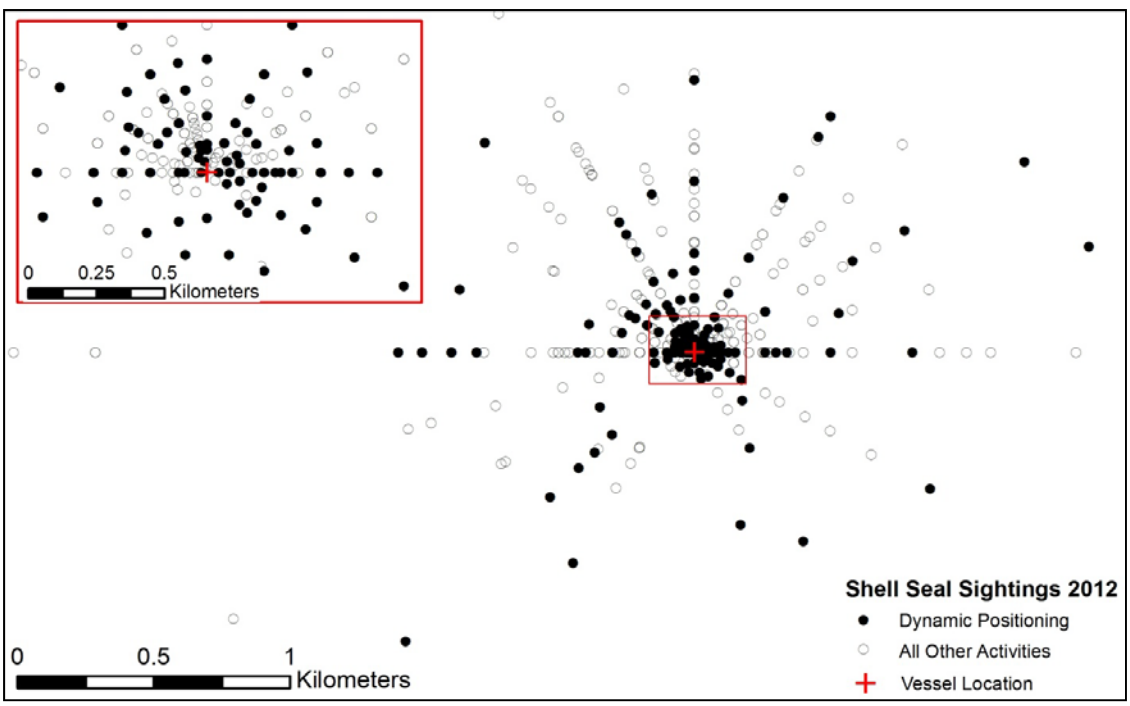


FIGURE 8.11. Locations of seal sightings relative to vessels operating in dynamic positioning (DP) and while operating without DP during Shell's exploratory drilling programs in the Chukchi and Beaufort seas, 2012.

### *Acoustic Monitoring of Seals*

Recorders deployed as part of the joint monitoring program for industrial activity and animal sounds in the Chukchi Sea were analyzed for seal detections. Bearded seals in particular, have been shown to call throughout periods of the year. There also has been some success in characterizing ringed, spotted and ribbon seal calls. The locations of the deployed recorders during the 2011–2012 winter and the 2012 summer recorder programs are shown in Figures 8.12 and 8.13, and the methods used for the analyses of the call detections are described in Chapter 3.

An industry-sponsored overwinter acoustics program was conducted in the Beaufort Sea beginning 30 September 2011 with deployment of six AURAL recorders, five of which were recovered in August 2012 (see Appendix C for detailed methods and results).

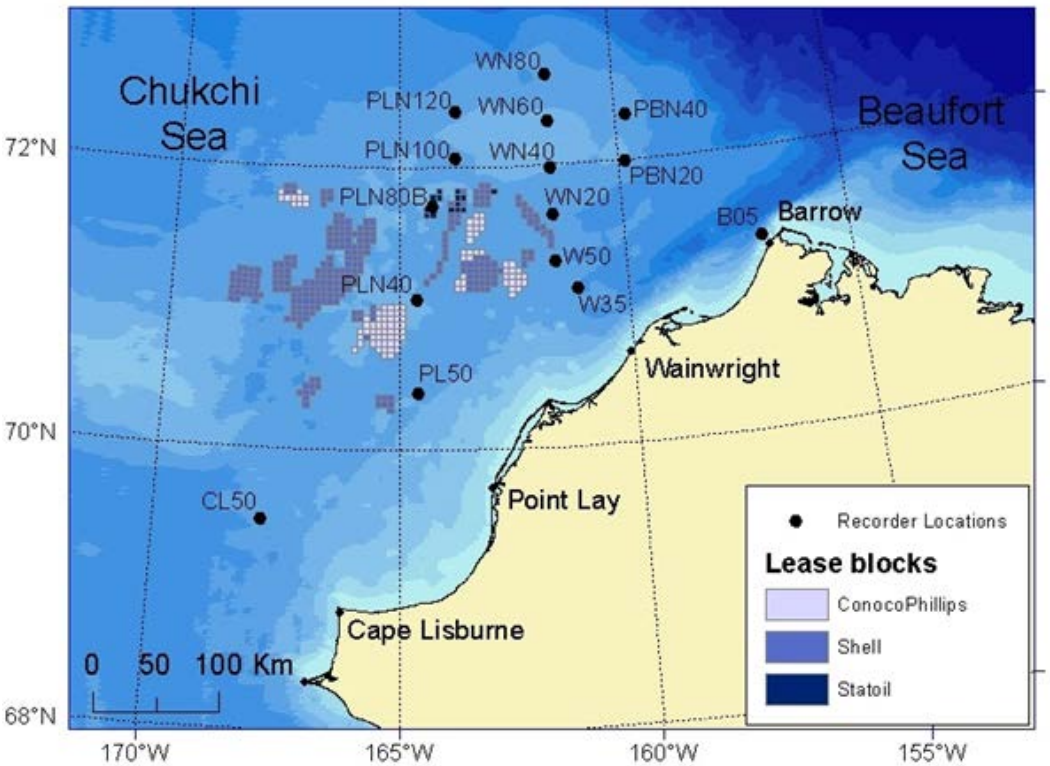


FIGURE 8.12. Recorder stations for winter 2011–2012 of the Joint Acoustic Monitoring Program in the northeastern Chukchi Sea. Shades of blue represent water depth.

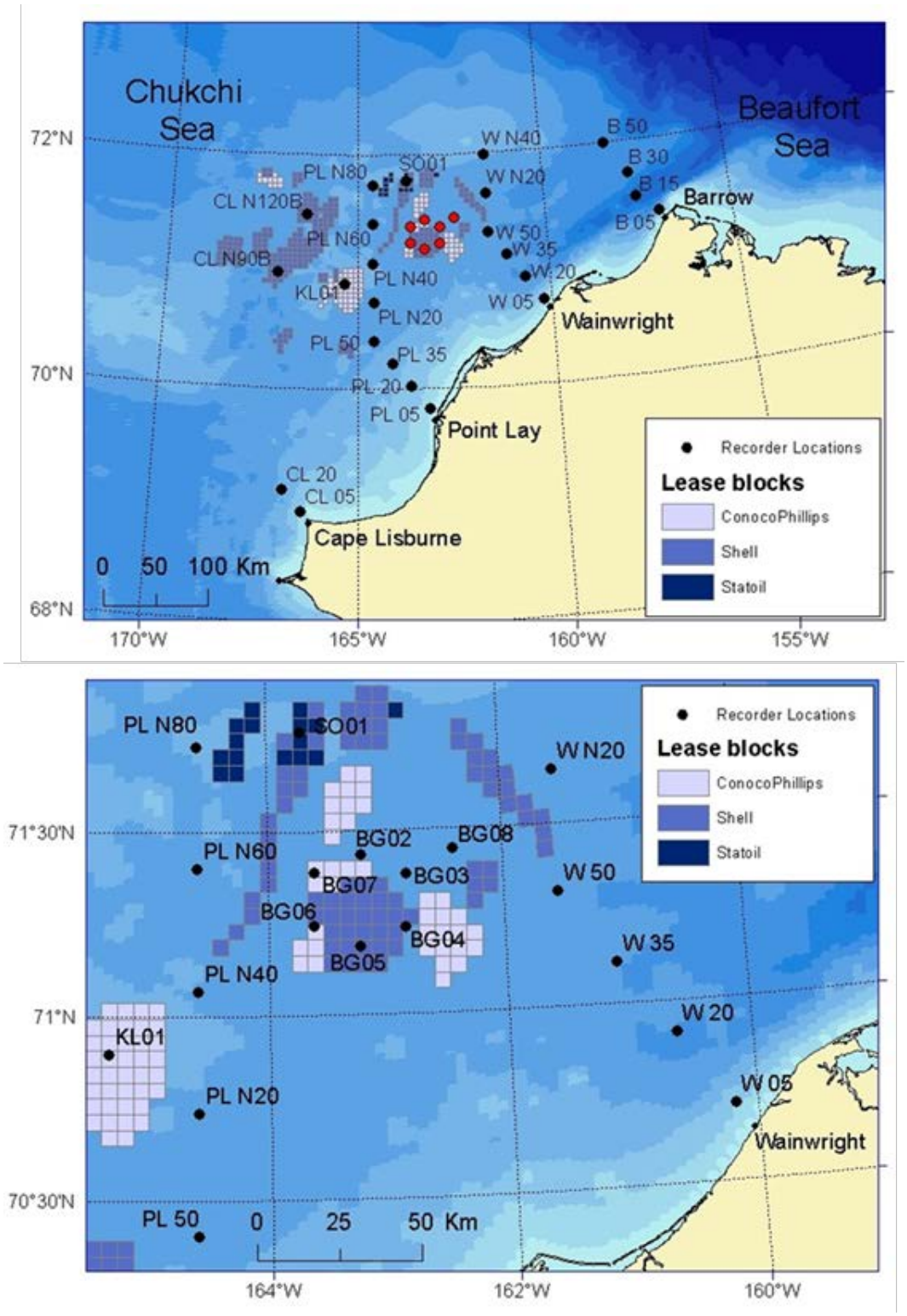


FIGURE 8.13. Recorder stations for the summer 2012 program in the northeastern Chukchi Sea: (top) the regional array and (bottom) the recorders at the lease areas. Shades of blue represent water depth.

### *Bearded Seal Call Detections*

***Winter 2011–2012 Program:*** Bearded seal detections in the Chukchi Sea began as soon as the recorders were deployed near Hanna Shoal in late August 2011. Six recorders were deployed in this area and limited (once or twice daily) but steady call detections occurred at most stations until 10 October. This was followed by a period of low to no detections at all stations until the last week of November, which marked the beginning of a period with steady bearded seal detections at all stations, although the amount of acoustic activity varied greatly between stations. Stations CL50, PL50 and to a lesser extent PLN40 did not have any significant increase in detections until the beginning of January. Detections at WN80 and PBN40 did not increase until May and April, respectively; stations WN60 and WN40 exhibited a similar pattern until their recording period ended earlier than expected. The northern Point Lay stations (PLN80, PLN100, and PLN120) and the Wainwright stations closest to shore (W35, W50, and WN20) showed a steady increase in bearded seal detections from late November with calls detected daily in most sound files from April until their retrieval. Except for the B05 recorder located near Barrow, no recorders lasted long enough to capture the end of the primary spring calling period. At B05 no calls were detected after 2 July (Fig. 8.14).

Throughout the 2011–2012 winter, the northern stations of the Point Lay line (PLN) had the highest call counts, surpassed only by B05 in April and May (Fig. 8.15). The high call counts at B05 may be partly due to misclassified bowhead and beluga calls in the spring and caution should be used when interpreting call counts for May and June because the stop dates of several recorders varied, causing different call count summation periods. The progressive increase in call counts from January to April is evident (Fig. 8.14). The northern Wainwright and Peard Bay (PBN) stations consistently had the lowest call counts. The detected calls consist primarily of upsweeping and downsweeping trills (Fig. 8.16; Van Parijs et al. 2001).

Bearded seal call detections in the Beaufort Sea during winter of 2011–2012 were temporally similar to those in the Chukchi Sea in that calls were detected sporadically throughout the winter sampling period with a notable increase in calls in April and May, coinciding with the breeding season (Appendix C).

MacIntyre et al. (2013) reported year-round detection of bearded seal calls in the Beaufort Sea from August 2008 through August 2010. Call activity during the study period increased with the formation of sea ice in the fall/winter with an annual peak in spring during mating and breakup of the ice (MacIntyre et al. 2013). Interannual variation in the timing of sea ice formation and breakup was reflected in the peak call detection periods each of the two years of the study (MacIntyre et al. 2013). It was also suggested that bearded seal calling behavior may be influenced by water temperature and related chemical properties, which are connected to both sea ice distribution and oceanographic currents (MacIntyre et al. 2013).

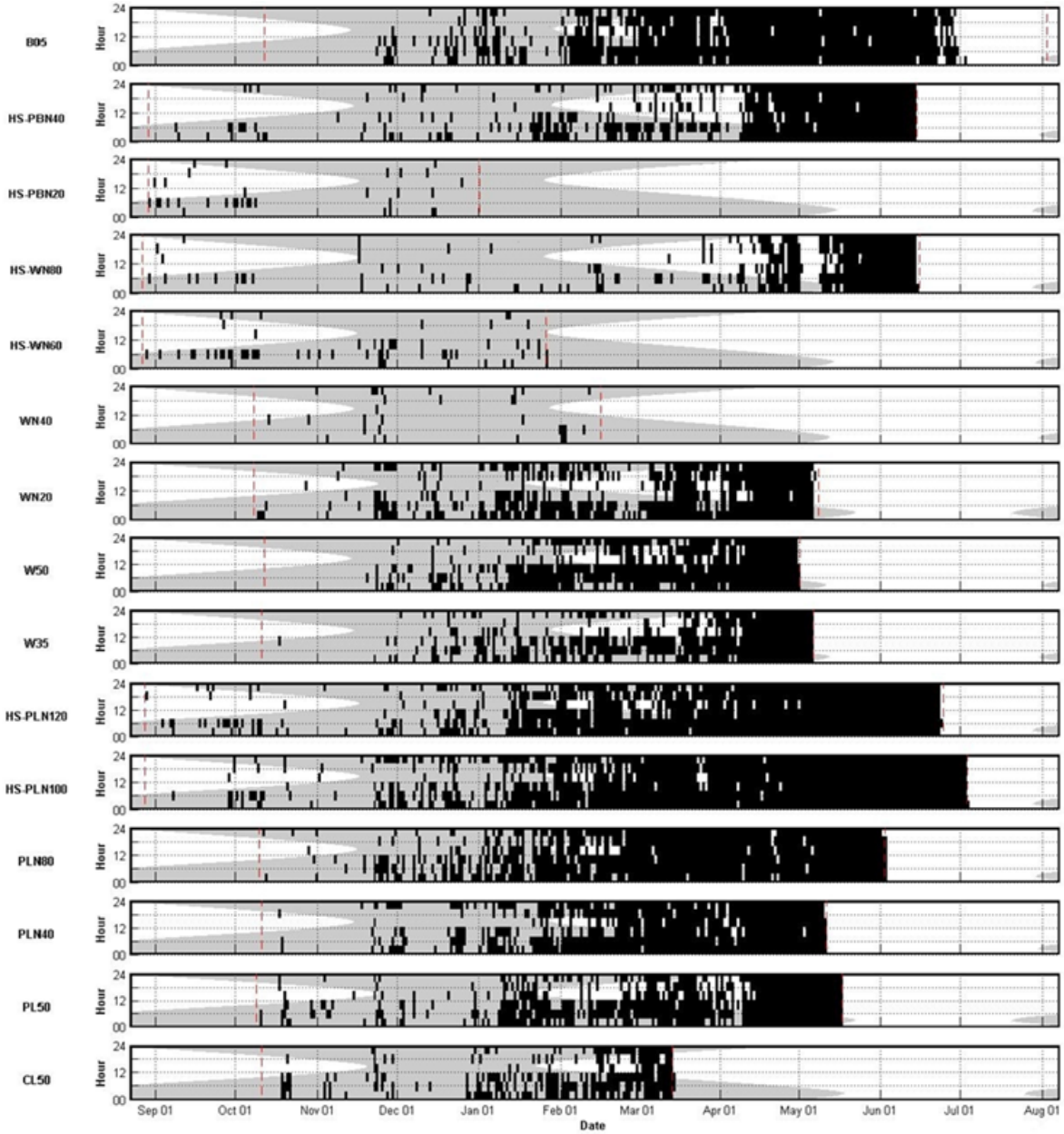


FIGURE 8.14. Winter 2011–2012 daily bearded seal call detections: Daily occurrence of call detections based on the manual analysis of 5% of the acoustic data recorded late August 2011 through early August 2012 in the northeastern Chukchi Sea for each station. Each black square represents a 4-hr period (one 30/40-minute file was recorded every four hours). Stations are ordered from (top) northeast to (bottom) southwest. The red dashed lines indicate the recording start and end dates. The shaded area shows the hours or darkness. See Appendix B for detailed maps of the recorder locations.

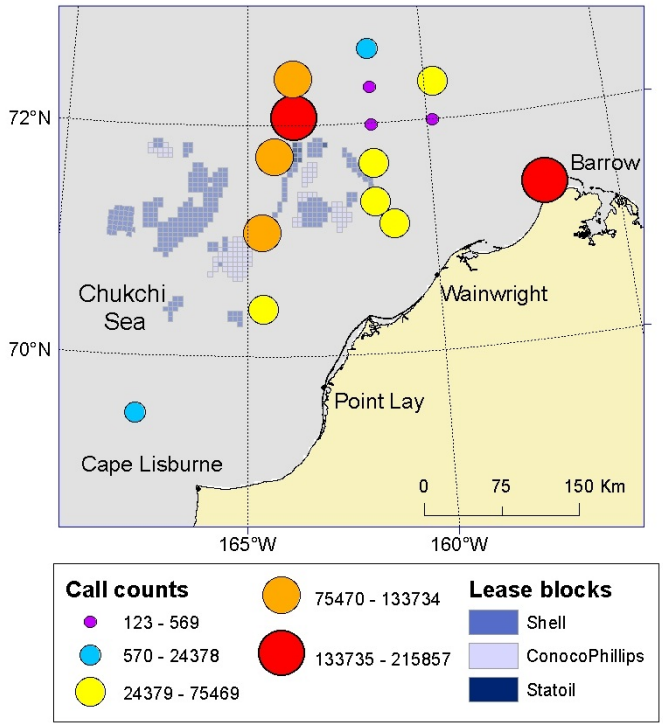


FIGURE 8.15. Bearded seal call count estimates* in the Chukchi Sea for 28 August 2011 through 1 August 2012 at all winter 2011–2012 recording stations. The gray background represents the 100% sea ice concentration that prevailed during much of the recording period. *Corrected sum of automated call detections in all files with manual detections.

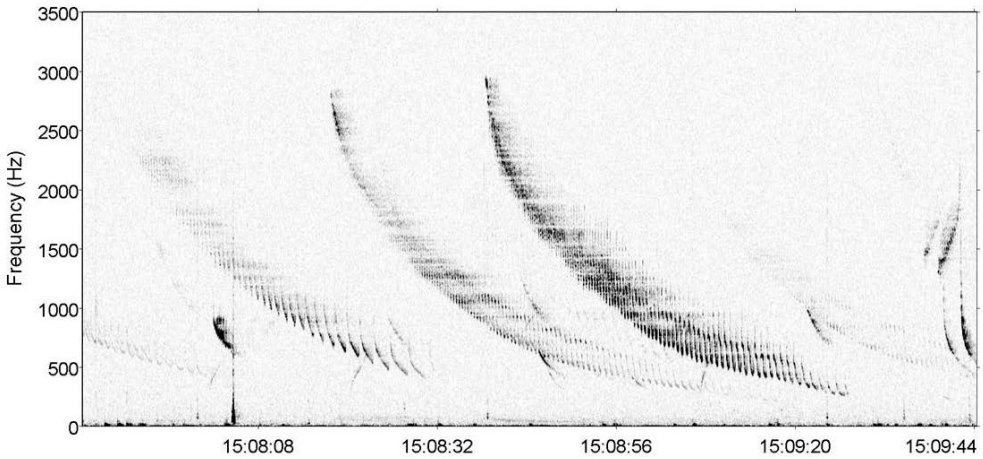


FIGURE 8.16. Spectrogram of bearded seal calls recorded 8 May 2012 at Station PLN100 (Frequency resolution: 2 Hz; Frame size: 0.128 s; time step: 0.032 s; Reisz window).

There were no obvious changes in bearded seal acoustic occurrence in winter 2011–2012 compared to previous years. The overall detection pattern for 2012 suggests that most bearded seals in the northeastern Chukchi Sea were concentrated to the north of the study area, near stations PLN80 and PLN100. Detections were typically lower on either side of these two stations.

The typical temporal distribution of detections consists of a steady increase in calling rates from October, peaking in May and June, which coincides with the mating season. Call detections usually stop abruptly in late June–early July, with very sporadic, or no detections thereafter. Bearded seals are the most common acoustically-detected marine mammal species in the winter programs.

***Summer 2012 Program***: Bearded seals were detected at all stations except PL50 (Appendix B) during the summer acoustics program in the Chukchi Sea. Acoustic detections were fairly evenly distributed across stations during the recording period with the exception of a few noticeable peaks at several stations. Specifically, small peaks occurred around mid-August at each of the following stations: PLN20, PLN40, KL01, and PLN60. Bearded seals were repeatedly detected between 13–23 September along the Pt. Lay (PL) line, north of PL35. There were also periods of higher acoustic detections on the Wainwright (W) and Cape Lisburne (CL) lines at stations W05–W20 and CLN90–CLN120 in September (Appendix B). These peaks, seen in the contour plots, drove the call counts up. The areas of higher acoustic activity included the coastal waters off Wainwright during the first three weeks of September (Appendix B), but were otherwise mainly located offshore and centered around the northern Cape Lisburne and Point Lay lines (Fig. 8.17; Appendix B). The Burger study area was part of an area of low call counts located north of Icy Cape (Fig. 8.17).

Typically, the detected bearded seal calls were produced irregularly and in small numbers. These calls were more variable (Fig. 8.18) and different from the long, complex spiraling songs common during the spring breeding period (Ray et al. 1969; Van Parijs et al. 2001).

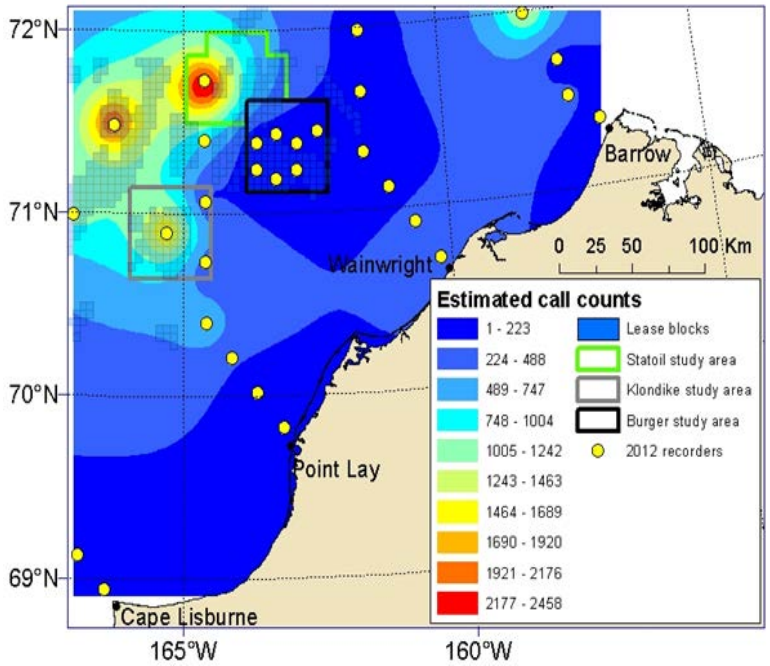


FIGURE 8.17. Interpolated bearded seal call counts based on the sum of automated call detections in all files with manual detections for 11 September–5 October (period when all 30 recorders were deployed) at all summer 2012 stations in the northeastern Chukchi Sea.

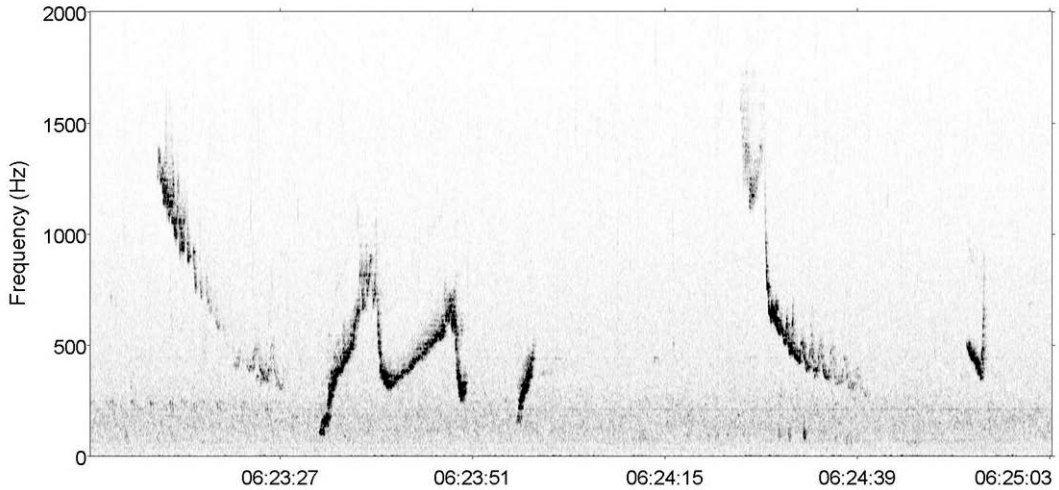


FIGURE 8.18. Spectrogram of bearded seal calls detected 19 August 2012 at Station PLN60 (Frequency resolution: 2 Hz; Frame size: 0.128 s; time step: 0.032 s; Reisz window).

The typical detection pattern in the summer data consists of a few sporadic detections in late July and August and a steady increase in detections in September peaking in October. The summer 2012 detections are consistent with the results from previous years. Bearded seal calls were most commonly detected in the northern and northwestern sections of the study areas. The coastal waters off Wainwright offered one counter-example to this offshore preference of bearded seals, although it was restricted to three weeks in September. A similar distribution pattern was observed in 2009 (Fig. 8.19). The steady increase in calling rate from September to May makes it difficult to compare estimated call counts between months. Fewer detections in July and August are attributed to behavior, not necessarily fewer animals. The lower call counts on the eastern side of Burger as well as W35 and W50 appear to coincide with the standby locations of the vessels supporting Shell's drilling operations, and could therefore be due to call masking.

Similarly, MacIntyre et al. (2013) reported year-round acoustic detection of bearded seal calls in the Beaufort Sea from August 2008 through August 2010 with relatively lower call-detection rates in August of each summer (MacIntyre et al. 2013).

