FINAL REPORT

MARINE MAMMAL DISTRIBUTION AND ABUNDANCE IN THE NORTHEASTERN CHUKCHI SEA, JULY-OCTOBER 2008–2011

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Upper – Spotted Seal in Hanna shoal, August 2011. Alexandra McFarland/CSESP
Lower – Group of walruses in the Burger Study area, October 2010. Jon Plissner/CSESP

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FINAL REPORT
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ACKNOWLEDGMENTS

ACRONYMS AND ABBREVIATIONS

~	Approximately
%	Percentage
AIC	Akaike's Information Criterion
AEWC	Alaska Eskimo Whaling Commission
ASAMM	Aerial Survey Arctic Marine Mammals
BOWFEST	Bowhead Feeding Study
BWASP	Beaufort Sea Aerial Survey Program
CDS	conventional distance sampling
CHAOZ	Chukchi Acoustic, Oceanographic, and Zooplankton study
COMIDA	Chukchi Offshore Monitoring in Development Area
CSESP	Chukchi Sea Environmental Studies Program
e.g.	exempli gratia (for example)
Fig.	Figure
IDW	Inverse Distance Weighting
i.e.	id est (that is)
ind km^{-2}	individuals per square kilometer
IWC	International Whaling Commission
km	kilometer
km^2	square kilometer
km^{-1}	per kilometer
LCL	Lower Confidence Limit
MCDS	multiple covariate distance sampling
MRDS	mark-recapture distance sampling
M/V	Merchant Vessel
n	sample size
NOAA	National Oceanic and Atmospheric Administration
OCSEAP	Outer Continental Shelf Environmental Assessment Program
R/V	Research Vessel
Sight	sightings
SLR	Single Lens Reflex
UCL	Upper Confidence Limit

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EXECUTIVE SUMMARY

ConocoPhillips initiated an interdisciplinary research program in 2008, with cofunding and participation of Shell, and, since 2010, Statoil. The Chukchi Sea Environmental Studies Program (CSESP) is ecosystem based, integrating survey components from physical and chemical oceanography, plankton, benthos, fish, sea bird, marine mammal, and acoustic studies. The main purpose of the integrated approach was to increase our understanding of how the continental shelf in the northeastern Chukchi Sea functions ecologically to better predict potential changes to the marine ecosystem due to climate change at a time when the area is simultaneously undergoing exploration for oil and gas reserves. Initially, the CSESP focused on the companies' respective offshore lease areas, but in 2011 the study area was expanded to include Hanna Shoal and areas outside the leased prospects, affording a broader assessment of previous years' results. Data collected in 2008–2010 has shown that the integrated approach is more powerful in understanding and therefore predicting changes of the marine ecosystem than considering the components separately.

This report focuses on the marine mammal data collected by the 2011 CSESP program. The 2011 data completes the fourth year of information collected on marine mammal distribution and abundance in the northeastern Chukchi Sea. This report summarizes and compares the 2011 marine mammal data to the results from previous years (2008–2010).

During the 7552 km on- and off-transect sampling effort in 2011, 46 cetacean sightings of 60 animals, 585 seal sightings of 607 animals, and 153 walrus sightings of 289 animals were recorded. No polar bears were sighted in 2011. In 2008–2010 a total of 13 polar bear sightings of 16 animals were recorded. Two polar bear sightings occurred in water, the rest were all on ice. The main conclusions based on the 2011 data in comparison with results from previous years and from other marine mammal studies are summarized as follows:

- For the first time during the four years of this study, bowhead whales were sighted throughout the month of August, with higher sighting rates (number of sightings per km effort) than in the fall.
- The low sighting rate of bowhead whales in the fall of 2011 was similar to 2008 and 2009, but much lower than in 2010.
- As in previous years, no beluga whales were observed during the summer and early fall, which is to be expected considering their distribution pattern and the timing of our study program.
- Minke whales, killer whales, and harbor porpoises were again recorded in 2011, with higher sighting rates than recorded during the previous years of this study. Although these species occur in low numbers, the encounters over the past four years suggest that these species may be regular visitors to the northeastern Chukchi Sea.
- The number of ringed/spotted seal sightings in the Klondike and Burger study areas in 2011 was similar to 2010 and 2008, but the densities in the Statoil study area were higher in 2011 than in 2010.
- Ringed/spotted seal densities in 2011 were higher in the Statoil study area than in the Burger study area, but not in the Klondike study area.
- Difference in seasonal density of ringed/spotted between the three low-ice years (2009−2011) and the heavy-ice year (2008), implies that sea ice presence was the main factor governing the seasonal occurrence of ringed/spotted seals.

- The number of bearded seal sightings in the prospect-specific study areas in 2011 was similar to 2010 and 2008, and higher than in 2009.
- Bearded seal density in the Burger study area in 2011 was similar to previous years, but was significantly lower than the observed densities in the Statoil study area in 2011. This could be related to the large numbers of walruses encountered in the Burger study area in 2011, which might have decreased food availability for bearded seals.
- Seasonal occurrence of bearded seals in 2011 was similar to 2008, with higher densities observed in the summer, whereas densities in 2010 were higher in the fall. Since both 2011 and 2010 were low-ice years and 2008 a heavy-ice year, presence of sea ice did likely not determine the seasonal distribution of bearded seals.
- The number of walrus sightings in 2011 was the highest recorded over the past four years. Most of the sightings were recorded in the third week of September possibly coinciding with walrus movements to onshore haulouts.
- As in previous years, highest walrus concentrations were observed in the Burger study area, which is likely used as a foraging area and as a migration corridor between coastal haul outs and the rich feeding grounds at Hanna Shoal.
- More adult walruses were sighted with juveniles in 2011 compared to previous years, but the reason for this is unclear.

CHAPTER 1

General Survey information

INTRODUCTION

Marine mammal research in the Chukchi Sea has a history spanning at least 30 years. An extensive research program was developed under the Outer Continental Shelf Environmental Assessment Program (OCSEAP) in 1975, with the intent to establish an environmental baseline for the Beaufort and Chukchi Seas. The objective of the OCSEAP was to collect sufficient data for predicting potential impacts from oil and gas exploration and development and identify mitigation measures to minimize these impacts. Various agencies were involved in performing ice seal, walrus, and whale studies to obtain information on distribution, feeding ecology, and behavior (e.g., Burns and Eley 1978; Lowry et al. 1978, 1980a, 1980b; Burns et al. 1981; Lowry and Burns 1981; Burns and Seaman 1986; Gilbert 1989a, 1989b; Gilbert et al. 1992). Aerial surveys have been flown to document the distribution and relative abundance of bowhead, gray, right, fin, and beluga whales, as well as other marine mammals in areas of potential oil and natural gas exploration, development, and production activities in the Alaskan Beaufort and northeastern Chukchi Seas since 1979 (e.g., Clarke et al. 1989, Ljungblad et al. 1984, 1986, 1987). The bowhead whale aerial survey program (BWASP) in the Beaufort Sea has been flown annually and comprises more than 30 years of data (Clarke and Ferguson 2010a). Aerial surveys in the Chukchi Sea were flown from 1989 to 1991 (Moore and Clarke 1993) and re-initiated in 2008 under the Chukchi Offshore Monitoring in Development Area (COMIDA) program after a 17-year lapse (Clarke and Ferguson 2010b). The BWASP and COMIDA aerial survey programs continued in 2011 and are now jointly known as the Aerial Surveys of Arctic Marine Mammals (ASAMM).

Since about the early 2000s there has been an increased focus on marine mammal and other environmental research in the Chukchi Sea, mainly due to a renewed interest in offshore oil and gas activities, and more recently in consideration of possible threats to the Arctic marine ecosystem from climate change. Useful information on whale movements and migration patterns has been obtained through satellite tagging studies of bowhead (Quakenbush et al. 2010) and beluga whales (Suydam et al. 2001, 2005). Satellite tags, radio transmitters, and dive recorders attached to bearded seals, ringed seals, and walruses have provided detailed information on seasonal movements in relation to the formation and retreat of sea ice, habitat use, and foraging behavior of individuals (Lowry et al. 1998; Jay and Hills 2005; Jay et al. 2006, 2010; Udevitz et al. 2009; Cameron et al. 2010; Speckman et al. 2010; Boveng et al. 2012; Herreman et al. 2012). Hunters from various villages bordering the Chukchi Sea have been an integral part of these tagging efforts and contributed greatly to the success of these studies. Information from tags on behavior and movements of individual animals is useful in evaluating and interpreting distribution and abundance data obtained through spring aerial surveys (e.g., Burns and Eley 1978; Fay et al. 1997; Gilbert 1989a, 1989b; Bengston et al. 2005). Passive acoustic monitoring is another tool that has become increasingly popular in marine mammal research and has provided valuable data on migration patterns through detection and recording of whale and seal vocalizations (e.g., Berchok et al. 2010; Delarue et al. 2011; Martin et al. 2009; Moore et al. 2006). The use of acoustic recorders allows monitoring of marine mammal presence in seasons when the Chukchi Sea is not accessible for aerial and vessel-based research.

Although research effort in the Chukchi Sea has been extensive, most studies were designed and implemented as stand-alone programs, making it difficult to integrate research findings. An exception is the Bowhead Feeding Study (BOWFEST) that has been ongoing since 2007 (e.g., Rugh et al. 2009; Berchok et al. 2010; Goetz et al. 2010) and the Chukchi Acoustic, Oceanographic, and Zooplankton (CHAOZ) study that started in 2010 (NOAA 2011). The main goal of both studies is to determine how physical oceanography and prey densities influence whale distribution and relative abundance.

Marine mammal monitoring and acoustic programs were implemented as part of industrial activities in the Chukchi Sea from 1989 to 1991, primarily as mitigation but also to document potential impacts from anthropogenic activities (e.g., Brueggeman et al. 1990, 1991, 1992a, 1992b). Oil and gas exploration activities halted in the early 90s, but resumed in 2006 in anticipation of the Chukchi Sea lease sale in 2008 (e.g., Brueggeman et al. 2009a; Funk et al. 2008, 2010; Ireland et al. 2009; Blees et al. 2010). ConocoPhillips initiated an interdisciplinary research program in 2008, with cofunding and participation of Shell, and, since 2010, Statoil. The Chukchi Sea Environmental Studies Program (CSESP) is ecosystem based, integrating survey components from physical and chemical oceanography, plankton, benthos, fish, sea bird, marine mammal, and acoustic studies. Initially, the CSESP focused on the companies' respective offshore lease areas, but in 2011 the study area was expanded to include Hanna Shoal and areas outside the leased prospects, affording a broader assessment of 2008 – 2010 results. Data collected in 2008–2010 has shown that the integrated approach is more powerful in understanding changes of the marine ecosystem than considering the components separately (Day et al. in prep.).

This report summarizes the marine mammal data sampled within the larger 2011 CSESP study area in comparison with the 2008–2010 data of the prospect-specific study areas. The 2011 study area and the three prospect-specific study areas (Klondike, Burger, and Statoil) discussed in this report are shown in Figure 1.1.

Purpose and Objectives

The purpose of this marine mammal study conducted during the Arctic summer and fall season (July – October) is to expand current knowledge regarding the abundance and distribution of marine mammals in the Chukchi Sea lease areas of ConocoPhillips, Shell, and Statoil. This information, combined with results from physical and chemical oceanography, plankton, benthos, fish, and acoustic studies, will contribute to developing a baseline for determining potential changes in marine mammal distribution and abundance resulting from natural environmental and anthropogenic influences. The marine mammal information obtained through the CSESP will also be used in developing mitigation measures for offshore oil and gas exploration and development and for evaluating the effectiveness of these measures.

There are three general objectives identified to achieve the purpose of this marine mammal study.

1. Summarize general survey and marine mammal sighting information;
2. Determine the annual and (where possible) seasonal variation in density and distribution of marine mammal species within the three prospect-specific study areas and within the Greater Hanna Shoal area; and
3. Integrate marine mammal results with other components of the CSESP to increase our understanding of ecological relationships.

Objectives 1 and 2 are discussed in this report. Objective 3 is only partially addressed, because specific analyses have not been conducted yet. We anticipate that more detailed analyses of objective 3 will be presented in future publications.

Structure of this report

The 2011 data completes the fourth year of information collected on marine mammal distribution and abundance in the northeastern Chukchi Sea by the CSESP program. We believed that the large amount of data collected to date was better presented as separate chapters, each with a specific topic. Collectively, these chapters will contain results of the three general objectives listed above. The chapters of the report and a brief description of their contents are as follows:

CHAPTER 1: GENERAL SURVEY INFORMATION

This is the current chapter. It provides an introduction to the overall program, a description of the study area, sampling design, and sampling protocol. It also summarizes general survey results, such as total sampling effort, total number of marine mammal sightings, and overall environmental conditions. The information in Chapter 1 is relevant for understanding the results presented in Chapters 2–4, but is not repeated in these chapters.

CHAPTER 2: DISTRIBUTION AND ABUNDANCE OF CETACEANS IN THE OFFSHORE NORTHEASTERN CHUKCHI SEA DURING THE OPEN WATER SEASON.

This chapter summarizes the results on cetacean presence and distribution during the four years of this study. It describes the seasonality of bowhead whale occurrence and the presence of other cetacean species.

CHAPTER 3: TEMPORAL AND SPATIAL ABUNDANCE OF ICE SEALS IN THE OFFSHORE CHUKCHI SEA DURING THE OPEN WATER SEASON.

This chapter summarizes the seasonal abundance of ice seals and how they are distributed spatially. The data collected in the three prospect-specific study areas in 2011 is compared to the 2008–2010 distribution and abundance data from these study areas. Results on ice seal abundance within the Greater Hanna Shoal study area are summarized separately.

CHAPTER 4: DISTRIBUTION AND MOVEMENTS OF WALRUS IN THE OFFSHORE CHUKCHI SEA DURING THE OPEN WATER SEASON

The intent of this chapter is to summarize the seasonal and spatial abundance of walrus in relation to the establishment of coastal haulouts and presence of sea ice. Information on group size and abundance of juveniles over the four years of this study is also included.

STUDY AREA

The Chukchi Sea is bordered to the west by the eastern Siberia Sea, to the south by the Bering Sea, and to the east by Alaska. The western boundary is the northernmost point of Wrangel Island to Cape Blossom and Cape Yukon, the southern boundary is the Arctic Circle, and the northern boundary is a line connecting Pt. Barrow to the northernmost point of Wrangel Island. The Chukchi sea is ~595,000 km^2, with water depths <50 m in 56% of the total area. The geomorphology of the Chukchi Sea shelf and the flow of summer water masses influence the local temperature and salinity ranges of surface and bottom waters. Oceanographic data recorded in 2008–2010 indicated that water masses in the Klondike study area were generally warmer and less saline than in the Burger study area (Weingartner and Danielson 2010). In 2008–2010, water temperatures ranged from -1.7 to 8°C among the three prospect-specific study areas. Generally, water temperature was highest in the Klondike study area, due to the influence of warm Bering Sea water entering the Chukchi Sea through the Central Channel (Fig. 1.1). The extent of temperature and salinity differences between the three study areas varied from year to year, depending on factors such as sea ice cover and prevailing wind speed and direction. The different physical characteristics are reflected by contrasting planktonic, benthic, and seabird communities (Blanchard et al. 2011; Hopcroft et al. 2011; Gall and Day 2011).

The study area of the Chukchi Sea Environmental Studies Program (CSESP) has changed over the past four years. In 2008 and 2009, the locations of the study areas were chosen based on the Chukchi Sea offshore prospects of interest to ConocoPhillips and Shell, consisting of two sites, the Klondike and Burger study areas. In 2010, an additional prospect-specific site was added based on the lease interests of the new project partner, Statoil (the Statoil study area). The Klondike and Burger study areas are located northwest of the village of Wainwright at offshore distances of approximately 220 kilometers (km) and 100 km, respectively. The Statoil study area is located approximately 240 km west of Point Barrow (Fig. 1.1). The size of each of the three study areas is ~3000 km^2.

In 2011, we surveyed a larger regional area encompassing the three prospect-specific study areas (Klondike, Burger, and Statoil) and Hanna Shoal to the north (Fig. 1.2). Hanna Shoal is considered to be an area of ecological importance in the northern Chukchi Sea. This larger encompassing 2011 study area is referred to as the Greater Hanna Shoal study area. The study design was based on the same transect grid used in 2008–2010, but more widely spaced to cover a larger area in the same amount of time. The methodology section of this chapter provides more details about the survey design. Generally, the extended Greater Hanna Shoal study area was designed to examine the previous year's results of the prospect-specific areas within a more regional context. In addition to sampling the Greater Hanna Shoal study area, marine mammal observations were also conducted during transits to and from Wainwright for crew changes and/or supply delivery. Opportunistic observations were conducted when the vessel was transiting to or from Nome, during buoy deployments and retrievals, and during other vessel activities.

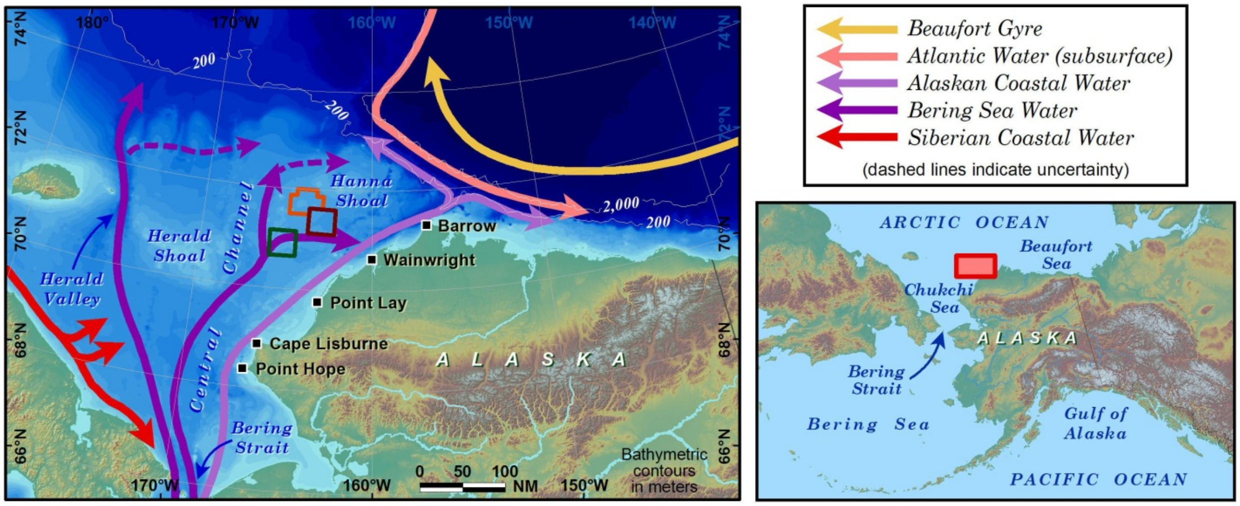


Figure 1.1 Main geographic features and prevailing currents in the Chukchi Sea

METHODOLOGY

This section outlines the methods and observation protocol used during the 2011 CSESP marine mammal survey. Generally, the observation protocol is similar to that used in 2008–2010 and also to other vessel-based marine mammal programs conducted in the Chukchi Sea. All surveys were conducted from the *R/V Westward Wind* in 2011 (Fig. 1.3), as was the 2009 survey season. In 2010, observations were conducted from two vessels, the *R/V Westward Wind*, and the *R/V Norseman II*, and in 2008 the survey vessel was the *M/V Bluefin*.

Sampling Design

Two biologists experienced in conducting Arctic marine mammal observations conducted daylight surveys from the bridge or bridge wings of a research vessel. In addition, an Inupiat communicator assisted with marine mammal observations during daylight hours from the bridge. During the surveys, the biologist observer recorded all marine mammals sighted along transect lines in each of the three study areas, and along transect lines from the study areas to Wainwright during crew changes and resupply trips.

In 2008–2010, two types of transect lines were delineated in the study areas; primary and secondary lines, both oriented in a north-south direction. The spacing between the primary transect lines was 3.7 km. Secondary transect lines were spaced at 1.85 km distance from the primary transect lines and were only surveyed when primary transect lines were not accessible (e.g., due to presence of sea ice) or if time allowed extra transect lines to be surveyed. In 2008 and 2009, the Klondike and Burger study areas were sampled three times in the period from 23 July to October 12 (2008) and 12 August to October 17 (2009). In 2010, observations along all primary transect lines were completed twice in the Klondike and Statoil study areas, and three times in the Burger study area in the period from 3 August to 8 October.

The 2011 Greater Hanna Shoal study area encompassed the three prospect-specific study areas (Fig. 1.2). Transect lines were more widely spaced, with lines every 11 to 13 km outside and 5.6 or 7 km inside the prospect-specific study areas. The denser sampling grid inside the Klondike, Burger, and Statoil areas allowed for a better comparison with results from previous years. Data collection took place in two separate cruises; during the first cruise transect lines were run only in the prospect-specific areas and during the second cruise transect lines were run in the entire Greater Hanna Shoal study area (which includes the prospect-specific study areas). Detailed information on dates and effort in km is provided in the section General Survey Results.

Additionally, we collected data on a more opportunistic basis in 2011 and in other years of the survey during acoustic buoy deployments and retrievals, during vessel activities for other scientific disciplines, and during transits between the study area and Wainwright or Nome. We combined these data into a category labeled “Other”, because this data was collected off-transect and did not always include information on sampling effort.

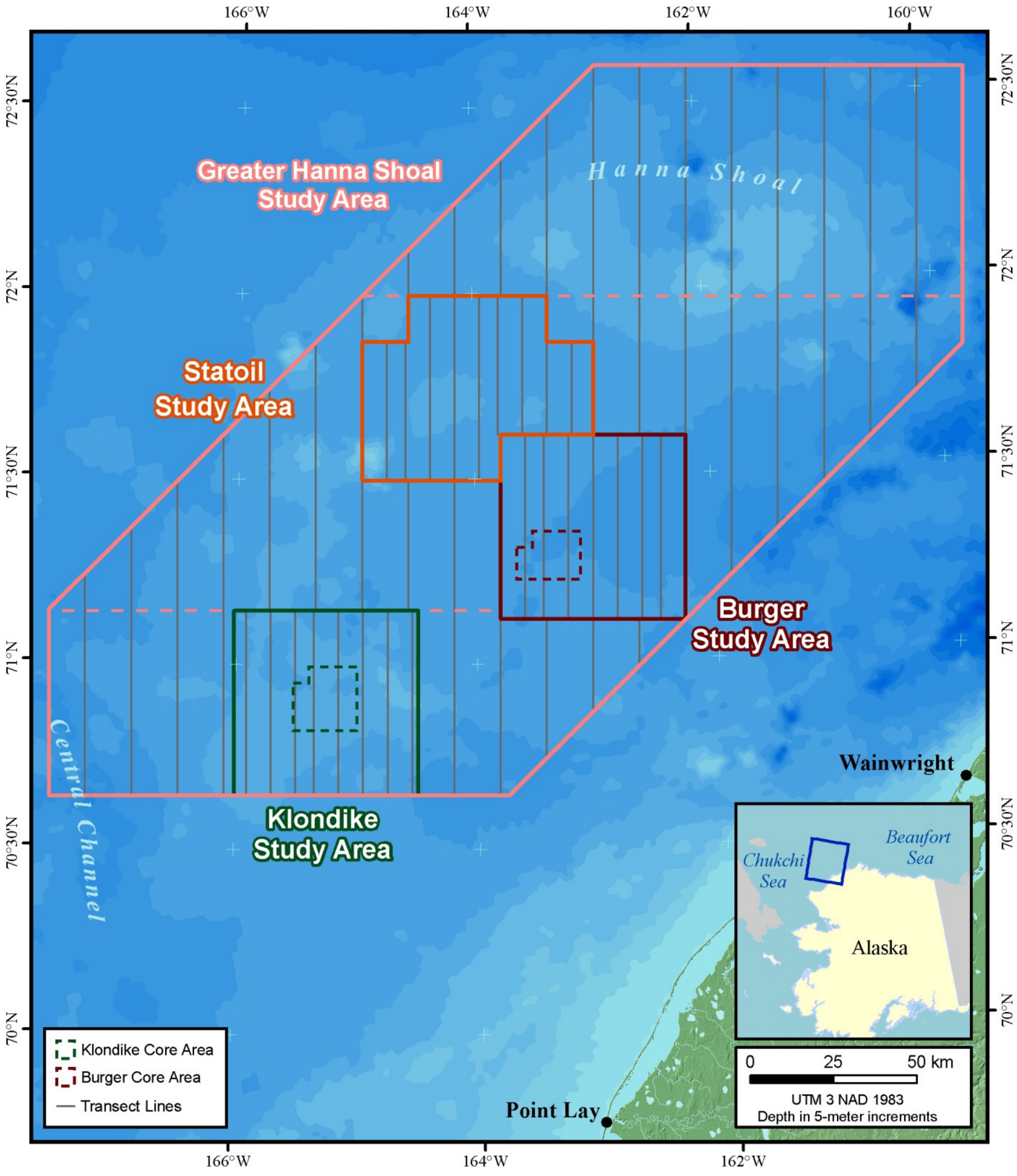


Fig.1.2. Location of the 2011 study area in the northeastern Chukchi Sea, including the three prospect-specific study areas and transect lines.

Figure 1.3. The research vessel *Westward Wind* was used for marine mammal observations in 2009, 2010 (partly), and 2011.

Data Collection Protocol

The observers systematically scanned an area of 180° centered on the vessel's trackline with the naked eye and Fujinon 7×50 reticle binoculars, while the vessel moved along the transect lines at a speed of 8–9 knots. Fujinon 14×40 gyroscopically-stabilized binoculars were available to verify species identification and behavior when needed. A Canon SLR camera with a 120-400 mm zoom lens was available for taking photographs of marine mammals, when possible, and photos were sometimes used to assist in marine mammal identification.

During line transect surveys, observers were on alternate 2-hour watches during daylight for about 10 to 14 hours/day, depending on weather conditions, day length, and the schedule of other scientific activities on the vessel. The observers alternated watches every two hours to avoid fatigue. Recorded data was defined as "on-effort" anytime the vessel was within 600 m of the transect line and traveling at least 6 knots. If the vessel strayed beyond this distance or traveled below the set speed, the data was defined as "off-effort." Observers resumed "on-effort" operations once the vessel returned to transect course and speed.

Navigation based software (TigerNav™) was used in 2009–2011 to record all vessel information on a real time basis. This information included date, time, vessel position, vessel speed, water depth, sea surface temperature and salinity. The observer on watch recorded environmental data, sighting info, and other information pertinent to the sighting, which was entered and stored on a Panasonic Toughbook™ computer using TigerObserver™ data acquisition software that was specifically developed for this science program. Both TigerNav™ and TigerObserver™ were synchronized to a server system present on the vessel, which automatically linked all marine mammal sighting data to the relevant navigational and oceanographic data.

Environmental Data

Environmental conditions can affect the probability of detecting marine mammals. The observers recorded environmental data at the start of each transect line, whenever there was an obvious change in one or more of the environmental variables, and whenever observers changed shifts. Recorded environmental data consisted of sea state (in Beaufort windforce scale according to NOAA), visibility (in km), ice cover (in 10% increments), distance from pack ice (in km), and sun glare (position and severity).

Sighting Information

Upon sighting a marine mammal (or group of animals), the observer recorded the species, group size, number of juveniles, position and heading relative to the vessel, behavior, movement, pace, whether the animal was seen in the water or on sea-ice, distance to the animal from the vessel, sighting cue, identification reliability, and initials of the observer who sighted the animal.

Ringed and spotted seals are often difficult to differentiate, especially when they appear at the surface for a short time or are detected at a large distance. The category "ringed/spotted seal" therefore was introduced to record seal sightings that could not be identified as either a ringed or spotted seal.

Distances to marine mammals were determined visually using reticle binoculars and/or by eye estimates. A rangefinder and clinometer were also available, though they were generally not used. Without a solid, contrasting target, rangefinders cannot take a reading. The purpose of the clinometer was to determine distances of animals in close proximity to the vessel, though this often proved to be challenging due to the combination of low observation height (estimated bridge height of 6.4 m) and vessel movements. Eye estimates were therefore preferred for animals at close distance from the vessel. The range finder, clinometer, and radar of the vessel were occasionally used for verification of estimated distances in presence of a proper target.

Visual observations were excluded from analyses when *(i)* sea states exceeded Beaufort scale 5 or wave height was greater than 2 m, because the probability of detecting marine mammals in high seas was too low or *(ii)* visibility along the transect lines was less than 300 m. In these cases transect lines were rerun under better conditions when possible. These criteria were established to match the seabird observation protocol.

Data Analyses

Environmental and marine mammal data recorded during the survey were divided into two categories and, depending on the objective, different subsets of the data were analyzed. The two categories are:

- On-transect data: includes all observations made while the vessel was traveling on transect lines within the prospect-specific study areas, the Greater Hanna Shoal study area, and on transits to and from Wainwright, Alaska.
- Off-transect data: includes all other observations, such as data collected on the transect connectors, buoy recorder and retrievals, and during vessel transits. Some off-transect effort was recorded opportunistically, i.e., observations were entered without associated effort data. This occurred when the vessel was on anchor at Wainwright for crew changes, or when animals were sighted when the observers were not officially on-watch.

General Survey and Marine Mammal Sighting Information

We used data from both on- and off-transect categories to summarize general survey conditions and sightings of marine mammal species in the study areas. An overview of environmental conditions during the 2011 survey in comparison with 2008−2010 is provided in this chapter. Details on the number of cetacean sightings and individuals recorded in each year can be found in Chapter 2, ice seal sightings and individuals in Chapter 3, and walrus sightings and individuals in Chapter 4.

Annual Variation in Marine Mammal Density and Distribution

To determine the annual variation in density of marine mammal species within and among study areas and seasons, we used corrected species (or species group) densities using on-transect data. Calculating abundance of marine mammals using sighting information from vessel-based line-transect surveys can result in an underestimation due to two types of detection bias (Marsh and Sinclair 1989):

1. Availability bias: this represents undercounting animals because they were not available for detection, i.e., they were not at the sea surface and therefore could not be seen. The availability bias is dependent on the amount of time an area of water is observed during a survey (determined by the area visible from the observer location on the vessel and vessel speed) and on the behavior of the marine mammal species (surface duration, dive cycle, and activity).
2. Perception bias: this represents undercounting animals that were available for detection but not observed. The perception bias is dependent on factors such as poor visibility, high sea states, distance from the observer, glare, observer fatigue, etc.

We analyzed distribution and abundance patterns for seals and walruses by estimating corrected densities (number of animals km^{-2}) for each study area and year using distance-sampling methodology (Buckland et al., 2001, 2004), which builds on the fundamental concept that the probability of detecting an animal decreases with increasing distance from the transect line. One of the assumptions of distance sampling is that all animals available at perpendicular-distance zero from the observer (i.e., on the transect's centerline) are detected [g(0)=1]. However, marine mammal sighting data from vessel-based line-transect surveys commonly violate this assumption due to availability and perception bias. Because information on dive time for seal and walrus species during the open water period does not exist, availability bias was not taken into account in this study. Likewise, no information was collected to determine perception bias and the assumption of g(0)=1 therefore resulted in underestimates of our corrected density data.

We used software program Distance 6.1 Release 1 (Thomas et al., 2010) for modeling a detection function with which the proportion of animals missed at different perpendicular distances from the transect line can be estimated. To derive at the optimal model for estimating the detection function for seals and walruses we conducted exploratory analyses that included a subset of the 2008-2011 data, based on the following criteria:

- Only on-transect data were used. These are the observations made while traveling along transect lines, because observations made along these lines meet the assumptions of line transect theory.
- Only sightings with similar sighting cues, and thus equal detection probability were used. This resulted in:
    - Exclusion of sightings on ice, because the detection probability of marine mammals on ice or in water varies greatly. For example, seals and walrus hauled-out on ice are easier to detect than those in water (they are at the surface for a longer duration than animals in water, often occur in groups, the complete body is visible, etc.). The total number of on ice sightings (on-and off transect) was too low for calculating a separate detection function for on ice sightings (seals n=13, walrus n=17).
    - Grouping of species of similar size, behavior, and color for datasets with low sample sizes. This resulted in grouping of ringed seals, spotted seals, and data recorded under the

ringed/spotted seal category. Detection functions for bearded seal and walrus was estimated separately.

We used the Conventional Distance Sampling (CDS) and Multiple Covariate Distance Sampling (MCDS) analyses engines from Program Distance 6.1. to conduct the exploratory analyses. First the data were run using CDS, and when no acceptable fit could be found, MCDS models were run introducing covariates into the model. Various strategies for truncation of perpendicular distances and binning were tested, as well as various covariates. The fit of all models was assessed using a combination of diagnostic plots, goodness-of-fit tests, and the Akaike's Information Criterion or AIC (Buckland et al. 2001), provided by the Distance software as part of each model output.

Using the detection function of the most optimal model of each species (or species group), we calculated corrected densities for each study area and year. Seasonal densities were determined for each year combining data of all study areas sampled during a specific year. Corrected density estimates and 95% confidence intervals for each species were generated using the density equation for line transects from Buckland et al. (2001).

$$\widehat{D} = \frac{n \cdot \widehat{E}(s)}{L \cdot \widehat{P}_a}$$

where $\widehat{D}$ is the corrected density of a species or species group in number per km^2; *n* is the number of sightings; *Ê(s)* is the mean cluster size of the sightings; *L* is the total length of the transect lines sampled (in kilometers), and $\widehat{P}_a$ is the probability of detection estimated by the model.

Density surface plots of on-transect sightings were developed to determine annual distribution patterns of ringed/spotted seals, bearded seals, and walruses within the three prospect-specific study areas (2008–2011) and the Greater Hanna Shoal area (2011). Density surface plots were estimated using the inverse distance weighting (IDW) method of interpolation using ArcGIS Spatial Analyst. The IDW method estimates cell values from a set of data points that have been weighted so that the farther a data point is from the cell being evaluated, the less weight it has in the calculation of the cell's value (Silverman, 1986). The sighting data was also weighted by group size. These densities were not corrected for effort or availability and perception bias. On-transect survey lines were included in the maps to show the level of effort within the study areas. Data from visual marine mammal surveys were also compared to acoustic call detections. Vocalizations of bearded seals and walruses detected on acoustic recorders deployed in the Chukchi Sea during the 2011 summer season were visually displayed in call count contour maps. Sighting data from visual observations were overlain on these maps to determine whether there was similarity between distribution patterns from visual and acoustic data.

Ecological Relationships

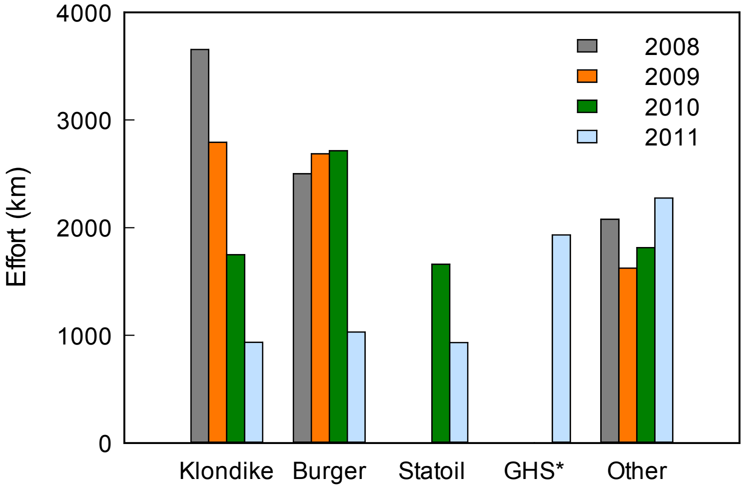
The third objective is intended to integrate results of the marine mammal survey with other components of the CSESP to increase our understanding of ecological relationships. Detailed analyses have not yet been conducted, but are planned for a later date and will be presented in a separate report or publication.

GENERAL SURVEY RESULTS

Systematic marine mammal surveys were conducted during two separate cruises in 2011. The duration of the first cruise was 21 days, from August 4 through August 24, and the second cruise lasted 37 days, from August 30 through October 5 (including transits to and from the study areas). During the first cruise we sampled only the three prospect-specific study areas, and during the second cruise we sampled the entire Greater Hanna Shoal area (including the prospect-specific study areas). Figure 1.4 shows the total survey effort for each study area in 2011 compared to previous years. Due to the wider line spacing in the three prospect-specific study areas in 2011 the total amount of line kilometers surveyed is smaller than in previous years.

During the 7552 km on- and off-transect sampling effort in 2011, 46 cetacean sightings of 60 animals, 585 seal sightings of 607 animals, and 153 walrus sightings of 289 animals were recorded. More details about the seal, walrus, and cetacean data are provided in Chapters 2–4.

Only a few polar bear sightings were recorded in the Chukchi Sea during the CSESP program, which is not surprising as the study is conducted during the open-water season and polar bears are strongly associated with sea ice (Table 1.1). No polar bears were sighted in 2011. In 2008–2010 a total of 13 polar bear sightings of 16 animals were recorded. Two sightings occurred in water, the rest were all



	Klondike	Burger	Statoil	Greater Hanna Shoal*	Other	Total
2008	3654	2500	-	-	2077	8231
2009	2793	2686	-	-	1625	7104
2010	1749	2714	1660	-	1815	7938
2011	**933**	**1030**	**933**	**1931**	**2275**	**7102**
Total	9129	8930	2593	1931	7792	30375

** Does not include lines sampled in Klondike, Burger, and Statoil*

Fig. 1.4. On-transect sampling effort in line kilometers for each study area and year. The category 'Other' contains off-transect effort. Sampling effort in sea states of Bf > 5 is not included. To avoid duplication, the Greater Hanna Shoal area does not include sampling effort in the three prospect-specific areas

on ice. Seven of these sightings (9 animals) were observed in 2008, all in or close to the Burger study area. All six polar bear sightings in 2009 (4 animals) and 2010 were observed outside the prospect-specific study areas during acoustic recorder deployments and retrievals.

There were several occasions during which observers were not able to determine whether a sighting was a seal or walrus (recorded as unidentified pinniped), or a pinniped or cetacean (recorded as unidentified). These situations occurred mainly when animals were observed at large distances from the vessel, when only a small part of the animal was visible, or when the animal was visible for a short duration. This sighting information is not included in Chapters 2–4 and we therefore summarized those sightings in Table 1.1. Unidentified pinnipeds were sighted 70 times from 2008-2011, with 74 individuals. All these records were of animals in water. Three sightings of unknown marine mammals occurred, all of which were in 2011.

Table1.1. Number of sightings and individual polar bear, unidentified pinnipeds, and unidentified marine mammals recorded each year. Data include on- and off- transect sampling effort and in water and on ice sightings.

	2008		2009		2010		**2011**		TOTAL	
	Sight	Ind	Sight	Ind	Sight	Ind	**Sight**	**Ind**	Sight	Ind
Polar Bear	7	9	3	4	3	3	**0**	**0**	13	16
Unidentified Pinniped	28	32	12	12	14	14	**16**	**16**	70	74
Unidentified	0	0	0	0	0	0	**3**	**3**	3	3
TOTAL	35	41	15	16	17	17	**19**	**19**	86	93

Polar bears on sea ice

Because environmental parameters can influence the effectiveness with which observers were able to detect animals, sea state and visibility conditions were compiled and presented in comparison with previous years (Fig. 1.5). In 2011, sea state 5 was the most prevalent sea state condition during all sampling effort and occurred mainly in the Burger study area (Fig. 1.6). In previous years, sea state 3 was the most common, together with sea state 4 in 2009 (mainly in the Klondike study area; Fig. 1.6). In 2010 and 2011, conditions above sea state 3 occurred most frequent in the Burger and Statoil study areas (Fig. 1.6). Visibility conditions also varied from year to year, though in each year most sampling effort occurred with visibility of 8 km or more (Fig. 1.5).

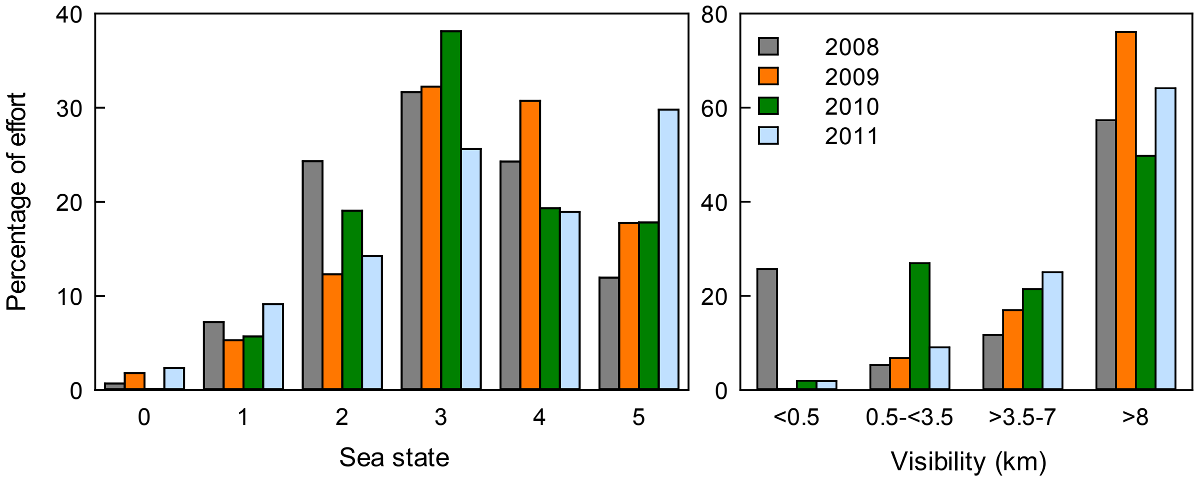


Fig. 1.5. Percentage of total sampling effort for various sea state and visibility conditions. Sea state is expressed in Beaufort windforce scale (NOAA) and visibility in kilometers.

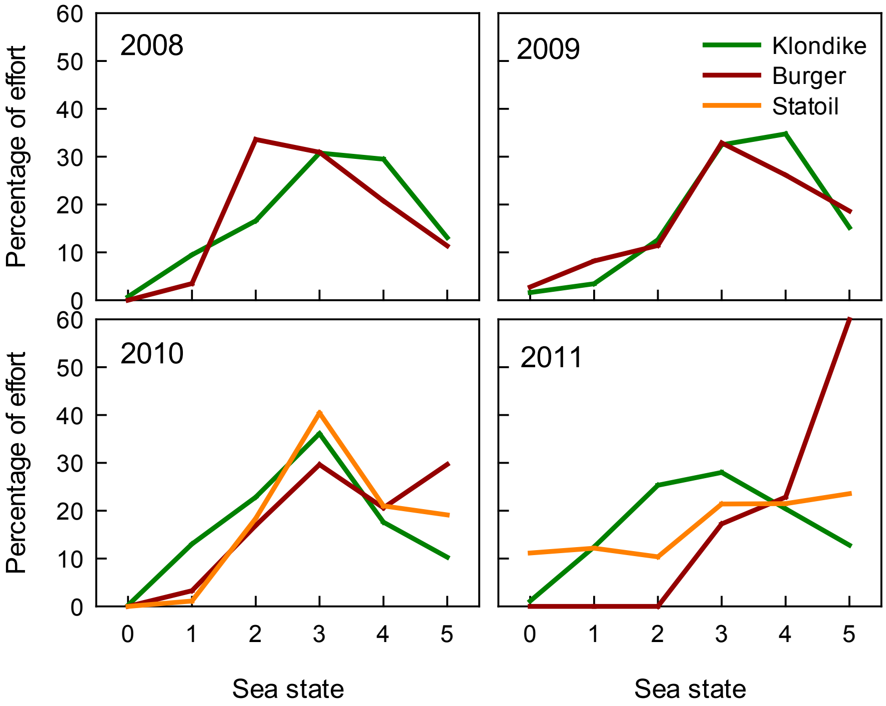


Fig. 1.6. Percentage of total sampling effort for various sea state conditions for each year and study area. Sea state is expressed in Beaufort windforce scale (NOAA).

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CHAPTER 2

DISTRIBUTION AND ABUNDANCE OF CETACEANS IN THE OFFSHORE NORTHEASTERN CHUKCHI SEA DURING THE OPEN WATER SEASON

INTRODUCTION

Three cetacean species are most commonly observed in the Chukchi Sea, the bowhead whale (*Balaena mysticetus*), beluga whale (*Delphinapterus leucas*), and gray whale (*Eschrichtius robustus*). All three species are migratory. Bowhead and beluga whales overwinter in the Bering Sea and migrate north to the Chukchi and Beaufort Seas during spring using open ice leads and polynyas as a migratory corridor. The main summer feeding grounds of bowhead whales are in the Mackenzie River Delta in the Canadian Beaufort Sea, but bowheads have also been observed feeding along their migratory path in the Alaskan Beaufort Sea and around Point Barrow (Mocklin 2009; Moore et al. 2010; Clarke et al. 2012). Beluga whales of the Chukchi Sea population are known to congregate in Kasegaluk Lagoon during summer from late June through mid- to late July (Suydam et al. 2001) after which they migrate farther north. Evidence from a small number of satellite-tagged belugas suggests that the range of these whales extends into the Arctic Ocean north of the Beaufort Sea (Suydam et al. 2005). Gray whales migrate over much larger distances from their wintering grounds in Baja California north along the eastern Pacific coast to Alaska (Rice and Wolman 1971; Calambokidis et al. 2002). Only a subset of the eastern gray whale population feeds in the Chukchi and Beaufort Seas, others remain more to the south and some migrate to the Sea of Okhotsk (Mate et al. 2011; Scordino et al. 2011).

Bowhead whales are an important subsistence resource for residents of Barrow, and other villages along the Chukchi and Beaufort Seas; bowhead whales have been used for food and fuel for the past 2,000 years. The bowhead whale is the primary species hunted, followed in importance by the beluga whale. Gray whales and minke whales comprise opportunistic catches and have not been taken in many years. Commercial hunting of bowheads in the North Pacific started when they were discovered around 1840 and ended 1921, when the worldwide population of the species declined to about 3,000 (Reilly et al. 2008). Moratoriums on commercial whaling came into place and are still in effect today. Subsistence harvests have continued and regulated since the late 1970s by quotas set by the International Whaling Commission (IWC) and allocated and enforced by the Alaska Eskimo Whaling Commission (AEWC). The importance of bowhead whales to Alaskan native residents and their endangered status under the U.S. Endangered Species Act (1970) has led to the extensive 30 year study of the Bering-Chukchi-Beaufort population. The population has been increasing over this period at an estimated rate of 3.4% (1.7–5%) per year in the presence of subsistence hunting (Zeh and Punt 2005) and may be approaching its pre-whaling levels (Reilly et al. 2008). However, due to the changing conditions in the Arctic and other natural and anthropogenic threats, concerns regarding the availability of bowhead whales as subsistence resources still remain.

Other cetacean species have also been sighted in the northeastern Chukchi Sea (e.g., harbor porpoise, killer whale, minke whale, and humpback whale), however, in low numbers as these species are considered to be extralimital to the Chukchi Sea. Of these species, the harbor porpoise has been the most regularly sighted cetacean (Suydam and George 1992, Haley et al. 2010). Few killer whales have been sighted by local hunters at Point Barrow each year (George et al. 1994), but are generally more common in the southern Chukchi Sea. Several sightings of humpback whales were recorded during vessel-based surveys in the Chukchi Sea in 2007 (Reiser et al. 2010) and, in August of that same year, a humpback whale with calf was observed as far as 54 miles east of Point Barrow in the Beaufort Sea (Hashagen et al. 2009). Northern range extension for species may be occurring in response to changing ice-conditions in the Arctic.

The goal of this vessel-based marine mammal study was to gather information on marine mammal distribution and abundance in the northeastern Chukchi Sea, specifically in and around three oil- and gas prospects. This chapter summarizes the cetacean data collected in 2011 and previous years (2008-2010).