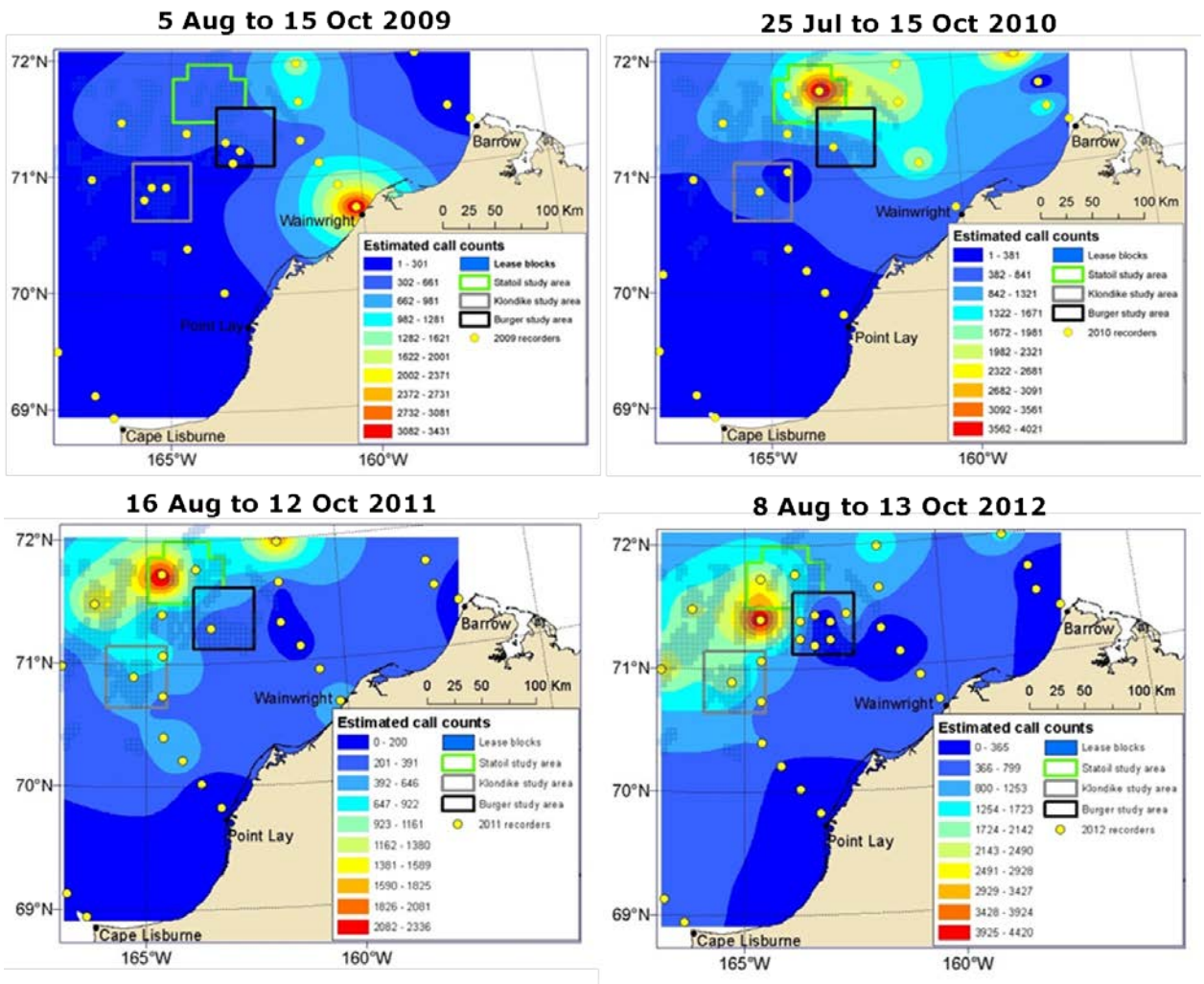


FIGURE 8.19. Summer bearded seal call counts: Radial basis-interpolated call counts based on the sum of automated call detections in all files with manual detections at all summer recording stations in the northeastern Chukchi Sea.

### *Ribbon Seal Call Detections*

***Winter 2011–2012 Program:*** No ribbon seal calls were detected in the winter 2011–2012 data.

***Summer 2012 Program:*** Ribbon seal calls were detected at two Burger stations and off Cape Lisburne (CLN120), Point Lay (PLN40 and PLN60), and Wainwright (WN40; Table 8.13). Four detections occurred in August and two in October. Two types of ribbon seal calls were detected: intense downsweeping sounds, with or without harmonic structure, corresponding to the short and medium sweeps described by Watkins and Ray (1977); and loud puffing sounds, as described by Watkins and Ray (1977; Fig. 8.20).

TABLE 8.13. Summer 2012 ribbon seal call detections: Dates of first and last call detections, both possible (i.e., record start and end) and actual, and the number and proportion of days on which a call was detected for each recording station in the northeastern Chukchi Sea. Stations without call detections were omitted.

| Station | Record Start | First Detection | Last Detection | Record End | Detection Days | % Days with Detection |
|---|---|---|---|---|---|---|
| BG05 | 12 Aug | 13 Aug | 20 Aug | 13 Oct | 2 | 3.2 |
| BG06 | 12 Aug | 20 Aug | 20 Aug | 13 Oct | 1 | 1.6 |
| CLN120 | 09 Aug | 13 Aug | 13 Aug | 08 Oct | 1 | 1.7 |
| PLN40 | 12 Aug | 20 Aug | 20 Aug | 13 Oct | 1 | 1.6 |
| PLN60 | 12 Aug | 08 Oct | 08 Oct | 08 Oct | 1 | 1.8 |
| WN40 | 10 Sep | 07 Oct | 07 Oct | 10 Oct | 1 | 3.3 |

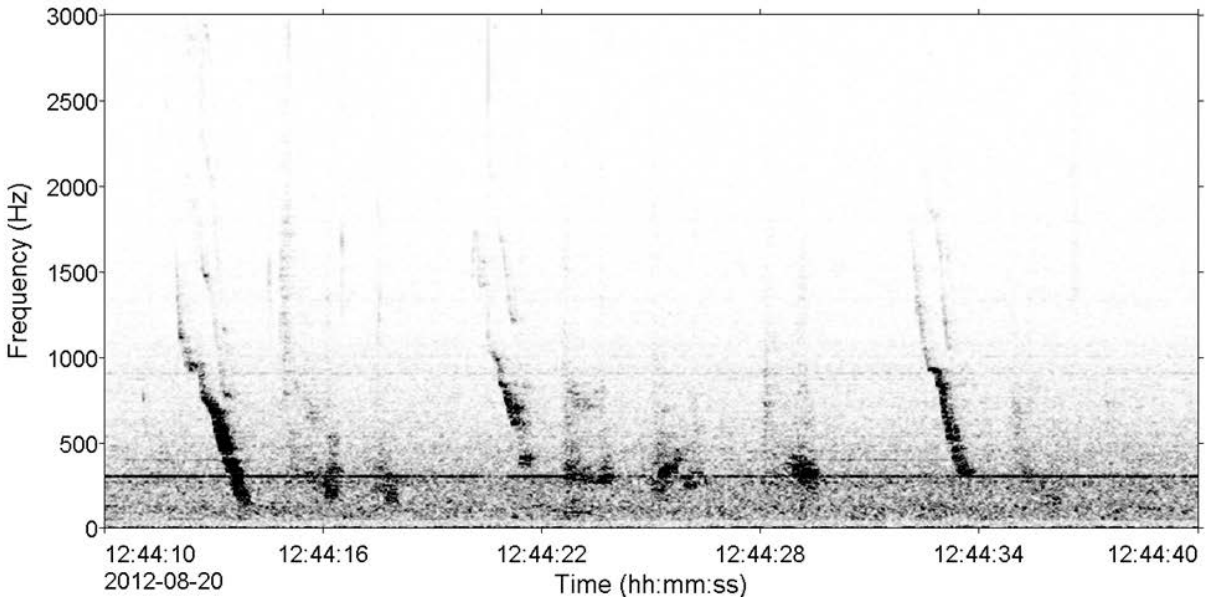


FIGURE 8.20. Spectrogram of ribbon seal calls recorded 20 August 2012 at Station BG06 (Frequency resolution: 2 Hz; Frame size: 0.128 s; time step: 0.032 s; Reisz window).

### *Ringed Seal Call Detections*

***Winter 2011–2012 Program:*** The first detection of ringed seal calls in the Chukchi Sea Acoustic Monitoring Programs was in winter 2009–2010. No ringed seal calls were detected in previous years' data because the call types were largely unknown, not because the seals were not in the area. The analysts targeted mainly bark and yelp calls (described by Stirling 1973; Fig. 8.21). Ringed seals likely produce other call types, but the descriptions of those call types are inadequate to confidently identify them.

Ringed seal calls were detected between 18 October 2011 and 26 June 2012 at all stations but PLN80. Detections occurred throughout the deployment period with no obvious spatial or temporal pattern. The number of detection days at each station was low, ranging from 1 to 14 with a mean of 5.5 (Fig. 8.22; Appendix B). Due to low calling rates the detection probability for ringed seal calls using the 5% manual analysis protocol is low (22%; see Appendix B), which means that the results presented here likely under-represent the occurrence of ringed seal calls.

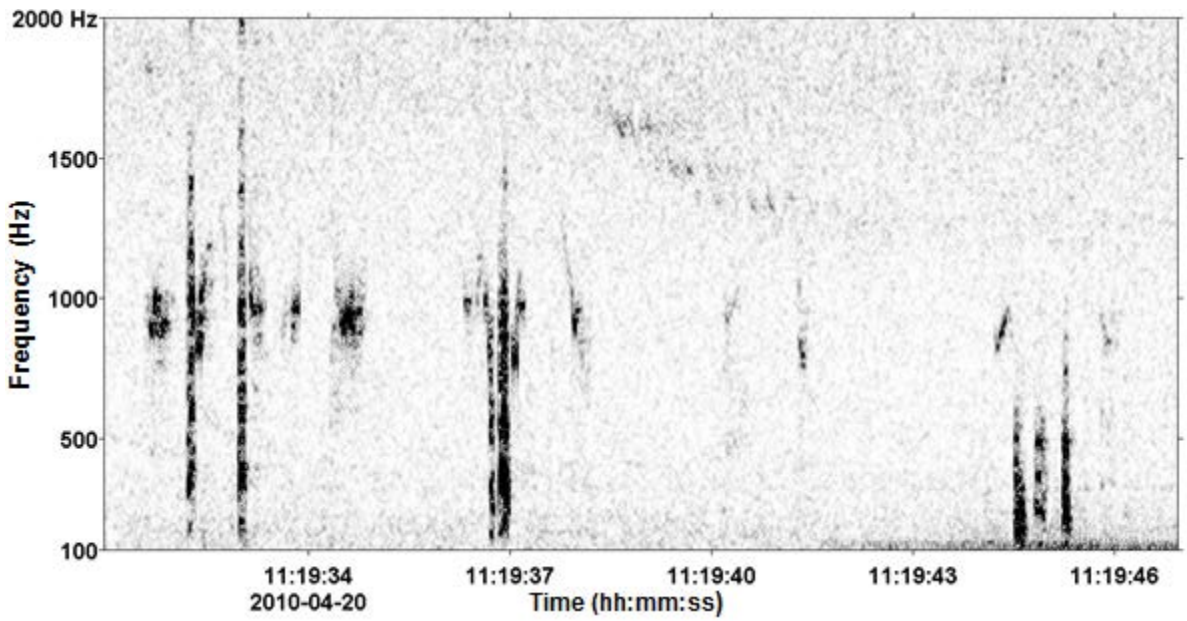


FIGURE 8.21. Spectrogram of ringed seal calls recorded 20 April 2010 at Station CL50 (2048 pt FFT, 512 pt advance, Hamming window; Delarue et al. 2011).

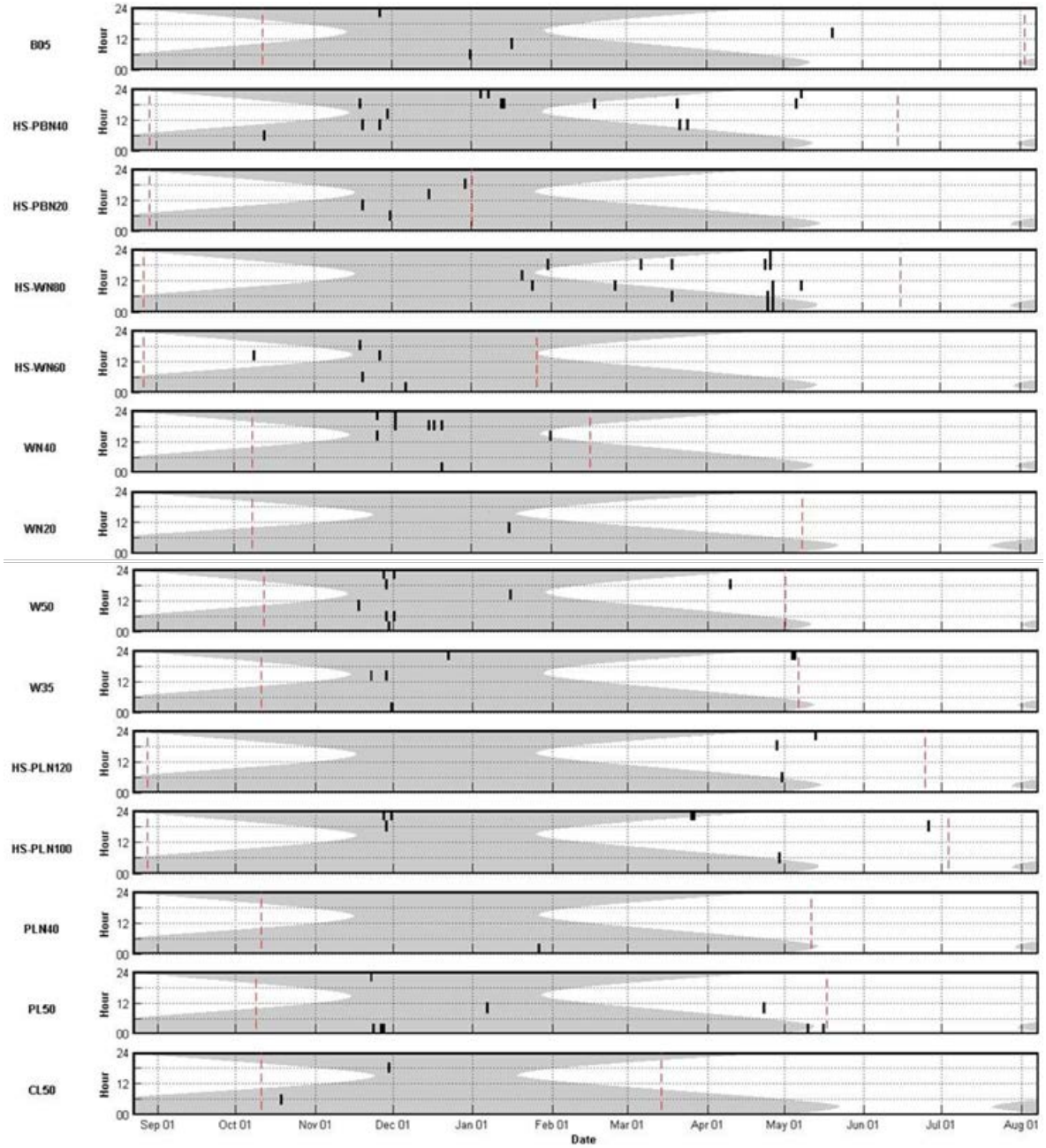


FIGURE 8.22. Winter 2011–2012 daily ringed seal call detections: Daily occurrence of call detections based on the manual analysis of 5% of the acoustic data recorded late August 2011 through early August 2012 in the northeastern Chukchi Sea for each station. Each black square represents a 4-hr period (one 30/40-minute file was recorded every four hours). Stations are ordered from (top) northeast to (bottom) southwest. The red dashed lines indicate the recording start and end dates. The shaded area shows the hours or darkness.

***Summer 2012 Program:*** Ringed seal calls were detected at 16 stations (including four Burger stations) between 13 August and 11 October 2012 (Fig. 8.23; Appendix B). The number of detection days at each station was low (1–5 days, mean of 2.1 days). Stations CLN120 and PLN60 had the highest number of detection days. Detection probability and calling rates were low, and these results underestimate the spatial and temporal distributions of ringed seals in the program area.

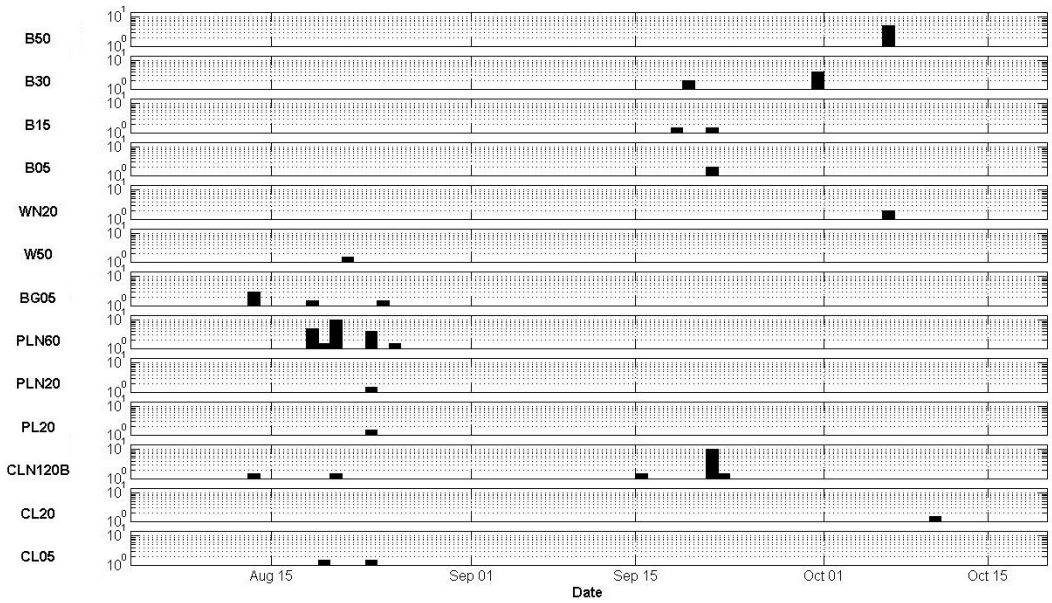


FIGURE 8.23. Summer 2012 daily ringed seal call detections: Daily number of 30-min sound files with call detections based on the manual analysis of 5% of the acoustic data recorded late July through mid-October 2012. The y-axis is on a logarithmic scale. Red dashed lines indicate recording start and end. Stations are ordered from northeast (top) to southwest (bottom). Stations without call detections were omitted and only one of the Burger stations is displayed. Shaded areas represent hours of darkness.

### *Spotted Seal Call Detections*

No spotted seal calls were detected manually in the winter 2011–2012 or summer 2012 datasets, not because they were necessarily absent from the program area, but owing to a lack of knowledge about their calls. Spotted seals are regularly seen in the program area in summer (e.g., Funk et al. 2009). Recorders placed near known spotted seal summer haulouts (e.g., in Kasegaluk Lagoon passes; Frost et al. 1993) could help researchers better understand spotted seal calls and assess the feasibility of acoustically surveying this species.

## *Discussion*

Ice seals are distributed widely across the Chukchi and Beaufort seas. Industry operations in 2012 and in all years since 2006 routinely encountered relatively large numbers of seals. Monitoring data from vessel and aerial platforms during industry operations indicate that seals are closely associated with ice

and are seen more frequently in areas where ice is most persistent within the study areas. That being said, seals were commonly seen throughout all areas where data were collected.

It is important to note that seals cannot be sighted in areas where no observation effort occurred, and therefore sighting locations are biased by the vessel and flight tracklines, which are focused on areas of interest for oil and gas exploration. Further, vessels sightings are collected opportunistically rather than systematically, which limits the analyses that can be done with them. As a result, completely ice-free waters contain a disproportionately high level of effort in comparison to areas in and around ice.

Despite these drawbacks mentioned above, when data from all vessels and all years are pooled, ice conditions emerge as being closely associated with seal presence. Given that seals use ice to haul out and then travel back and forth from haulouts to foraging areas, it seems logical that seals would be encountered more frequently either among or close to ice-covered waters. The insignificant result for the influence of ice conditions on sighting rates of seals from stationary vessels in the Beaufort Sea may be due to low effort in some ice bins. Another consideration is that vessels operating in the Beaufort Sea, and particularly those sitting on station, are in close proximity to land. The availability of another haulout location may dilute the effect of ice condition on seal presence.

Acoustic data collected by the Chukchi Sea monitoring program support the visual observation data regarding the distribution of seals in the Chukchi Sea. Independently collected data from the Aerial Surveys of Arctic Marine Mammals (ASAMM) program funded by the Bureau of Ocean and Energy Management (BOEM) also reported distribution data that reflect similar patterns to those described here (Clark et al. 2013). Systematic vessel-based surveys conducted by a single observer from a relatively low platform as part of the industry sponsored Chukchi Sea Environmental Studies Program (CSESP) also reported wide distribution of ice seals in their study area, which included the Burger prospect where drilling operations occurred in 2012 (Aerts et al. 2012).

Ringed seals spend winter in the waters of the Chukchi and Beaufort seas, but it is generally thought that most bearded and spotted seals move seasonally with the advance and retreat of sea ice in these areas. Acoustic data collected over the winter of 2011–2012 in the Chukchi Sea indicates a steady increase in bearded seal calls from November through the winter and into the spring. These data suggest that the area is used fairly extensively by bearded seals during the winter. The vocalizations of ringed, spotted, and ribbon seals are not yet known well enough to reliably detect animals acoustically. Continued improvement of the characterization of seal vocalizations will provide insight concerning the distribution and abundance of animals in the study area outside of the open-water season.

In addition to ice, other environmental factors influence the ability of PSOs to detect and identify seals. Ice often influences the numbers of seals that are available for sighting, whereas Beaufort wind force can greatly influence sea state, condition of the water surface, and the ability of PSOs to see seals even when they are present. Seals generally do not show much of their bodies above the surface of the water. It is therefore not surprising that sighting rates drop off quickly as the Beaufort Wind Force increases. The 2012 results from moving vessels are consistent with observations from 2006–2011 and indicate that sighting rates decrease substantially as Beaufort Wind Force reaches three and greater. Data from studies conducted in 2011 suggested that, regardless of the number of observers on watch, the probability of detecting a seal at 200 m (656 ft) in conditions of Beaufort four or five is below 0.15 (Hartin et al. 2011; Beland et al. 2011). Additionally, the presence of sea ice dampens the effects of wind and waves on sighting conditions, which increases the likelihood that seals will be detected in areas with or near ice.

### *Impacts of Drilling and Exploration Activities*

The reactions of ice seals and most pinnipeds to drilling and related activities have not been studied extensively. Previous studies have reported ringed seals near drillships drilling in the Arctic during summer and fall (Ward and Pessah 1986; Brueggman et al. 1992; Gallagher et al. 1992; Brewer et al. 1993; Hall et al. 1994). Richardson et al. (1990, 1991) reported that ringed and bearded seals approached and dived within 50 m (164 ft) of an underwater sound projector broadcasting continuous low-frequency drilling sounds. The authors estimated that sound levels at depths greater than a few meters at the 50 m (164 ft) distance was ~130 dB re 1 μPa. These observations, like our current data, suggest at least some tolerance of drilling noise by seals. Richardson et al. (1995) point out however, that it is not known if the numbers and behaviors of seals near the drill ships or playback sites differed from those that would have occurred without drilling and this is true in the current study as well. Blackwell et al. (2004) reported little or no reaction of ringed seals after exposure to underwater sound from construction activities on a man-made island in the Alaskan Beaufort Sea. Moulton et al. (2005) reported that ringed seal densities in spring did not appear to be affected by proximity to construction, drilling, and oil production activities at a man-made island in the Beaufort Sea. Frost and Lowery (1988) reported decreased densities of ringed seals in spring near artificial islands, some of which had active drilling occurring.

Detection distances of seals observed from the drilling vessels were rarely greater than 300 m (984 ft) and often were substantially less. Sound measurements of the drillship *Discoverer* on site in the Chukchi Sea placed the 120 dB (rms) radius for continuous sound at ~1.5 km (0.93 mi) during drilling of the pilot hole and 8.1 km (5.0 mi) for drilling of the mud-line cellar. In the Beaufort Sea, the distance to the 120 dB (rms) radius was ~0.66 km (0.41 mi) for drilling of the pilot hole and ~6.2 km (3.9 mi) for the mud-line cellar (Austin et al. 2013). These measurements indicate that seals were often seen within the behavioral disturbance zone for nonimpulsive sounds recognized by the National Marine Fisheries Service (NMFS). Seals approached, entered and often remained in areas ensonified to these levels for extended periods of time. Seals often swim near the surface and due to pressure release effects of sound near the surface of the water may be exposed to lower sound levels while at the surface than occur deeper in the water column (Richardson et al. 1995). We do not have measurements of the dive patterns of the seals that frequented the drilling rigs in 2012, but it is likely that they were exposed to levels of continuous sound above 120 dB (rms) for at least part of the time they were in the vicinity of the rigs, and multiple times during the drilling program.

Data collected onboard the drilling vessels in both the Chukchi and Beaufort seas in 2012 suggest that seals routinely approached the vessels while they were stationary and remained in the general vicinity of drilling throughout the operational period. Some individual seals were seen daily for weeks at a time while the *Kulluk* was moored at the drill site in the Beaufort Sea. Seals were seen around the rigs during periods when drilling was active and during periods when other types of operations were occurring other than drilling. In general, there was little difference between active drilling periods and non-drilling periods in the closest point of approach of seals, the length of time that they remained around the rigs, or the behavior of seals observed near the rigs. Seals showed no overt reactions or behavioral changes associated with the exploration activities regardless of the specific activities that were occurring.

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# 9. PACIFIC WALRUS MONITORING

## *Introduction*

Pacific walruses (Aiviq; *Odobenus rosmarus divergens*) aggregate into large groups throughout their range. Hundreds or thousands of walruses may be observed on pack ice and adjacent ice floes, and smaller groups are dispersed in open water habitats during summer in the Chukchi Sea. They use the pack ice and ice floes of the Chukchi Sea as resting platforms between feeding bouts. Walruses feed primarily on benthic invertebrates in relatively shallow water <80 m (262 ft) deep (Reeves et al. 2002; Dehn et al. 2007), and the high rates of benthic productivity (Dunton et al. 2005) on the continental shelf of the Chukchi Sea, particularly around Hanna Shoal, provide them with abundant summer food.

Large numbers of walruses generally have not used terrestrial haulouts in the eastern Chukchi Sea because, until recently, remnant sea ice over the continental shelf provided haulout locations at and near their feeding areas during summer. Traditional knowledge, however, indicates that smaller groups of walruses have occasionally come ashore during the fall migration, with irregular use reported for areas near Pt. Hope, Cape Lisburne and Cape Thompson. Walruses in the western Chukchi Sea along the Chukotka coast of Russia have historically used terrestrial haulouts as far north as Wrangel Island during summer and fall, and at least some of the sites have been occupied by large numbers of walruses in most years since records have been kept (Belikov et al. 1996). Male walruses that remain in the Bering Sea during summer also use terrestrial haulouts throughout the summer (Jay and Hills 2005).

Studies of walruses in the Chukchi Sea have been conducted by various agencies and industry over the past two to three decades. Many of the data were collected during the 1980's to 1990s and fewer surveys of walruses in the Chukchi Sea were conducted in late 1990s and early 2000s. Increased interest in exploration of offshore oil and gas resources beginning in 2006 led to the establishment of ongoing, large-spatial-scale, vessel, aerial, and acoustic monitoring programs conducted by industry to provide information on Pacific walruses and other marine mammals that use the Chukchi Sea. The large-area network of acoustic recorders, coupled with aerial surveys along the Chukchi Sea coast from Pt. Barrow to Pt. Hope, and opportunistic vessel observations have provided broad-scale detection of marine mammals throughout the eastern Chukchi Sea. In 2012 Shell began offshore aerial photographic surveys (see Chapter 3) that focused effort over the Burger drilling prospect.

In addition to the industry monitoring efforts, various government agencies have also increased their efforts to better understand walrus distribution and behavior in the Chukchi Sea. The Bureau of Ocean Energy Management (BOEM) has sponsored the Aerial Surveys of Arctic Marine Mammals (ASAMM) project conducted by scientists from the National Marine Mammal Laboratory (NMML) that began flying in the Chukchi Sea in 2008. The United States Geological Survey (USGS) has conducted walrus tagging studies since 2004 in the Bering Sea and began deploying tags in the Chukchi Sea in 2007.