METHODOLOGY

Sampling Design and Observation Protocol

Two biologists experienced in conducting Arctic marine mammal observations conducted daylight surveys from the bridge or bridge wings of a research vessel. In addition, an Inupiat communicator assisted with marine mammal observations during daylight hours from the bridge. In 2008–2010, we sampled only the prospect-specific study areas along north-south oriented transect lines. In 2011, we surveyed a larger regional area encompassing the three prospect-specific study areas and Hanna Shoal to the north. This study area is referred to as the Greater Hanna Shoal study area. The sampling design was similar to 2008–2010, but transect lines were more widely with lines every 11 to 13 km outside and 5.6 or 7 km inside the prospect-specific study areas. The denser sampling grid inside the Klondike, Burger, and Statoil areas allowed for a better comparison with results from previous years.

The observers systematically scanned an area of 180° centered on the vessel's trackline with the naked eye and Fujinon 7×50 reticle binoculars, while the vessel moved along the tracklines at a speed of 8–9 knots. Observers were on alternate 2-hour watches during daylight for 10 to 14 hours/day, depending on weather conditions, day length, and the schedule of other scientific activities on the vessel. Navigation based software (TigerNav™) was used to record all vessel information on a real time basis. This information included date, time, vessel position, vessel speed, water depth, sea surface temperature and salinity. The observer on watch recorded environmental data, sighting info, and other information pertinent to the sighting, which was entered and stored on a Panasonic Toughbook™ computers using TigerObserver™ data acquisition software. The methodology section of Chapter 1 provides more details about the survey design and observation protocol.

Data Analyses

Environmental and marine mammal data recorded during the survey were divided into two categories as described in Chapter 1; on-transect and off-transect data. Some off-transect effort was recorded opportunistically, i.e., observations were entered without associated effort data. This occurred when the vessel was on anchor at Wainwright for crew changes, or when animals were sighted when the observers were not officially on-watch.

We used data from both the on- and off-transect categories to summarize the number of cetacean sightings and individuals observed during each of the four survey years for each area as presented in the section "General Survey and Sighting Information". The results presented in the section "Annual Variation in Cetacean Abundance and Distribution" were based on on-transect data only.

No corrected densities were calculated using Program Distance for cetacean species, due to the low number of sightings and individuals recorded each year and in each study area, which would result in an unreliable detection function and would also introduce very large confidence intervals for each estimated density.

RESULTS

We conducted marine mammal surveys during two separate cruises in 2011; one in August and one in September/October. The August cruise focused on sampling marine mammal data in the three prospect-specific study areas, whereas in September/October we collected data in the Greater Hanna Shoal area (which included the Klondike, Burger, and Statoil study areas). We present the results in two different sections as summarized here.

1. General survey and cetacean sighting information, which includes all data collected during on- and off-transect effort for each year and each study area;
2. Annual variation of cetacean abundance and distribution in the three prospect-specific study areas and in the Greater Hanna Shoal study area.

General Survey and Cetacean Sighting Information

A total of five cetacean species were observed in 2011 (Table 2.1); bowhead whale, gray whale, minke whale (*Balaenoptera acutorostrata*), killer whale (*Orcinus orca*), and harbor porpoise (*Phocoena phocoena*). The bowhead whale was the most commonly observed species in 2011 and 2010, but was only sighted twice in 2009 and 2008. Unlike 2008–2010, during which bowhead whales were only observed during their fall migration (late September or October), we sighted bowheads throughout the month of August in 2011. Gray whale sightings within the three prospect-specific study areas were rare; most observations were made in nearshore waters during transits to and from Wainwright. No beluga whales were observed in any of the four years of the CSESP program from 2008–2011. One minke whale was observed in 2011 in the Klondike study area, the remaining minke whales were sighted farther south during transits between the study area and Nome. A total of eight killer whale sightings were documented between 2008 and 2011; six killer whale sightings (75%) were observed in 2011. The number of harbor porpoises sighted in 2011 (two sightings of three animals) was similar to previous years of the study. The most northern sighting of harbor porpoises during the four years of this study was recorded in 2011 in the Statoil study area. Besides the number of sightings and individuals recorded for each year and study area, Table 2.1 also provides the number of sightings corrected for effort (Sight 100 km^{-1}) that allows a comparison between years and study areas (see also Figure 2.3 and 2.4).

Table 2.1. Number of cetacean sightings and individuals recorded in 2008–2011 for each study area and year. The column Sight 100 km^{-1} shows the number of sightings corrected for effort allowing comparison between years and areas. The category "Other" contains off-transect data for which effort information was not always available.

	KLONDIKE			BURGER			STATOIL			GREATER HANNA SHOAL			OTHER		TOTAL	
	Sight	Ind	Sight 100 km^{-1}	Sight	Ind	Sight 100 km^{-1}	Sight	Ind	Sight 100 km^{-1}	Sight	Ind	Sight 100 km^{-1}	Sight	Ind	Sight	Ind
2011																
Bowhead whale	6	7	0.643	5	8	0.414	0	0	0	0	0	0	4	6	15	21
Gray whale	0	0	0	0	0	0	0	0	0	1	2	0.049	7	8	8	10
Minke whale	1	1	0.107	0	0	0	0	0	0	0	0	0	2	4	3	5
Unid. whale	1	1	0.107	2	3	0.166	0	0	0	1	1	0.049	2	3	6	8
Killer whale	4	4	0.429	0	0	0	0	0	0	0	0	0	2	3	6	7
Harbor porpoise	0	0	0	0	0	0	1	2	0.102	0	0	0	1	1	2	3
2010																
Bowhead whale	0	0	0	19	28	0.679	1	2	0.060	Not Surveyed			16	24	36	54
Gray whale	0	0	0	1	2	0.036	0	0	0				13	17	14	19
Humpback whale	0	0	0	0	0	0	0	0	0				2	7	2	7
Unid. whale	1	1	0.057	2	2	0.071	0	0	0				0	0	3	3
Harbor porpoise	0	0	0	0	0	0	0	0	0				1	3	1	3
2009																
Bowhead whale	0	0	0	2	3	0.073	Not Surveyed			Not Surveyed			0	0	2	3
Fin whale	0	0	0	0	0	0							1	3	1	3
Gray whale	0	0	0	1	1	0.037							41	95	42	96
Humpback whale	0	0	0	0	0	0							3	4	3	4
Minke whale	1	1	0.035	0	0	0							2	2	3	3
Unid. whale	0	0	0	1	1	0.037							2	2	3	3
Harbor porpoise	0	0	0	0	0	0							2	3	2	3
Dall's porpoise	0	0	0	0	0	0							2	5	2	5
2008																
Bowhead whale	0	0	0	2	2	0.072	Not Surveyed			Not Surveyed			0	0	2	2
Gray whale	2	3	0.053	1	1	0.036							12	18	15	22
Minke whale	0	0	0	0	0	0							1	1	1	1
Unid. whale	0	0	0	0	0	0							9	11	9	11
Killer whale	2	9	0.053	0	0	0							0	0	2	9
Harbor porpoise	3	7	0.079	0	0	0							0	0	3	7
Dall's porpoise	0	0	0	0	0	0							1	1	1	1
TOTAL																
Bowhead whale	6	7	0.065	28	41	0.294	1	2	0.038	0	0	0	20	30	55	80
Fin whale	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	3
Gray whale	2	3	0.022	3	4	0.032	0	0	0	1	2	0.049	73	138	79	147
Humpback whale	0	0	0	0	0	0	0	0	0	0	0	0	5	11	5	11
Minke whale	2	2	0.022	0	0	0	0	0	0	0	0	0	5	7	7	9
Unid. whale	2	2	0.022	5	6	0.053	0	0	0	1	1	0.049	13	16	21	25
Killer whale	6	13	0.065	0	0	0	0	0	0	0	0	0	2	3	8	16
Harbor porpoise	3	7	0.032	0	0	0	1	2	0.038	0	0	0	4	7	8	16
Dall's porpoise	0	0	0	0	0	0	0	0	0	0	0	0	3	6	3	6

In 2011, the distances relative to the vessel at which we sighted cetacean species ranged from 50 m to >10 km (= at horizon), with 55% of the sightings occurring at distances <1000 m (Fig. 2.1). The median sighting distance was ~1200 m.

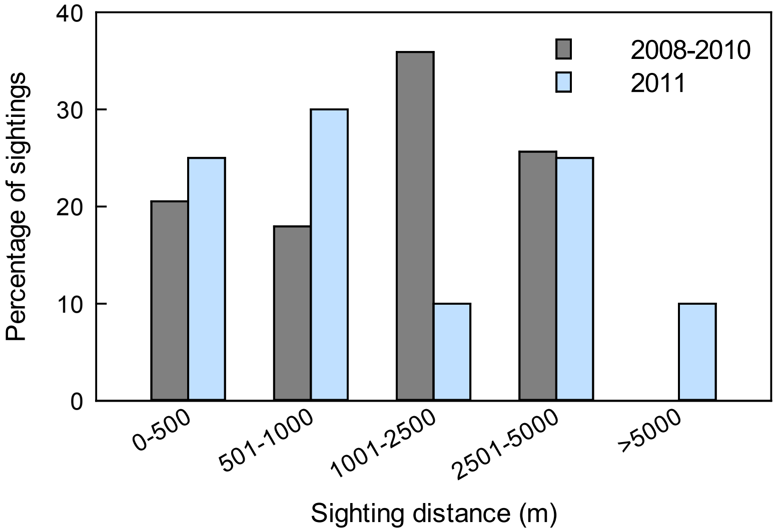

Fig. 2.1. Radial distance (in m) from the vessel at which cetaceans were sighted as a percentage of total number of sightings.

Annual Variation in Cetacean Abundance and Distribution

Effects of Environmental Conditions on Detection

Environmental parameters can influence the effectiveness with which observers are able to detect cetaceans. Figures 2.2 and 2.3 show the results of cetacean sighting rates (number of sightings per 100 km effort) for each sea state and visibility category. Similar patterns were found when using mysticete data only (these species are generally larger than odontocetes) and these figures are therefore not displayed here. There was no clear pattern between cetacean sightings rate and sea state category, although the combined sighting rates of sea states 0-2 seemed generally higher than for sea states 3-6. Both during 2011 and 2008-2010 cetacean sighting rates were highest when visibility was >8 km, likely because the most common sighting cue for whales is their blow, fluke, or (if present) dorsal fin that are difficult to see in low visibility conditions. No clear pattern in sighting rate was apparent for visibility conditions <8 km.


Gray whale blow

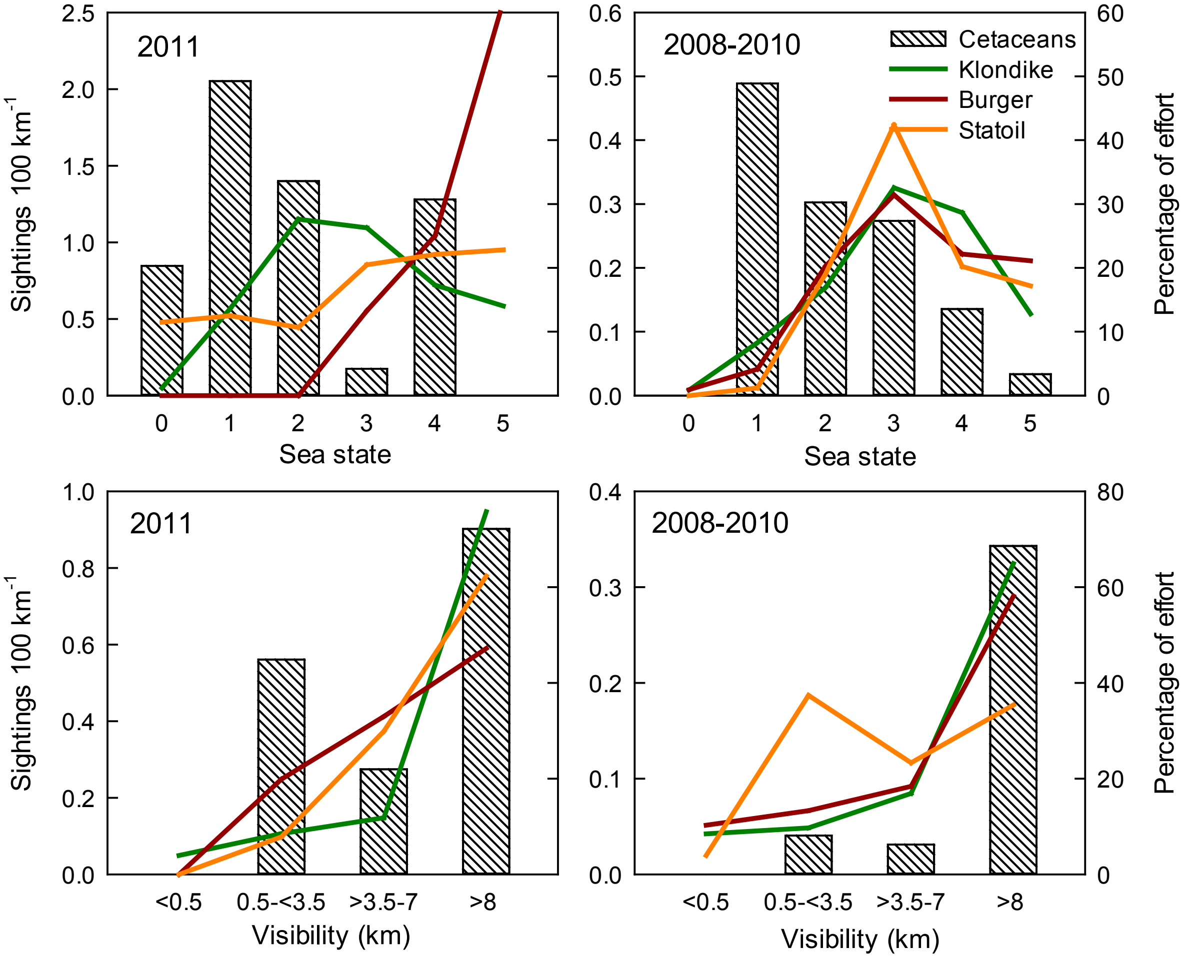

Fig. 2.2. Number of cetacean sightings per km effort for each sea state (Beaufort Windforce scale) and visibility category based on on-transect data in the three prospect-specific study areas. The lines show percentage of sampling effort for each sea state and visibility category within the three study areas.

As stated earlier, bowhead whales were the most commonly sighted cetacean species in 2011. In 2011, bowhead whales were recorded in August (13 sightings of 18 animals) for the first time since the start of this study in 2008. A large number of these sightings were recorded in the Klondike study area (Fig. 2.3) where bowhead whales have not been sighted during the other three years of this study. The number of bowhead sightings per km effort (sighting rate) in the Burger study area in 2011 was also higher than in previous years, with the majority of these sightings occurring in August. Gray whales were not seen in the three prospect-specific study areas in 2011. However, they were recorded in the Greater Hanna Shoal area (Figs. 2.4 and 2.5), at higher sighting rates than previously recorded within the prospect-specific study areas during 2008–2010. The sighting rates of the remaining cetacean species (minke whale, killer whale, and harbor porpoise) were also highest in 2011.

Whale Abundance and Distribution

Bowhead whales

Bowhead whales use the northern Chukchi Sea as a migration corridor traveling between the winter breeding grounds in the Bering Sea and summer feeding areas in the Canadian Beaufort Sea. Most of the 2011 sightings occurred in August (Fig.2.5). Only four bowhead whales (two sightings) were observed early in October. This was much less than the 54 bowheads (37 sightings) recorded 6–8 October 2010.

Other whales

Gray whale sightings in the offshore northeastern Chukchi Sea have been rare during the four years of this vessel-based survey; 94% of all gray whales (n=147) have been sighted nearshore, off Wainwright during crew transfers (Fig. 2.6). In 2011, three gray whale sightings of four animals were observed at Hanna Shoal. Minke whale, killer whale, and harbor porpoises were again observed in 2011, as they had been in previous years of this study. All sightings of these cetacean species (except for one harbor porpoise sighting of two animals in the Statoil study area in 2011) were recorded in the southern part of our study area, at Wainwright or south of Point Hope (Fig. 2.6).

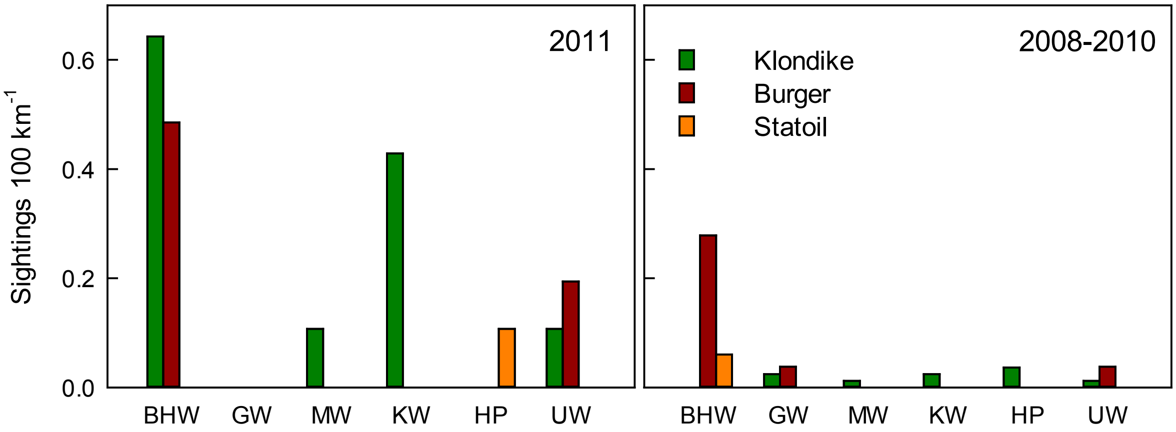

Fig. 2.3. Number of cetacean sightings per 100 km sampling effort within the three prospect specific study areas for 2011 and for 2008–2010 based on on-transect data. BHW=bowhead whale, GW=gray whale, MW=minke whale. KW=killer whale, HP=Harbor porpoise, UW=unidentified whale.

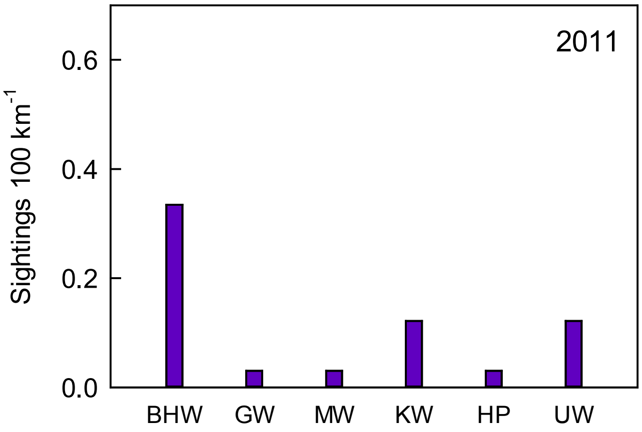

Fig. 2.4. Number of cetacean sightings per 100 km sampling effort within Greater Hanna Shoal in Sep-Oct 2011 based on on-transect data. BHW=bowhead whale, GW=gray whale, MW=minke whale. KW=killer whale, HP=Harbor porpoise, UW=unidentified whale.

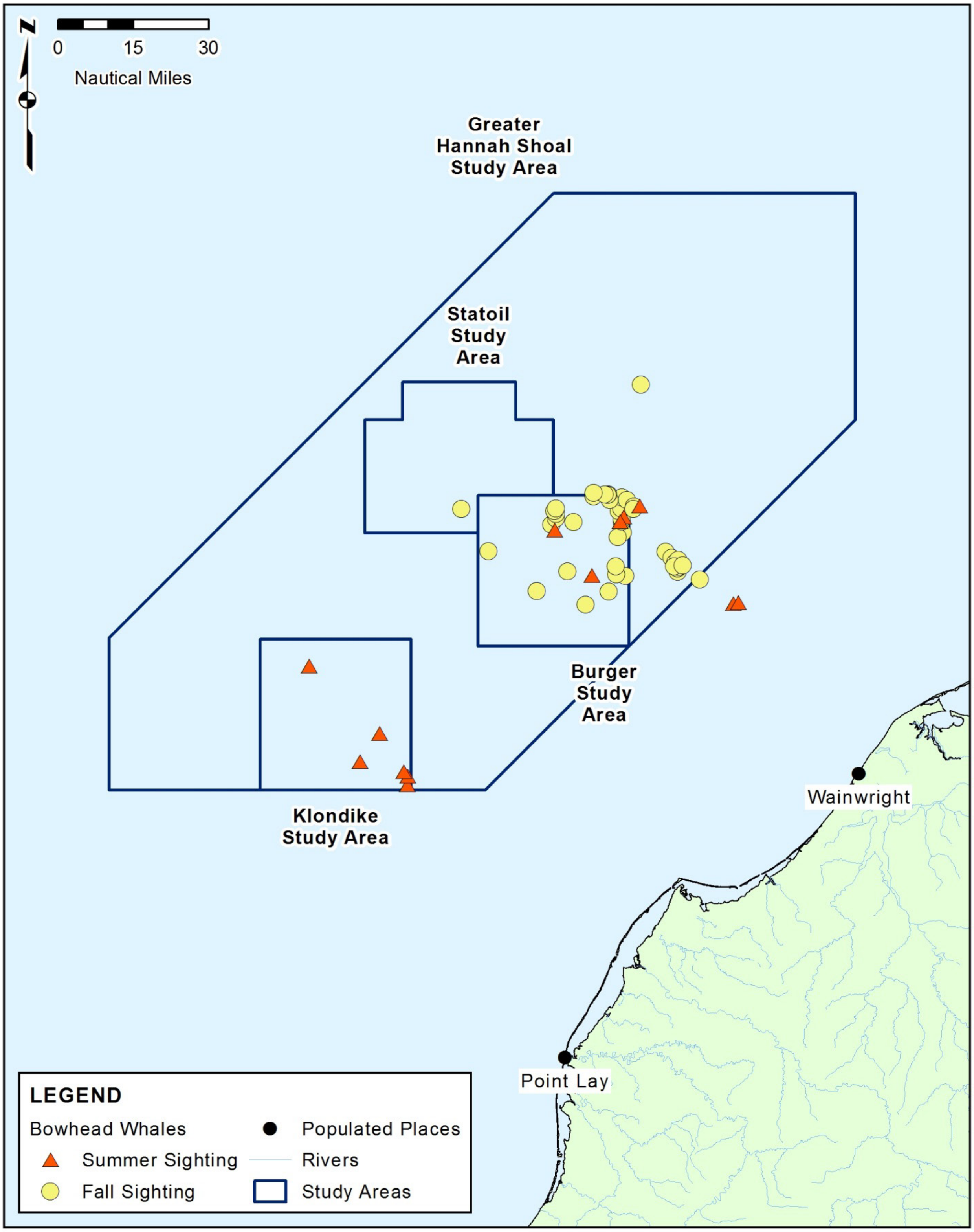

Fig 2.5. Bowhead whale sightings (on- and off-transect) recorded in 2008–2011 during the summer (Jul/Aug) and fall (Sep/Oct). All summer sightings and two fall sightings were recorded in 2011.

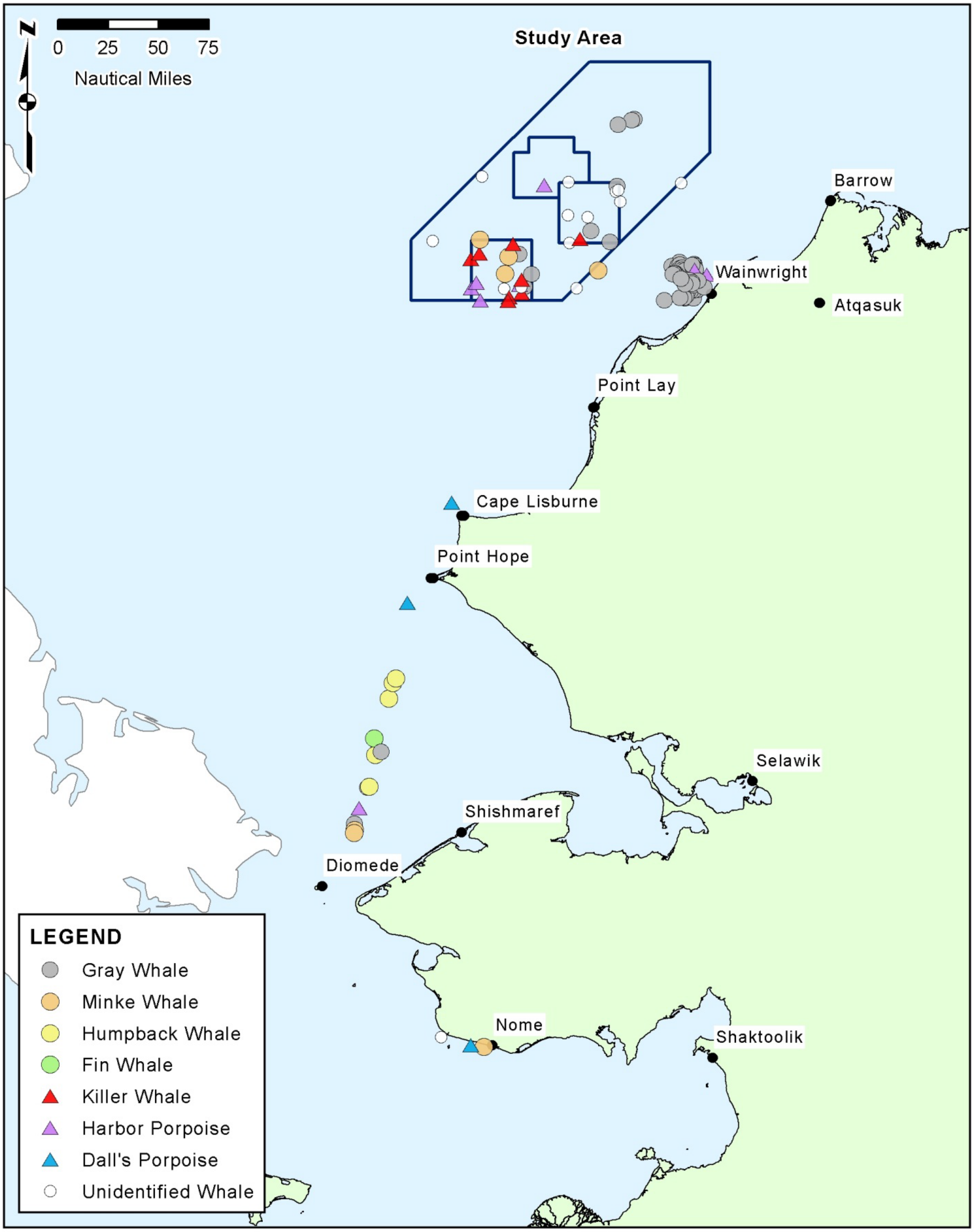

Fig 2.6. Sightings of other cetacean species (no bowhead whales) during on- and off-transect effort from 2008–2011. This sighting information includes the observations recorded during transits between Nome and the study areas.

DISCUSSION

Most bowheads migrate through the Chukchi Sea starting early April and the majority has passed Point Barrow late July. Bowhead whale sightings are therefore not common in the northern Chukchi Sea in August (Aerts et al. 2011; Clarke et al. 2011, 2012), making the high sighting rate of bowhead whales throughout August 2011 observed during this study unusual. Distribution plots of bowhead whale call counts in the first two weeks of August also show a high concentration of calls in the vicinity of the three prospect-specific study areas (Delarue et al. 2012), thereby confirming the visual vessel-based observations. The low sighting rate of bowhead whales in the fall of 2011 was similar to 2008 and 2009, but much lower than in 2010, possibly indicating a late fall migration. An unusually late fall migration across the Beaufort Sea was also considered to be the reason for the low fall bowhead sighting rates observed during the ASAMM surveys in 2011 (Clarke et al. 2012).

No beluga whales have been sighted during the four years of vessel-based marine mammal surveys in the three prospect-specific study areas. Belugas were not sighted in the 2011 Greater Hanna Shoal area that extends farther north than the three prospect-specific study areas sampled in previous years. The area and timing of our survey likely limits the probability of encountering beluga whales. In the northern Chukchi Sea beluga whales have been recorded mainly in spring from early April to early or mid-July (Delarue et al. 2011; Clarke et al. 2012). This pattern is consistent with satellite tagging data showing most beluga whales move farther north in July, mainly residing along the continental shelf break between Point Barrow and the Canadian border (Suydam et al. 2001, 2005). Belugas migrate back to the Bering Sea in the fall and may be encountered during their southward migration to the Bering Sea. Data results from 2008–2011 aerial surveys show that sighting rates were highest around Point Barrow during the fall (Clarke et al. 2012). Data on beluga vocalizations also demonstrate belugas migrating past Barrow in October and November (Delarue et al. 2011).

Gray whales occur most frequently in shallow coastal waters (Reeves et al. 2002), where benthic prey is abundant. During our vessel-based surveys from 2008–2011, we observed few gray whales in offshore waters and most sightings occurred along the coast near Wainwright during crew transfers. Benthic sampling in that area revealed a high biomass of amphipods (Blanchard et al. 2010), gray whale's preferred prey species. The three offshore sightings of four gray whales in the Hanna Shoal area are of interest due to their rarity of occurrence in recent years. In the 1980s and early 1990s gray whales were frequently observed feeding near Hanna Shoal (Moore 2000), but no gray whales were sighted there during the aerial surveys from 2008–2011 (Clarke et al. 2012).

Minke whales, killer whales, and harbor porpoises have a widespread distribution, but sightings in the northeastern Chukchi Sea are uncommon. No minke whales were reported in the northeastern Chukchi Sea study area during aerial surveys conducted in 1982-1991 (Moore and Clarke 1992), 2008-2010 (Clarke et al. 2011) or 2006-2010 (Thomas et al. 2011), however five confirmed sightings of six minke whales were recorded during the 2011 COMIDA survey, including what is likely the farthest north confirmed minke whale sighting recorded in the Chukchi Sea (Clarke et al. 2012). Minke whale vocalizations during the summer were detected for the first time in 2011 (Delarue et al. 2012). During the four years of this study we counted nine minke whales in seven sightings. Four solitary animals were seen in the northeastern Chukchi Sea at about 70-71° N latitude, and all others were sighted south of Point Hope during transits between the study area and Nome. Killer whales were only observed in 2008 and 2011 during the CSESP study, mostly in the Klondike study area. Calls from killer whales, as detected on acoustic recorders deployed in the Chukchi Sea each year since 2006, were first detected in the summer of 2007, and since then each year from 2009–2011, predominantly off Cape Lisburne and Point Lay. Killer whales have never been observed during aerial surveys from 1982–1991 and 2008–2011

(Clarke, pers.comm.). Although this information suggests that killer whale sightings are unusual in the northern Chukchi Sea, subsistence hunters do see a few killer whales each year in the Point Barrow region during July and August (George et al. 1994)[1].

Harbor porpoises have been observed occasionally in the northern Chukchi Sea. Suydam and George (1992) reported nine records of harbor porpoise in the Barrow area in 1985–1991. More recently, during the summer and fall of 2006–2008, harbor porpoises were recorded by observers on vessels conducting marine mammal monitoring and mitigation programs during industry activities (Haley et al. 2010). In this study, we sighted harbor porpoises each year during 2008–2011, but in low numbers (total of eight sightings of 16 animals, of which one animal was sighted south of Point Hope). Although the sighting rates are low, the harbor porpoise seems to be a fairly regular visitor in the northeastern Chukchi Sea.

CONCLUSION

- For the first time during the four years of this study, bowhead whales were sighted throughout the month of August, with higher sighting rates (number of sightings per km effort) than in the fall.
- The low sighting rate of bowhead whales in the fall of 2011 was similar to 2008 and 2009, but lower than in 2010.
- As in previous years, no beluga whales were observed during the summer and early fall, which is to be expected considering their distribution pattern and the timing of our study.
- Minke whales, killer whales, and harbor porpoises were again recorded in 2011, with higher sighting rates than recorded during the previous years of this study. Although these species occur in low numbers, the encounters over the past four years suggest that these species may be regular visitors to the northeastern Chukchi Sea.

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[1] NOTE: In August 2012, 13 killer whales were sighted about 6 miles northeast of Barrow during the bowhead whale aerial survey sponsored by the NMFS, BOEM, and other federal agencies. A few days later, observers from the CSESP Program spotted a pod of 25 to 30 orcas near Hanna Shoal, a shallow-water area northwest of Barrow.

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CHAPTER 3

ICE SEAL DISTRIBUTION AND ABUNDANCE IN THE OFFSHORE NORTHEASTERN CHUKCHI SEA DURING THE OPEN WATER SEASON

INTRODUCTION

Four species of phocid seals inhabit the northeastern Chukchi Sea and western Beaufort Sea either seasonally or year-round; the ringed seal (*Pusa hispida*), spotted seal (*Phoca largha*), bearded seal (*Erignathus barbatus*), and ribbon seal (*Histriophoca fasciata*). All four species are closely associated with sea ice. The sea ice provides many advantages to the seals, such as a solid substrate to breed, give birth, raise young, molt, and rest. Other benefits of living on ice include accessibility to abundant food supply, shelter in ice ridges, isolation from terrestrial predators (though not from polar bears venturing on the pack ice), and passive transport to new feeding grounds (Burns 1970, 2002; Riedman 1990). The Chukchi Sea is generally covered by sea ice from about November through July and is mostly ice free in late summer and fall, a process that drives the seasonal movement and distribution patterns of seals (Burns 1981a, 1981b; Nelson et al. 1984). During the open-water period, seals use the Chukchi Sea mainly for foraging. Only the ringed and some bearded seals are known to be year-round residents in the Chukchi Sea (Burns et al. 1981; Kelly, 1988a, 1988b). Spotted seals, ribbon seals, and most bearded seals migrate south towards the Bering Sea during the fall (Boveng et al. 2008; Burns 1970; Lowry et al. 1998, 2000).

Although all four species of Arctic ice seals are closely associated with sea ice, they differ in usage and preference of ice habitat and seasonal movements related to the sea ice. Little is known about the abundance and distribution of ice seals during the open-water season in the offshore Chukchi Sea, since most studies have been conducted in the spring, counting animals hauled out on the ice (Bengston et al. 2005; Burns and Eley 1978; Frost et al. 1988). Satellite tagging data has revealed that ringed seals, spotted seals, and bearded seals cover large distances during the open water season (Boveng et al. 2012; Cameron et al. 2010a; Crawford et al. 2012; Herreman et al. 2012; Kelly et al. 2010a; Lowry et al. 1998, 2000). Each species has a different foraging strategy. Lowry et al. (1998, 2000) determined that spotted seal make foraging trips from coastal haul-out sites, spending an average of two days at haul-out sites between successive foraging trips that average nine days. Ringed seals are not known to make foraging trips. They spent 90% or more of their time in the water during the open-water period and early part of freeze-up when they forage most intensively (Kelly et al. 2010a).

Changes in sea ice habitat due to warming climate trends and ocean acidification, which may alter important aspects of the Arctic marine ecosystem, are major concerns for the conservation status of ice seals. The potential impacts to seal populations are also of concern to Alaskan native hunters, for which seals (and particularly bearded and ringed seals) are important subsistence resources. Other factors that have the potential to impact ice seals include oil and gas exploration and development, commercial fisheries, and shipping; however future impacts to ice seals from these factors are likely to be localized and therefore considered less significant compared to the far-reaching changes expected in sea ice and ocean conditions (Boveng et al. 2008, 2009; Cameron et al. 2010b Kelly et al. 2010b).

To expand our understanding of the seasonal and spatial distribution of ice seals in the offshore Chukchi Sea during the open water season, we conducted a vessel-based marine mammal survey as part of an interdisciplinary ecological study in and near three proposed exploratory oil and gas prospects. This chapter summarizes the data collected during the past four years (2008-2011), with a focus on the results of 2011.

METHODOLOGY

Sampling Design and Observation Protocol

Two biologists experienced in conducting Arctic marine mammal observations conducted daylight surveys from the bridge or bridge wings of a research vessel. In addition, an Inupiat communicator assisted with marine mammal observations during daylight hours from the bridge. In 2008–2010, we sampled only the prospect-specific study areas along north-south oriented transect lines. In 2011, we surveyed a larger regional area encompassing the three prospect-specific study areas and Hanna Shoal to the north. This study area is referred to as the Greater Hanna Shoal study area. The sampling design was similar to 2008–2010, but transect lines were more widely with lines every 11 to 13 km outside and 5.6 or 7 km inside the prospect-specific study areas. The denser sampling grid inside the Klondike, Burger, and Statoil areas allowed for a better comparison with results from previous years.

The observers systematically scanned an area of 180° centered on the vessel's trackline with the naked eye and Fujinon 7×50 reticle binoculars, while the vessel moved along the tracklines at a speed of 8–9 knots. Observers were on alternate 2-hour watches during daylight for 10 to 14 hours/day, depending on weather conditions, day length, and the schedule of other scientific activities on the vessel. Navigation based software (TigerNav™) was used to record all vessel information on a real time basis. This information included date, time, vessel position, vessel speed, water depth, sea surface temperature and salinity. The observer on watch recorded environmental data, sighting info, and other information pertinent to the sighting, which was entered and stored on a Panasonic Toughbook™ computers using TigerObserver™ data acquisition software. The methodology section of Chapter 1 provides more details about the survey design and observation protocol.

Data Analyses

Environmental and marine mammal data recorded during the survey were divided into two categories as described in Chapter 1; on-transect and off-transect data. Some off-transect effort was recorded opportunistically, i.e., observations were entered without associated effort data. This occurred when the vessel was on anchor at Wainwright for crew changes, or when animals were sighted when the observers were not officially on-watch.

We used data from both the on- and off-transect categories to summarize the number of ice seal sightings and individuals observed during each of the four survey years for each area as presented in the section "General Survey and Ice Seal Sighting Information". We used only on-transect data to estimate corrected seal densities within the three prospect-specific study areas and the Greater Hanna Shoal study area and for generating kernel density maps. We estimated corrected densities, using the Program Distance (Thomas et al. 2010), to determine the annual variation in ice seal abundance within and between the study areas. The methodology section of Chapter 1 provides detailed information about the density and other analyses conducted.

The large percentage of unidentified seal sightings (US – meaning it could be any of the four seal species observed) must be taken into account to avoid underestimating densities for each separate seal species. The density of unidentified seals was therefore also estimated. The ratio of ringed/spotted and bearded seal densities for each study area and year was used to estimate the proportional density of each of these two species from the unidentified seal densities. This estimated proportional density was then added to the observed densities to obtain more accurate species densities. Applying the ratio of identified seal species to the unidentified individuals assumes that the challenge in identifying seals to species level is similar for each species. Considering the conditions of these occurrences (animal at large distance from the vessel or at the surface for a brief moment), this is very likely to be true. The adjustment increased densities for each species, but did not change observed trends in occurrence.

RESULTS

We conducted marine mammal surveys during two separate cruises in 2011; one in August and one in September/October. The August cruise focused on sampling marine mammal data in the three prospect-specific study areas, whereas in September/October we collected data in the Greater Hanna Shoal area (which included the Klondike, Burger, and Statoil study areas). We present the results in three different sections as summarized here.

1. General survey and ice seal sighting information, which includes all 2011 data and data from 2008–2010 (on- and off-transect);
2. Annual variation of seal density and distribution in the three prospect-specific study areas, comparing the 2011 ice seal sightings with data from 2008-2010, using only on-transect data; and
3. Ice seal distribution and abundance in the Greater Hanna Shoal area, using only 2011 on-transect data collected during the September/October cruise.

General Survey and Ice Seal Sighting Information

Sea ice was absent from the study areas during the sampling period from 5 August through 5 October 2011. As in previous years, ribbon seal sightings were rare in 2011 (Table 3.1.). We recorded two ribbon seal sightings of one animal each; one positive identification in the Klondike study area on August 6 and one probable ribbon seal in the Statoil study area on September 16. No ribbon seals were observed in 2010 and 2009, and six animals were sighted in 2008. The number of ringed, spotted, and bearded seal sightings was high in 2011, and with effort taken into account even higher than in 2008, a year with presence of sea in the study areas. Because positive identification of ringed and spotted seal is challenging (Fig. 3.1), we had introduced the category ringed/spotted seals in 2008. In all other figures of this Chapter we have combined the sighting information of ringed, spotted and ringed/spotted seals. In 2011, the distances relative to the vessel at which we sighted seal species ranged from 6–2500 m, with most sightings occurring between 100 and 500 m (Fig. 3.2). In previous years most seals were sighted at distances from 100-250 m. Swimming and looking were the most common behaviors observed for all seal species.

Table 3.1. Number of seal sightings and individuals recorded in 2008–2011 for each study area and year (on ice sightings: 11 sightings of ~147 seals in 2008 and 2 sightings of 2 seals in 2009 are excluded). The category "Other" contains off-transect data for which effort data was not always available.

	KLONDIKE			BURGER			STATOIL			GREATER HANNA SHOAL			OTHER		TOTAL	
	Sight	Ind	Sight km^{-1}	Sight	Ind	Sight km^{-1}	Sight	Ind	Sight km^{-1}	Sight	Ind	Sight km^{-1}	Sight	Ind	Sight	Ind
2011																
Ringed Seal	5	5	0.005	1	1	0.001	19	19	0.019	35	35	0.017	14	14	74	74
Spotted Seal	4	4	0.004	3	3	0.002	6	7	0.006	20	20	0.010	20	20	53	54
Ringed/Spotted Seal	10	11	0.011	5	5	0.004	34	34	0.035	42	42	0.021	36	47	127	139
Bearded Seal	20	21	0.021	9	9	0.007	61	62	0.062	32	32	0.016	64	64	186	188
Ribbon Seal	1	1	0.001	0	0	0.000	1	1	0.001	0	0	0.000	0	0	2	2
Unid. Seal	9	9	0.010	11	11	0.009	20	22	0.020	57	61	0.028	46	47	143	150
2010																
Ringed Seal	2	2	0.001	0	0	0.000	3	3	0.002	Not Surveyed			9	9	14	14
Spotted Seal	3	3	0.002	4	4	0.001	2	2	0.001				15	15	24	24
Ringed/Spotted Seal	16	16	0.009	12	12	0.004	14	15	0.008				25	25	67	68
Bearded Seal	8	8	0.005	37	37	0.013	51	53	0.031				16	16	112	114
Unid. Seal	12	12	0.007	22	23	0.008	8	8	0.005				21	22	63	65
2009																
Ringed Seal	5	5	0.002	10	10	0.004	Not Surveyed			Not Surveyed			4	4	19	19
Spotted Seal	7	7	0.002	3	3	0.001							6	7	16	17
Ringed/Spotted Seal	31	35	0.011	25	26	0.009							11	11	67	72
Bearded Seal	6	6	0.002	20	21	0.007							6	6	32	33
Unid. Seal	19	19	0.007	18	18	0.006							12	12	49	49
2008																
Ringed Seal	53	61	0.014	10	10	0.004	Not Surveyed			Not Surveyed			38	45	101	116
Spotted Seal	18	19	0.005	13	14	0.005							24	27	55	60
Ringed/Spotted Seal	89	99	0.024	23	23	0.008							49	56	161	178
Bearded Seal	27	28	0.007	44	45	0.016							40	43	111	116
Ribbon Seal	4	4	0.001	2	2	0.001							0	0	6	6
Unid. Seal	185	280	0.049	42	42	0.015							106	145	333	467
TOTAL																
Ringed Seal	65	73	0.007	21	21	0.002	22	22	0.008	35	35	0.017	65	72	208	223
Spotted Seal	32	33	0.003	23	24	0.002	8	9	0.003	20	20	0.010	65	69	148	155
Ringed/Spotted Seal	146	161	0.016	65	66	0.007	48	49	0.018	42	42	0.021	121	139	422	457
Bearded Seal	61	63	0.007	110	112	0.012	112	115	0.042	32	32	0.016	126	129	441	451
Ribbon Seal	5	5	0.001	2	2	0.000	1	1	0.000	0	0	0.000	0	0	8	8
Unid. Seal	225	320	0.024	93	94	0.010	28	30	0.011	57	61	0.028	185	226	588	731

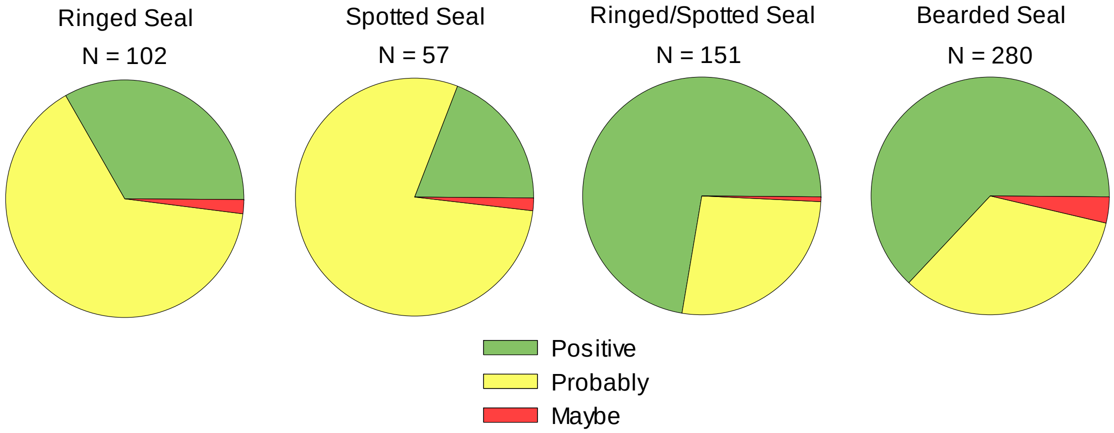


Fig. 3.1. Reliability of seal species identification. Positive means 100% certainty, probably 50-75% certainty, and maybe 25-50% certainty. When reliability of identification was <25% seal species were recorded as unidentified seals.

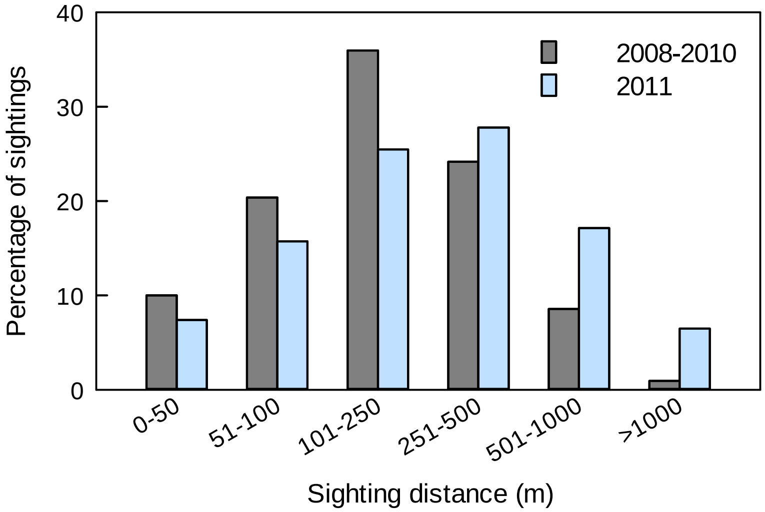


Fig. 3.2. Radial distance (in m) from the vessel at which seals were sighted as a percentage of total number of sightings.

Annual Variation in Seal Density and Distribution in the Prospect-Specific Study Areas

Effects of Environmental Conditions on Detection

Environmental parameters can influence the effectiveness with which observers are able to detect seals. For example, most seals were sighted when the sea state (Beaufort windforce) was low, with number of sightings decreasing with increasing sea states (Fig. 3.3). The correlation between number of seal sightings and sea state has to be taken into account when calculating densities or determining seal distribution within the study area, because sea state conditions during sampling efforts within the study areas varied. In 2011, for example, almost 60% of the sampling effort in the Burger study area occurred with a sea state of 5, whereas sea state conditions were more consistent in the Klondike and Statoil study areas (Fig. 3.3). Overall sea state conditions during the 2008–2010 was very similar among the three prospect-specific study areas, in part because they represent average sea state conditions calculated over three years instead of one (as is the case for the 2011 figure).