The integrated use of these platforms (vessel, aerial, satellite tagging and acoustic) to acquire data on marine mammal movements and distribution has enhanced our understanding and detection of natural patterns in distribution and movement of walruses in the Chukchi Sea, as well as potential changes in behavior and distribution that could be associated with oil and gas exploration and development.

## *Distribution*

Walrus typically overwinter in the Bering Sea and move northward with the receding pack ice edge during spring. These movements have been monitored since 2009 with acoustic recorders deployed in the fall of each preceding year (Fig. 9.1). In the spring of 2012 walruses were first detected on the northern Pt. Lay line of acoustic recorders in late June/early July (PLN100, Table 9.1) for 3 days and for six days in July on the recorder nearest to Barrow (B05, see Fig. 9.1). Unfortunately, most of the recorders deployed in fall of 2011 stopped working before the dates in mid-May to mid-June when walruses have been detected in the study area in previous years (14 May in 2011, 12 June in 2010, and 6 June in 2009). Therefore these dates are not likely accurate accounts of the first returns to the study area in 2012, but indicate that walrus were in the study area well before industry operations began. Clarke et al. (2013) observed twelve sightings of 573 walruses on the first flight of the 2012 season (30 June 2012) in the nearshore area of the northeastern Chukchi Sea.

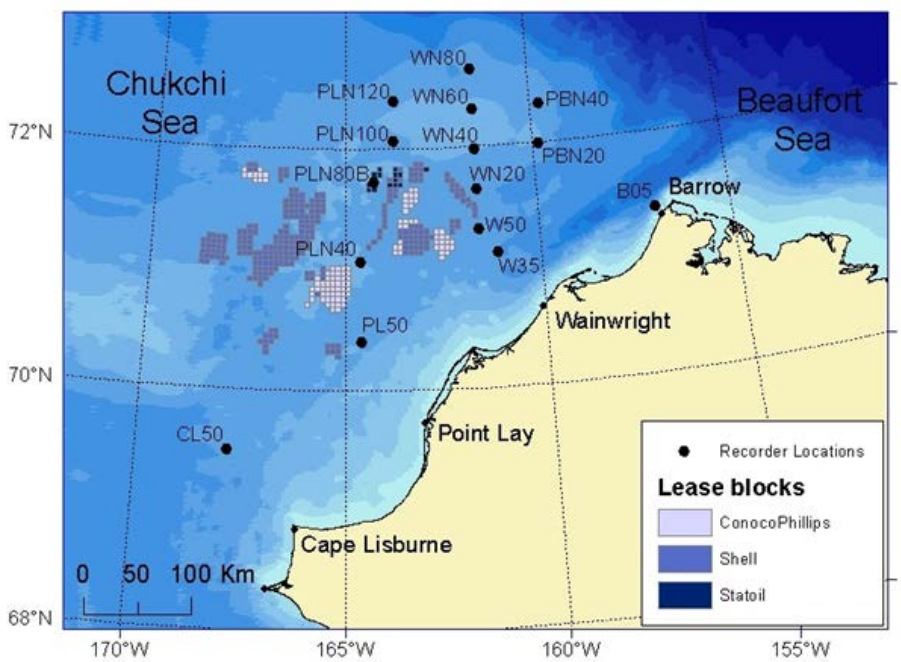


FIGURE 9.1. Acoustic recorder stations for winter of the Joint Acoustic Monitoring Program in the northeastern Chukchi Sea. Shades of blue represent water depth.

TABLE 9.1. Spring walrus call detections: Dates of first call detections and the number of days on which a call was detected manually for each recording station in the northeastern Chukchi Sea.

| Station | Spring 2012 | | | Spring 2011 | | | Spring 2010 | | | Spring 2009 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First dection | Detection days | Record end | First dection | Detection days | Record end | First dection | Detection days | Record end | First dection | Detection days | Record end |
| B05 | 22-Jul | 6 | 1-Aug | 20-Jun | 2 | 6-Aug | 17-Jul | 3 | 29-Jul | – | – | – |
| B35 | – | – | – | – | – | – | – | – | – | 5-Jul | 9 | 2-Aug |
| PBN40 | – | 0 | 14-Jun | – | – | – | – | – | – | – | – | – |
| PBN20 | – | 0 | 31-Dec | – | – | – | – | – | – | – | – | – |
| WN80 | – | 0 | 14-Jun | – | – | – | – | – | – | – | – | – |
| WN60 | – | 0 | 26-Jan | – | – | – | – | – | – | – | – | – |
| WN40 | – | 0 | 15-Feb | 26-Jun | 36 | 31-Jul | 22-Jun | 53 | 17-Aug | 18-Jun | 22 | 9-Aug |
| WN20 | – | 0 | 7-May | – | – | – | – | – | – | – | – | – |
| W50 | – | 0 | 30-Apr | 19-Jun | 3 | 30-Jul | 20-Jun | 16 | 7-Jul | **6-Jun** | 38 | 8-Aug |
| W35 | – | 0 | 6-May | – | – | – | 21-Jun | 19 | 21-Jul | – | 0 | 13-Apr |
| PLN120 | – | 0 | 23-Jun | – | – | – | – | – | – | – | – | – |
| PLN100 | **24-Jun** | 3 | 3-Jul | – | – | – | – | – | – | – | – | – |
| PLN80 | – | 0 | 3-Jun | 19-Jun | 36 | 28-Jul | – | 0 | 21-Mar | – | 0 | 4-Jun |
| PLN40 | – | 0 | 10-May | **14-May** | 30 | 27-Jul | 22-Jun | 25 | 26-Jul | 16-Jun | 17 | 20-Aug |
| PL50 | – | 0 | 17-May | 14-Jun | 19 | 28-Jul | – | 0 | 21-May | – | – | – |
| CL50 | – | 0 | 14-Mar | 29-May | 15 | 26-Jul | **12-Jun** | 14 | 18-Jul | – | 0 | 31-May |

As walrus move north into their Chukchi Sea summering grounds they remain closely associated with sea ice. The 2012 field season was a moderate ice year with ice pans persisting in the prospect area (Burger drilling site) until mid-September (Fig. 9.2). Large numbers of walruses were sighted on ice floes as late as 15 September with 38% of sightings (89% of walruses) from 25 July to 14 September in 2012 occurring on ice. Similarly, Clarke et al. (2013) observed 91% of walruses hauled out on ice from 30 June to 14 September 2012, during the ASAMM project. Vessel-based surveys conducted under the Chukchi Sea Environmental Studies Program (CSESP), a joint-industry monitoring program sponsored by Shell, ConocoPhillips, and Statoil, also reported large numbers of walruses in the Burger prospect area that coincided with sea ice in September 2012 (Aerts et al. 2012).

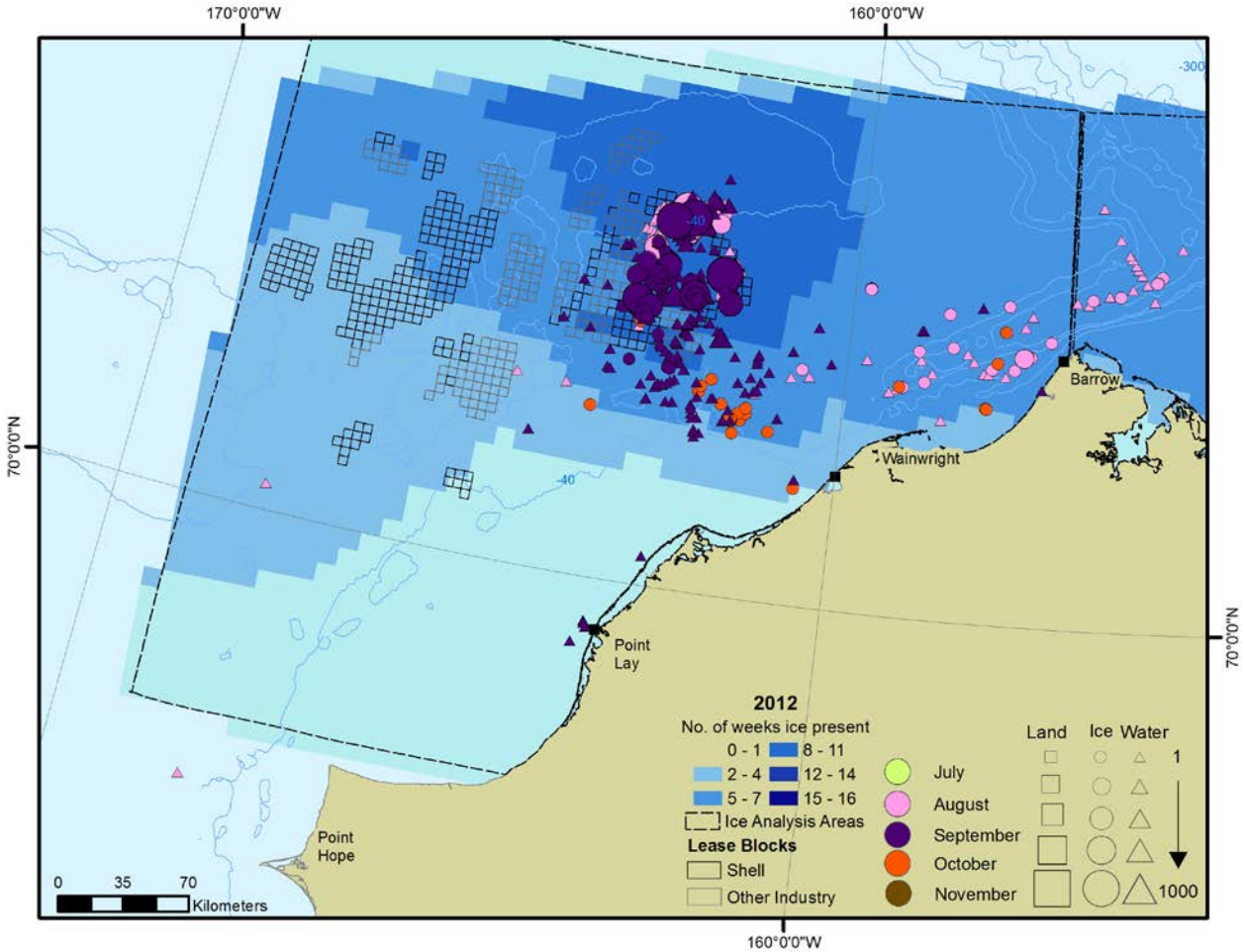


FIGURE 9.2. Pacific walrus sightings recorded from industry-sponsored vessel and aerial platforms in the Chukchi Sea during 2012. Sightings were plotted on a map of ice persistence in a standard area of the Chukchi Sea from 18 July through 10 October.

Large numbers of walruses were sighted on ice floes in September over the Hanna Shoal area. Forty two percent of all walrus sightings in 2012 (including vessel and aerial) were from aerial surveys flown over the Burger drilling site that used digital cameras to collect the sightings data. Processing the data from these surveys is time consuming and data were still preliminary at the time this report was written. Given that these data are preliminary, caution should be used when comparing the 2012 walrus sightings distribution with those from previous years. Aerial surveys over the prospect were the priority in 2012 and surveys of the nearshore area did not begin until mid-August. Only five aerial surveys were flown in the nearshore area during 2012 and this low amount of effort resulted in low numbers of sightings in the coastal areas relative to previous years. ASAMM flights commenced on 29 June and observed walruses (151 sightings of 5927 walruses) on 19 of the 27 surveys flown in July 2012 with large numbers observed in the nearshore coastal areas (Clarke et al. 2013).

Figures 9.2–9.8 provide a visual depiction of vessel and aerial sightings of walruses in the Chukchi Sea each year since 2006 in relation to sea ice cover. Sightings were plotted on yearly maps of ice persistence in a standard area from 18 July through 10 October (Chapter 2: Background and Context). Ice cover in 2006, 2008 and 2012 in the Chukchi Sea study area was more persistent than it was in 2007, 2009, 2010 and 2011. Even in years with greater ice persistence, however, there was variability in ice composition in the study area. In 2008, the ice was broken into small pieces that walrus clung to in small groups, whereas in 2012 and 2006, bigger floes persisted through much of the season that supported large groups of walrus. In these three years, walrus remained offshore using the ice well into September. In low ice years (2007, 2009, 2010 and 2011) many walrus used terrestrial haulouts along the Alaskan Chukchi Sea coast (see *Walrus use of Terrestrial Haulouts* section below) once sea ice retreated off the continental shelf and no longer provided a platform from which to feed. Although this pattern was observed in 2009 and 2011, these movements were not as evident in the sightings data due to lower amounts of industry-sponsored monitoring effort in those years. Walrus distribution in the Alaskan Chukchi Sea appears intricately linked to the presence of sea ice close to their preferred foraging areas near Hanna Shoal well into September. Moreover, this relationship is emphasized by these data given that sighting locations are biased by the vessel and flight tracklines, which are focused on areas of interest for oil and gas exploration activities typically only performed in open water or water with very low ice concentration. As a result, a disproportionately high level of monitoring effort has occurred in completely ice-free waters in comparison to areas in and around ice.

Pacific walruses are uncommon in the Beaufort Sea. Only 25 Pacific walruses in 22 groups were recorded by vessel-based PSOs in the Beaufort Sea from 2006–2012 (Fig. 9.9). Walrus sightings were recorded in 2007 (six sightings), 2008 (three sightings), 2010 (two sightings) and 2012 (14 sightings). Pacific walrus sightings were not recorded during vessel-based surveys in the Beaufort Sea during 2006, 2009 or 2011. Five sightings (six individuals) of Pacific walrus were recorded during aerial surveys in 2006. One walrus cow-calf pair was sighted in 2007, two sightings of adult walruses were recorded in 2008 and there were 11 sightings of 12 individual walruses during aerial surveys in 2010. Pacific walrus sightings were not recorded during aerial surveys in the Beaufort Sea in 2012.

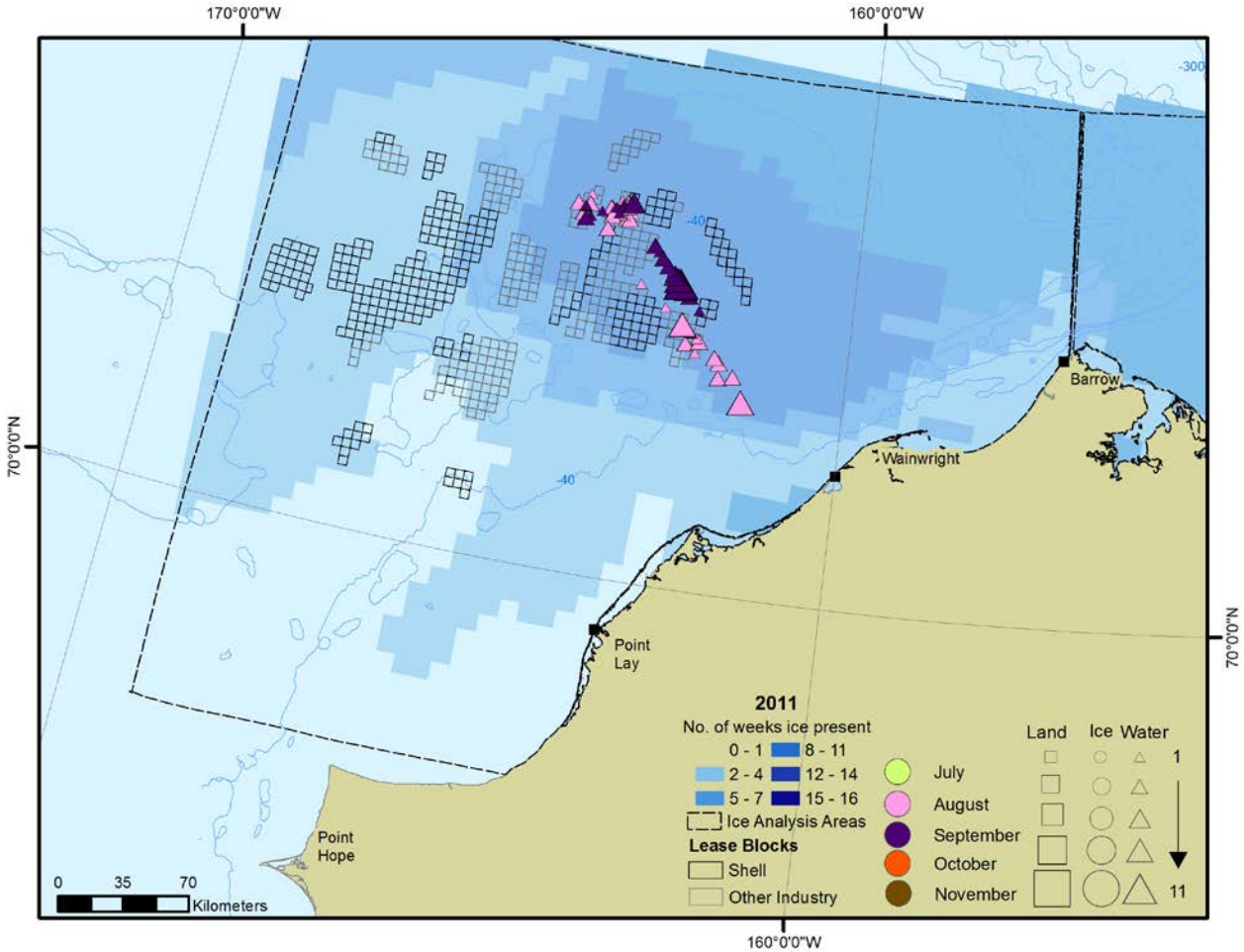


FIGURE 9.3. Pacific walrus sightings recorded from industry-sponsored vessel platforms in the Chukchi Sea during 2011. There was no industry-sponsored aerial program in the Chukchi Sea during 2011. Sightings were plotted on a map of ice persistence in a standard area of the Chukchi Sea from 18 July through 10 October.

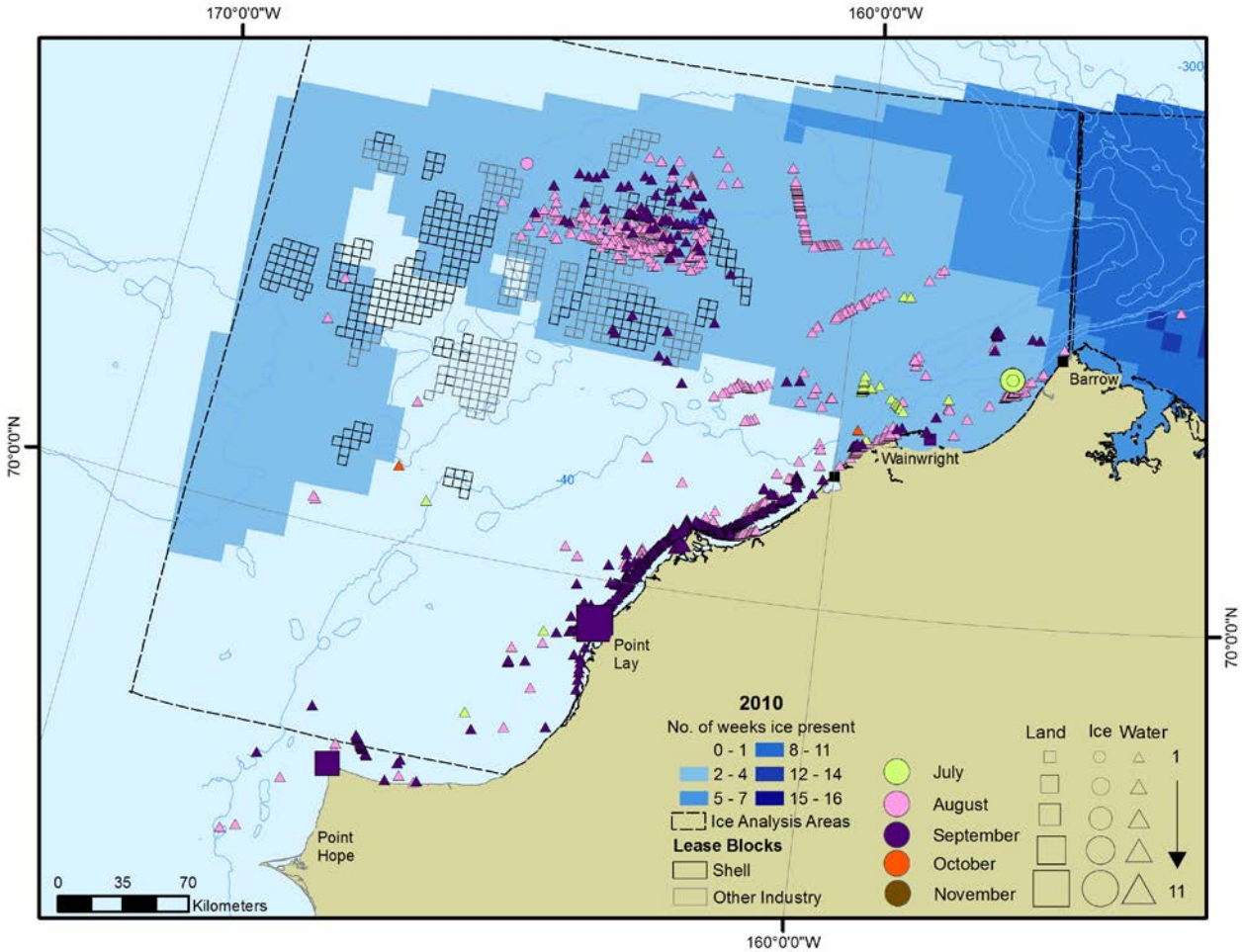


FIGURE 9.4. Pacific walrus sightings from industry-sponsored vessel and aerial platforms in the Chukchi Sea during 2010. Sightings were plotted on a map of ice persistence in a standard area of the Chukchi Sea from 18 July through 10 October.

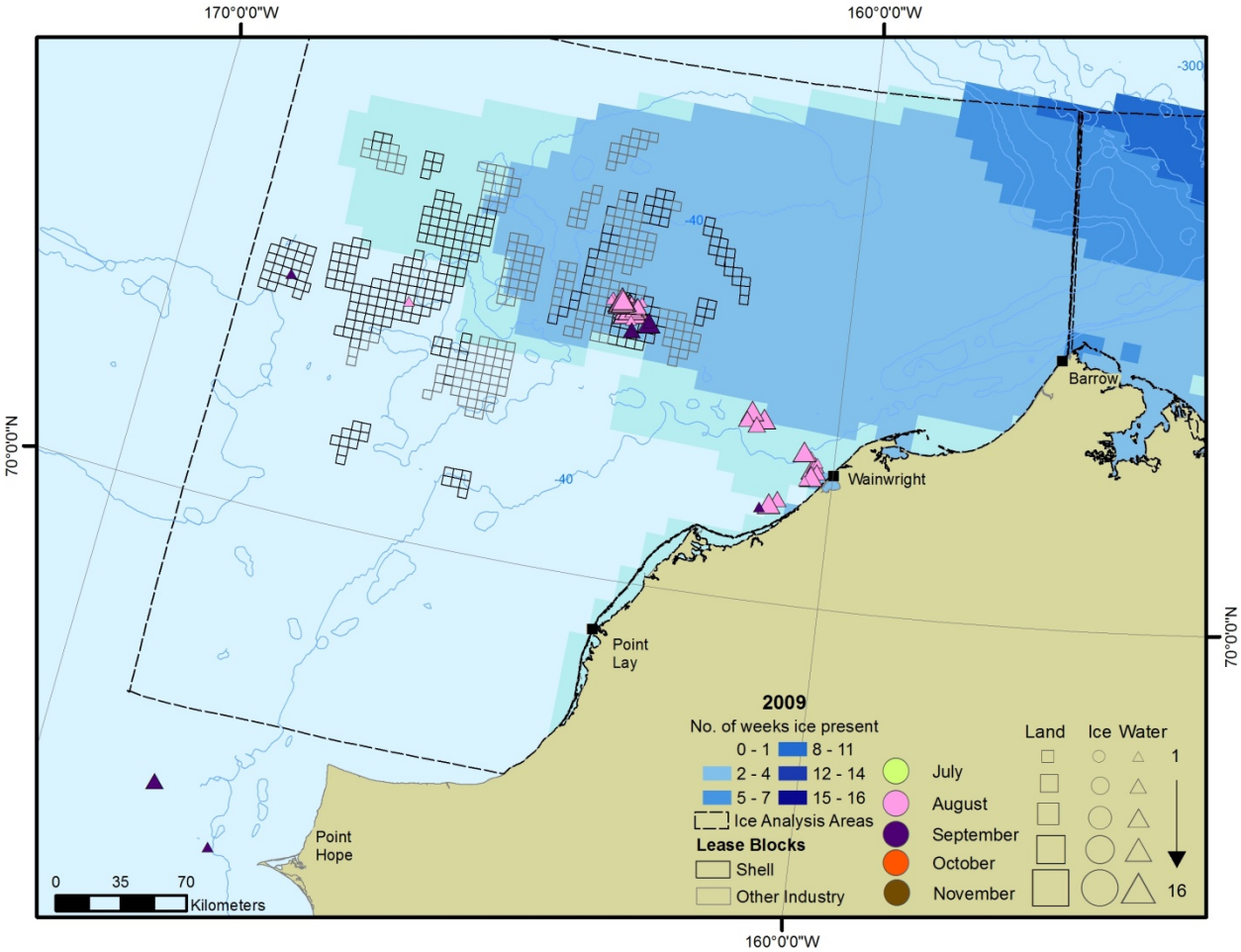


FIGURE 9.5. Pacific walrus sightings from industry-sponsored vessel platforms in the Chukchi Sea during 2009. There was no industry-sponsored aerial program in the Chukchi Sea during 2009. Sightings were plotted on a map of ice persistence in a standard area of the Chukchi Sea from 18 July through 10 October.

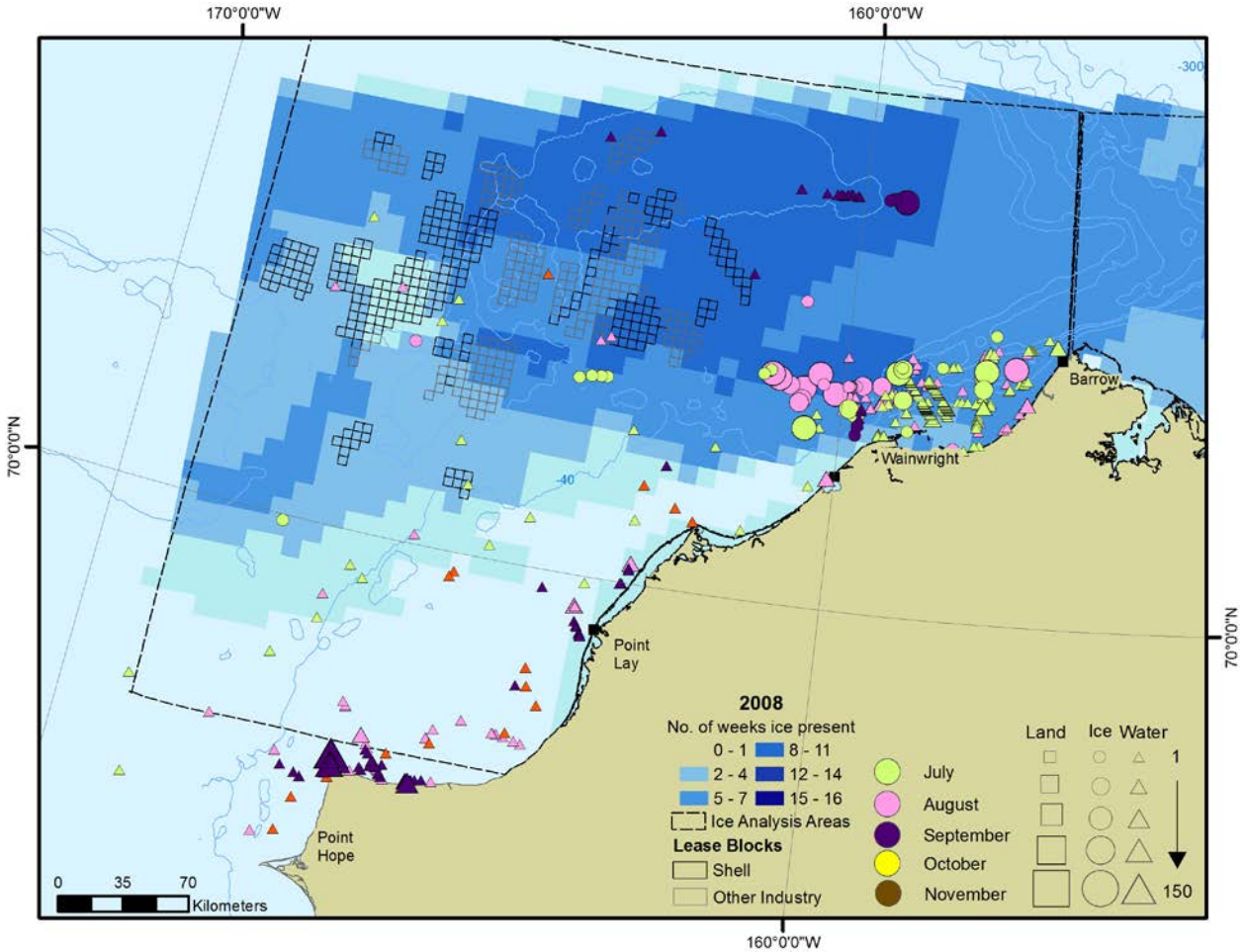


FIGURE 9.6. Pacific walrus sightings from industry-sponsored vessel and aerial platforms in the Chukchi Sea during 2008. Sightings were plotted on a map of ice persistence in a standard area of the Chukchi Sea from 18 July through 10 October.

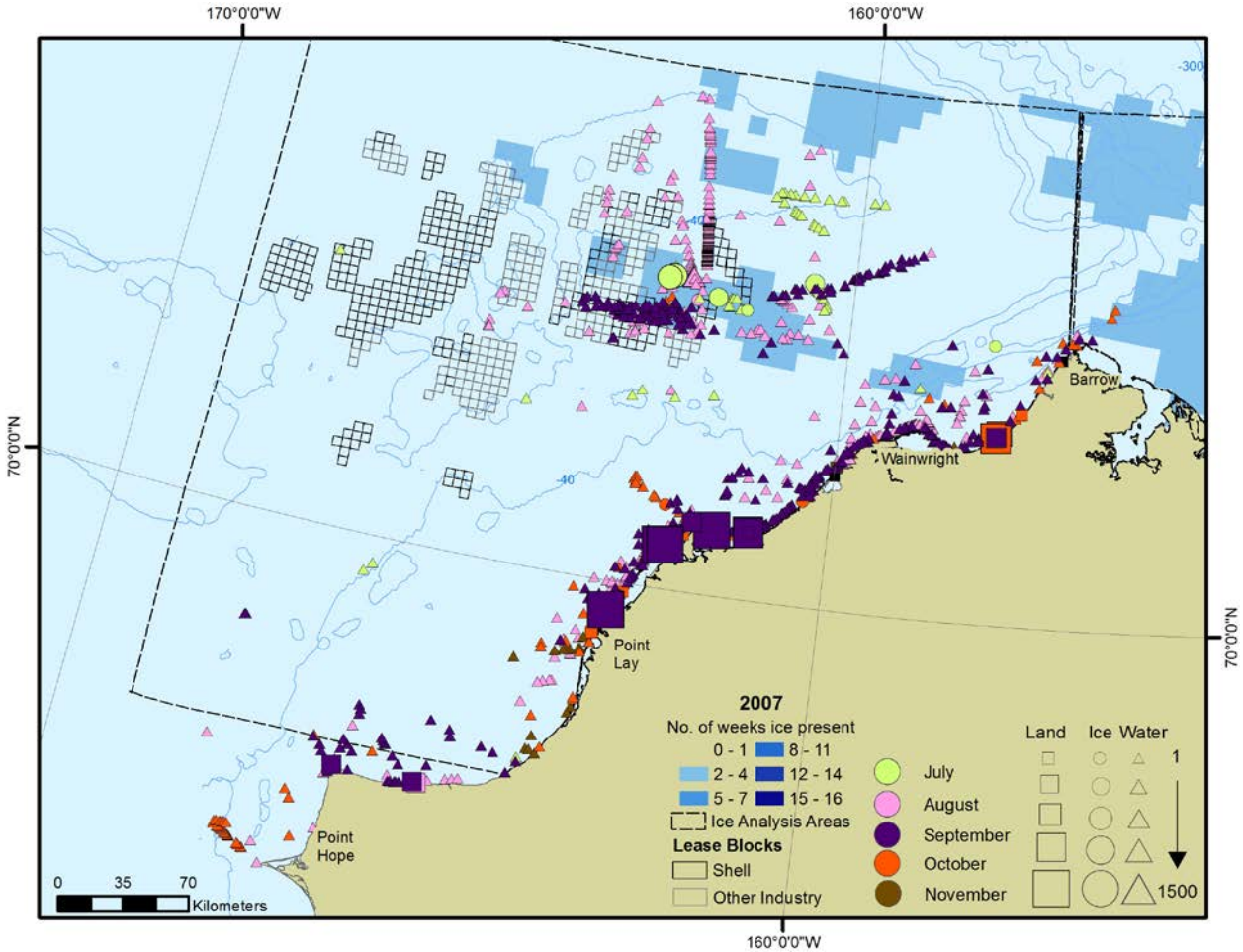


FIGURE 9.7. Pacific walrus sightings from industry-sponsored vessel and aerial platforms in the Chukchi Sea during 2007. Sightings were plotted on a map of ice persistence in a standard area of the Chukchi Sea from 18 July through 10 October.

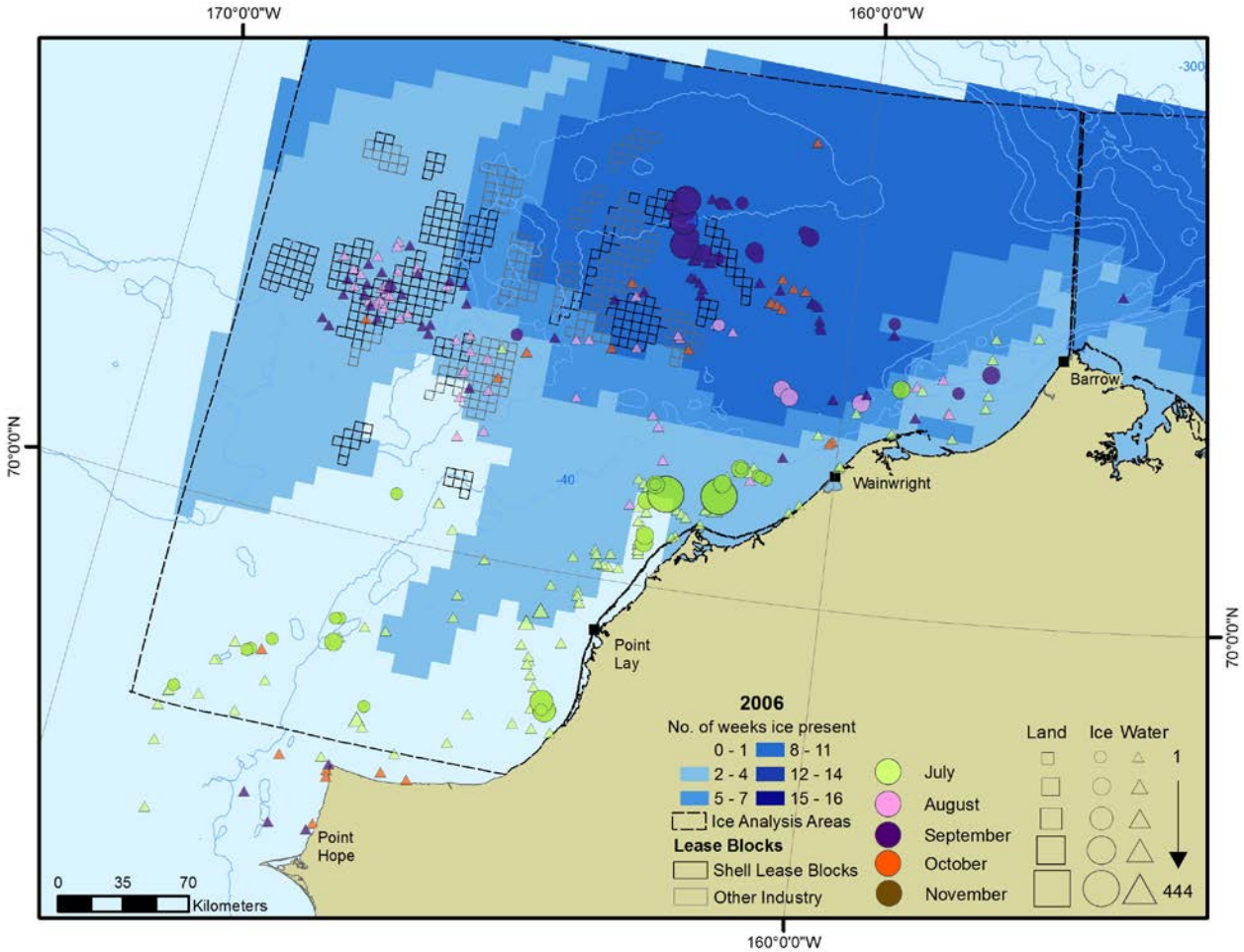


FIGURE 9.8. Pacific walrus sightings from industry-sponsored vessel and aerial platforms in the Chukchi Sea during 2006. Sightings were plotted on a map of ice persistence in a standard area of the Chukchi Sea from 18 July through 10 October.

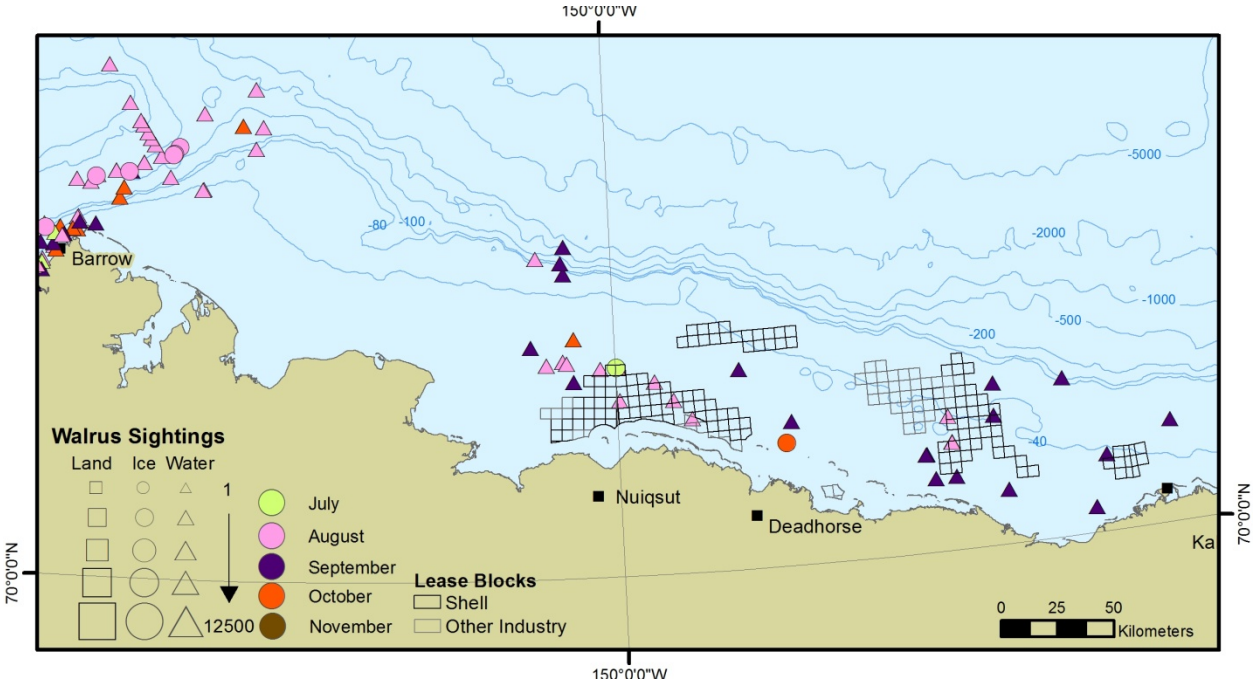


FIGURE 9.9. Pacific walrus sightings from industry-sponsored vessel and aerial platforms in the Beaufort Sea during 2006–2012.

The relationship between sea ice cover and walrus sighting rates during the 2012 open water season was tested quantitatively. We hypothesized that sea ice near where Shell's vessels operated in the Chukchi Sea during 2012 likely influenced the numbers of walruses that were present in the area. If true, this would result in more animals being available for detection by PSOs and therefore higher sighting rates in areas closer to pack ice and in waters with greater ice cover.

Vessel-based walrus sightings and effort data from the Chukchi Sea in 2012 were partitioned into bins based on the amount of ice cover (>10% and <10%) and absence of ice (i.e., open water). Considerable vessel-based monitoring effort occurred in areas with and without ice in 2012, which allowed for a meaningful comparison of walrus sighting rates between different bins. Chi-square tests were used to compare the two ice bins to each other and also the <10% ice bin to open water. More detailed methods used for these analyses are provided in Appendix A.

Walrus sighting rates for each bin are shown in Figure 9.10. Sighting rates were significantly greater in areas with >10% ice cover compared to areas with <10% ice cover ($\chi^2 = 23.6$, $df = 1$, $p < 0.001$), and sighting rates in locations with <10% ice were significantly higher than those in open-water locations ($\chi^2 = 99.1$, $df = 1$, $p < 0.001$; Figure 9.10). These results from 2012 suggested that walruses preferred habitat with sea ice as opposed to open water, and when ice was present they selected areas with higher ice concentrations (>10%) compared to areas with sparse ice cover (<10%).

The relationship between vessel-based walrus sighting rates and ice was evident in varying degrees during offshore exploration programs in several other years since 2006; however, several factors biased those results (Funk et al. 2011). Limited or even no monitoring effort within or near ice precluded our ability to make meaningful comparisons of sighting rates between bins in some years (e.g., 2007, 2010). Additionally, large groups of walruses were encountered during several years in open-water areas far removed from ice, presumably as they transited to onshore haulout areas after ice receded beyond the continental shelf. The relationship between sea ice distribution in the Chukchi Sea and onshore walrus haulouts is discussed in greater detail below in, *Walrus Use of Terrestrial Haulouts*.

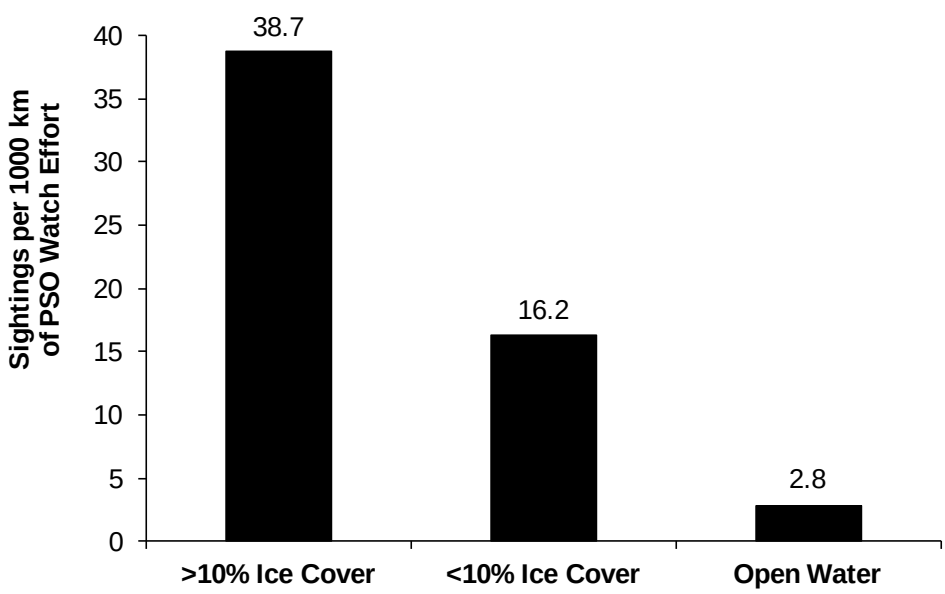


FIGURE 9.10. Vessel-based walrus sighting rates by percent ice cover and open water in the Chukchi Sea during offshore exploration activities in 2012.

The southward migration of walruses generally occurs in late September to early October and relatively few sightings have been recorded in October in most years. After concluding the 2012 seismic survey program in the north-central Chukchi Sea on 15 November, the ION vessels began to transit south towards Dutch Harbor. During a 5.5-hour period on 16 November, the PSOs aboard the ION vessels observed 179 sightings of 1728 individual Pacific walruses just south of Point Hope (Beland et al. 2013). Nearly all (97%; *n*=174) of these sightings were of animals in the water (Beland et al. 2013).

### *Acoustic Distribution*

Walrus distribution is also monitored using acoustic recorders deployed in wide area arrays across the Chukchi Sea study area (Chapter 3). Acoustic detections of walruses during summer 2012 were initially largely restricted to the northern part of the study area. These detections lasted from 8 August until ~10 September. Between 26 August and 9 September, detections were restricted to a small number of stations with only 17% of active stations detecting walrus, compared to 44% before and 51% after that period. A negative relationship in the number of detection days as a function of distance to Hanna Shoal was observed among the Burger stations. Stations on the north-east side of Burger (closest to Hanna Shoal; recorders BG02, BG03, and BG08) had walrus detections on 65–91% of days, while the other four stations on the south-west side of Burger detected walrus on 27–43% of days. Call count isopleths revealed a predominant presence of walrus on the southwest side of Hanna Shoal (W50–BG08) and near Point Lay (Fig. 9.11).

Walrus sightings from vessel and aerial monitoring coincided with the predominant presence of walrus calls detected by acoustic recorders on the southwest side of Hanna Shoal (Fig. 9.11). Walrus sightings appeared to be more numerous on the west side of the call count isopleths, but this may also be a result of more monitoring effort occurring on that western side.

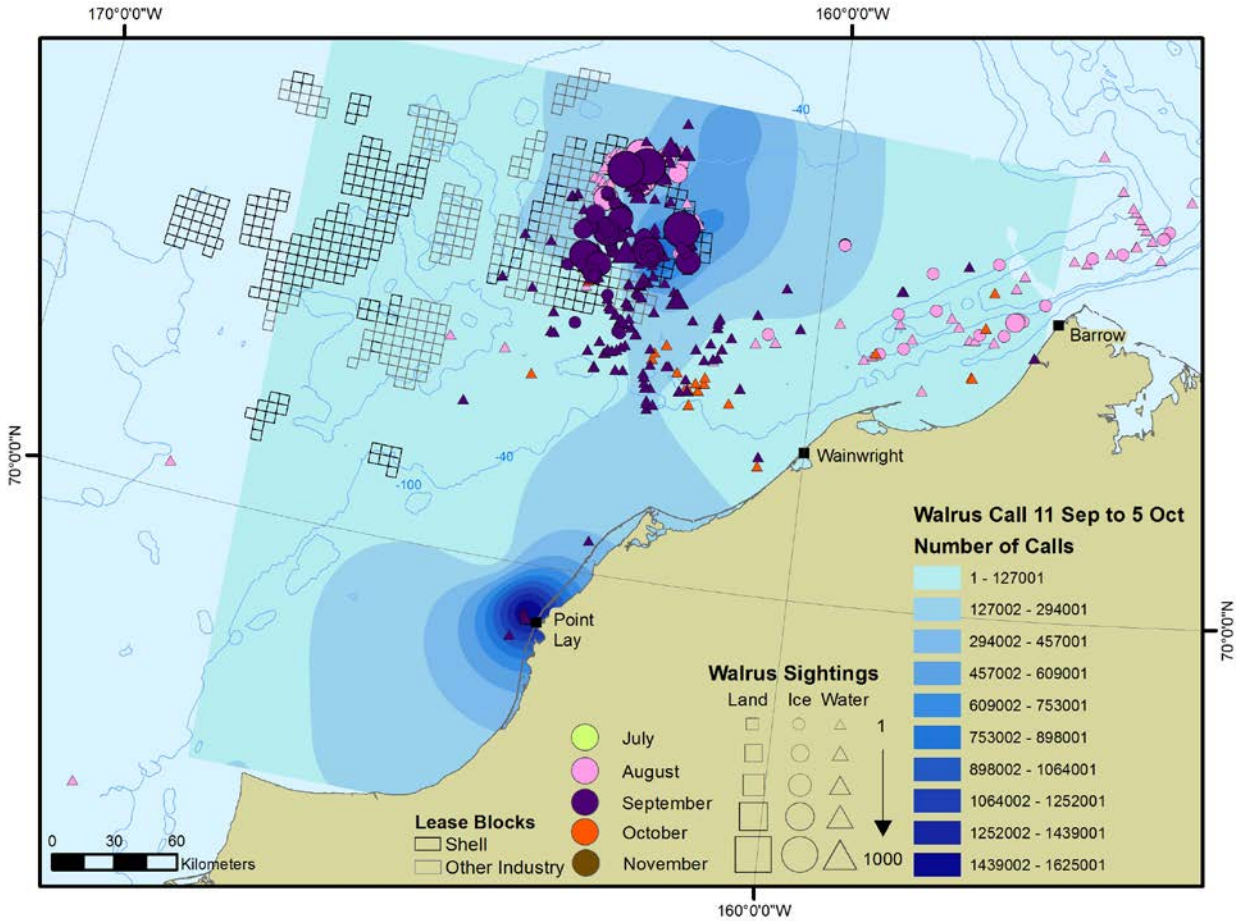


FIGURE 9.11. Industry-sponsored vessel and aerial walrus sightings plotted over the interpolated walrus call counts based on the sum of automated call detections in all files with manual detections for 11 September to 5 October (period when all 30 recorders were deployed) at all summer 2012 stations in the northeastern Chukchi Sea.

Walrus call detections off Point Lay began in the third week of August 2012, but did not become continuous until the beginning of September. Interestingly, sea ice was still present on or near Hanna Shoal until at least the middle of September. Although call counts were similar in the offshore Burger area (at BG08 recorder station, see Fig. 5 in Appendix B) and the coastal Point Lay area (at PL05 recorder station, see Fig. 5 in Appendix B) during the first three weeks of September, they increased to twice that amount in the coastal Point Lay area (at PL05 recorder station) in the last three weeks of recording. There were few industry-sponsored coastal aerial surveys flown in 2012 making it hard to corroborate these acoustic detections with visual sightings. One survey flown on 28 September reported seven walrus sightings in the Point Lay area and, given the high sea states at the time of the survey, it was likely that other walruses were present in the area but missed by observers. ASAMM aerial surveys observed walruses close to shore in the Point Lay area in September and October 2012 (Clarke et al. 2013).

Acoustic data indicate that the greatest extent of walrus spatial distribution during the 2012 open-water season occurred in late September/early October (50–76% of active stations with detections), possibly due to walrus dispersing following the disappearance of sea ice at Hanna Shoal and migrating toward the northern Chukotka coast where they typically aggregate in the fall. The above-average

number of detection days in the coastal area of Cape Lisburne (at station CL05) indicates that many walrus followed the coast between Point Lay and Cape Lisburne as they left the study area. Jay et al. (2012) noted that walrus used the nearshore area of northwestern Alaska (Point Lay area) in June during their northward migration, then again in late August and September during the period from 2009 to 2011.

Acoustic recorders in the Chukchi Sea have detected walruses during summer in a consistent pattern for multiple years (Fig. 9.12). Detections have been high in the Hanna Shoal area from 2009–2012 (Fig. 9.12). These data were consistent with other studies that found Hanna Shoal has been used both in the past and present as a foraging area for walrus (Jay et al. 2012). In three of the four years (2010, 2011 and 2012) the recorders just off Point Lay have also had high numbers of detections. Terrestrial haulouts were observed in the Point Lay area in 2007, 2010 and 2011, and likely explain the high numbers of detections in this area.

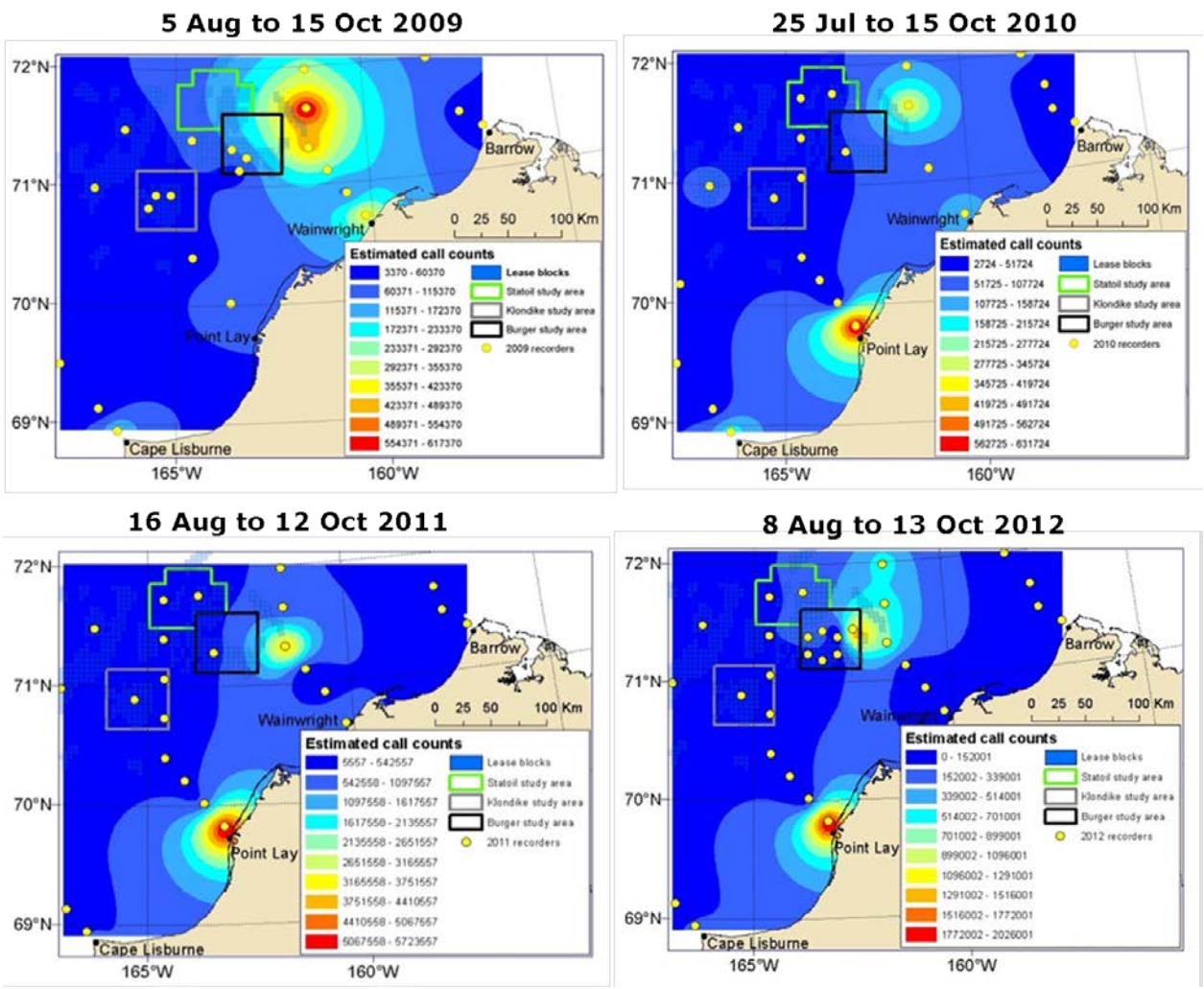


FIGURE 9.12. Summer walrus call counts: Radial basis-interpolated call counts based on the sum of automated call detections in all files with manual detections at all summer recording stations in the northeastern Chukchi Sea.