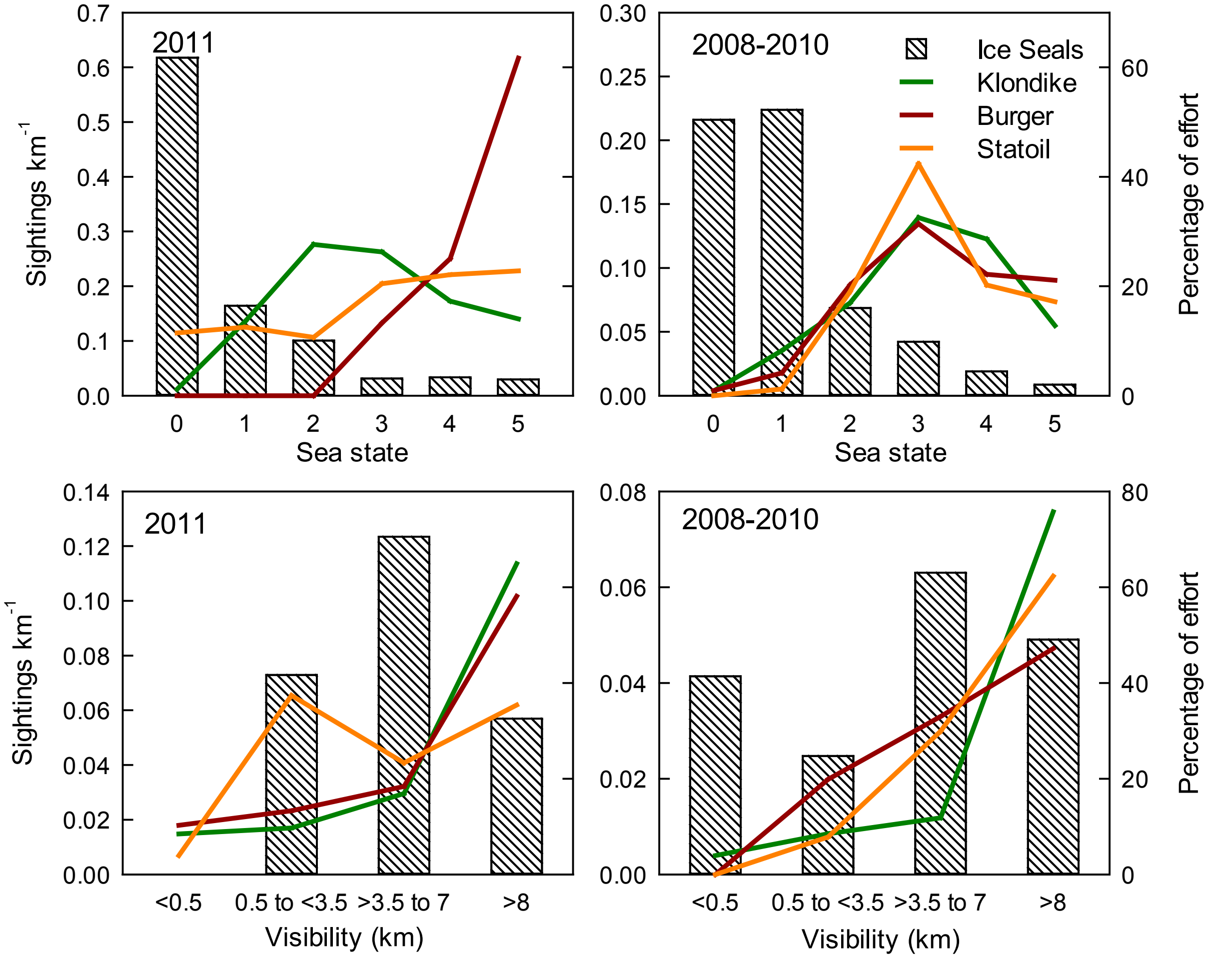


Fig. 3.3. Number of seal sightings per km effort for each sea state (Beaufort windforce scale) and visibility category based on on-transect data in the three prospect-specific study areas. The lines show percentage of sampling effort at each sea state and visibility category within the three study areas.

Visibility conditions also affect the probability with which animals can be detected; however, a clear pattern between number of seal sightings and visibility was not apparent in 2011 and 2008–2010 (Fig.3.3). The lack in correlation between visibility conditions and the number of seal sightings might be explained by the distances at which most seals were sighted, i.e., 0.5 km or less (Fig. 3.2). Visibility conditions in the Klondike and Burger study areas were very similar in 2011, whereas the visibility in the Statoil study area was generally lower (Fig. 3.3).

Seal Density

Seal densities were calculated using Program Distance (Thomas et al. 2010). A detailed description of the general methodology is summarized in Chapter 1. The 2008–2011 database provided a sufficient large sample size for determining detection functions for ringed/spotted seals, bearded seals, and unidentified seals separately. The best fitting model for the detection function of ringed/spotted seals was the half-normal model with Beaufort sea state and vessel as covariates. For bearded and unidentified seals it was the hazard-rate model, with Beaufort sea state as covariate. The best results were obtained with a truncation distance of 500 m, and sea state data grouped into two categories (low = 0-2; high = 3-5). Densities, with 95% confidence intervals, were calculated for ringed/spotted, bearded, and unidentified seals for each study area and year, using the estimated *f(0)* from the MRDS detection function from all on-transect data (Figs. 3.4, 3.5). Densities were also calculated for each season and year, with data from Jul/Aug representing summer and from Sep/Oct representing fall (Figs. 3.4, 3.5). Large confidence intervals were caused by the occurrence of sightings in clusters.

Average ringed/spotted seal densities of on-transect data for each year and study area from 2008–2011 ranged from 0.011 to 0.121 ind km^{-2}, with the lowest value in the Burger study area in 2010 and highest value in the Klondike study area in 2008. Densities for each year and season ranged from 0.008 to 0.138 ind km^{-2} for Jul/Aug 2009 and Jul/Aug 2008, respectively. Ringed/spotted seal densities were higher in the fall in 2009 and 2010, but not in 2008 and 2011.

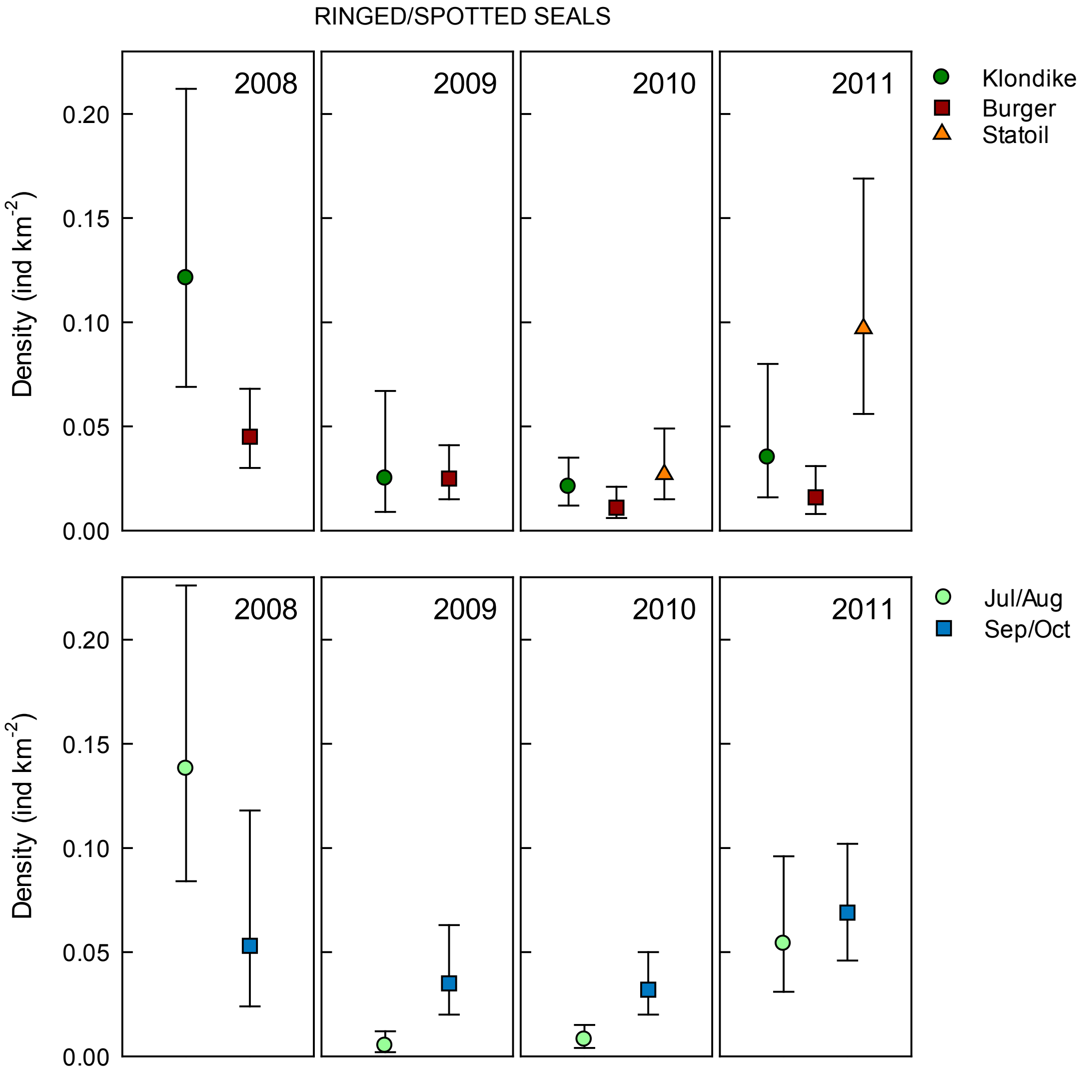


Fig. 3.4. Annual density of ringed/spotted seals (with 95% Confidence Intervals) for each prospect-specific study area and for the summer (Jul/Aug) and fall (Sep/Oct) seasons.

Average bearded seal densities of on-transect data for each year and study area from 2008–2011 ranged from 0.003 to 0.086 ind km^{-2}, with the lowest value in the Klondike study area in 2009 and highest value in the Statoil study area in 2011. In 2008-2010, the density of bearded seals was lower in the Klondike study area than in the Burger (significant in 2008 only) and Statoil study areas. In 2011, bearded seals were highest in the Statoil study area, with significantly greater numbers than in the Burger study area. The large confidence intervals for the 2011 bearded seal density in the Statoil and Klondike study areas reflect the clustered occurrence of bearded seals (see also Fig. 3.7).

Average bearded seal densities for each season and year ranged from 0.004 to 0.056 ind km^{-2}, with the lowest density occurring in summer (Jul/Aug) 2009 and the highest in summer 2011. Both in 2011 and 2008, the majority of bearded seals were sighted in the summer season, although this was only statistically significant in 2011. No sea ice was present in 2011, whereas 2008 was a year with significant ice cover in the study areas. In 2010, the highest densities were observed during the fall (Sep/Oct). In 2009, we didn't observe a seasonal trend was observed.

Average densities of unidentified seals during on-transect effort for each year and study area ranged from 0.008 to 0.098 ind km^{-2}, and for each season from 0.002 to 0.106 ind km^{-2} (Table 3.2). Since unidentified seal sightings consists of ringed, spotted, and bearded seals, the actual densities for ringed/spotted and bearded seals as displayed in the two figures above are higher. The adjusted densities are the sum of the identified seal densities and their proportional densities of the unidentified seals. This adjustment increased densities for each species but did not change observed patterns in abundance between study areas and seasons.

Table 3.2. Ringed/spotted and bearded seal densities (ind km^{-2}) and adjusted densities with unidentified species densities. Ind km^{-2} = individuals per square kilometer; RSS = Ringed/Spotted Seal, BS = Bearded Seal.

		IND KM^{-2}		RATIO		IND KM^{-2}	ADJUSTED	IND KM^{-2}
		RSS	BS	RSS	BS	US	RSS	BS
KLONDIKE	2008	0.121	0.012	91%	9%	0.098	0.210	0.021
	2009	0.025	0.003	89%	11%	0.009	0.033	0.004
	2010	0.021	0.008	72%	28%	0.010	0.028	0.011
	2011	0.035	0.032	52%	48%	0.012	0.041	0.038
BURGER	2008	0.045	0.026	63%	37%	0.025	0.061	0.035
	2009	0.025	0.011	69%	31%	0.009	0.031	0.014
	2010	0.011	0.024	31%	69%	0.012	0.015	0.032
	2011	0.016	0.015	52%	48%	0.017	0.025	0.023
STATOIL	2010	0.027	0.06	31%	69%	0.008	0.029	0.066
	2011	0.097	0.086	53%	47%	0.030	0.113	0.100
JUL/AUG	2008	0.138	0.026	84%	16%	0.106	0.227	0.043
	2009	0.005	0.004	56%	44%	0.006	0.008	0.007
	2010	0.008	0.008	50%	50%	0.002	0.009	0.009
	2011	0.054	0.056	49%	51%	0.016	0.062	0.064
SEP/OCT	2008	0.053	0.013	80%	20%	0.038	0.084	0.020
	2009	0.035	0.008	81%	19%	0.011	0.044	0.010
	2010	0.032	0.043	43%	57%	0.021	0.041	0.055
	2011	0.069	0.022	76%	24%	0.038	0.098	0.031

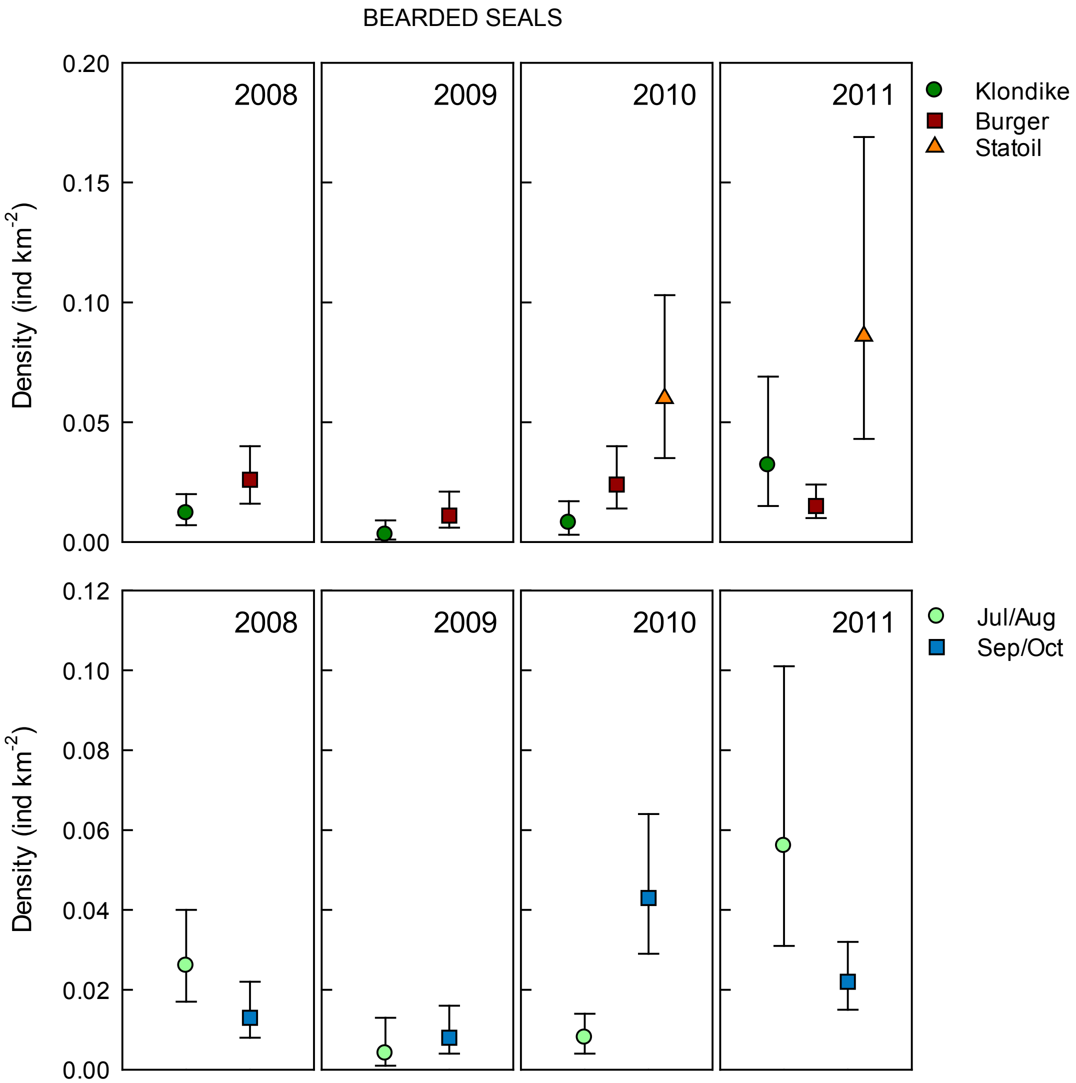


Fig. 3.5. Annual density of bearded seals (with 95% Confidence Intervals) for each prospect-specific study area and for the summer (Jul/Aug) and fall (Sep/Oct) seasons.

Seal Distribution

Kernel density maps of on-transect sighting data collected in the three prospect-specific study areas were developed to display the inter-annual spatial distribution of ringed/spotted seals and bearded seals for each study area and year using the Inverse Distance Weighting (IDW) technique (see Chapter 1 for methodology details). The IDW kernel densities are not corrected for availability and perception bias, which was not considered to be necessary because these maps were intended to show patterns in spatial distribution, rather than providing information on small scale seal densities. Effort lines were included in the maps to show what part of the area was surveyed during a particular season and year (Figs 3.6 and 3.7). The distribution of ringed/spotted seals varied from year to year, with a concentration in the south-central part of the Klondike study area in 2008 and 2009, an even distribution among the three study areas in 2010, and a concentration in the north-central part of the Statoil study area in 2011. The distribution of bearded seals showed a more consistent pattern among years, with highest densities in the most northerly study areas (Burger and Statoil).

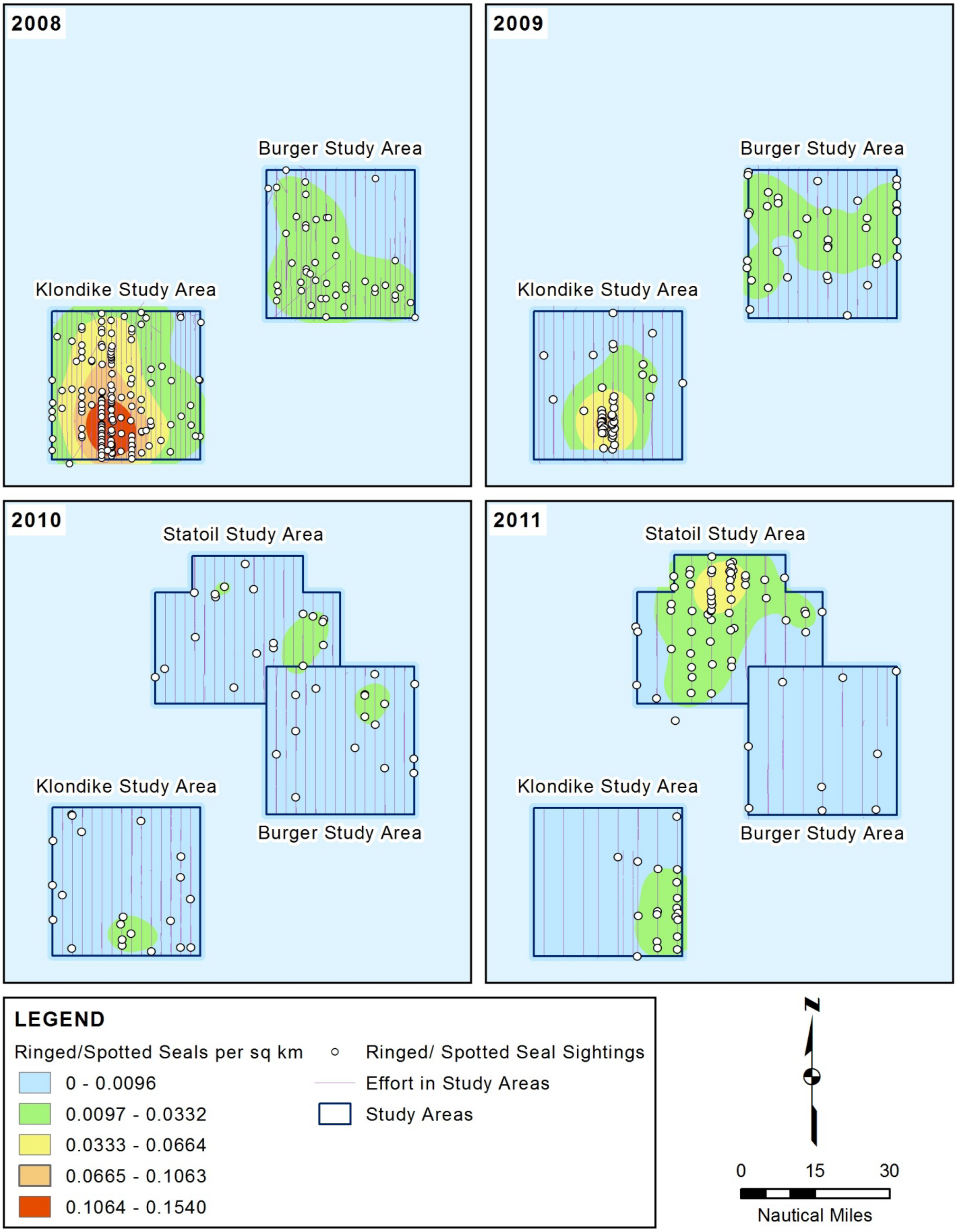


Fig 3.6. Ringed/Spotted seal distribution in the three prospect-specific study areas for each year from 2008-2011. Sightings are from on-transect data, excluding on-ice sightings.

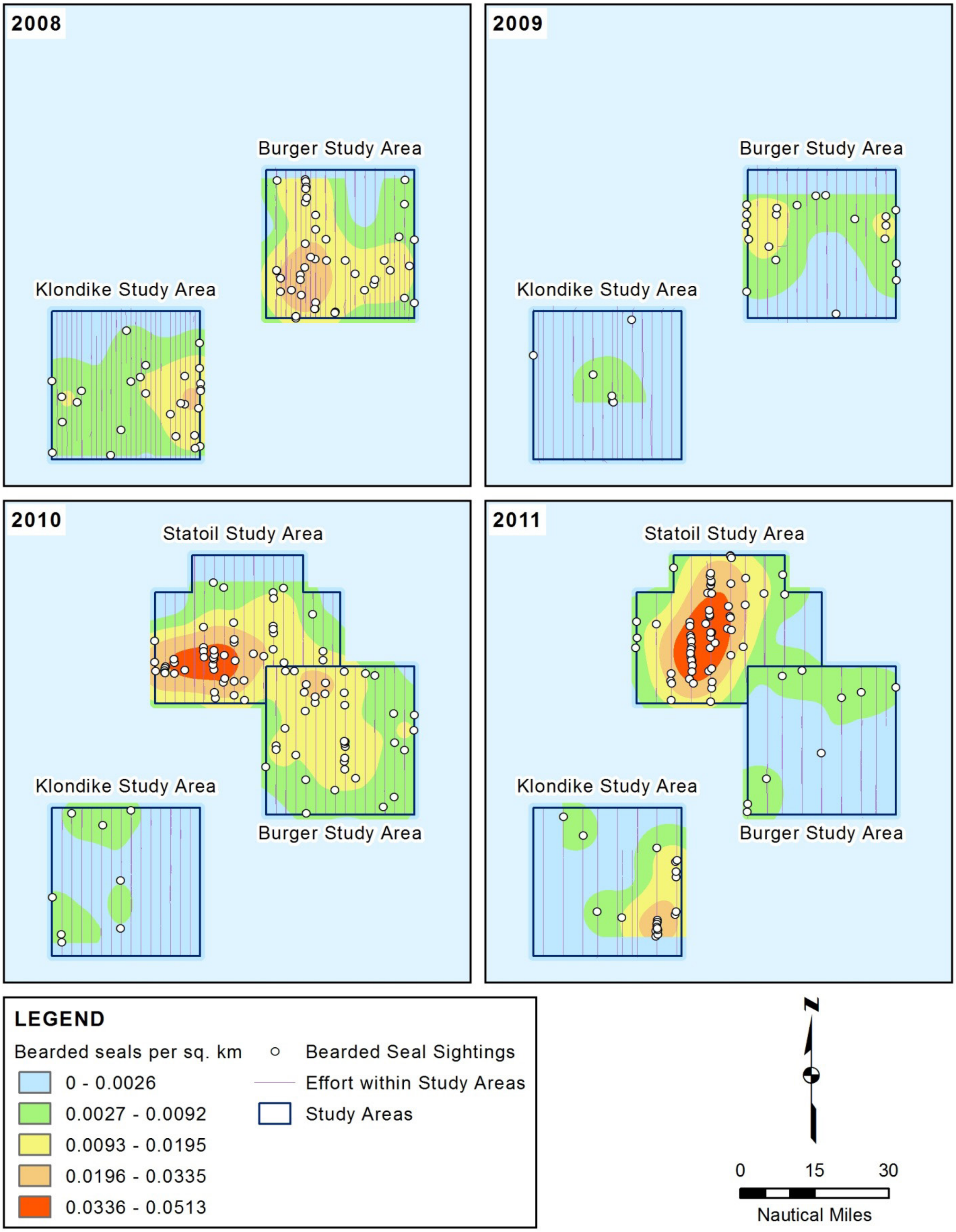


Fig 3.7. Bearded seal distribution in the three prospect-specific study areas for each year from 2008-2011. Sightings are from on-transect data, excluding on-ice sightings.

Seal Density and Distribution in the Greater Hanna Shoal Study Area

This section summarizes the results of the marine mammal survey in the Greater Hanna Shoal area that took place from 31 August to 5 October 2011. It includes on-transect sampling effort within the three prospect-specific study areas during that time period, which accounted for about 41% of the total effort in the Greater Hanna Shoal study area. During a total of 3430 km on-transect effort, we recorded 254 seal sightings of 258 individuals (Table 3.3).

Table 3.3. Number of on-transect seal sightings and individuals recorded in the Greater Hanna Shoal area from 31 August to 5 October 2011. Total of on-transect effort was 3430 km.

	GREATER HANNA SHOAL		
	Sightings	Individuals	Sight km^{-1}
2011			
Ringed Seal	43	43	0.013
Spotted Seal	30	30	0.009
Ringed/Spotted Seal	55	55	0.016
Bearded Seal	47	47	0.014
Ribbon Seal	1	1	0.000
Unidentified Seal	78	82	0.023
TOTAL	254	258	0.074

Effects of Environmental Conditions on Detection

The number of seal sightings per sea state condition in the Greater Hanna Shoal area followed the same pattern as for the three prospect-specific study areas, with observers recording higher number of seal sightings during lower sea state conditions. Sea state 5 was the most frequent occurring sea state condition during the sampling effort in the Greater Hanna Shoal area (Fig. 3.8). Visibility conditions of 8 km or more occurred most frequently (>60%); higher visibility conditions did not result in more seal sightings (Fig. 3.8) because most seals were sighted at distances of 0.5 km or less.

Seal Density and Distribution

Seal densities for the Greater Hanna Shoal study area were also calculated using Program Distance (Thomas et al. 2010). The detection functions for ringed/spotted and bearded seals based on data from all four years were used to calculate densities of ringed/spotted and bearded seals, with 95% confidence intervals, for the Greater Hanna Shoal study area (Figs. 3.9). The marine mammal survey in the Greater Hanna Shoal area took place from 31 August to 5 October 2011. Large confidence intervals were caused by occurrence of sightings in clusters and/or excess number of zero sightings. Bearded seal density in the Greater Hanna Shoal area was significantly lower than the ringed/spotted seal density, with 0.015 ind km^{-2} and 0.049 ind km^{-2}, respectively (Fig. 3.9). Both ringed/spotted and bearded seals were observed in higher concentrations in the northern part of the Greater Hanna Shoal study area (Figs. 3.10 and 3.11). To understand to what extent the sea state conditions determined this distribution pattern, we plotted the transect lines sampled under low sea state conditions (0-2) and high sea state conditions (3-5) as two separate colors. As was expected, the majority of seals were sighted when sea state conditions were low. Sea state conditions were taken into account when calculating densities, as it was included as a covariate in the best fitting model. However, when interpreting kernel density maps displaying data from one survey from, sea state conditions should be taken into consideration before drawing conclusions about seal distributions.

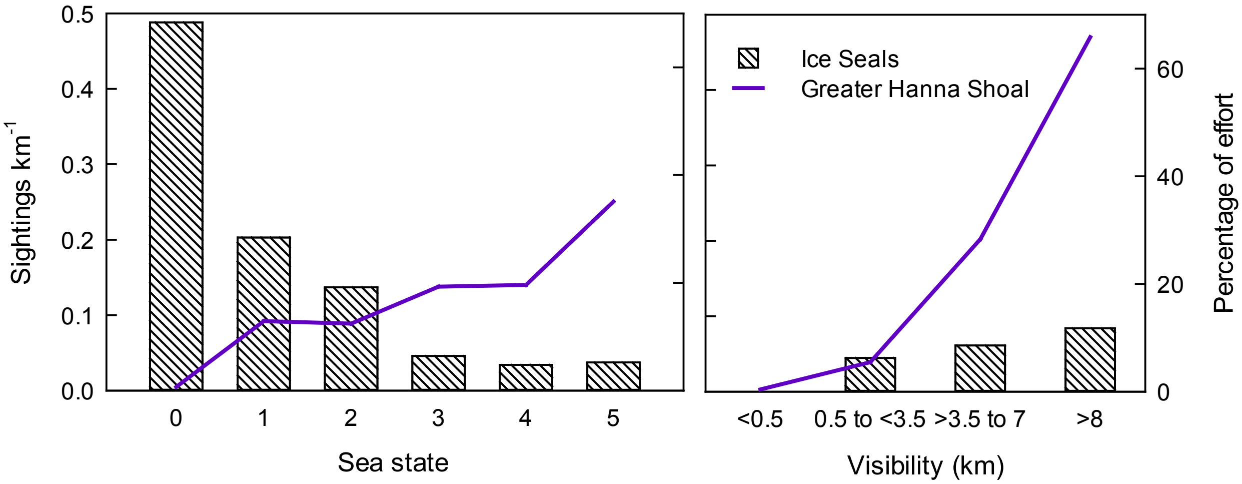


Fig 3.8. Number of seal sightings per km effort for each sea state (Beaufort Windforce scale) and visibility (km) category based on on-transect data in the Greater Hanna Shoal study area. The percentage of effort that occurred under each sea state and visibility category is shown for the Greater Hanna Shoal area.

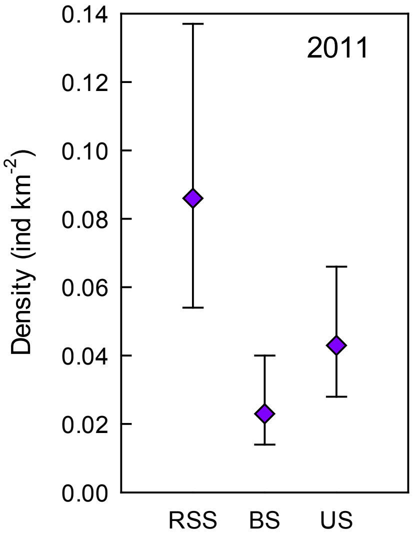


Fig. 3.9. Density of seal species (with 95% confidence Intervals) in the Greater Hanna Shoal study area in 2011. RSS = ringed/spotted seals, BS = bearded seal, and US = unidentified seals

We compared vessel-based visual bearded seal observations recorded in the Greater Hanna Shoal area during 31 August to 5 October with bearded seal vocalizations recorded in the northeastern Chukchi Sea during that same time period (Fig. 3.12). Comparisons between visual and acoustic data for ringed/spotted seals were not conducted, because their vocalizations were detected only sporadically during the open-water season (Delarue et al. 2012). The high bearded seal density in the northern part of the Greater Hanna Shoal study area was apparent in both the visual and call count data, unfortunately call count data from the recorders in the most northern part of the survey area were not available. Generally, call count data and visual observations were not expected to be very consistent for bearded seals, since their vocalizations are less frequent during the summer and therefore not expected to represent actual presence (Delarue et al. 2012).

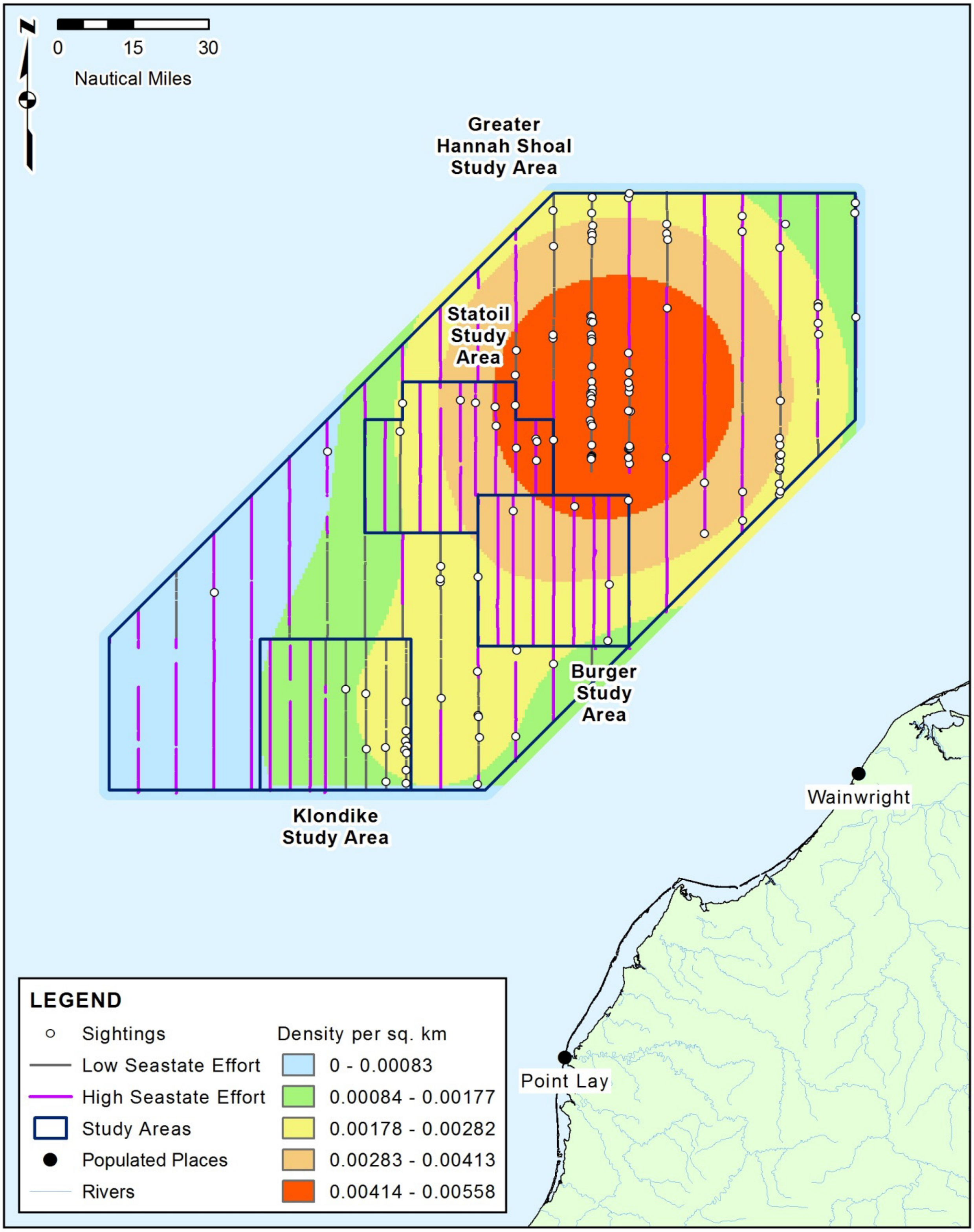


Fig. 3.10. Ringed/spotted seal distribution in the Greater Hanna Shoal study area, September–October 2011. Sightings are from on-transect data, excluding on-ice sightings. Gray effort lines were sampled with low sea state (0-2) and dark purple lines with high sea state (≥ 3).

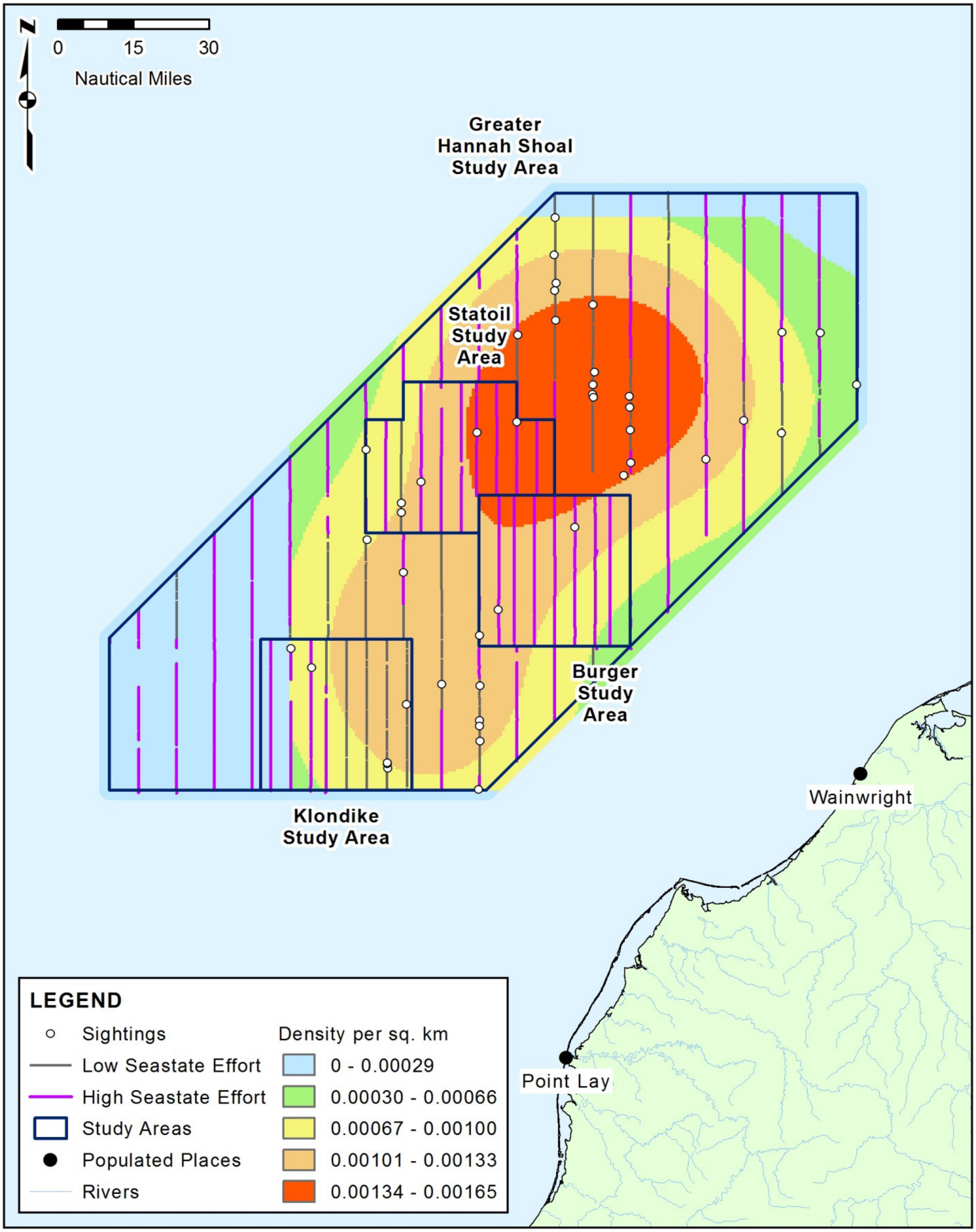


Fig. 3.11. Bearded seal distribution in the Greater Hanna Shoal study area, September–October 2011. Sightings are from on-transect data, excluding on-ice sightings. Gray effort lines were sampled with low sea state (0-2) and dark purple lines with high sea state (≥ 3).

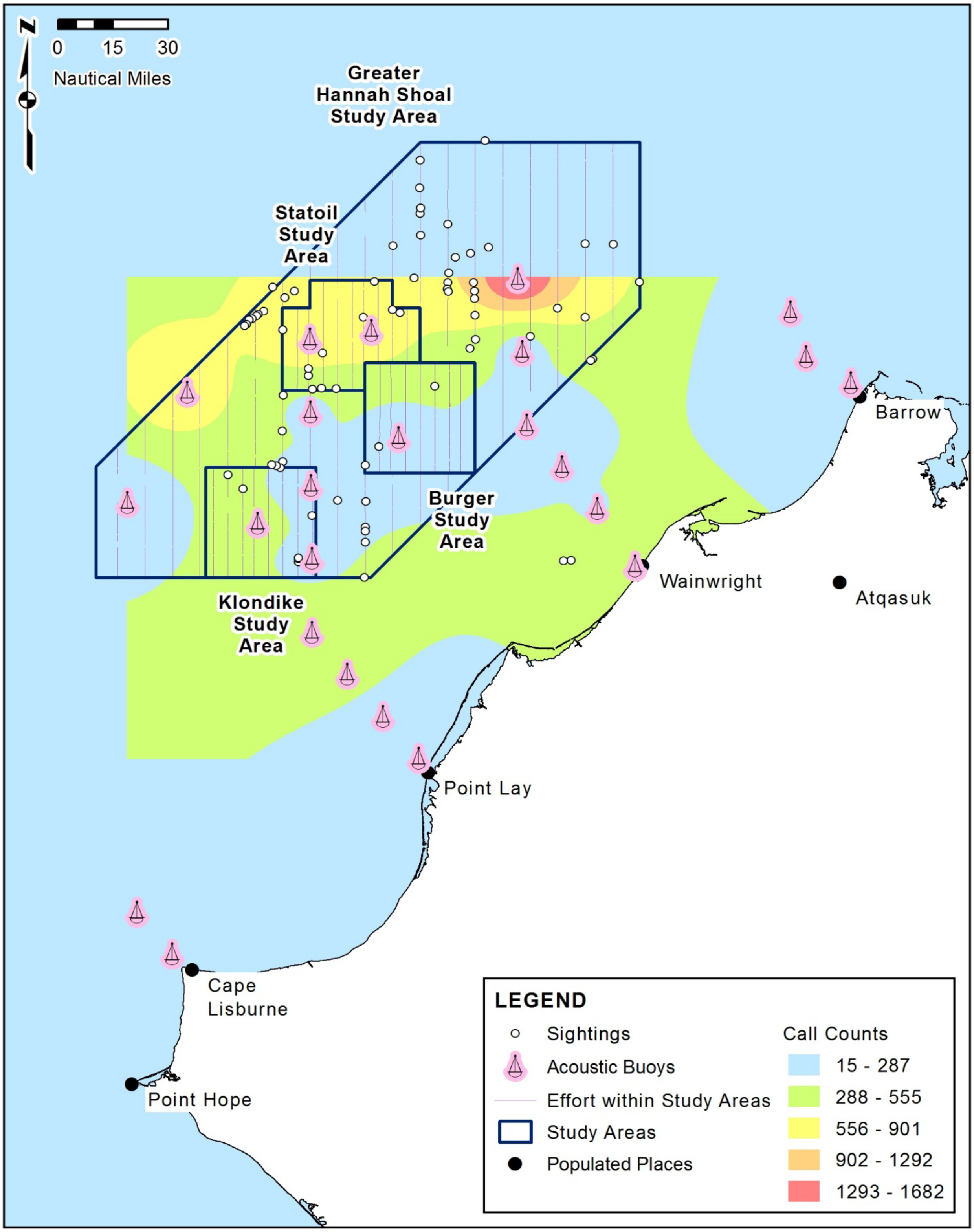
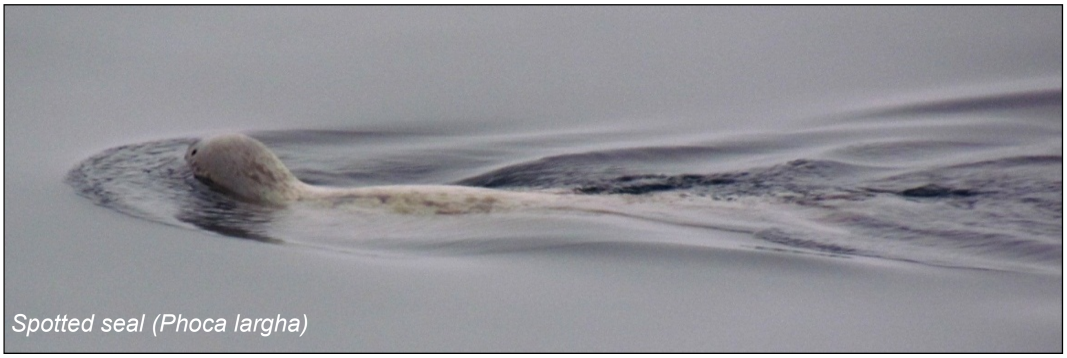


Fig. 3.12. Bearded seal call-count surface plots and visual sightings (on- and off-transect) in the Greater Hanna Shoal area, Aug–5 Oct 2011. Call count data for the northern part of the study area is not yet available. Call count data courtesy of JASCO Applied Sciences.

DISCUSSION

The number of ringed/spotted seal sightings in the Klondike and Burger study areas in 2011 was similar to 2010 and 2008, but the densities in the Statoil study area were higher in 2011 than in 2010. In 2008-2010, there was no significant difference in seal densities among the three study areas within years, although based on kernel density maps and records of off-transect sightings, there appeared to be a slight tendency for preference of the Klondike and Statoil study areas (Aerts et al. submitted). A difference among study areas was more apparent in 2011, where the densities in the Statoil study area were notably higher than in the Burger study area. Due to the large confidence intervals this difference was less apparent between the Klondike and Burger study areas. The Klondike and Statoil study areas are affected by Bering Sea Water from the Central Channel and have a stronger pelagic component than the Burger study area. The biomass of zooplankton species, such as copepods and euphausiids, was generally higher in the Klondike than in the Burger study area, although less apparent in 2010 (Day et al. submitted). Ringed seal diet shows pronounced seasonal variation and mainly target shrimp, amphipods, and mysids during spring and summer (Burns and Eley, 1978; Lowry et al., 1980a). In 2009 and 2010 (both low-ice years) the number of seals observed was highest in the fall, whereas this was not apparent in 2011 (also a low-ice year). Ringed seals spent 90% or more of their time in the water during the open-water period and early part of freeze-up when they forage most intensively (Kelly et al., 2010). Ringed/spotted seals tended be more abundant in the fall in 2011, which is similar to the other two low-ice years (2009-2010), but different from the heavy ice year (2008) when higher densities were observed in the fall. This implying that sea ice presence governed the seasonal density of ringed/spotted seals.

The number of bearded seal sightings in the prospect-specific study areas in 2011 was similar to 2010 and 2008, but lower than in 2009. In 2008-2010, bearded seal densities were higher in the Burger (2008) and Statoil (2010) study areas than in the Klondike study area (Aerts et al. submitted), and benthic studies suggest that the density and biomass of their potential food sources was also higher in these study areas (Blanchard et al., submitted). In 2011, the densities in the Burger and Statoil study areas were not significantly higher than in the Klondike area, partly due to the clustered occurrence that resulted in large confidence intervals. Although the bearded seal density in the Burger study areas was similar to other years, it was significantly lower than the observed densities in the Statoil study area in 2011. The lower densities of bearded seals in the Burger study area could be related to the large numbers of walruses encountered there in 2011, which might have decreased food availability for bearded seals. Trophic interactions between walrus and bearded seals in the Chukchi Sea have been reported before (Lowry et al. 1980b). Seasonal occurrence of bearded seals in 2011 was similar to 2008, with higher densities observed in the summer, whereas densities in 2010 were higher in the fall. Since both 2011 and 2010 were low-ice years and 2008 a heavy ice year, presence of sea ice did likely not determine the seasonal distribution of bearded seals.