### *Fall and Winter Detections*

The 2011 winter program introduced recorders on the eastern, northern, and western sides of Hanna Shoal, which had not yet been acoustically surveyed. These recorders revealed the consistent presence of walrus from late August to early October, with a peak on the north-central part of the Shoal (WN60; Fig. 9.13). After the deployment of the winter recorders, the southwesterly shift in the distribution of call detections suggests walruses moving out of the area (Fig. 9.13). Detections during the remainder of the fall on these recorders were similar to those from the three previous years, except for one station. The one exception at 37 km (20 nmi) offshore of Wainwright (station WN20, see Fig. 9.1), which was not part of previous winter programs, there were only a few detections and most were concentrated in a three-day peak, which perhaps indicated an area-wide, southerly movement of walrus. Detections at WN20 were similar to those collected by the summer 2011 recorder at this site, suggesting this location as a walrus hotspot in the northeastern Chukchi Sea in some years.

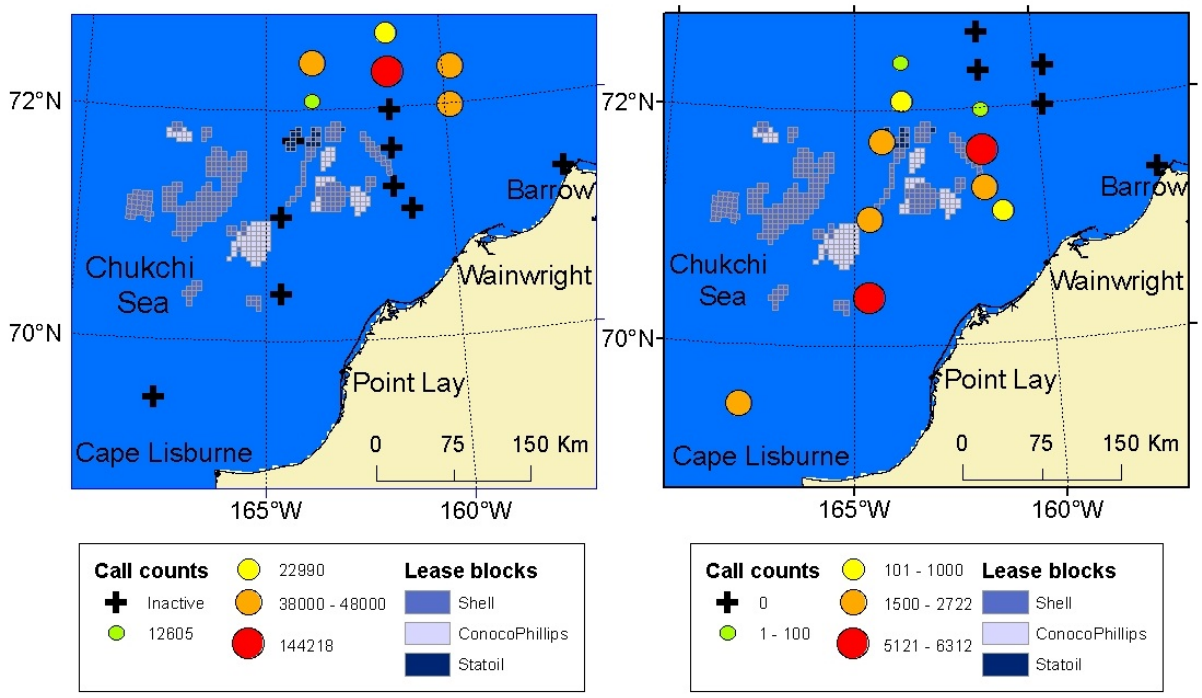


FIGURE 9.13. Walrus call count estimates* in the Chukchi Sea at all winter 2011–2012 recording stations. (Left) from 29 August to 10 October 2011; (right) from 12 October to 31 December 2011. The winter recorders were not deployed until 10 October. The blue background indicates ice-free areas. No ice was present on 10 September or 22 October (mean detection date, left and right, respectively; NOAA 2012). *Corrected sum of automated call detections in all files with manual detections, see Appendix B for details.

In the winter of 2011–2012, walruses were detected on 14 (*n*=15 recorders deployed) of the overwinter recorders with the last detection heard on 20 December 2011 (Table 9.2 and Fig. 9.1). In previous years walrus calls were last detected on 27 February in 2011 (winter 2010–2011; *n*=7 recorders deployed), 22 January in 2010 (winter 2009–2010; *n*=8 recorders deployed), and 20 November 2008 (winter 2008–2009; *n*=7 recorders deployed; Table 9.2).

TABLE 9.2. Winter walrus call detections: Dates of last call detections, both possible (i.e., record start and end) and actual, and the number of days on which a call was detected manually for each recording station in the northeastern Chukchi Sea.

| Station | Winter 2011-2012 | | | Winter 2010-2011 | | | Winter 2009-2010 | | | Winter 2008-2009 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Record Start | Last dection | Detection days | Record Start | Last dection | Detection days | Record Start | Last dection | Detection days | Record Start | Last dection | Detection days |
| B05 | 13-Oct | – | 0 | 16-Oct | – | 0 | 12-Oct | – | 0 | – | – | – |
| B35 | – | – | – | – | – | – | – | – | – | 14-Oct | – | 0 |
| PBN40 | 29-Aug | 8-Oct | 27 | – | – | – | – | – | – | – | – | – |
| PBN20 | 29-Aug | 7-Oct | 27 | – | – | – | – | – | – | – | – | – |
| WN80 | 27-Aug | 9-Oct | 29 | – | – | – | – | – | – | – | – | – |
| WN60 | 27-Aug | 8-Oct | 35 | – | – | – | – | – | – | – | – | – |
| WN40 | 8-Oct | 1-Nov | 2 | 10-Oct | 14-Dec | 1 | 13-Oct | – | 0 | 15-Oct | 17-Oct | 1 |
| WN20 | 8-Oct | 23-Nov | 22 | – | – | – | – | – | – | – | – | – |
| W50 | 12-Oct | 20-Oct | 3 | 10-Oct | – | 0 | 14-Oct | 18-Nov | 1 | 15-Oct | 25-Oct | 2 |
| W35 | 12-Oct | 23-Oct | 3 | – | – | – | 14-Oct | – | 0 | 14-Oct | – | 0 |
| PLN120 | 28-Aug | **20-Dec** | 33 | – | – | – | – | – | – | – | – | – |
| PLN100 | 28-Aug | 28-Nov | 21 | – | – | – | – | – | – | – | – | – |
| PLN80 | 11-Oct | 3-Dec | 3 | 11-Oct | 20-Nov | 1 | 14-Oct | – | 0 | 16-Oct | **20-Nov** | 1 |
| PLN40 | 11-Oct | 26-Nov | 7 | 11-Oct | **27-Feb** | 2 | 13-Oct | **22-Jan** | 2 | 17-Oct | – | 0 |
| PL50 | 9-Oct | 18-Nov | 8 | 11-Oct | – | 0 | 16-Oct | – | 0 | – | – | – |
| CL50 | 11-Oct | 4-Nov | 5 | 15-Oct | – | 0 | 16-Oct | 16-Dec | 1 | 12-Oct | – | 0 |

## *Potential Impacts of 2012 Offshore Exploration Activities on Walrus*

The potential impacts of offshore exploratory drilling activities in Arctic waters have not been studied extensively. Data collected by PSOs aboard the drill ship *Discoverer* and associated support vessels in the Chukchi Sea along with aerial photographic survey data collected over the drill site were used to investigate potential impacts to walrus distribution and behavior from offshore exploration activities in the Alaskan Chukchi Sea during 2012. As noted above, interannual variation in walrus distribution in the Chukchi Sea is closely connected to the temporal and spatial distribution of sea ice over preferred walrus foraging areas of the outer continental shelf. The influence of sea ice on walrus distribution is important to consider when assessing potential impacts from anthropogenic activities on walruses.

### *2012 Aerial Photographic Surveys in the Drilling Area*

Aerial photographic surveys were flown over the Burger drilling site in the Alaskan Chukchi Sea from 15 August through 3 November 2012 (see Chapter 3). A total of 4406 km (2738 mi) of on-effort was obtained during 18 offshore surveys. The survey grid was centered on Shell's Burger exploratory drill site. Survey effort ranged from 0 to 680 km (0 to 423 mi) per survey based on analysis criteria and environmental conditions. The data from these surveys have only been through the "quick review" analysis (see Chapter 3). We expect to find more walrus sightings from these surveys once the "detailed review" analysis is completed, thus the sightings numbers presented here are likely underestimates, but serve as a preliminary assessment of walrus distribution in the drilling area during 2012.

Due to safety restrictions, aerial photographic surveys were only flown if drilling support vessels were present in the prospect area, thus all surveys occurred while vessel activity was taking place on the Burger prospect. Anchor handling activities occurred during approximately 20% of the total survey effort (873 km or 542 mi of effort) and were concentrated in the first half of the field season (until 9 September). Drilling activity was taking place during 31% of the survey effort (1380 km or 857 mi).

Drilling started on 9 September and lasted only one day before the rig was forced to move by approaching sea ice. Drilling resumed on 23 September and lasted through 24 October (Fig. 9.14). General vessel activities were ongoing near the drill site during the remaining forty-nine percent of the total survey effort (2153 km or 1338 mi) and occurred periodically throughout the survey period.

There were 284 walrus sightings (3153 individuals) recorded during preliminary reviews of Shell's photographic aerial survey data from the drilling area in 2012. Of these sightings, only 170 (1933 individuals) were recorded on-transect during conditions that met the analysis criteria (see Appendix A) and were used in the following analyses. Walruses were observed on 29% of surveys and the overall sighting rate was 38.6 sightings/1000 km or 621 mi. Sighting rates ranged from 0–820 sightings/1000 km or 621 mi and 0–16,273 individuals/1000 km or 621 mi (Table 9.3). Walrus were only sighted in the month of September in the photographic survey area. The highest daily sighting rate occurred on 10 September, although the survey effort was very low due to high sea states in the open water on this date. Further, the 10 September survey had the highest ice concentrations on the northern half of the survey area and the on-transect effort occurred only on these northern transects. Thus the sighting rate from this survey overestimates walrus relative abundance across the entire survey area because only the ice covered areas where walrus were located were surveyed.

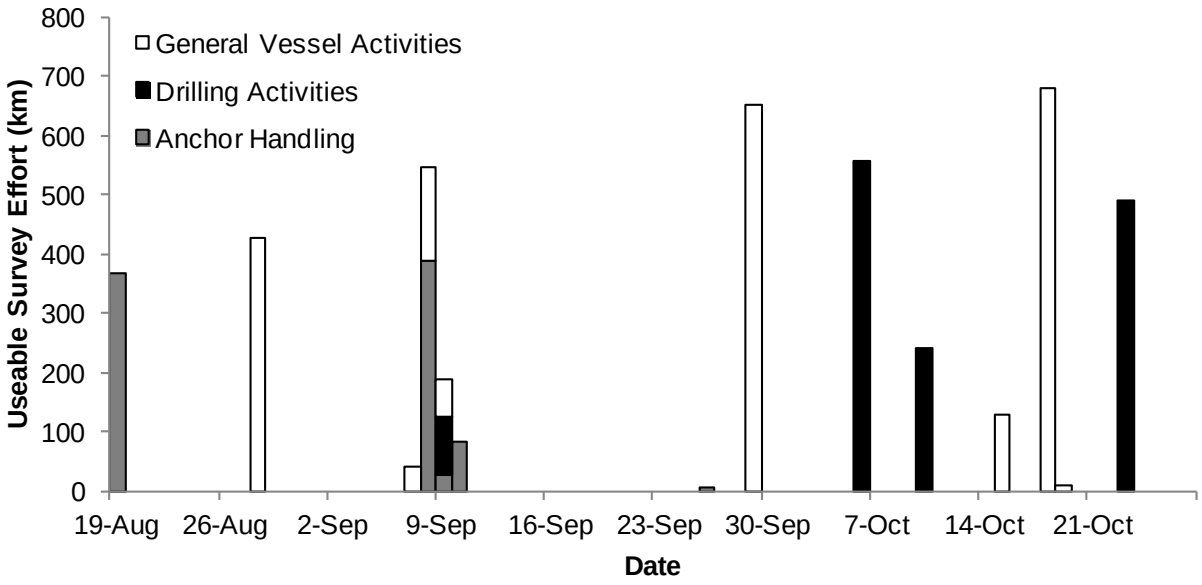


FIGURE 9.14. Daily photographic aerial survey effort over the Burger drill site by vessel activity during 19 August–27 October 2012, Alaskan Chukchi Sea.

TABLE 9.3. Survey effort, walrus sightings, walrus sighting rates, and vessel activities during photographic aerial surveys in the Chukchi Sea: 19 August–27 October 2013.

| Date in 2012 | Survey No. | Effort (km) | Vessel Activities | Sightings | Individuals | Sightings / 1000 km | Individuals / 1000 km |
|---|---|---|---|---|---|---|---|
| 19-Aug | 1 | 368 | Anchor | 0 | 0 | 0.0 | 0.0 |
| 21-Aug | 2 | 0 | - | - | - | - | - |
| 28-Aug | 3 | 426 | General Activities | 0 | 0 | 0.0 | 0.0 |
| 7-Sep | 4 | 40 | Anchor/General | 0 | 0 | 0.0 | 0.0 |
| 8-Sep | 5 | 544 | Anchor/General | 34 | 251 | 62.5 | 461.1 |
| 9-Sep | 6 | 187 | Drilling/Anchor/General | 20 | 191 | 107.0 | 1022.0 |
| 10-Sep | 7 | 84 | Anchor | 69 | 1368 | 820.8 | 16273.1 |
| 26-Sep | 8 | 5 | Drilling/ Anchor | 0 | 0 | 0.0 | 0.0 |
| 29-Sep | 9 | 651 | General Activities | 47 | 123 | 72.2 | 188.9 |
| 30-Sep | 10 | 0 | - | - | - | - | - |
| 6-Oct | 11 | 556 | Drilling | 0 | 0 | 0.0 | 0.0 |
| 10-Oct | 12 | 241 | Drilling | 0 | 0 | 0.0 | 0.0 |
| 15-Oct | 13 | 127 | General Activities | 0 | 0 | 0.0 | 0.0 |
| 18-Oct | 14 | 680 | Anchor/General | 0 | 0 | 0.0 | 0.0 |
| 19-Oct | 15 | 8 | General Activities | 0 | 0 | 0.0 | 0.0 |
| 22-Oct | 16 | 0 | - | - | - | - | - |
| 23-Oct | 17 | 488 | Drilling | 0 | 0 | 0.0 | 0.0 |
| 27-Oct | 18 | 0 | - | - | - | - | - |
| Total/Weighted Average | | 4406 | | 170 | 1933 | 38.58 | 438.72 |

Sighting rates of walruses in water from aerial photographic data were higher during the anchor handling period (63.0 sightings/1000 km or 621 mi) than during drilling (5.1 sightings/1000 km or 621 mi) or general vessel activities (21.8 sightings/1000 km or 621 mi; Table 9.4). The difference between observed and expected sighting rates was statistically significant (Chi-square test, $p < 0.001$). When sighting rates during drilling were compared to sighting rates during general vessel activities the difference between observed and expected sighting rates was also statistically significant (Chi-square test, $p = 0.033$). These data alone suggest that walrus may have been avoiding the drilling activities occurring at the Burger prospect. Most drilling activity, however, occurred late in the open-water season when the ice had retreated out of the survey area and most walruses had already left the area. Further. the large number of sightings during anchor handling, which is one of the noisiest activities (see Chapter 4), suggest that sighting rates were more dependent on the time of year and ice presence than they were on the activity occurring at the prospect.

TABLE 9.4. Survey effort, walrus sightings in water, and walrus sighting rates during aerial surveys in the Chukchi Sea for each drill site activity: 19 August–27 October 2012. The last column shows the total effort, sightings and individuals and the average value of sightings/1000 km and individuals/1000 km.

| | Drilling Activities | Anchor Handling | General Vessel Activities | Total or Average |
|---|---|---|---|---|
| Effort (km) | 1380 | 873 | 2153 | 4406 |
| Sightings | 7 | 55 | 47 | 109 |
| Individuals | 20 | 370 | 123 | 513 |
| Sightings/1000 km | 5.1 | 63.0 | 21.8 | 24.7 |
| Individuals/1000 km | 14.5 | 423.9 | 57.1 | 116.4 |

The average distance of walrus sightings from the drill site during drilling activities, as determined from a preliminary review of aerial photographs, was similar to the distance of sightings from anchor handling activities and from general vessel activities: 32.67 km (20.30 mi), 34.39 km (21.37 mi), and 31.91 km (19.83 mi), respectively. Sighting distances of walruses in water from the drill site during anchor handling did not differ from the distances that walruses were seen from general vessel activities (Mann-Whitney U, $p = 0.949$; Table 9.5). There were not enough sightings during drilling activities to compare with anchor handling or general vessel activities. The closest distance to the drill site that a walrus was sighted in aerial photographs was 20.30 km (12.61 mi) during anchor handling activities. During three of the four surveys when walrus were sighted, ice was concentrated on the first three transect lines, which were approx 20–40 km (12–25 mi) from the drill site. All of the walrus sightings were associated with the ice, thus the distances of walruses from the drill site during these three surveys likely were more related to the distribution of ice around the drill site than they were to avoidance of the drill site by walruses.

TABLE 9.5. Minimum, maximum and mean distance (km) of walrus sightings from the drill site by activity at the drill site in the Chukchi aerial survey area.

| | In Water | | | | On Ice | | | |
|---|---|---|---|---|---|---|---|---|
| | Distance from Drill Site (km) | | | | Distance from Drill Site (km) | | | |
| Activity at Drill Site | Mean | Min | Max | n | Mean | Min | Max | n |
| Drilling | 32.67 | 31.98 | 32.92 | 7 | 31.36 | 22.13 | 34.12 | 13 |
| Anchor Handling | 34.39 | 20.30 | 51.91 | 55 | 30.74 | 20.30 | 36.61 | 48 |
| General Activities | 31.91 | 20.74 | 41.47 | 47 | - | - | - | 0 |
| Total | 33.21 | 20.30 | 51.91 | 109 | 30.87 | 20.30 | 36.61 | 61 |

### *Closest Point of Approach to Vessels*

CPAs (closest point of approach) of Pacific walrus on ice and in water were considered separately because regulatory requirements were different for each of these situations, as were their sightability by PSOs (Bisson et al. 2013). Walruses were more easily detected on ice than in the water. Mean CPA for walruses on ice observed from moving vessels was 4.8 times greater than the mean CPA for walruses observed in water (Table 9.6). Mean CPA for walruses on ice observed from stationary vessels was 9.3 times greater than the mean CPA for walruses observed in water (Table 9.7). Ice management activities involved primarily scouting and monitoring with minimal contact between ice and vessels, and vessels were instructed to maintain a distance of 800 m (0.5 mi) from walruses on ice whenever possible. The mean CPA for walruses on ice during ice management was 5440 m (17,848 ft), which reflects the fact that no ice management occurred if walruses were on or near the ice that was to be managed.

The mean CPA for walruses observed in water from stationary vessels during drilling activities was 273 m (896 ft; Table 9.7). The closest approach of a walrus to a project vessel in the Chukchi Sea was a juvenile walrus which approached the *Tor Viking* and physically contacted the vessel many times, probably attempting to haulout on the vessel.

On average, Pacific walruses in water approached moving vessels as well as stationary vessels at similar distances (Mann Whitney rank sum test: M = 1859, p = 0.063; Tables 9.6 and 9.7). Pacific walruses in water approached moving vessels to similar distances during anchor handling and general vessel activities (Mann Whitney rank sum test: M = 1022, p = 0.366).

TABLE 9.6. Comparison of mean walrus CPA distances in water and on ice by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during moving periods.

| Moving Vessel Activity | In Water | | | On Ice | | |
|---|---|---|---|---|---|---|
| | Mean CPA[a] (m) | Range (m) | n | Mean CPA[a] (m) | Range (m) | n |
| AnchorHandling | 589 | 50 – 1500 | 20 | 4564 | 1000 – 7000 | 4 |
| Drilling Activities | 648 | 15 – 3560 | 9 | 3379 | 2173 – 4657 | 8 |
| Ice Management | 50 | – | 1 | 5440 | 3000 – 8000 | 4 |
| General Vessel Activities | 747 | 30 – 5000 | 117 | 2927 | 913 – 8000 | 23 |
| Total | 715 | 15 – 5000 | 147 | 3445 | 913 – 8000 | 39 |

[a] CPA=Closest Point of Approach.

TABLE 9.7. Comparison of mean walrus CPA distances in water and on ice by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during moving periods.

| Stationary Vessel Activity | In Water | | | On Ice | | |
|---|---|---|---|---|---|---|
| | Mean CPA[a] (m) | Range (m) | n | Mean CPA[a] (m) | Range (m) | n |
| AnchorHandling | 944 | 400 – 1600 | 4 | 7000 | – | 1 |
| Drilling Activities | 273 | 50 – 1088 | 5 | 6264 | – | 1 |
| Ice Management | 438 | 300 – 575 | 2 | 5456 | 2444 – 8268 | 10 |
| General Vessel Activities | 534 | 5 – 3256 | 21 | 4065 | 1943 – 10000 | 8 |
| Total | 539 | 5 – 3256 | 32 | 5017 | 1943 – 10000 | 20 |

[a] CPA=Closest Point of Approach.

### *Reaction Behaviors to Vessels*

When we looked at each vessel activity in 2012, we saw the majority of Pacific walruses exposed to different vessel activities exhibited no reaction to vessels (58% of sightings; Fig. 9.15). The majority of walrus sightings occurred during general vessel activities (77%, *n*=138). Looking was the most commonly observed reactions for walruses exposed to anchor handling, drilling activities and ice management (54%, 43%, and 67%, respectively) with fewer observations of change direction, increase speed and splash.

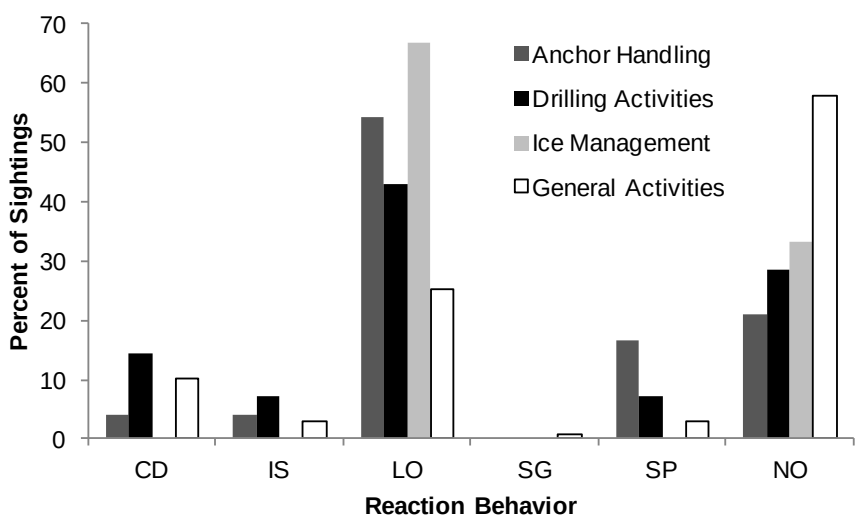


FIGURE 9.15. Percentages of Pacific walrus reactions to vessels for animals exposed to different vessel activities in the Chukchi Sea, 2012. Sightings were of animals in water, *n* = 179. CD = Change Direction, IS = Increase Speed, LO = Look at Vessel, SG = Interact with Gear, SP = Splash, NO = No Reaction.

### *Detailed Encounter Results during a Period of Ice Scouting*

Ice scouting and management activities in the Chukchi Sea during 2012 involved significant communication between PSOs and vessel operators. Whenever possible, these activities were restricted to periods with good visibility to allow for large detection distances of marine mammals in the area prior to approaching or entering the main ice edge. Walruses hauled out on ice often were detected by PSOs using "Big Eye" binoculars aboard ice management vessels at distances between 5 and 8 km (3.1 and 5.0 mi). The location of these animals was communicated to vessel operators and shore-based project managers, and such distances from animals were maintained unless the ice was deemed potentially hazardous to the safety of the operation. Only small amounts of hazardous ice were managed in the Chukchi Sea drilling area by the *Fennica* and *Tor Viking* between 31 August and 13 September, and no ice with marine mammals directly associated with it was managed or approached closer than was operationally necessary. All operational decisions related to ice scouting and management involved significant assessment of the distribution of marine mammals known to be in the area prior to any detailed instructions being delivered from Shell's shore-based management team in Anchorage to the vessels. All operational instructions clearly prohibited vessel interactions with marine mammals on or near ice. Shell was issued a "take-by-harassment" LOA from USFWS as a precautionary measure to protect the safety of the drilling operation if necessary; however, there were no intentional takes of walruses or any other marine mammals during 2012.

An exclusion zone of 805 m (0.5 mi) around walruses on ice is enforced by USFWS, which is one reason our mean CPAs for walrus on ice are significantly higher than for walrus in water. They also are more easily detected on ice at greater distances compared to walruses in water. The following is a report based on an account whereby USFWS permitted Shell on 13 September 2012 to slowly sail the *Fennica*, Shell's primary ice-management vessel, into some sea ice that posed a risk to the safety of the drilling operation at Burger. The loosely-packed ice was associated with walruses, which allowed for the vessel to safely maneuver and maximize its distance from groups of animals hauled out on the ice. PSOs were instructed to pay particular attention to potential walrus reactions, group sizes, and CPAs. This offered a basis to investigate the efficacy of a marine exclusion zone for walruses.

The *Fennica* reported a sighting of approximately 35 groups of walruses on 13 September 2012. The focus of PSOs during this sighting was on the groups of walruses closest to the vessel and the reaction of those walruses. For this reason, some groups of walruses farther away from the vessel were not counted and their reactions may not have been observed, although based on the following results from this sighting event it is unlikely that many of the more-distant walruses reacted to the vessel. The sighting was recorded as a single sighting, but the detailed, sequential comments covering the entire operations allowed for a breakdown into specific groups by reaction. Reaction groups were broken down into: "on ice and stayed on ice," "on ice and moved into water," or "in water." The most common reaction to the vessel, other than moving into the water, was looking at the vessel.

PSOs aboard the *Fennica* recorded approximately 1200 walruses during the ice-scouting event on 13 September 2012. Of these, approximately 450 walruses were first detected on ice and subsequently entered the water. The mean CPA to the vessel for walruses that entered the water was 525 m (1722 ft). Walruses observed entirely in the water totaled 55 individuals with a mean CPA of 270 m (886 ft). In several cases, several individuals in a group would enter the water and some would not. Individuals and groups of walruses that were detected on ice and did not enter the water as the vessel passed totaled approximately 750 walruses, with a mean CPA of 962 m (3156 ft or 0.6 mi).

The mean CPA for walruses on ice that did not enter the water was 1.8 times greater than the mean CPA for walruses on ice that entered water (Table 9.8). There was a significant difference in the CPA of

walruses on ice that did not enter water compared to walruses that did enter the water (Mann Whitney rank sum test: M = 87, p = 0.040). These results provide empirical support for the marine exclusion zone of 805 m (0.5 mi) given that animals were much less likely to enter the water when the vessel did not approach within this distance.