Spotted seal (*Phoca largha*)

CONCLUSION

- The number of ringed/spotted seal sightings in the Klondike and Burger study areas in 2011 was similar to 2010 and 2008, but the densities in the Statoil study area were higher in 2011 than in 2010.
- Ringed/spotted seal densities in 2011 were higher in the Statoil study area than in the Burger study area, but not in the Klondike study area.
- Difference in seasonal density of ringed/spotted between the three low-ice years (2009−2011) and the heavy-ice year (2008), implies that sea ice presence was the main factor governing the seasonal occurrence of ringed/spotted seals.
- The number of bearded seal sightings in the prospect-specific study areas in 2011 was similar to 2010 and 2008, and higher than in 2009.
- Bearded seal density in the Burger study area in 2011 was similar to previous years, but was significantly lower than the observed densities in the Statoil study area in 2011. This could be related to the large numbers of walruses encountered in the Burger study area in 2011, which might have decreased food availability for bearded seals.
- Seasonal occurrence of bearded seals in 2011 was similar to 2008, with higher densities observed in the summer, whereas densities in 2010 were higher in the fall. Since both 2011 and 2010 were low-ice years and 2008 a heavy-ice year, presence of sea ice did likely not determine the seasonal distribution of bearded seals.

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CHAPTER 4

WALRUS DISTRIBUTION AND MOVEMENTS IN THE OFFSHORE CHUKCHI SEA DURING THE OPEN WATER SEASON

INTRODUCTION

The Pacific walrus (*Odobenus rosmarus divergens*) inhabits Russian and Alaskan waters. Their northern distribution boundary ranges from the eastern East Siberian Sea to the western Beaufort Sea and their southern boundary ranges from eastern Kamchatka to Bristol Bay (Fay 1982). The walrus is a migratory species inhabiting the Bering Sea in winter and foraging in the Chukchi Sea during summer. During spring, adult females, subadults, calves, and some adult males follow the northward receding ice pack into the Chukchi Sea where they congregate in broken pack-ice habitat. A part of the population, consisting primarily of adult males, remains in the Bering Sea during the summer months foraging from coastal haulouts (Garlich-Miller et al. 2011). In late fall, when the ice pack expands southward, walruses in the Chukchi Sea migrate back to the Bering Sea.

When in the Chukchi Sea, walruses prefer hauling out on broken pack-ice close to productive feeding areas, because foraging from pack ice is energetically more efficient than from shore. Walruses have been observed returning to the same ice floe between feeding bouts (Ray et al. 2006), and exploiting a fairly broad range of ice types and ice concentrations in order to stay in preferred foraging areas (Freitas et al. 2009; Jay et al. 2010). Walruses feed at depths of less than 80 meters (Fay and Burns 1988; Born et al. 2003), although they are capable of diving to depths of more than 250 m (Born et al. 2005). The average dive depth presumably reflects higher productivity of prey organisms in shallow waters (Fay and Burns 1988; Jay et al. 2001; Grebmeier et al. 2006a, 2006b). When sea ice recedes northwards past the continental shelf over deeper waters, many walrus abandon the ice and move to coastal haulouts (Fay and Burns 1988; Jay et al. 2001; Kovacs et al. 2010) from which preferred foraging areas might be more energetically costly to access. Starting around the mid 1990s, reductions in summer sea-ice cover has coincided with an increased use of coastal haulouts by large walrus aggregations of various age and sex classes along the coast of Russia, on Wrangel Island, and on several locations along the northern Chukotka coastline (Kavry et al. 2008; Kochnev 2004; Ovsyanikov et al. 2007 – cited in Garlich-Miller et al. 2011). Large aggregations of walruses hauling out along the coast of Alaska have also been observed during low ice years since 2007, mainly at Point Lay and Icy Cape (Clarke et al. 2012; Fischbach et al. 2009; Thomas et al. 2010a). The size of the aggregations and duration of coastal haulout occupation appear to be related to sea ice conditions. When aggregations of walruses are disturbed at coastal haulouts, trampling events can cause mortalities of subadults and calves (Fischbach et al. 2009; Garlich-Miller et al. 2012).

Decreasing summer sea-ice cover in the Chukchi Sea is one of the major concerns for the future status of the Pacific walrus. Other threats, such as contaminants, oil and gas exploration activities, commercial fisheries, and shipping appear to have a minor influence on the walrus population, perhaps because of the current limited understanding of the mechanistic influence of these factors on walrus abundance (Jay et al. 2011; Garlich-Miller et al. 2011). To expand our understanding of the seasonal and spatial distribution of walruses in the offshore Chukchi Sea in and near three proposed exploratory oil and gas prospects during the open water season we conducted a marine mammal survey as part of an interdisciplinary ecological study (Chukchi Sea Environmental Studies Program [CSESP]). This chapter summarizes the walrus data collected during the past four years, with a focus on the results of 2011.

METHODOLOGY

Sampling Design and Observation Protocol

Two biologists experienced in conducting Arctic marine mammal observations conducted daylight surveys from the bridge or bridge wings of a research vessel. In addition, an Inupiat communicator assisted with marine mammal observations during daylight hours from the bridge. In 2008–2010, we sampled only the prospect-specific study areas along north-south oriented transect lines. In 2011, we surveyed a larger regional area encompassing the three prospect-specific study areas and Hanna Shoal to the north. This study area is referred to as the Greater Hanna Shoal study area. The sampling design was similar to 2008–2010, but transect lines were more widely with lines every 11 to 13 km outside and 5.6 or 7 km inside the prospect-specific study areas. The denser sampling grid inside the Klondike, Burger, and Statoil areas allowed for a better comparison with results from previous years.

The observers systematically scanned an area of 180° centered on the vessel's trackline with the naked eye and Fujinon 7×50 reticle binoculars, while the vessel moved along the tracklines at a speed of 8–9 knots. Observers were on alternate 2-hour watches during daylight for 10 to 14 hours/day, depending on weather conditions, day length, and the schedule of other scientific activities on the vessel. Navigation based software (TigerNav™) was used to record all vessel information on a real time basis. This information included date, time, vessel position, vessel speed, water depth, sea surface temperature and salinity. The observer on watch recorded environmental data, sighting info, and other information pertinent to the sighting, which was entered and stored on a Panasonic Toughbook™ computers using TigerObserver™ data acquisition software. The methodology section of Chapter 1 provides more details about the survey design and observation protocol.

Data Analyses

Environmental and marine mammal data recorded during the survey were divided into two categories as described in Chapter 1; on-transect and off-transect data. Some off-transect effort was recorded opportunistically, i.e., observations were entered without associated effort data. This occurred when the vessel was on anchor at Wainwright for crew changes, or when animals were sighted when the observers were not officially on-watch.

We used data from both the on- and off-transect categories to summarize the number of walrus sightings and individuals observed during each of the four survey years for each area as presented in the section "General Survey and Ice Seal Sighting Information". We used only on-transect data to estimate corrected walrus densities within the three prospect-specific study areas and the Greater Hanna Shoal study area and for generating kernel density maps. We estimated corrected densities, using the Program Distance (Thomas et al. 2010), to determine the annual variation in walrus abundance within and between the study areas. The methodology section of Chapter 1 provides detailed information about the density and other analyses conducted.

RESULTS

We conducted marine mammal surveys during two separate cruises in 2011; one in August and one in September/October. The August cruise focused on sampling marine mammal data in the three prospect-specific study areas, whereas in September/October we collected data in the Greater Hanna Shoal area (which included the Klondike, Burger, and Statoil study areas). More details are provided in Chapter 1 of this report. We present the results on walrus data in three different sections as summarized here.

1. General survey and walrus sighting information, which includes all data from 2011 and from 2008–2010 (on- and off-transect);
2. Annual variation of walrus density and distribution in the three prospect-specific study areas, comparing the 2011 walrus sightings with data from 2008-2010, using only on-transect data; and
3. Walrus distribution and abundance in the Greater Hanna Shoal area, uisng only 2011 on-transect data collected during the September/October cruise.

General Survey and Walrus Sighting Information

During the 2011 field season we recorded a total of 289 walruses in 153 sightings along 7552 km, with 5147 km on-transect and 2405 km off-transect effort. About 10% of the total number of animals (23 individuals in 16 sightings) was observed during off-transect effort, resulting in 0.007 walrus sightings km^{-1} (Table 4.1). Off-transect effort consisted of opportunistic observations during acoustic recorder deployment and retrieval, during transits to and from Wainwright and Nome, and during other vessel activities. The other 90% (266 individuals in 137 sightings) was recorded during on-transect effort in the different study areas (Table 4.1). The highest number of walrus sightings in 2011 was observed in the Burger study area (0.081 sightings km^{-1}), which was consistent with previous years. No walruses were observed in the Klondike study area in 2011. The numbers of on-transect walrus sightings and individuals in 2011, corrected for effort, were higher than in previous years (Table 4.1), even when the 174 individuals seen on-ice during the 2008 season were taken into account.

Sea ice was absent in the study area during the 2011 CSESP program. Sea ice was only encountered within the study areas during the 2008 surveys, until mid-September. In 2009 and 2010, limited sea ice was encountered north of the study areas during deployments of acoustic recorders. A total of 9 sightings of 875 walruses on ice were recorded in 2008, with one sighting estimated at 700 animals (Table 4.1). In 2009, 8 on-ice sightings of 45 walruses were recorded during the deployment of acoustic recorders in early August. All on-ice sightings occurred in areas of sea-ice cover between 10–30%. The total number of on-ice sightings accounted for 4% of all walrus sightings and 54% of all individuals recorded in 2008–2011.

Table 4.1. Number of walrus sightings and individuals recorded in 2008-2011 for each survey area and year. Only on-transect data is included in the study areas, sightings during off-transect are included under the category OTHER.

	2011		2010		2009		2008		TOTAL	
	WATER	ICE	WATER	ICE	WATER	ICE	WATER	ICE	WATER	ICE
KLONDIKE										
Sightings	0	0	4	0	5	0	5	0	14	0
Individuals	0	0	7	0	7	0	19	0	33	0
Sight km^{-1}	0	-	0.002	-	0.002	-	0.001	-	0.002	-
Ind km^{-1}	0	-	0.004	-	0.002	-	0.005	-	0.004	-
BURGER										
Sightings	98	0	22	0	33	0	24	7	177	7
Individuals	202	0	40	0	60	0	45	174	347	174
Sight km^{-1}	0.081	-	0.008	-	0.012	-	0.009	-	0.019	-
Ind km^{-1}	0.216	-	0.014	-	0.022	-	0.016	-	0.036	-
STATOIL										
Sightings	17	0	11	0					28	0
Individuals	30	0	19	0	Not Surveyed				49	0
Sight km^{-1}	0.017	-	0.007	-					0.011	-
Ind km^{-1}	0.031	-	0.011	-					0.019	-
GREATER HANNA SHOAL*										
Sightings	22	0							22	0
Individuals	34	0	Not Surveyed						34	0
Sight km^{-1}	0.011	-							0.011	-
Ind km^{-1}	0.017	-							0.017	-
OTHER (OFF-TRANSECT)										
Sightings	16	0	19	0	82	8	13	2	130	10
Individuals	23	0	67	0	202	45	28	701	320	746
Sight km^{-1}	0.007	-	0.010	-	0.046	-	0.006	-	0.016	-
Ind km^{-1}	0.010	-	0.036	-	0.114	-	0.013	-	0.039	-
TOTAL										
Sightings	153	0	56	0	120	8	42	9	371	17
Individuals	289	0	133	0	269	45	92	875	783	920
Sight km^{-1}	0.020	-	0.007	-	0.016	-	0.005	-	0.012	-
Ind km^{-1}	0.038	-	0.017	-	0.037	-	0.011	-	0.025	-

** Does not include numbers recorded in Klondike, Burger, and Statoil to avoid double counts*

Pacific Walrus

The distances relative to the vessel at which we sighted walruses in 2011 ranged from 5 to 3700 m, with 86% of the sightings occurring at distances of 500 m or less (Fig. 4.1). In previous years (2008–2010), the percentage of sightings at 500m or less was 72% (Fig. 4.1).

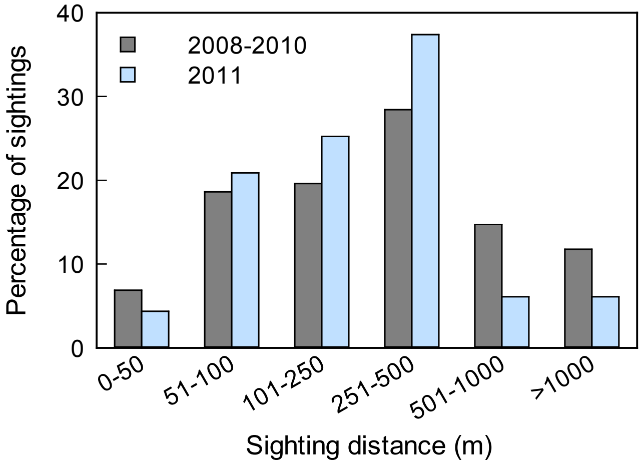

Fig. 4.1. Radial distance (in m) from the vessel at which walruses in water were sighted as a percentage of total number of on-transect sightings.

Annual Variation in Walrus Density and Distribution in the Prospect-Specific Study Areas

Effects of Environmental Conditions on Detection

The influence of sea state and visibility conditions on the detection of walruses was less apparent than for seals (see Chapter 3). Although in 2011 the number of walruses sighted per km effort (sighting rate) under sea state condition 0 was high (~7 sightings 100 km^{-1}), an even higher sighting rate was recorded for sea state 5 (~9 sightings 100 km^{-1}). The records from 2008–2010 also did not show a correlation between walrus sighting rate and sea state conditions (Fig. 4.2). The different sea state conditions within the three study areas during the marine mammal surveys were therefore not expected to have a large influence on the number of sightings. Because walruses are bigger, have large tusks, occur more often in groups, and generally remain longer at the surface, they are easier to detect than seals. Hence, a relationship between walrus detections and sea state is less apparent than for seals.

There was no apparent correlation between visibility conditions and number of walrus sightings per effort in 2011 and in 2008–2011 (Fig. 4.2). The main reason that visibility conditions did not show a clear pattern with number of walrus sightings was that the majority of walruses (>80%) were sighted at distances of 500 m or less (Fig. 4.1).

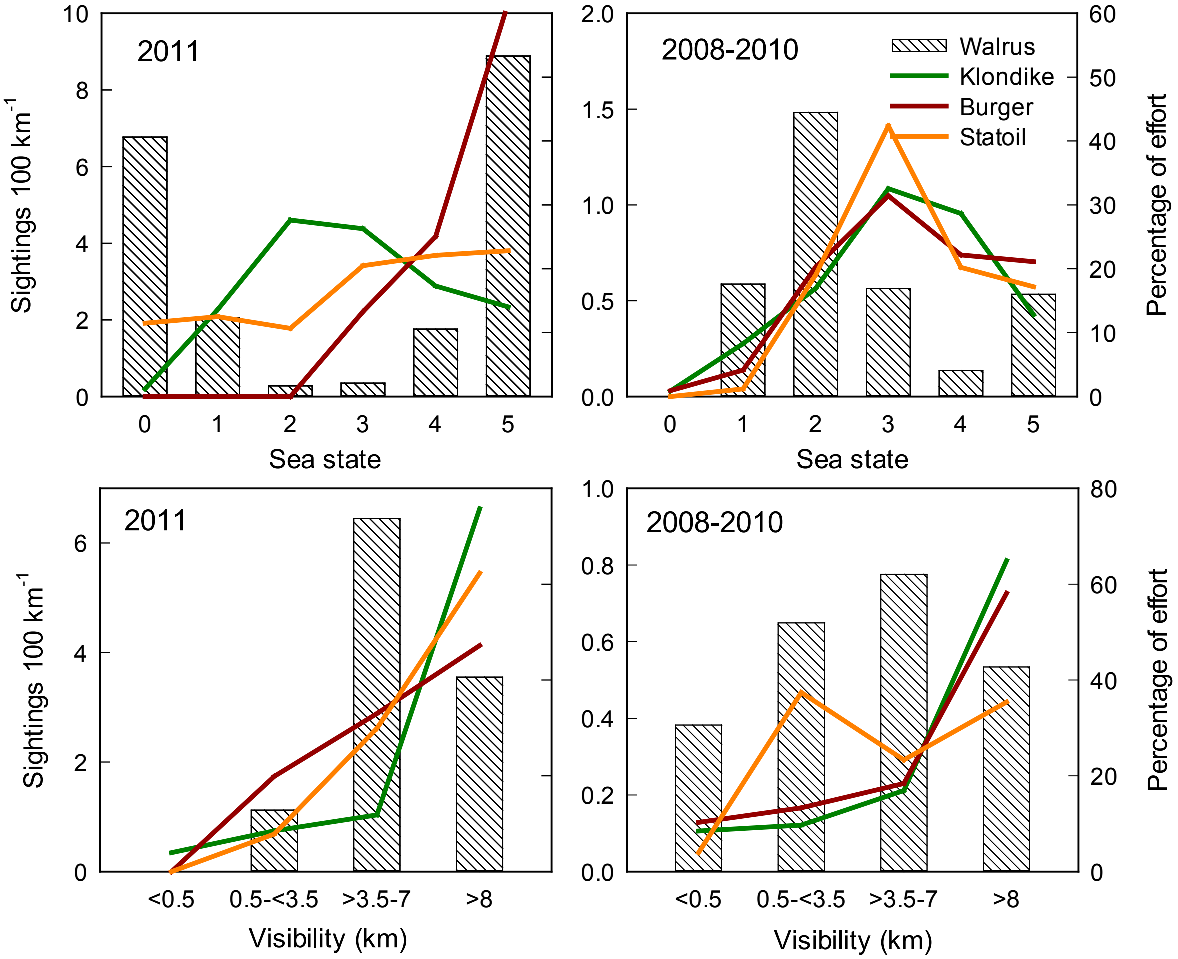

Fig. 4.2. Number of walrus sightings per 100 km effort for each sea state (Beaufort windforce scale) and visibility (km) category based on on-transect (in water) data in the three prospect-specific study areas. The percentage of effort that occurred under each sea state and visibility category is shown for the three study areas as a line.

Walrus density

Walrus density was calculated using Program Distance (Thomas et al. 2010b). A detailed description of the general methodology is summarized in Chapter 1. Four years of data provided an adequate sample size of on-transect walrus sightings (n=241) to determine a reliable walrus detection function. The best fitting model was the Hazard rate model, with Beaufort sea state as covariate. The best results were obtained with a truncation distance of 1.5 km (referring to the perpendicular distance from the transect line) and sea state data grouped into two categories (low = 0-2; high = 3-5). Walrus densities, with 95% confidence intervals, were calculated for each study area and year, using the estimated *f(0)* from the MRDS detection function from all on-transect walrus data (Figs. 4.3). We also calculated seasonal walrus densities for the summer (Jul/Aug) and fall (Sep/Oct) of each year (Fig. 4.4). Average walrus densities of on-transect data for each year and study area ranged from 0 ind km^{-2} in the Klondike study area and to 0.25 ind km^{-2} in the Burger study area in 2011. Seasonal walrus densities ranged from 0.001 to 0.10 ind km^{-2}, with the lowest density in Jul/Aug 2008 and the highest in Sep/Oct 2011 (Table 4.2). The large confidence intervals were caused by occurrence of sightings in clusters. No walruses were encountered in the Klondike study area in 2011. The walrus densities in the Klondike study area in 2008–2010 were low, but only significantly lower than Burger and Statoil in 2009 and 2011. The walrus density in the Burger study area in 2011 was significantly higher than any density recorded in 2011 and previous years (Fig. 4.3). Seasonal walrus densities did not show a consistent pattern between years. In 2011, the highest walrus density was observed in the fall. There was no seasonal difference in walrus density in 2010. In 2009, highest walrus density was recorded in the summer. In 2008, when sea ice was present in the study areas till mid-September, we encountered the highest densities of walruses in the fall.

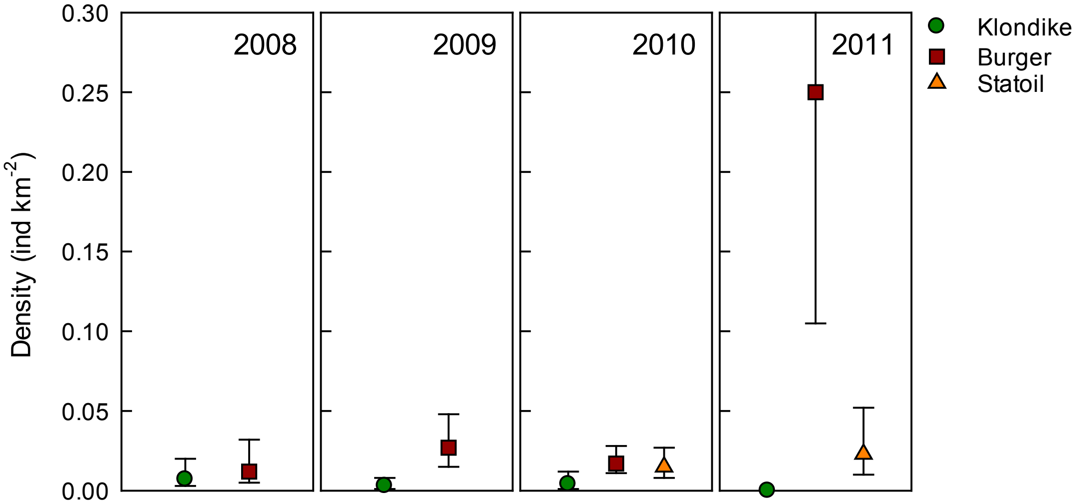

Fig. 4.3. Walrus density in number of individuals km^{-2} (ind km^{-2}) for each study area and year. Only on-transect data were used (excluding on-ice sightings). Upper Level Confidence limit for Burger 2011 is 0.593 ind km^{-2}.

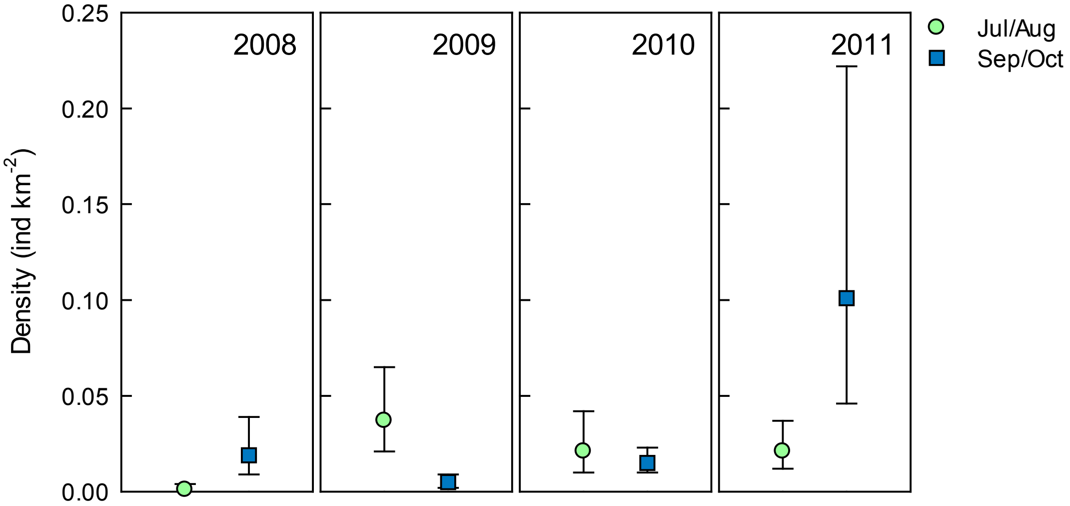

Fig. 4.4. Walrus density in number of individuals km^{-2} (ind km^{-2}) for the summer (Jul/Aug) and fall (Sep/Oct) of each year. Only on-transect data were used (excluding on-ice sightings).

Table 4.2. Summary of walrus density (ind km^{-2}) for each prospect-specific study area and season. LCL=lower confidence limit, UCL=upper confidence limit.