Table 9.8. Comparison of mean walrus CPA distances walrus reactions from the *Fennica* during Shell's exploratory drilling operations in the Chukchi Sea, 13 September 2012.

| Walrus Reaction | Mean CPA[a] (m) | s.d. | Range (m) | n |
|---|---|---|---|---|
| On ice that did not enter water | 962 | 945 | 200 - 5031 | 25 |
| On ice that entered water | 525 | 233 | 200 - 1000 | 12 |
| In water | 270 | 178 | 50 - 518 | 8 |

[a] CPA=Closest Point of Approach. This value is the marine mammal's closest point of approach to the observers.

### *Helicopter Encounters*

In all but one occasion in 2012, vessels associated with Shell's exploratory drilling program in the Chukchi Sea were moved away from walruses on ice prior to helicopter operations. The one detailed account for reactions of walruses to helicopters from 2012 is summarized below.

*Nordica* PSOs observed approximately 30 walruses resting on a piece of ice 2500 m (1.6 mi) away from the vessel on 6 August 2012 at 19:48. The search and rescue helicopter was scheduled to run drills on the *Nordica*. The pilots were informed of the location of the walruses before approaching the *Nordica*. The helicopter completed a personnel hoist at 20:02 and landed on the vessel's helicopter deck at approximately 20:06. The walruses remained on the ice throughout the hoist and landing activities. Before the helicopter departed, the walruses were resighted and their location was relayed to pilots. The helicopter lifted off the deck at 20:18, with the nose facing the walruses, and briefly traveled in their direction before turning away. The walruses remained on the ice during the lift off and only entered the water after the helicopter had turned and changed direction. At this point all 30 walruses entered the water at a moderate pace and in an orderly fashion with no splashing observed. The walruses entered on the far side of the floe, which could have potentially blocked the view of splashing - if it occurred. After entering the water, a minimal amount of splashing was visible as the walruses swam. In addition, a single walrus was observed on a piece of ice in line with, but 700 m (0.43 mi) away from, the ice that the herd was occupying. The single animal remained on the ice, and only entered the water about four minutes after the larger group had done so.

### *Walrus Sightings and Received Sound Levels from Drilling and Supporting Activities*

Walrus sightings from both vessel and aerial platforms associated with 2012 exploratory drilling operations and related support activities were plotted over the median sound pressure levels during different activities in 2012 (Figs. 9.16–9.20; Kriging-interpolated). Levels were interpolated between recorders from the Joint Studies regional array, the Joint Studies "Burger array" hexagon, and the dedicated drilling recorders moored near the drill site (see Chapter 3).

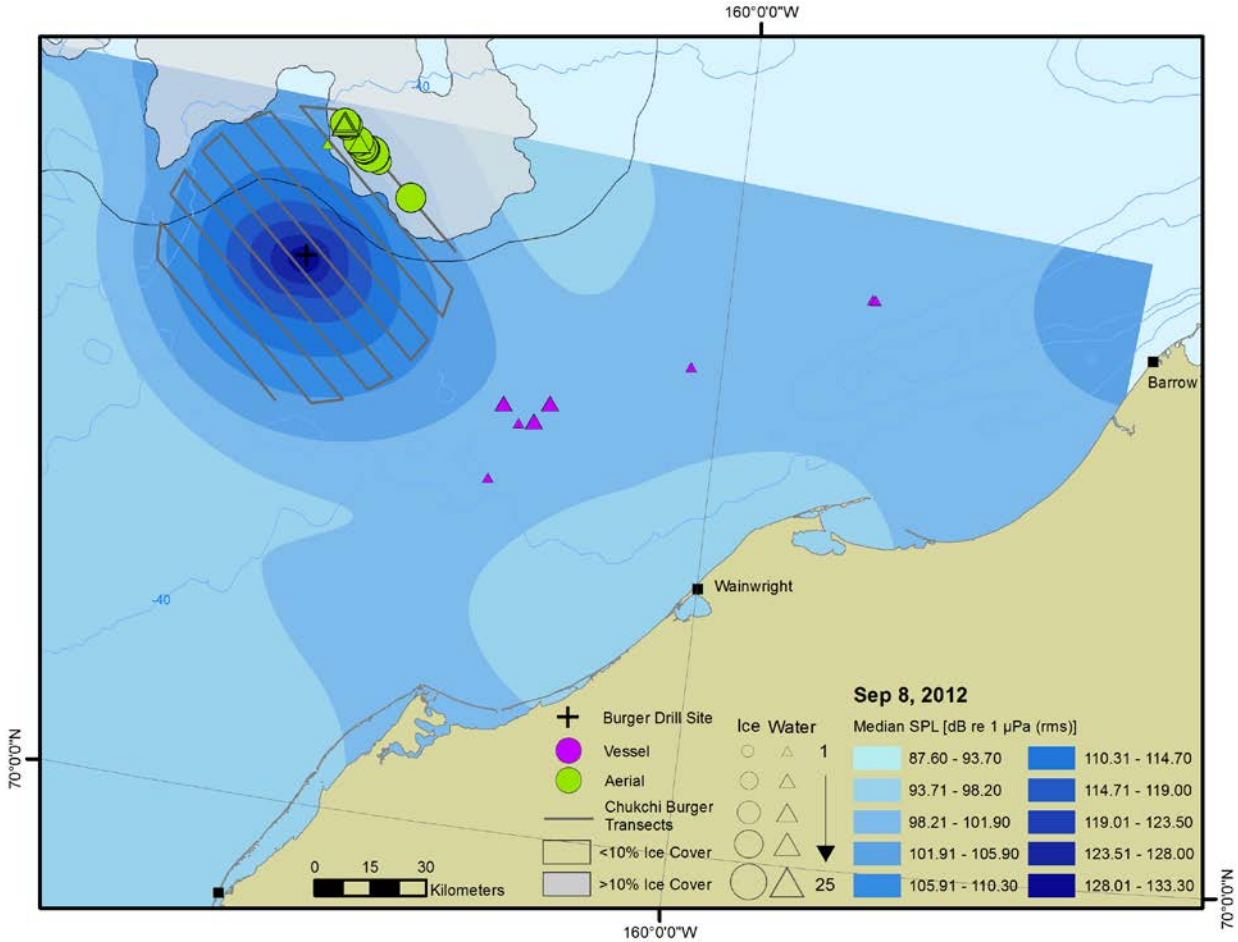


FIGURE 9.16. Pacific walrus sightings from industry-sponsored vessel and aerial (photographic and PSO) platforms overlaid on the median of the total sound pressure levels (Kriging-interpolated) received during **anchor handling and general vessel activities** on 8 September 2012. Gray shading represents areas with >10% ice cover and the outline around the ice area shows the ice edge and the extent of ice cover that is <10%.

Preliminary review of data from an aerial photographic survey on 8 September 2012 detected 45 sightings of 334 individual walruses in the Burger survey area, with 53% of the sightings on ice. On that same day, five vessels (*Affinity*, *Aiviq*, *Guardsman*, *Kulluk*, and *Sisuaq*) reported eight sightings of 28 individuals, all in open water. Activities taking place on 8 September were anchor handling and general vessel activities. All aerial sightings and two of the vessel sightings occurred during the anchor-handling time period, and the other six vessel sightings took place during general vessel activities. No vessel-based sightings were in areas where RLs in the water were estimated to be ≥120 dB (rms). Figure 9.16 shows the locations of the aerial and vessel sightings, and median sound pressure levels for 8 September during the time when anchor handling and general vessel activities were taking place. The clumping of the aerial sightings on the north-east edge of the survey area coincided with the only location of ice in the survey area on 8 September. This clumping pattern is more likely related to ice presence than it is to avoidance by walruses of the activity occurring at the prospect.

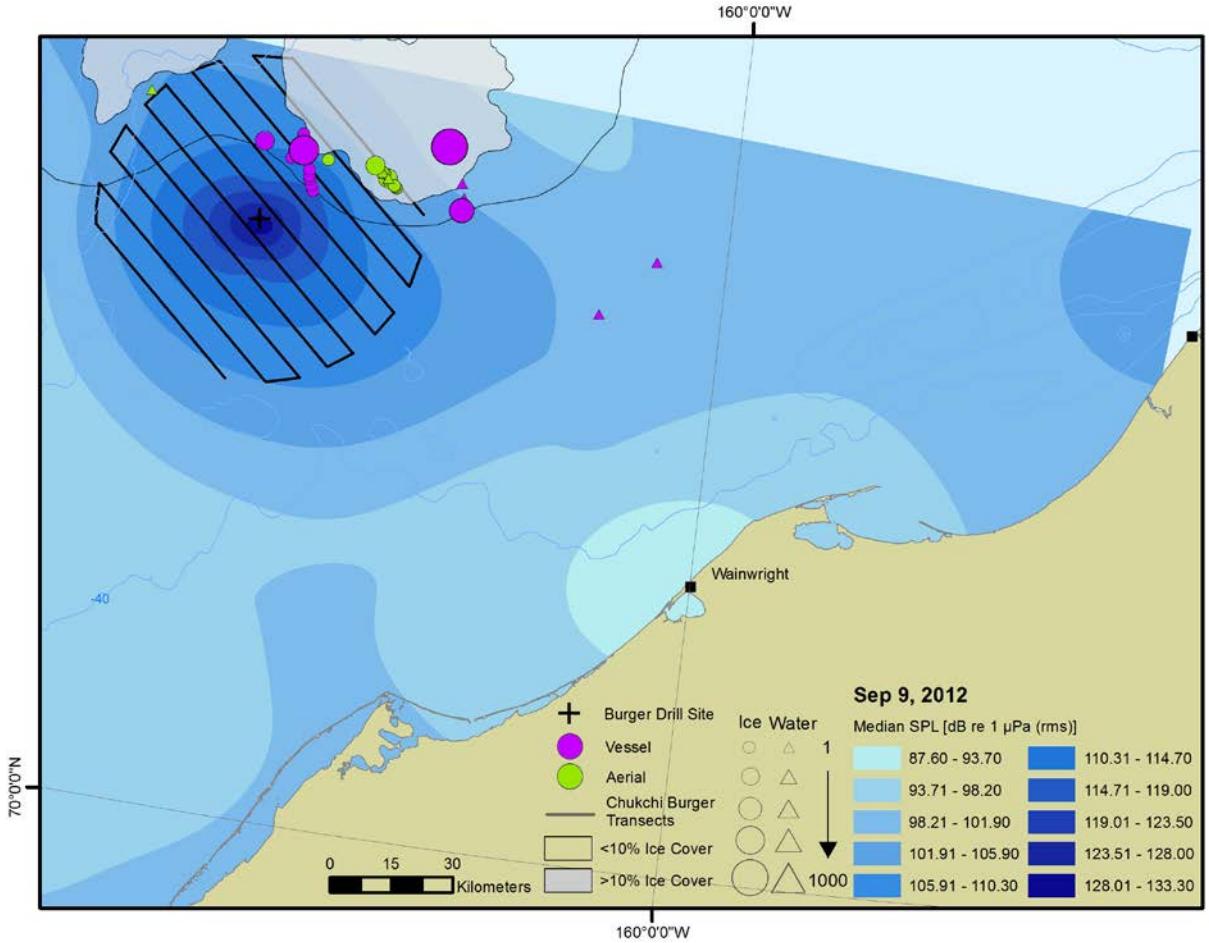


FIGURE 9.17. Pacific walrus sightings from industry-sponsored vessel and aerial (photographic and PSO) platforms overlaid over the median of the total sound pressure levels (Kriging-interpolated) received during **drilling activities, anchor handling and general vessel activities** on 9 September 2012. Gray shading represents areas with >10% ice cover and the outline around the ice area shows the ice edge and the extent of ice cover that is <10%.

Preliminary review of data from an aerial photographic survey on 9 September 2012 detected 26 sightings of 330 walruses in the Burger survey area, with 57% of the sightings occurring on ice. On that same day four vessels (*Tor Viking*, *Guardsman*, *Fennica*, and *Nordica*) recorded 21 sightings of 1871 individuals, with 67% of the sightings on ice. Activities taking place on 9 September were drilling, anchor handling and general vessel activities. All aerial sightings and 14 of the vessel-based sightings occurred during the drilling time period, five of the vessel sightings occurred during anchor handling, and the remaining two vessel sightings took place during general vessel activities. One vessel sighting was in an area where RLs in the water were estimated to be ≥120 dB (rms), however, that sighting of 474 individuals were hauled out on ice and likely would not have been exposed to levels of sound comparable to animals in the water. Figure 9.17 shows median sound pressure levels and the locations of the aerial and vessel sightings for 9 September during the time when drilling, anchor handling and general vessel activities were taking place. All of the ice in the survey area was located on the north-east half of the survey lines where the walrus sightings occurred, thus this pattern again may be more related to ice presence than on the activity occurring at the prospect.

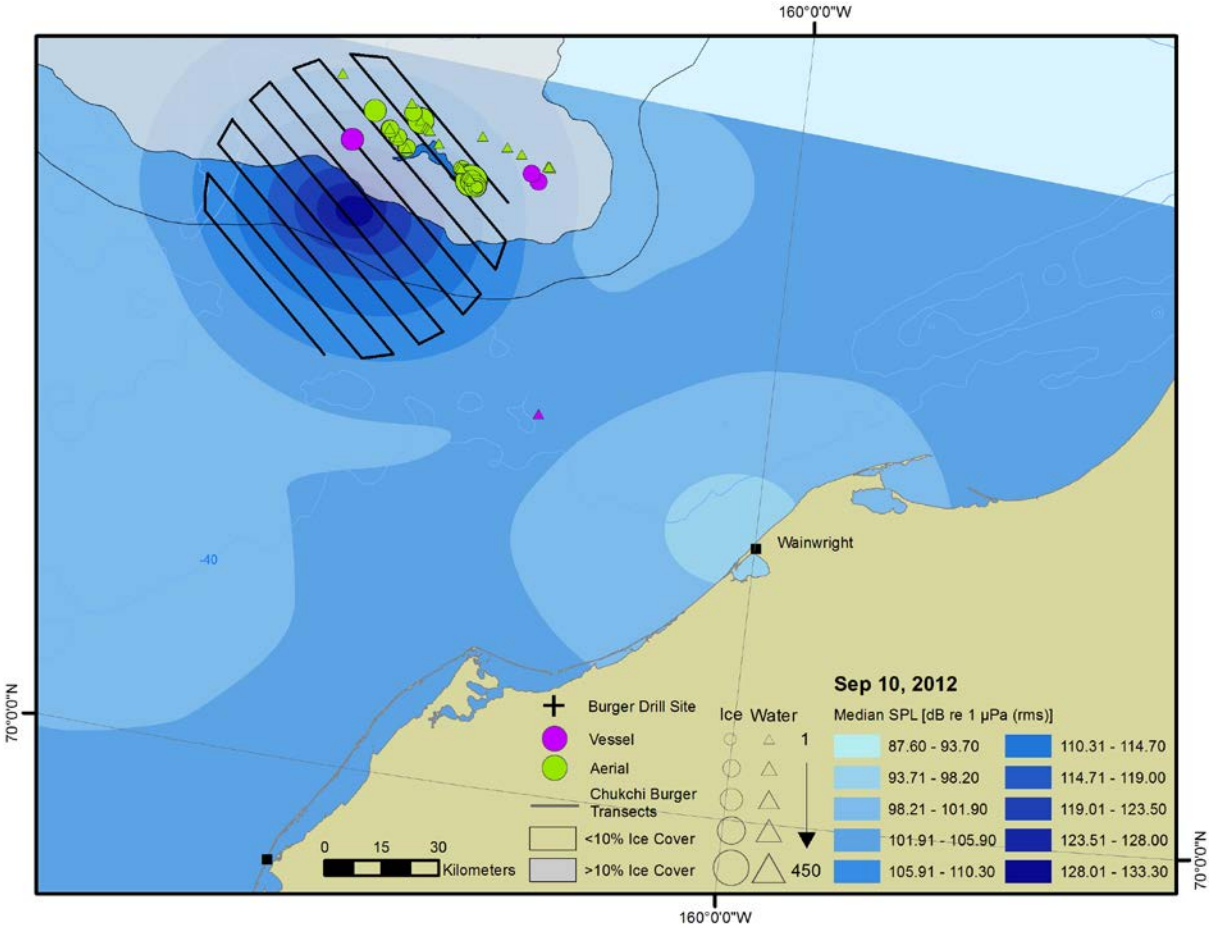


FIGURE 9.18. Pacific walrus sightings from industry-sponsored vessel and aerial (photographic and PSO) platforms overlaid over the median of the total sound pressure levels (Kriging-interpolated) received during **anchor handling and general vessel activities** on 10 September 2012. Gray shading represents areas with >10% ice cover and the outline around the ice area shows the ice edge and the extent of ice cover that is <10%.

An aerial photographic survey on 10 September 2012 detected 116 sightings of 1776 individual walruses in the Burger survey area, with 42% of the sightings on ice. On that same day two vessels (*Fennica* and *Nordica*) recorded four sightings of 149 individuals, with 75% of the sightings on ice. Anchor handling and general vessel activities were the only activities taking place on 10 September 2012 while the drillship *Discoverer* was preparing to move offsite in response to sea ice approaching the Burger prospect. All aerial sightings and three of the vessel sightings occurred during the anchor handling time period as the *Discoverer* was unmoored, and the remaining vessel sighting took place during general vessel activities. One vessel sighting was in an area where RLs in the water were estimated to be ≥120 dB (rms); however, the 91 individuals were hauled out on ice and likely would not have been exposed to levels of sound comparable to animals in the water. Figure 9.18 shows the locations of the aerial and vessel-based sightings, and median sound pressure levels for 10 September while anchor handling and general vessel activities were taking place. Similar to the previous two days, all of the ice in the survey area was located on the north-east half of the survey lines where the walrus sightings occurred, and it does not appear that walruses were reacting to activities associated with the Burger prospect.

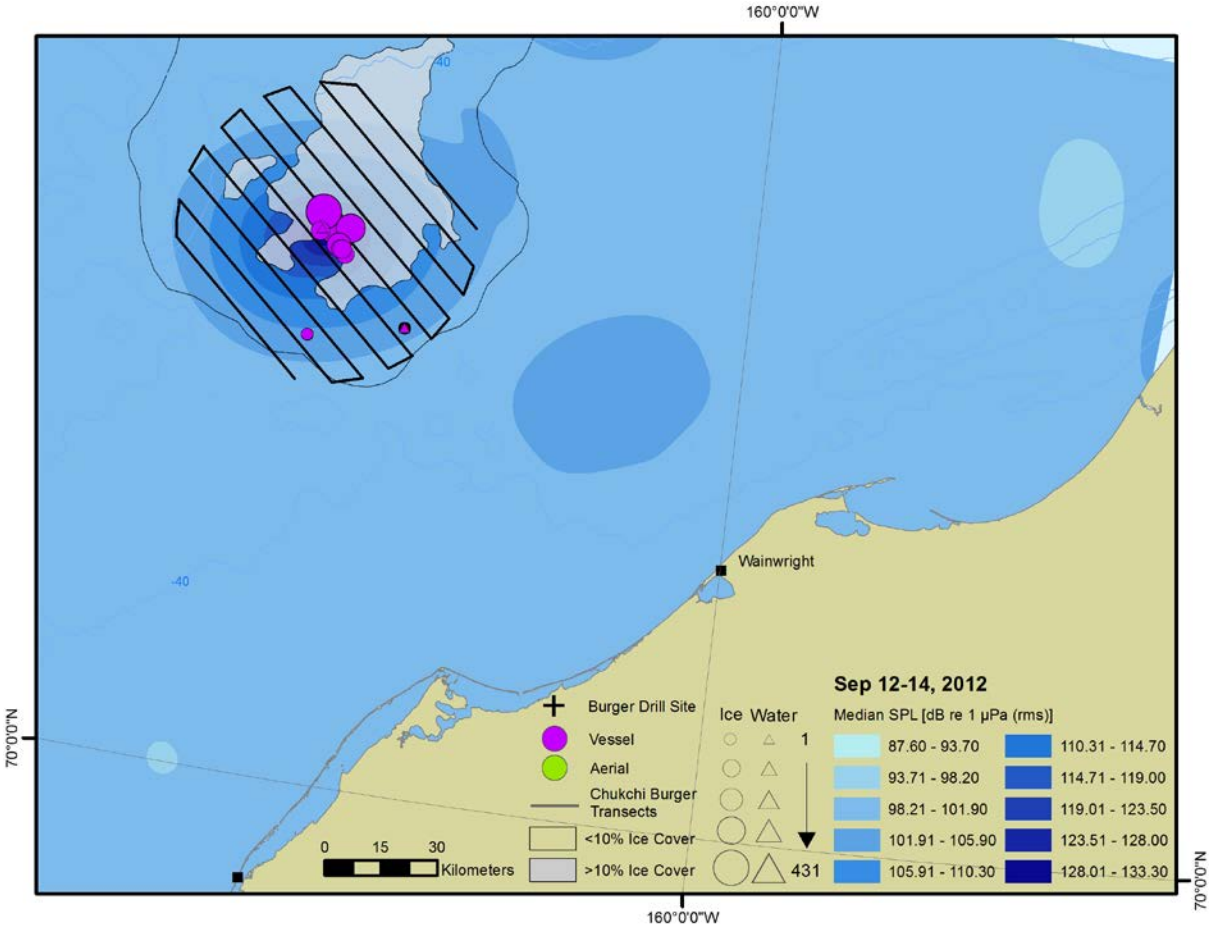


FIGURE 9.19. Pacific walrus sightings from industry-sponsored vessel and aerial (photographic and PSO) platforms overlaid over the median of the total sound pressure levels (Kriging-interpolated) received during **ice management and general vessel activities** from the 12–14 September 2012. Gray shading represents areas with >10% ice cover and the outline around the ice area shows the ice edge and the extent of ice cover that is <10%.

From 12–14 September 2012, PSOs aboard three different vessels (*Tor Viking*, *Fennica* and *Nordica*) recorded 19 sightings of 987 walruses, with 79% of the sightings on ice. No photographic aerial surveys were flown on these days due to inclement weather. Activities taking place on 12–14 September were ice management and general vessel activities. Eighteen of the sightings occurred during ice management activities, and the remaining vessel sightings took place during general vessel activities. Eleven of the vessel sightings were in areas where RLs in the water were estimated to be ≥120 dB (rms), however, 325 individuals (eight groups) were hauled out on ice and likely would not have been exposed to levels of sound comparable to those in the water. The remaining three sightings of four individuals were observed in water with estimated RLs of 130 and 140 dB (rms), and likely would have been exposed to these sound levels from ice-management activities. Figure 9.19 shows the locations of vessel-based walrus sightings and median sound pressure levels in the region for 12–14 September during the time when ice management and general vessel activities were taking place. Walrus sightings were clumped in the vicinity of the vessels that were working at the Burger prospect area. Ice was scattered throughout this area, and the walrus do not appear to have avoided the vessel activities at the prospect.

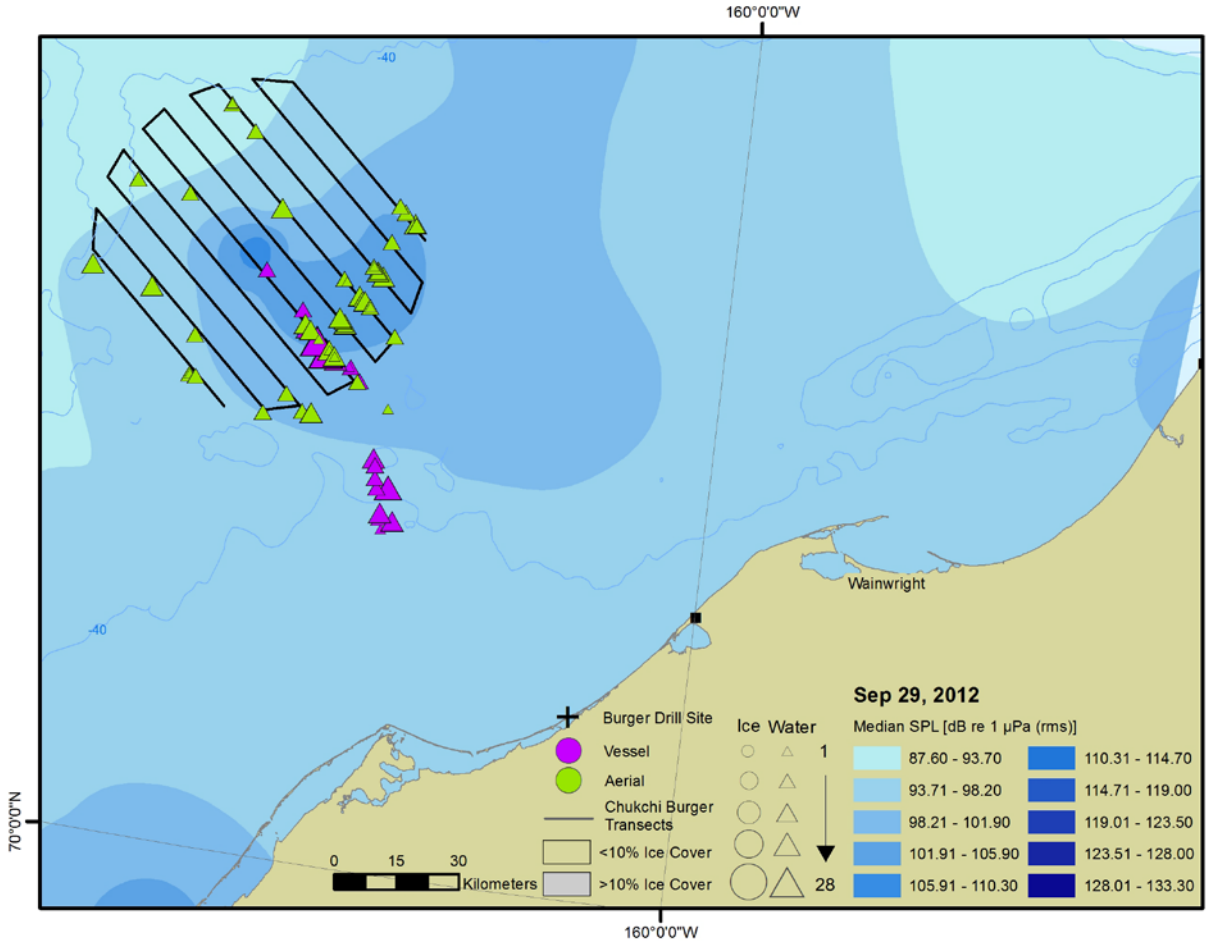


FIGURE 9.20. Pacific walrus sightings from industry-sponsored vessel and aerial (photographic and PSO) platforms overlaid over the median of the total sound pressure levels (Kriging-interpolated) received during **general vessel activities** on 29 September 2012. No ice was present in the survey area on this date.

On 29 September 2012, an aerial photographic survey estimated 82 groups of 196 walruses in the Burger survey area, and all of the animals were in the water as opposed to on ice. On that same day, PSOs aboard four vessels (*Tor Viking*, *Guardsman*, *Fennica*, and *Nanuq*) observed twenty-one groups totaling 122 individuals, all of which were in water. No drilling, anchor handling, or ice management activities took place on 29 September, and all walruses were recorded in areas where estimated RLs in the water were ≤120 dB (rms). Figure 9.20 shows the locations of the aerial and vessel-based sightings, and medial sound pressure levels from general vessel activities on 29 September. Large numbers of walruses were moving through the region on this day, and sightings were widely scattered throughout the survey area. Ice was completely absent from the survey area and continental shelf at this time.

More sightings on 29 September were located on the southeast edge of the survey area (Fig. 9.20), which may indicate a movement toward the Point Lay coastal area, where acoustic recorders picked up high call counts late in September. This southward shift in walrus distribution toward more nearshore areas was similar to observations in previous years after ice retreated beyond the continental shelf. It is possible that some walruses were avoiding vessel activities at the Burger prospect; however, the larger

distributional pattern suggests a closer relationship to the absence of sea ice and the annual movement of walruses from summer feeding grounds in the Chukchi Sea to areas south and west for winter.

Walruses were not observed during ION's brief period of seismic acquisition in the Chukchi Sea in mid-November, 2012. Given the lack of sightings and the typical migratory timing of walurses from the Chukchi Sea, it is unlikely that significant numbers of walruses would have been present and exposed to RLs from seismic activity. The only walruses observed by ION PSOs were south of Point Hope as the vessel departed the Arctic, which was after all seismic survey activity had concluded.

## *Walrus use of Terrestrial Haulouts*

Pacific walrus terrestrial haulouts along the Alaskan Chukchi Sea coast were first observed in 2007 and then again in 2009, 2010, and 2011 (Fig. 9.21). These terrestrial haulouts are thought to have resulted from the rapid retreat of sea ice beyond the shelf break in the Chukchi Sea during these years. Once the sea ice retreated to deeper water away from preferred feeding areas walrus abandoned the ice and moved to shore. In 2007, haulouts occurred at eight different locations between Barrow and Cape Lisburne. The haulouts were smaller, more numerous, and more dispersed along the Chukchi Sea coast than they were in 2009–2011 when animals were concentrated at only one or two locations (Fig. 9.22). The barrier islands in the Point Lay area had the highest walrus counts in three of the four years that terrestrial haulouts were observed (Table 9.9). Walruses began arriving at the terrestrial haulouts between mid-August and early-September. The length of time they used the terrestrial haulouts varied in each year from 12 days in 2009 to as long as 51 days in 2011. Jay et al. (2012) noted that in 2009 and 2010, tagged walruses used the nearshore area immediately surrounding the terrestrial haulout, but did not appear to travel farther from the haulout. In 2011, about half of the tagged walruses made round trips to an area just south of Hanna Shoal.

It is not clear why animals made these trips to Hanna Shoal in 2011, but did not appear to make them in 2009 or 2010. The nearshore area of Point Lay has low macroinfaunal biomass dominated by the sand dollar (*Echinarachnius parma;* Feder et al. 1994), which is not a typical prey item of walruses (Sheffield and Grebmeier 2009). This may explain why walruses did not stay in the area longer in 2009 and 2010. Animals arrived at the haulout about two weeks sooner in 2011 than they did in 2009 or 2010 and remained in the area into the first week of October rather than departing in the third or fourth week of September, as occurred in the previous two years.

The Hanna Shoal area is a known walrus foraging area, but is a much greater distance from the Pt. Lay haulout than are offshore areas near Pt. Lay where acoustic detections of walruses occurred and tagged animals were located. Animals at terrestrial haulouts in 2009 and 2010 may have been ready to continue south and therefore did not make the trip to Hanna Shoal as they did in 2011. In 2011, these trips may have extended the amount of time that the haulout was used, or the trips may simply have been required for sustenance given the early date of arrival at, and late date of departure from, the haulout. It is unclear to what extent foraging from shore affects walrus energetics and behavior.

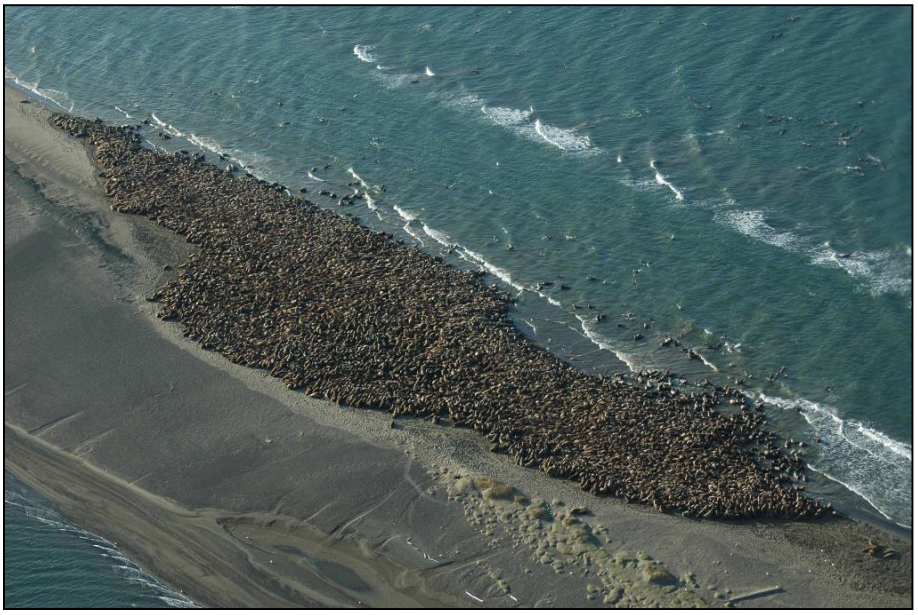

FIGURE 9.21. Pacific walrus haulout on the Chukchi Sea coast east of Icy Cape, 18 September 2007. Note walrus in the water moving to and from the haulout site.

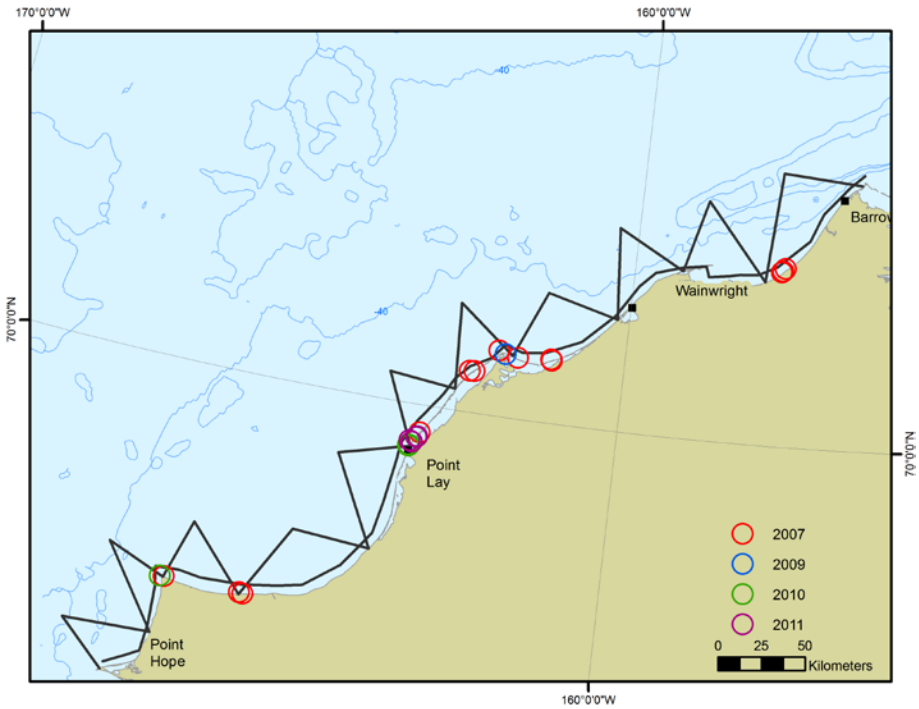


FIGURE 9.22. Locations of Pacific walrus terrestrial haulouts during aerial surveys in the eastern Chukchi Sea during 2007, 2009, 2010 and 2011. Locations in 2009 and 2011 are approximate locations based on verbal descriptions and visual maps.

TABLE 9.9. Dates of first and last terrestrial haulout sightings, and date and area of highest counts in the northeastern Chukchi Sea.

| Year | First Observed | Last Observed | No. Days Observed[a] | Highest Counts | | | Source |
|---|---|---|---|---|---|---|---|
| | | | | Number[b] | Date | Area | |
| 2007 | 28-Aug | 9-Oct | 10 | 3,547 | 18-Sep | Point Lay | Thomas et al. 2009 |
| 2009 | 2-Sep | 13-Sep | 3 | 2,500 | 2-Sep | Icy Cape | Clarke et al. 2011 |
| 2010 | 30-Aug | 24-Sep | 10 | 15,000 | 6-Sep | Point Lay | Christman et al. 2011 and Thomas and Koski 2011 |
| 2011 | 10-Aug | 18-Oct | 18 | 20,000 | 26-Aug/ 13-Sep | Point Lay | Garlich-Miller et al. 2011 |

[a] most of the haulouts in 2009, 2010 and 2011 were resighted at the same locations

[b] the 2007 count comes from a photograph, but all other years are rough estimates based on naked eye visuals

In summer 2007, an acoustically-detected inshore movement of walrus toward Wainwright occurred on 23–24 August starting from 20 nmi offshore of Wainwright (station W20). An offshore movement from Wainwright out to 20 nmi offshore (station W20) occurred a few days later, starting on 28 August (Fig. 9.23). The absence of detections 40 nmi offshore (at station WN40) between these inshore/offshore movements suggests that walrus present in this area may also have headed inshore although the trend is less obvious, possibly due to the greater distance between WN40 and W20 than between W20 and the adjacent recorders. Overall in 2007, the Wainwright detections were concentrated 40 nmi offshore (at station WN40) located near Hanna Shoal. The inshore stations had short detection peaks presumably associated with the inshore movements of walruses. Walruses appeared to use the area off Wainwright more extensively than the rest of the northeastern Chukchi Sea during this time.

Detections at the Point Lay recorders were relatively limited compared to the Wainwright recorders (Fig. 9.24), except within 10–15 nautical miles from shore around 15 August and between 22 and 30 August. The timing of the later detections corresponds to the inshore/offshore movement observed at the Wainwright line and could indicate a possible haul-out near Point Lay, though visual confirmation of a haulout near Point Lay did not occur until 11 September.

Walruses were observed from vessels in open water with increasing frequency in late August during two of the four years that terrestrial walrus haulouts were detected (2007 and 2010; Fig 9.25). The August spike in sightings was not evident in 2009 and 2011, likely due to relatively lower amounts of vessel-based monitoring effort in both years. One vessel (*Mt. Mitchell*) was operating in 2009 and two vessels (*Synergy* and *Duke*) were operating in 2011 compared to numerous vessels in 2007 and 2010. Each of the late-August walrus sighting spikes in 2007 and 2010 occurred one to two weeks following the retreat of sea ice beyond the continental shelf. In 2006, 2008, and 2012, the three years when at least some sea ice remained over the continental shelf, the number of walrus sightings from vessels was consistent throughout August and no terrestrial haulouts were recorded.

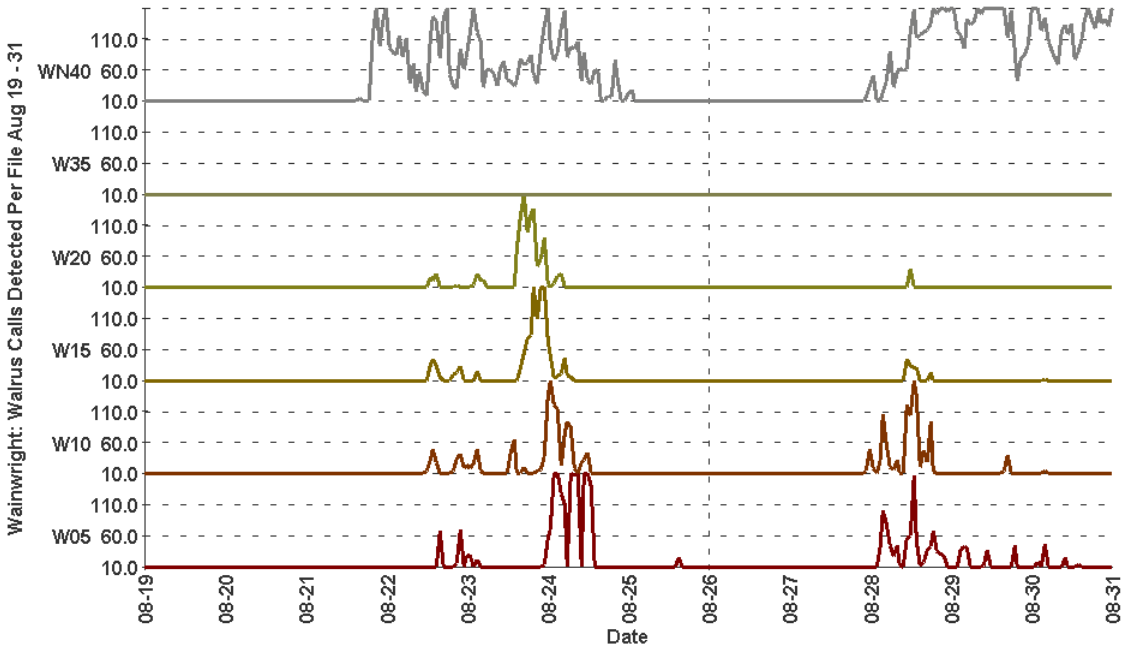


FIGURE 9.23. Walrus detections at the Wainwright recorders during phase 1 of the 2007 summer deployment. The graph focuses on the period 19–31 August.

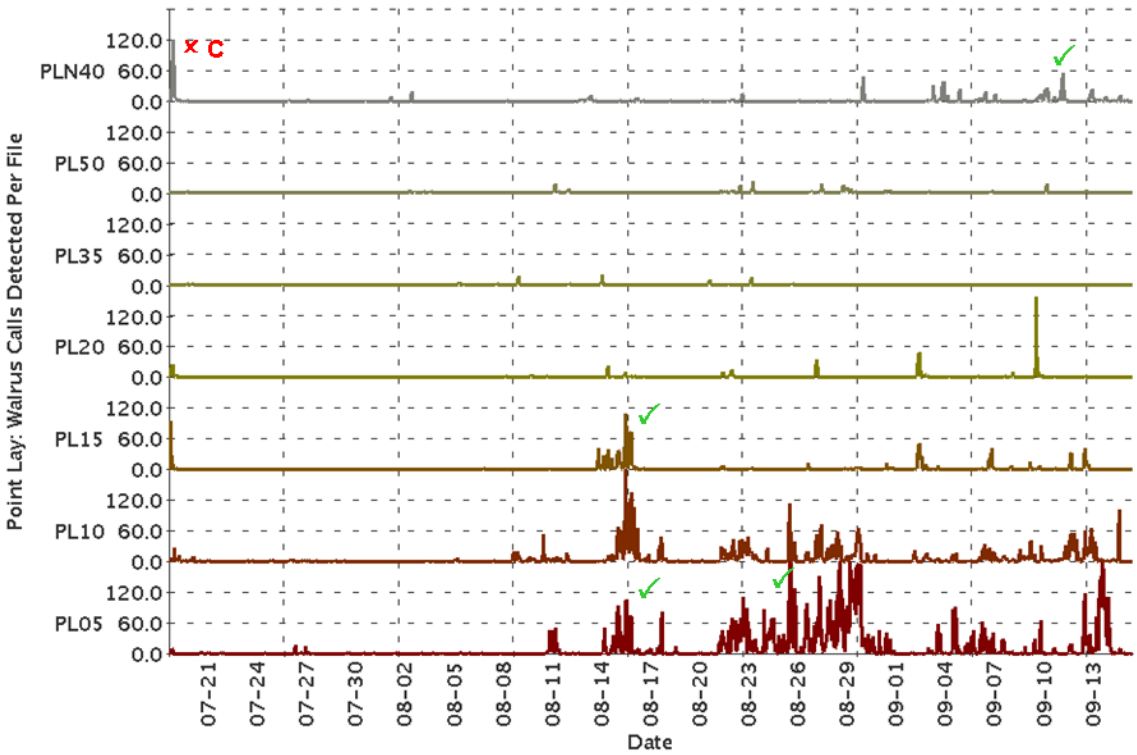


FIGURE 9.24. Walrus detections at the Point Lay recorders during phase 1 of the 2007 summer deployment. The green check marks show manual confirmation of walrus presence.

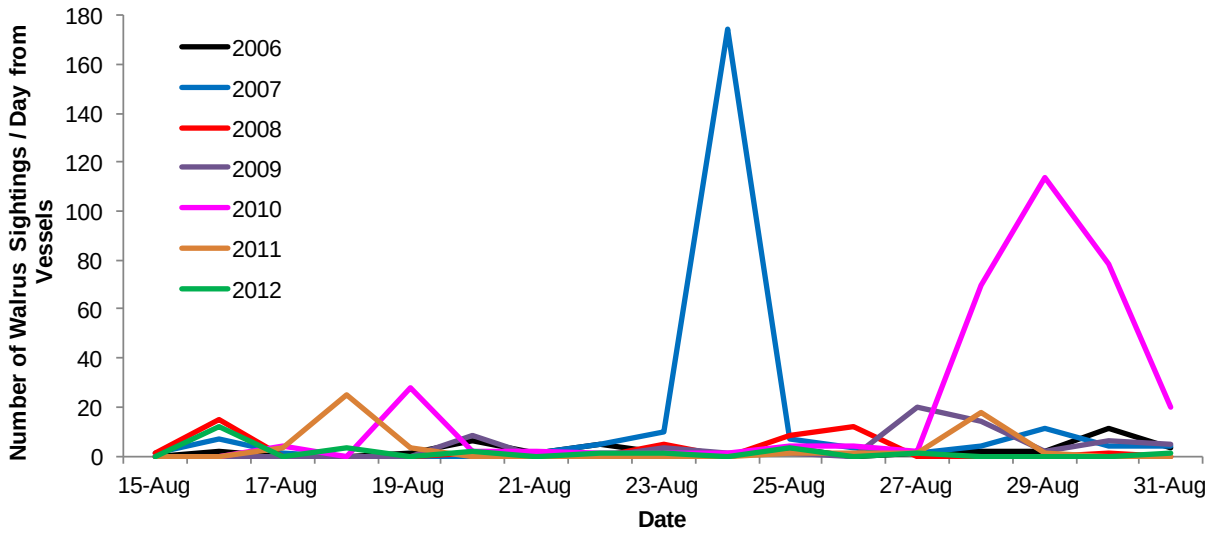


FIGURE 9.25. Daily walrus numbers in late-August, 2006–2012, based on vessel sightings in the Chukchi Sea during summer and fall.

## *Discussion*

Walruses observed during industry-sponsored monitoring programs in the Chukchi Sea from 2006–2012 typically occurred in small groups in water or larger groups of several hundred or more hauled out on ice or land. The distributions of Pacific walruses were quite different among the seven years of monitoring. During years with greater amounts of ice in the study area (2006, 2008, and 2012), walrus sightings were closely associated with the ice and their distributions varied depending on the location of the ice. Walrus sighting rates from nearshore aerial surveys declined substantially during August and September as the pack ice retreated offshore. Walruses appeared to have left nearshore areas, and presumably remained near the pack ice, which was present in offshore areas outside of the Chukchi Sea nearshore/sawtooth survey area. In 2012, aerial photographic surveys were flown in the offshore area around the Burger exploratory drill site, and walrus sightings rates were highest when ice was present in the survey area. If nearshore aerial surveys were flown more frequently in 2012 we would have expected more sightings in the Point Lay area because acoustic recorders detected large numbers of walrus calls in that area (Fig. 9.11).

In contrast, during low ice years (2007, 2009, 2010 and 2011) walruses appeared to have abandoned the retreating pack ice by late August and eventually traveled to terrestrial haulouts along the Alaskan Chukchi Sea coast, which were presumably closer to their Chukchi Sea feeding grounds than any remaining pack ice. Use of terrestrial haulouts by walruses is common on the Chukotka coast (Belikov et al. 1996), but is less common in the Alaskan Chukchi Sea. Large numbers of walruses at numerous terrestrial haulout sites along the Alaskan Chukchi Sea coast have not been previously documented, but it may become more common if the trend of reduced ice cover in the Chukchi Sea in summer continues. How the use of terrestrial haulouts along the Chukchi Sea coast will impact walruses is unknown. A haulout mortality event in 2009 indicated that disturbance at large haulouts may be lethal for smaller animals. Udevitz et al. (2013) suggested, based on modeling of walrus demographics, that such events, if they occurred frequently enough, could have population level consequences. Cooper et al. (2006) reported at least nine Pacific walrus calves separated from adult females in waters as deep as 3000 m

(9843 ft) in July and August of 2004 in the Canada Basin of the Arctic Ocean, presumably due to the rapid seasonal sea-ice retreat during that year. The authors speculated that walruses may be ill adapted to such rapid retreat of sea-ice.

The USGS tagging data have also provided information on the responses of walrus to the unprecedented changes in the pattern of sea ice melt in response to climate change since beginning in 2007 (Jay et al. 2012). Tagging data agree with our visual and acoustic observations that walruses generally try to remain with even small amounts of remnant ice as long as possible before abandoning the ice to move to terrestrial haulouts. Further, they often remain in the water for a number of days or weeks before making their way to haulouts on shore. Some of the tagged walruses have been seen to move to and from these large haulouts, presumably to feed (Jay et al. 2012).

During the seven years of this joint monitoring study, the aerial, vessel-based, and acoustic data appear to align well with the known distributions and habitat use of walruses under the different environmental conditions encountered. An interesting and previously undocumented observation during our studies was a decrease in the numbers of seals in the nearshore areas in 2007 and 2010 when the walrus were using the beach haulouts. This may have implications for subsistence seal hunters in coastal waters of the Chukchi Sea during late summer.

Forty-two sightings of 574 Pacific walruses were recorded while drilling activities were occurring in the Chukchi Sea during 2012. Not all of these animals were observed in areas where received sound levels from drilling activities were ≥120 dB (rms). Thirty-eight sightings of 94 walruses were observed during drilling activities but outside the ≥120 dB (rms) radii for these activities. The remaining 480 walruses observed during drilling activities in the Chukchi Sea in 2012 were in areas where received levels in the water were estimated to be ≥120 dB (rms), however, 474 of these individuals (99%) were hauled out on ice and likely would not have been exposed to levels of sound comparable to those in the water. The remaining six walruses observed during drilling periods, two of which were recorded from the *Discoverer* and four from the *Tor Viking*, were in the water where estimated received levels were ≥120 but <160 dB (rms).

No walruses were observed in areas with estimated sound levels of ≥160 dB (rms) from exploratory drilling activities in 2012. This may be due to the areas ensonified at higher sound levels being very small in comparison to 2D and 3D seismic programs. These small ensonified areas also may not have overlapped with the natural distribution of walruses, or individuals may have been able to avoid these ensonified areas altogether. Most drilling occurred later in the year after most walruses had already left the area.

As a result of no walruses being observed in areas ensonified above 160 dB (rms) during 2012, walrus distribution was investigated in the context of different drilling and related support vessel activities. On average, walrus closest point of approach (CPA) to moving vessels was similar to that for stationary vessels (means of 715 and 539 m, or 2346 and 1768 ft, respectively). Sample sizes were too small to analyze differences in CPAs between drilling and related support vessel activities in 2012. Walrus tended to react more to anchor handling, drilling activities, and ice management than to general vessel activities, with looking being the most commonly observed reaction.

Funk et al. (2007, 2009) observed reduced walrus density within 1 km (0.6 mi) of a shallow hazards survey airgun source relative to the densities at 1–15 km (0.6–9 mi). Hartin et al. (2011) also noted a general tendency toward lower sighting rates in areas where RLs were ≥160 dB (rms) compared to walrus sighting rates in areas with lower RLs. These results suggest walruses might move away from high-energy sound levels from seismic surveys, but similar reactions to the drilling activities in 2012 were not evident.

Delarue et al. (2011) reported reduced walrus call detection rates with increased sound pressure levels from airgun pulses in the Alaskan Chukchi Sea in 2010. Few walrus calls were detected when the mean sound pressure level from airguns was above 140 dB (rms). It was unclear if this reduced call detection rate was due to masking (an inability to detect calls that may have been present) or an actual change in walrus calling behavior. Detailed investigation suggested that at least some of the decrease in call detection rates at higher seismic sound pressure levels was the result of reduced walrus call production, either in amplitude or frequency of calls (Delarue et al. 2011). Studies in 2012 showed some indication of reduced call detections by walruses adjacent to industry activities, though results were far from definitive and may have been more related to masking or habitat effects.

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# 10. POLAR BEAR MONITORING

This chapter presents polar bear (Nanuq, *Ursus maritimus*) monitoring results from the industry Joint Monitoring Program (JMP) during offshore exploration activities in the Alaskan Chukchi and Beaufort seas. Polar bear sightings during the 2012 monitoring programs originated primarily from protected species observers (PSOs) onboard vessels with a small number of additional detections from aerial surveys. Comparisons of 2012 results are made with those from similar programs in 2006–2011, when relevant.

Differences in sea ice extent among years and the nature of operations (e.g., proximity to ice) likely resulted in the observable differences in the distribution and behavior of polar bears, which are closely associated with ice. The 2012 season included exploratory drilling activities which often operated in close proximity to ice when compared to marine seismic programs from 2006–2011. Sea-ice cover also varied greatly among years from 2006–2012, both locally in the Beaufort and Chukchi seas and Arctic wide (Kovacs et al. 2010). Spatial and temporal sea-ice extents in the Chukchi Sea study area were, on average, less than in the Beaufort Sea study area from 2006–2012 (see Chapter 2: *Background and Context*). Localized areas in the Chukchi Sea prospect areas saw heavier ice conditions well into September in 2006, 2008 and 2012 when most adjacent areas were sea-ice free. In 2007, 2009 and 2010 only one polar bear was seen in the Chukchi Sea, which was mostly ice free early in the season as the pack ice retreated far to the north beyond the prospect area.

## *Chukchi and Beaufort Seas Aerial Survey Sightings*

Aerial surveys were conducted in 2006–2008, 2010 and 2012 in the Chukchi and Beaufort seas. A total of 26 polar bear sightings involving 32 individuals were recorded in the Chukchi Sea (Table 10.1). The majority (58%) of these sightings were opportunistically sighted off transect. The 2012 nearshore aerial survey had three polar bears sightings (3 individuals). All three were seen on 28 September on the coast north of Wainwright. Those sightings corresponded with the time of year when the walrus have been seen hauled out on the beaches. Although no Pacific walrus were observed hauled out on the Chukchi coast during 2012, they were seen nearby on the nearshore aerial survey and detected on the acoustic recorders near Point Lay. Of the polar bears observed in the Chukchi Sea during survey years from 2006–2012, 19% (*n*=5) were in the water, 69% (*n*=18) were on land and 12% (*n*=3) were on ice.

During the Beaufort Sea aerial surveys a total of 70 polar bear sightings involving 142 individuals were recorded (Table 10.1). The majority of polar bear sightings were off-transect (66%, *n*=46) and involved bears located on the barrier islands. The off-transect bears were typically recorded during aircraft transit to and from the survey area or during aircraft turns at the end of a survey line.

TABLE 10.1. Number of polar bear sightings (number of individuals) recorded by aerial surveys in the Chukchi and Beaufort Seas during exploration programs, 2006, 2007, 2008, 2010 and 2012.

| Survey Location | 2006 | 2007 | 2008 | 2010 | 2012 |
|---|---|---|---|---|---|
| **Chukchi Sea** | 5 (9) | 1 (1) | 17 (19) | 0 | 3 (3) |
| **Beaufort Sea** | 1 (1) | 27 (46) | 21 (65) | 17 (23) | 4 (7) |
| **Total Polar Bears** | **6 (10)** | **28 (47)** | **38 (84)** | **17 (23)** | **7 (10)** |

Neither of the aerial surveys are designed for the purposes of detecting polar bears, and during 2012 the aircraft actively avoided certain areas where polar bears are frequently seen (i.e., Pt. Lay and the barrier islands along the Beaufort Sea coast). In combination with the absence of sea ice in the survey area during much of the season, aerial sightings of polar bears in the Beaufort Sea were infrequent. The sightings that did occur were mainly at the start and end of the season, when polar bears were associated with sea ice that was present during the early summer and again as new ice developed during the early fall. Sighting rates are highly variable among years due to the inconsistent distribution of effort over the survey area.