		KLONDIKE	BURGER	STATOIL	JUL/AUG	SEP/OCT
2011	ind km^{-2}	0	0.250	0.023	0.021	0.101
	UCL	0	0.593	0.052	0.037	0.222
	LCL	0	0.105	0.010	0.012	0.046
2010	ind km^{-2}	0.004	0.017	0.015	0.021	0.015
	UCL	0.012	0.028	0.027	0.042	0.023
	LCL	0.001	0.011	0.008	0.010	0.010
2009	ind km^{-2}	0.003	0.027	not surveyed	0.037	0.005
	UCL	0.008	0.048		0.065	0.009
	LCL	0.001	0.015		0.021	0.002
2008	ind km^{-2}	0.007	0.012	not surveyed	0.001	0.019
	UCL	0.020	0.032		0.004	0.039
	LCL	0.003	0.005		0.000	0.009

Group sizes of walruses observed in water were fairly constant between the four years of this survey, with average group size ranging from 1.9–2.4 animals and maximum group size from 12–16 animals. Over the course of the season, there were spikes in the number of walruses observed, some years more apparent than others (Fig. 4.5). In 2011, there was a large spike in number of walruses during the week of September 18–24. In 2009, the spike occurred earlier in the season (week of August 23–September 3). In 2010, there was no obvious spike observed, and in 2008 the number of walruses in water increased only after September 11. The occurrences of these spikes were similar for adults and juveniles (Fig. 4.5). In 2011, adult/juvenile pairs were observed frequently; one out of three adult walruses sighted in water was with a juvenile (it was not always clear if the juvenile was a calf or yearling). In 2008, only one out of six adults sighted in water was observed with a juvenile. In 2009 and 2010 adult/juvenile pairs were observed approximately one out of five adult sightings.

Walrus Distribution

Kernel density maps of on-transect sighting data collected in the three prospect-specific study areas were developed to display the spatial distribution of walruses for each study area and year (Figs 4.6). The IDW kernel densities are not corrected for availability and perception bias, which was not considered to be necessary because these maps were intended to show patterns in spatial distribution, rather than providing information on small scale walrus densities. Effort lines were included in the maps to show what part of the area was surveyed during a particular year.

The distribution of walruses varied from year to year, with highest densities in the most northerly study areas (Burger and Statoil) and mainly concentrated in the northeasterly corner of these areas (Fig. 4.6). Concentrations of walruses were observed in the Burger study area each year, with very high numbers in 2011 (especially when compared to 2010).

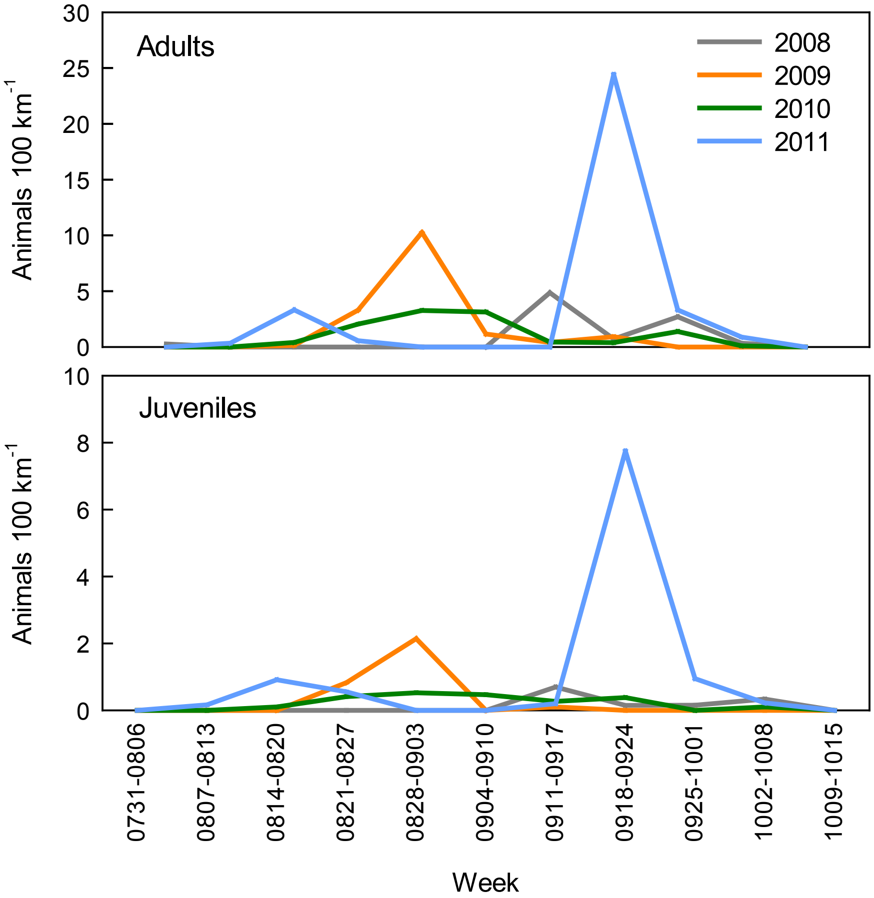

Fig 4.5. Number of adults and juveniles observed over the course of the open water season for each year from 2008–2011. Numbers are based on on-transect data (excluding on-ice sightings).

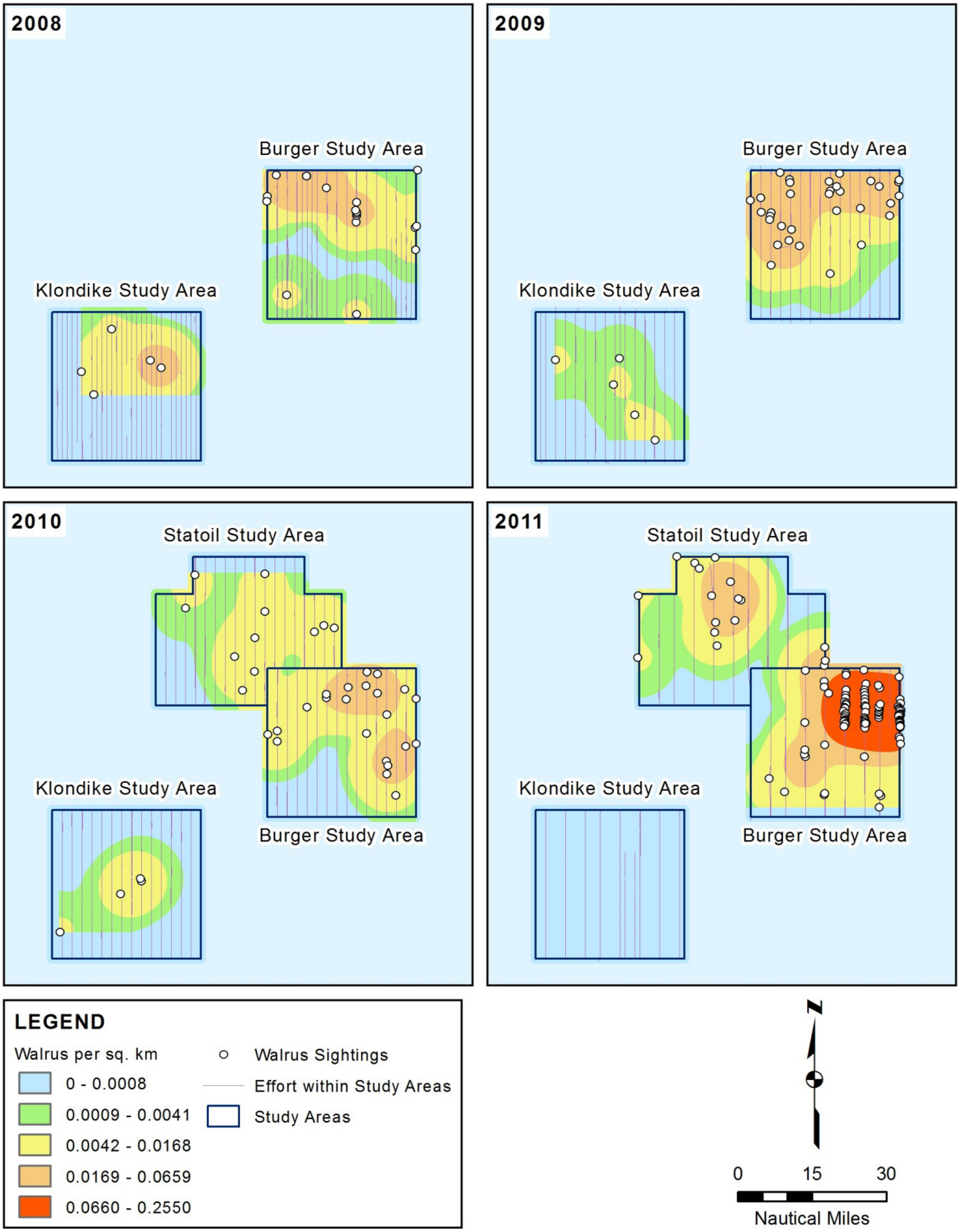

Fig 4.6. Walrus distribution in the three prospect-specific study areas for each year from 2008–2011. Sightings are from on-transect data, excluding on ice sightings

Walrus Density and Distribution in the Greater Hanna Shoal Study Area

This section summarizes the results of the marine mammal survey in the Greater Hanna Shoal study area that took place from 31 August to 5 October 2011. During a total of 3430 km on-transect effort, we recorded 116 sightings of 225 individuals. Roughly 41% of the total effort in the Greater Hanna Shoal study area was within the three prospect-specific study areas.

Effects of Environmental Conditions on Detection

The influence of sea state and visibility conditions on the detection of walruses in the Greater Hanna Shoal area (Fig. 4.7) was similar as for the three prospect-specific study areas (Fig. 4.2), which was expected because of the overlap in the data used for this analyses. The sea state conditions did not influence the probability of detecting walruses as much as for seals, because walruses are bigger, have large tusks, occur more often in groups, and generally remain longer at the surface, which makes them easier to detect than seals.

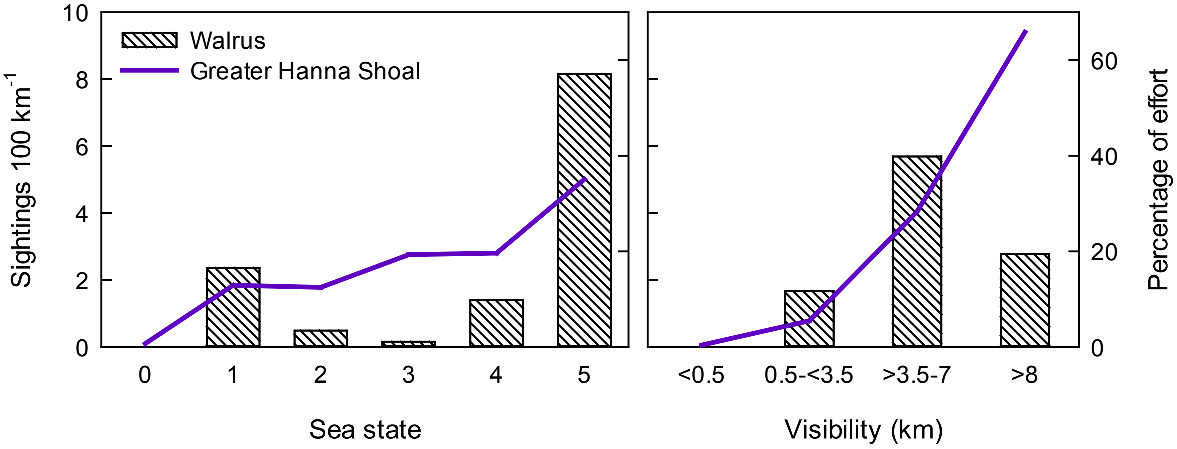

Fig 4.7. Number of walrus sightings per 100 km effort (bars) for each sea state (Beaufort Windforce scale) and visibility (km) category based on on-transect data in the Greater Hanna Shoal study area. The percentage of effort that occurred under each sea state and visibility category is shown for the Greater Hanna Shoal area.

Walrus Density and Distribution Greater Hanna Shoal Area

The overall walrus density in the Greater Hanna Shoal area in the fall of 2011 (Sep-Oct) was 0.020 walruses km^{-2} (95% CI 0.008 – 0.050). This density is basically an average representing a larger offshore area that includes the three prospect-specific study areas. The kernel density map of on-transect sighting data collected in the Greater Hanna Shoal study area displays the spatial distribution of walruses in the fall of 2011 (Fig 4.8). These kernel densities were not corrected for availability and perception bias or for effort. Effort lines were included, showing the sea state conditions during time of sampling. A clear relation between sea state conditions and number of sightings was not apparent for walrus, as was also noted earlier (Figs 4.2 and 4.7). For the Greater Hanna Shoal study area the hotspot of walruses was concentrated in the northeastern part of Burger. A similar distribution, with a general hotspot around the Burger study area was also recorded for walrus call counts in 2011 (Fig. 4.9). Because the acoustic recorders deployed at Hanna Shoal will be retrieved later in 2012, call detection data for the fall of 2011 is not yet available for the most northern part of the Greater Hanna Shoal area.

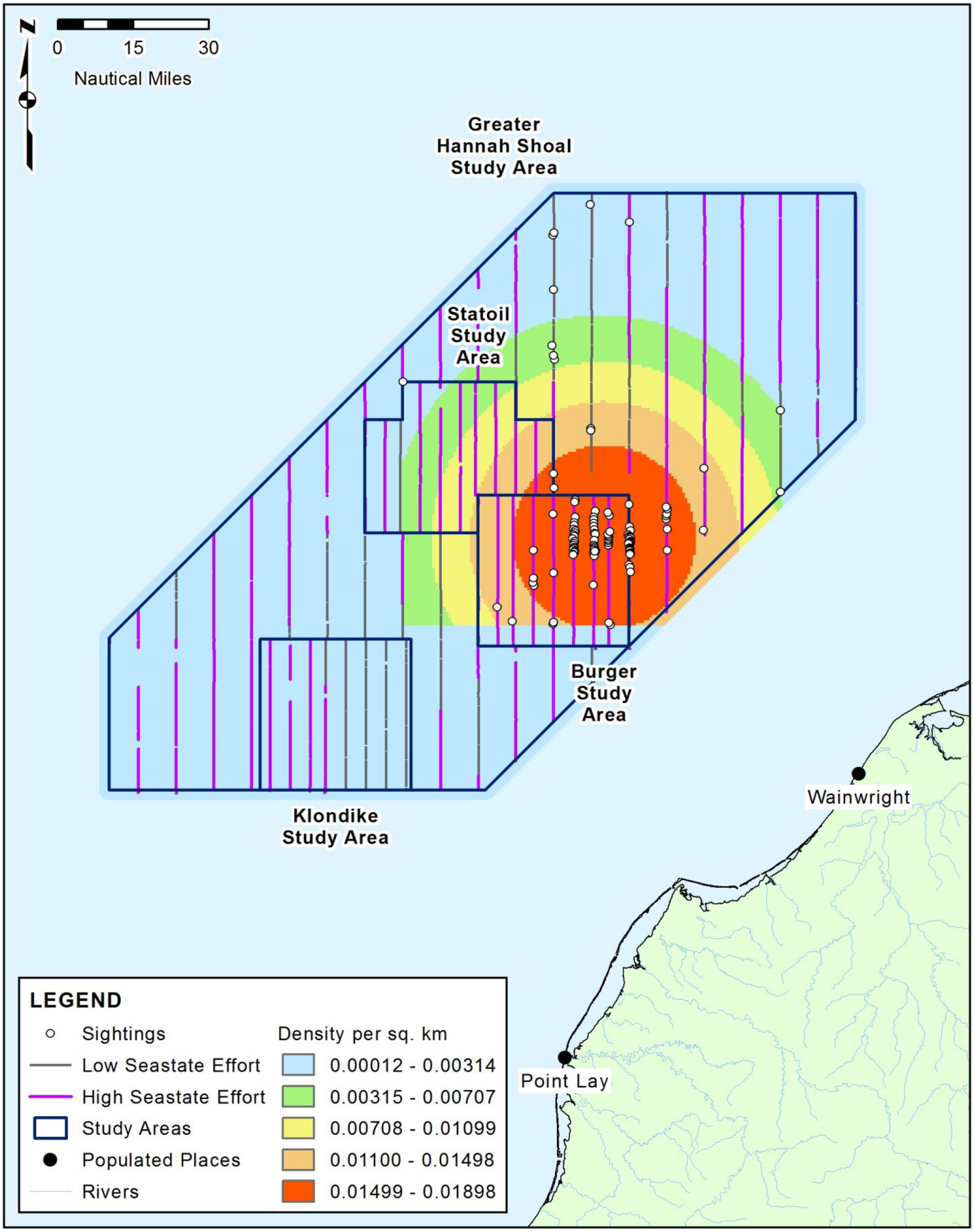

Fig. 4.8. Walrus distribution in the Greater Hanna Shoal study area, September-October 2011. Sightings are from on-transect data, excluding on-ice sightings. Gray effort lines were sampled with low sea state (0-2) and dark purple effort lines with high sea state (≤3).

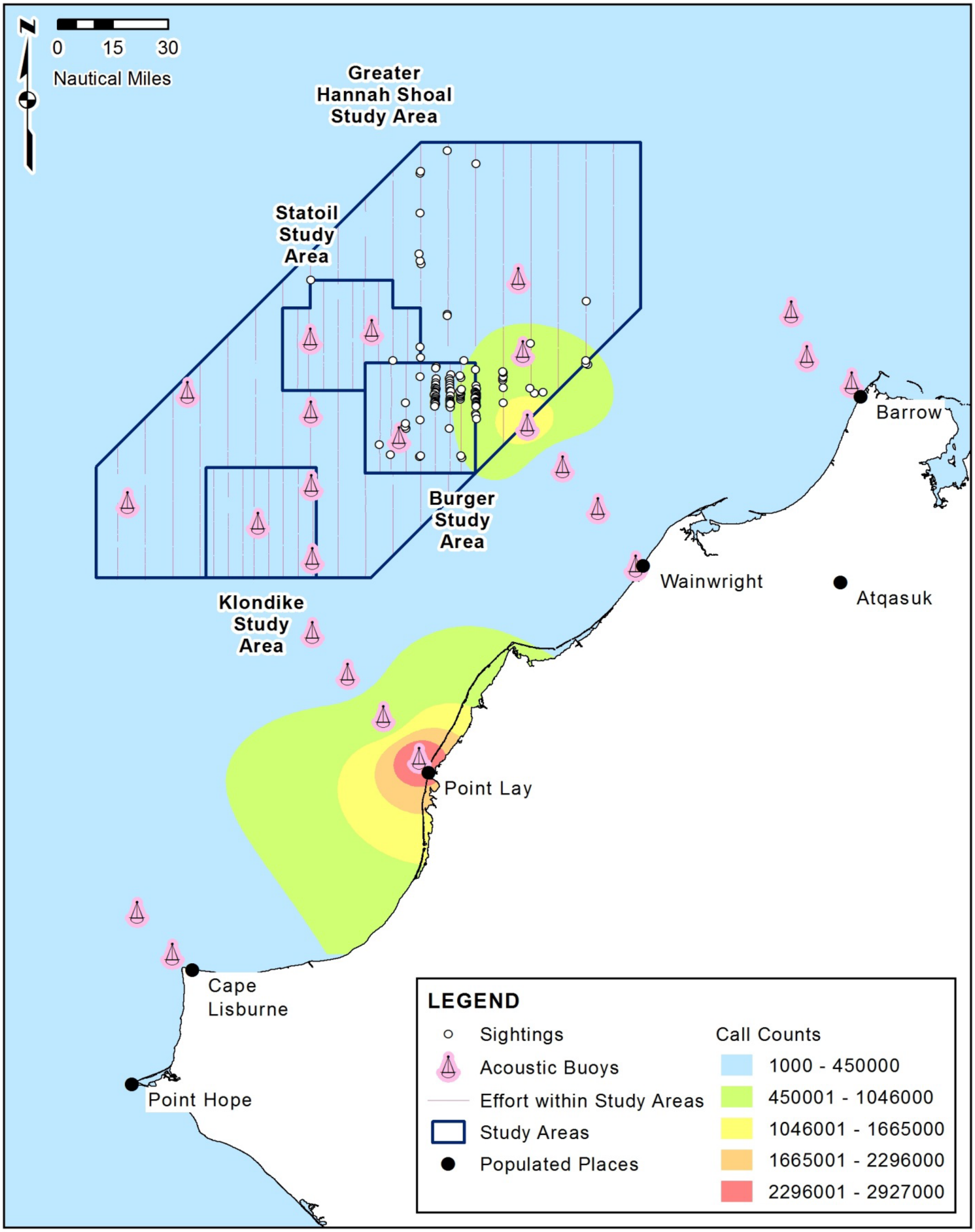

Fig. 4.9. Walrus call-count surface plots (based on total number of calls detected at each station) and visual sightings (on- and off-transect) in the Greater Hanna Shoal area for the period 31 Aug–5 Oct 2011. Call count data for the northern part of the study area are not yet available. Call count data courtesy of JASCO Applied Sciences.

DISCUSSION

Data on walrus distribution and abundance in the offshore northeastern Chukchi Sea during the open-water season of 2008–2011 has shown that the abundance of walruses varied annually, but that the distribution among the three prospect-specific study areas was fairly constant. Highest concentrations were found in the Burger and Statoil study areas and lowest numbers in the Klondike study area. The annual variation in numbers of walruses observed in water was most likely related to availability of sea ice habitat and utilization of coastal haulout sites. During the three year of surveys from 2008–2010 we had one heavy ice year (2008), a year where the influence of warm Bering Sea Water resulted in warm, ice free waters early in the season (2009), and an intermediate year with regard to water temperature and sea ice melt (2010). The fourth year (2011) was characterized by an early ice retreat. Walrus sightings in water were low in the summer of 2008, when animals were observed hauled out on the sea ice in large aggregations (one on-ice sighting of walruses was estimated at ~700 animals). Starting mid-September, when sea ice retreated outside the study areas, we observed larger numbers of walruses in water. The summer density of walrus in water in 2008 was lower than the summer and fall densities in other years, likely because foraging trips from sea ice haul outs tend be shorter than from terrestrial haulouts (Udevitz et al. 2009) and large aggregations of walruses on coastal haulouts were not observed in 2008 (Garlich-Miller 2011; Thomas et al. 2010a). Walruses in 2008 were therefore expected to spend less time in water transiting to and from foraging areas.

The number of walruses observed over the course of the open water season for each year from 2008–2011, indicates that the differences in walrus densities between years were in part attributed to when and where the survey vessel was running the transect lines and the timing of formation of coastal haul-outs. In 2009, there was a peak in walrus observations at the end of August that coincided with movement of walruses to coastal haulouts (Fischbach et al. 2009; Garlich-Miller et al. 2011). In 2010, increasing numbers of walrus sightings were recorded starting at the end of August; the period during which coastal haulouts were formed that year (Clarke et al. 2012). In 2011, aerial surveys documented a walrus haulout consisting of ~1,000–2,000 animals near Point Lay starting around mid-August that was occupied by walruses until early October (Clarke et al. 2012). We observed a small peak in sighting rates around mid-August 2011, when these coastal haul-outs were observed to form. An increase in walrus presence was also observed as a peak in walrus call count detections that occurred between 23 August and 5 September and likely indicated a continued migration of walrus to coastal haulouts (Delarue et al. 2012). The peak of walrus sightings from the vessel-based survey during the third week of September was unusually high and likely coincided with walrus movements between coastal haulouts and foraging areas. An increase in walrus call detections were also observed that week (Delarue et al. 2012).

High concentrations of walruses observed in the Burger study area each year likely indicate the presence of a preferred foraging area. The high benthic biomass and abundance in the area compared to the Klondike and Statoil study areas (Blanchard et al. 2011) confirm this assumption. Some of the walruses encountered in the Burger and Statoil study area might be traveling between coastal haulouts and Hanna Shoal, although walrus telemetry data collected in 2008–2011 indicated that areas of heavy foraging in the Chukchi Sea correspond to areas of reported high benthic biomass (Jay et al. 2012). This observation confirms our assumption that high concentrations of walruses observed in the Burger study area likely indicate the presence of a preferred foraging area.

CONCLUSION

- The number of walrus sightings in 2011 was the highest recorded over the past four years. Most of the sightings were recorded in the third week of September, possibly coinciding with walrus movements from sea ice to onshore haulouts.
- As in previous years, highest walrus concentrations were observed in the Burger study area, which is likely used as a foraging area and as a migration route between coastal haul outs and the rich feeding grounds at Hanna Shoal.
- More adult walruses were sighted with juveniles in 2011 compared to previous years, but the reason for this is unclear.

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