## *Chukchi Sea Vessel-based Polar Bear Sightings*

From 2006–2012 there were a total of 72 polar bear sightings involving 88 individuals form only three years, 2006, 2008, and 2012. Ten of the polar bear sightings (13 individuals) were recorded either in 2006 (five sightings) or 2008 (five sightings), whereas 62 polar bear sightings (75 individuals) were recorded in 2012 (Table 10.2). Of the polar bears sighted in 2006 and 2008, 30% were on ice, 40% were in water and 30% were on land. In 2012, 75% of the polar bears were observed on ice and 25% were observed in the water.

TABLE 10.2. Number of polar bear sightings (number of individuals) recorded by PSOs onboard vessels in the Chukchi Sea during exploration programs, 2006–2012.

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| **Polar Bears in Water** | 2 (2) | 0 | 2 (2) | 0 | 0 | 0 | 16 (16) |
| **Polar Bears on Ice** | 3 (3) | 0 | 0 | 0 | 0 | 0 | 46 (59) |
| **Polar Bears on Land** | 0 | 0 | 3 (6) | 0 | 0 | 0 | 0 |
| **Total Polar Bears** | **5 (5)** | **0** | **5 (8)** | **0** | **0** | **0** | **62 (75)** |

The 2012 season saw an increase in the overall number of vessels operating in the study area and in the number of vessels operating near ice when compared to previous years. In 2012, sea ice persisted into September at the planned drilling site in the Chukchi Sea and ice scouting and management were necessary. Additionally, the seismic survey that occurred in 2012 took place in October and November as sea ice was forming. In prior years, 2D, 3D and shallow hazards seismic surveys only operated in areas away from ice. Of the 19 vessels associated with the 2012 exploration programs, six reported polar bear sightings in the Chukchi Sea, and 97% of sightings were from vessels working in and near ice. Most polar bears were sighted in September (72%) and 32 of these bears were seen from 12 to 14 September during ice management and scouting periods from four vessels (Fig. 10.1). Comments associated with sightings indicated that some polar bears may have been sighted and recorded by more than one vessel. For the purposes of this report, each polar bear sighting is considered as a distinct individual to avoid underestimation; however, this total probably overestimates the actual number of bears present at certain times.

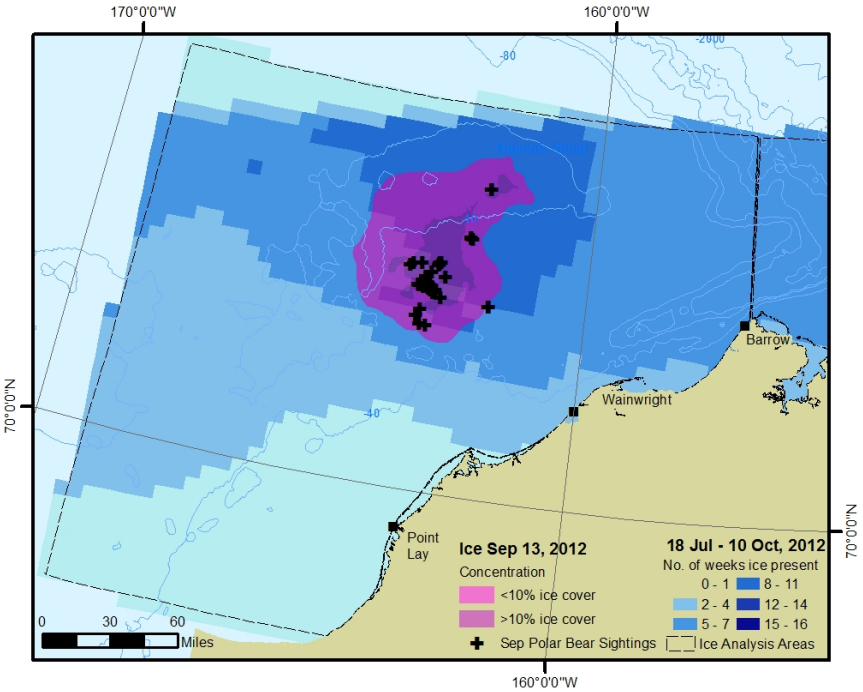


FIGURE 10.1. Polar bears sightings during September 2012 relative to average ice conditions seen on 13 September 2012 (purple shading) and ice presence during the July through October study period (blue shading).

Polar bear sightings from 2006–2012 were examined in relation to categories representing different concentrations of ice and distances from ice (Fig. 10.2). Distances from each polar bear sighting to the nearest edge of the pack ice were estimated from satellite images produced by Shell Ice and Weather Advisory Center (SIWAC) and NOAA. Polar bears were strongly associated with heavier ice conditions, and less so with loose ice conditions or open water. Since 2006, there were four bears seen >32 km (20 mi) from the ice pack. Three of these bears were seen in September 2012 shortly after the ice receded near the prospect. The fourth bear was seen in 2008, and PSOs reported that the bear was observed walking on an ice floe. The resolution of the satellite imagery used in this analysis probably did not detect the small amounts of ice present where the bear was observed.

The small number of polar bear sightings in the Chukchi Sea from 2006–2012 that met the data analysis criteria ($n$=56) precluded meaningful analyses of sighting rates with respect to most environmental variables. However, the mean closest point of approach (CPA) for polar bears, both in the water and on the ice/land, to the observer location was 2.1 km (1.3 mi; range 0–7 km [0–4.3 mi], $n$=56). The mean CPA for bears on land or ice was 2.8 km (1.7 mi; range 0–7 km [0–4.3 mi], $n$=40) and for bears in water 0.42 km (0.3 mi; range 0–1610 km [0–1.0 mi], $n$=16).

Bears on ice were often initially sighted at much greater distances than were those seen in the water. This was partially attributed to the sightability of bears on ice while using Big Eyes and other monitoring tools, and the implementation of mitigation measures, which steered vessels away from ice where bears were located. For bears sighted on ice, mitigation was required for 25% of the total sightings. "Alter course" was the most requested mitigation measure to maintain the 800 m (.5 mi) separation distance for bears on ice as stipulated by the LOA. For polar bears sighted in water, mitigation was required for 25% of the sightings.

Movement patterns of bears sighted on ice, with respect to the vessel, included "no movement" for 50% of the sightings; "neutral" in 35% of the sightings, "move away" in 13% of the sightings and "move towards" in 2% of the sightings. Neutral movement indicated an animal moved in some fashion that was neither toward nor away from the vessel. The movement of bears sighted in the water relative to the vessel had "no movement" in 45% of the sightings, "movement away" from the vessel occurred in 30% of the sightings, "movement toward" the vessel occurred in 20% of the sightings, and "neutral movement" was recorded for 5% of the sightings.

Reactions to the vessels included "no reaction" in 68% of sightings, "look" in 31% of sightings and "increase in speed" in 1% of sightings. Reaction to the vessel included "look" in 45% of sightings, "increase in speed" in 30% of sightings, "no reaction" in 25% of sightings and "change in direction" in 20% of sightings.

Sighting duration was calculated in 2012 for bears on ice and bears in water From vessels that were moving, the average length of time that a bear on ice was visible was ~20 min (range 1 min–5 h) and if the vessel was stationary, the average duration of sightings was ~1 h (range 2 min–5 h 13 min). In 2012, the average sighting duration from moving vessels of bears in the water was ~4 min (range 0–10 min) and from stationary vessels the average length of time that a bear was visible was ~1 h (range 17 min–6 h 58 min). The longest sighting of a polar bear in water occurred over a ~7 hour time span.

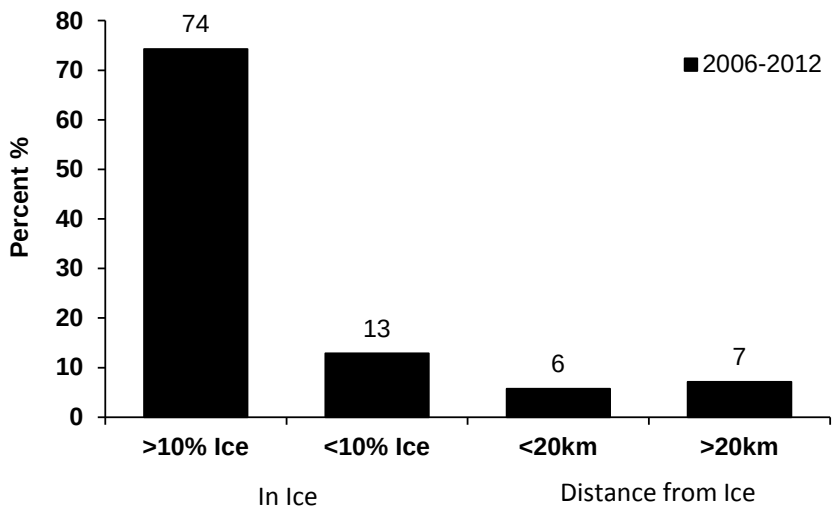


FIGURE 10.2. Percentage of polar bear sightings in water and on ice, by ice concentration and distance from ice pack in the Chukchi Sea during exploration programs, 2006–2012 (*n*=72).

### *Polar Bear Encounters during Drilling in the Chukchi Sea, 2012*

PSOs aboard the drillship *Discoverer* recorded three polar bear sightings in the Chukchi Sea during 2012, each of which involved a single animal that approached the *Discoverer* in open water while the ship was anchored, but not actively drilling. The first of these polar bears was observed on 8 September at a distance of ~300 m (984 ft) from the vessel. The *Discoverer* was idle at the Burger drill site at the time of the sighting, and an anchor-handling vessel was in the process of connecting anchor lines to the drillship. The bear swam alternately toward and away from the vessel at distances between 300 and 700 m (984 and 2297 ft). Reactions to the vessel of "change direction" and "look" were noted by PSOs. The bear

continued with this behavior for approximately one hr before swimming off into fog and snow, and it was not seen again. Similar to other vessel-based polar bear sightings in the Chukchi Sea since 2006, this animal was relatively close to sea ice. Satellite imagery from 9 September, the day after the polar bear sighting, indicated the main ice edge was ~14 km (8 mi) from the *Discoverer* (Fig. 10.3).

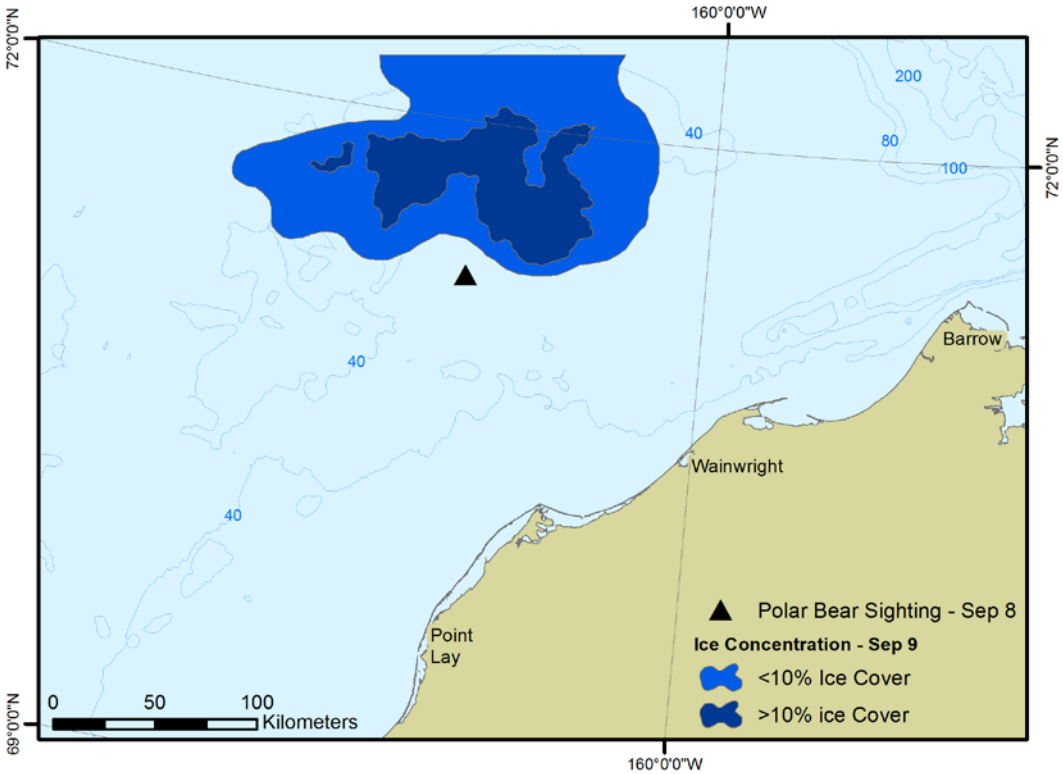


FIGURE 10.3. Location of a polar bear sighting from the drillship *Discoverer* on 8 September 2012 while the rig was stationary and being moored at the Burger drill site. Remotely-sensed ice imagery was not available on 8 September but is shown for 9 September.

The second and third polar bears observed from the *Discoverer* in 2012 were recorded a short time apart on the morning of 20 September. It is possible that these sightings were of the same individual, but this could not be confirmed so PSOs recorded their observations as two different sightings. The *Discoverer* was anchored at a standby location ~40 km (25 mi) to the east of Burger on 20 September after departing the drill site on 10 September due to approaching sea ice. The first bear recorded on 20 September was initially detected ~100 m (328 ft) from the *Discoverer* during the pre-dawn hours. It swam around the drillship two times over the course of ~30 min and approached to within one to two m of the vessel (three to seven ft) before swimming off.

A polar bear was observed three hours after the last sighting of the encounter described above and demonstrated similar behaviors. PSO records indicated the bear swam around the vessel repeatedly over the course of seven hours. The bear investigated features of the vessel in a curious fashion, particularly the sponsons, which are ledge-like structures on the hull located just above the water line. At one point it appeared the bear tried to haul out on one of the sponsons but it did not actually do so and remained in the water throughout the sighting event. Photographs taken of this bear as it interacted with the vessel revealed what appeared to be a radio-frequency identification (RFID) tag in its left ear (Fig. 10.4).

FIGURE 10.4. Photographs of a polar bear observed on 20 September 2013 from the drillship *Discoverer*, including a close-up of what appeared to be a radio tag in its left ear. The bear swam around the drillship for ~7 hr, interacted with the vessel, but remained in the water throughout the sighting event. The *Discoverer* was anchored at a standby location ~40 km (25 mi) east of the Burger drill site.

The two bears (possibly a re-sighting of the same bear a few hrs apart) observed in open water from the drillship *Discover* on 20 September were ~40 km (25 mi) from the nearest sea ice (Fig. 10.5). This ice was located south of Burger after drifting over the drill site from the northeast during a large storm event. Only one polar bear was seen by a Shell project vessel in the Chukchi Sea after 20 September 2012. The bear was recorded from the *Fennica* on 22 September as the vessel scouted lingering sea ice in the project area.

This last polar bear sighting from industry vessels in late September 2012, coincided with the time at which the Alaskan Chukchi Sea becoming sea-ice free. Sea ice did not begin reforming in the Chukchi Sea until late October. No polar bears were observed during active drilling in the Chukchi Sea during 2012.

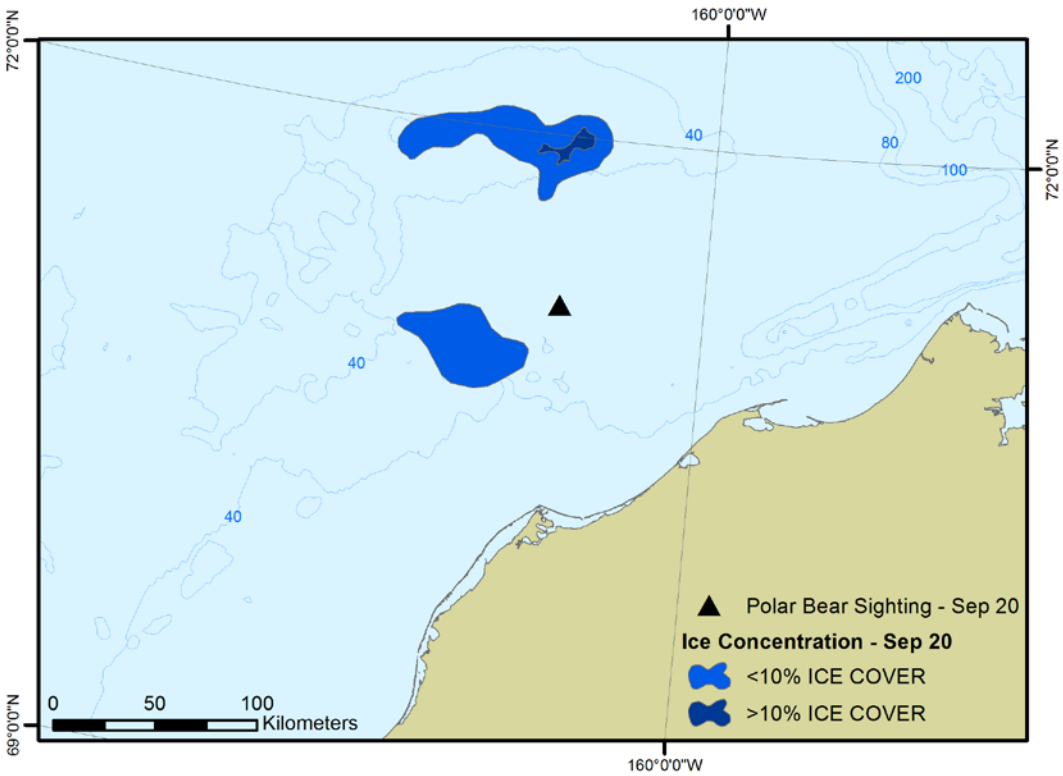


FIGURE 10.5. Location of two polar bear sightings, potentially of the same bear a few hrs apart, from the drillship *Discoverer* on 20 September 2012 while the vessel was anchored at a standby location ~40 km (25 mi) east of the Burger drill site. Remotely-sensed ice imagery was not available on 8 September but is shown for 9 September.

### *Polar Bear Encounters during Seismic in the Chukchi Sea, 2012*

During seismic survey operations near the U.S.-Russian border in the Chukchi Sea on 13 November to 15 November, the PSOs aboard the *Geo Arctic* and the *Polar Prince* observed 12 sightings of 13 individual polar bears in addition to a large number of other marine mammal sightings including bowhead whales and seals. The large number of sightings during this period was likely influenced by temporal and weather factors, as well as by habitat factors such as ice conditions and perhaps food availability. The area was covered by variable amounts of new and small pancake ice, ranging from 5% to 100% ice-cover over the course of the two days. The percentage of ice-cover and ice thickness (between 4–8 inches thick) increased as the vessels travelled west along the survey line on 14 November.

All but one of the polar bear sightings from the *Geo Arctic* occurred while the full array was active. However, all polar bear sightings were observed on ice, and likely were not exposed to RSLs ≥160 dB (rms). The initial behavior recorded of nearly all polar bears was "walking/traveling on ice" and the only other initial behavior recorded was "resting". Polar bears observed from the *Geo Arctic* and *Polar Prince* were most often recorded as having no reaction (~83%) to the vessels. The only polar bear sightings that exhibited a reaction to the vessel were observed looking at the vessel and increasing speed in response to the *Geo Arctic.*

### *Polar Bears Potentially Ensonified at Various Sound Levels*

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. 2004

a, b). Very little in-water sound enters the air where it would be audible to animals that are on ice. Polar bears, unlike other marine mammals, are typically surface dwelling or found on land or ice where exposure to underwater sound is typically weak or undetectable owing to the pressure release effects near the surface of the water or to differences in the propagation of sounds in water and in air (Richardson et al. 1995). In 2006–2012, there were 36 polar bears sighted from industry vessels that were within the ≥120 dB (rms) isopleth. Of the 36 bears, 31 of them were on ice and the other five were sighted while swimming and likely would not have been exposed to levels of sound comparable to marine mammals present well below the surface. Twelve polar bears (11 on ice, one in water) were observed in areas where RSLs from exploration activities were estimated to be ≥160 dB (rms). The 11 bears on ice would not have been exposed directly to these sound levels. The one bear seen swimming likely would have been exposed to a lower level of sound than was measured given that polar bears typically swim with their heads above water.

## *Beaufort Sea Vessel-based Polar Bear Sightings*

From 2006 to 2012 there were 94 polar bear sightings (276 individuals) from vessels in the Beaufort Sea (Table 10.3). These numbers should be viewed with some caution, as sightings are potentially overestimated given the vessel effort and number of vessels operating in close proximity to each other. Most bears (71%) were sighted on land, 17% were sighted in water and 11% were sighted on ice. For bears that were sighted on land, most were seen on Cross Island or other barrier islands. From 2006–2012, 84 polar bears were sighted in areas with a water depth <50 m (164 ft), nine were sighted in areas with water depths 50–200 m (164–656 ft) and one was sighted in an area with depths >200 m (656 ft). The average group size per sighting was three bears (range 1–24). The larger group sightings (>3 bears) were mostly associated with Cross Island or the barrier islands. The two largest group sightings (17 and 24 polar bears) occurred over two days in late-August of 2012 on Cross Island. Polar bears are known to forage and utilize carcasses of bowheads left from the subsistence hunts in the fall (September–October). Traditional knowledge provided by hunters in the region corroborates this information (Miller et al. 2006).

TABLE 10.3. Number of polar bear sightings (number of individuals) recorded by PSOs onboard vessels in the Beaufort Sea during exploration programs, 2006–2012.

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| **Polar Bears in Water** | 1 (2) | 1 (1) | 8 (8) | 0 | 0 | 0 | 6 (6) |
| **Polar Bears on Ice** | 1 (1) | 0 | 0 | 0 | 3 (5) | 0 | 7 (19) |
| **Polar Bears on Land** | 2 (6) | 35 (110) | 6 (26) | 4 (9) | 4 (4) | 0 | 16 (79) |
| **Total Polar Bears** | **4 (9)** | **36 (111)** | **14 (34)** | **4 (9)** | **7 (9)** | **0** | **29 (104)** |

Of the 27 polar bears that were sighted in water or on ice, three were associated with ice conditions >10%, 10 were in ice conditions <10%, four were <20 km (12.4 mi) from ice and 10 were >20 km (12.4 mi) from ice (Fig. 10.6). Of the 10 bears that were >20 km (12.4 mi) from ice, all were within 37 km (23 mi) of land. Most of the polar bears were associated with the barrier islands, precluding a meaningful analysis of sighting rates by distance from ice.

The CPA for polar bears was calculated using sightings that occurred during periods of effort that met criteria for detection reliability (*n*=63; see Appendix A). Polar bears that were sighted in water had a mean CPA of 0.12 km (0.07 mi; range 0.03–0.2 km [0.02–0.12 mi], *n*=9), for bears on ice the mean was 1.6 km (0.99 mi; range 0.82–3.8 km [0.5–2.3 mi], *n*=12) and for bears on land the mean was 1.5 km (0.95 mi; range 0.43–4.0 km [0.27–2.5 mi], *n*=42). CPAs and sighting duration results were similar to polar bears seen in the Chukchi Sea. Vessels maintained a larger CPA to bears seen on ice or land due to the greater sightability of bears on land and ice, which allowed earlier detection by PSOs.

Movements of the 79 bears on ice or land with respect to the vessel included "no movement" in 61% of sightings, "neutral" in 24% of the sightings, "move away" in 11% of the sightings and "move towards" in 2% of the sightings. Reaction to the vessel for bears on ice and land included "no reaction" in 80% of sightings, "look" in 13% of sightings, one polar bear was seen "increasing in speed" as a reaction to the vessel, and another was observed "rushing" as a reaction to the vessel.

Movement patterns for the 16 bears sighted in water with respect to the vessel included "neutral" in 67% of the sightings, "move away" in 20% of the sightings and "move towards" in 13% of the sightings. Reactions to the vessel included "no reaction" in 47% of sightings, "look" in 47% of sightings, and a report of one polar bear interacting with the vessel.

Sighting durations of polar bears in the Beaufort Sea were similar to the sighting duration for polar bears sighted in the Chukchi Sea. In general, polar bear sightings from moving vessels tended to have shorter sighting durations than polar bear sightings from vessels that were stationary. Average sighting durations of polar bears that were on land or ice were longer than those of polar bears sighted in the water. In 2012, the average sighting duration of an on land/ice polar bear was ~9 min from a moving vessel. There were no sightings of a polar bear in water from a moving vessel in 2012. From a stationary vessel, the average sighting duration of an on land/ice polar bear was ~3 h 15 min and ~40 min for a polar bear in the water.

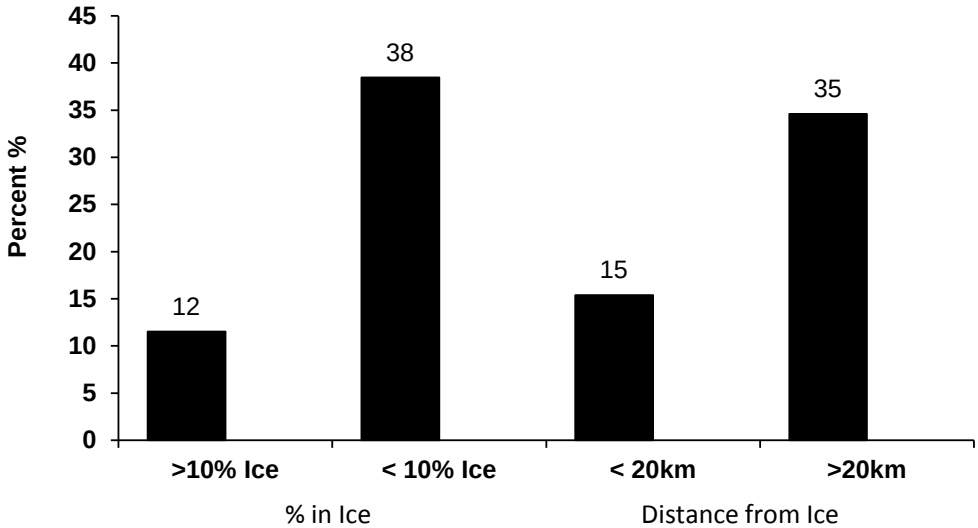


FIGURE 10.6. Percentage of polar bear sightings in water and on ice, by ice concentration and distance from ice pack in the Beaufort Sea during exploration programs, 2006–2012, (*n*=27).

### *Polar Bear Encounters during Drilling in the Beaufort Sea, 2012*

There were no polar bears observed from the *Kulluk* during Shell's 2012 exploratory drilling program in the Beaufort Sea. As described above for all years combined, the majority of vessel-based polar bear sightings in the Beaufort Sea in 2012 were associated with barrier islands or sea ice. The Beaufort Sea was sea-ice free in 2012 when drilling began on 3 October, and the Sivulliq drill site is ~21 km (13 mi) from the nearest barrier island. A total of 15 polar bears (three different sightings) were observed from support vessels during periods when the *Kulluk* was actively drilling in the Beaufort Sea during 2012. All of the bears observed during drilling were associated with Cross Island, which is ~72 km (45 mi) from the Sivulliq drill site.

### *Polar Bear Encounters during Seismic in the Beaufort Sea, 2012*

There were no polar bears observed during seismic survey operations in the Beaufort Sea in 2012. All of the polar bears sighted during seismic operations were observed on ice between 13 and 15 November in the Chukchi Sea.

### *Polar Bears Potentially Ensonified at Various Sound Levels*

Out of the 94 polar bears recorded from 2006–2012, 91 polar bears were recorded where the received sound level in the water was estimated to be <120 dB (rms), 77 of these polar bears were on ice or land. Three polar bears were recorded where the received sound level in the water was estimated to be between 159–120 dB (rms), one of which was in the water. As described above, polar bears are typically surface dwelling which likely reduces the received sound levels of anthropogenic sounds measured as similar distances but lower in the water column.

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