FINAL REPORT

MARINE MAMMAL DISTRIBUTION AND ABUNDANCE IN THE NORTHEASTERN CHUKCHI SEA DURING SUMMER AND EARLY FALL, 2008−2012

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FINAL REPORT
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TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS iii
EXECUTIVE SUMMARY iv

CHAPTER 1 GENERAL SURVEY INFORMATION 1-1
INTRODUCTION 1-1
- Purpose and Objectives 1-2
- Structure of this Report 1-2

STUDY AREA 1-3
METHODS 1-5
- Survey Design 1-5
- Data Collection Protocol 1-6
  - Environmental Data 1-7
  - Sighting Information 1-7
- Data Analyses 1-8
  - General Survey and Marine Mammal Sighting Information 1-8
  - Annual Variation in Marine Mammal Density and Distribution 1-8
  - Ecological Relationships 1-10

RESULTS 1-11
LITERATURE CITED 1-17

CHAPTER 2 CETACEAN DISTRIBUTION AND ABUNDANCE 2-1
RESULTS 2-1
- Cetacean Sighting Summary 2-1
- Annual Variation of Bowhead and Gray Whale Abundance and Distribution 2-3
  - Effects of Environmental Conditions on Detection 2-3
  - Bowhead Whales 2-4
  - Gray Whales 2-7

DISCUSSION 2-9
CONCLUSION 2-11
LITERATURE CITED 2-11
ATTACHMENT A: Additional Cetacean Sightings **........ 2-12**

CHAPTER 3 SEAL DISTRIBUTION AND ABUNDANCE 3-1
RESULTS 3-1
- Seal Sighting Information 3-1
- Annual Variation in Seal Density and Distribution 3-4
  - Effects of Environmental Conditions on Detection 3-4
  - Seal Density 3-5
  - Seal Distribution 3-10

DISCUSSION 3-13
CONCLUSION 3-14
LITERATURE CITED 3-15

CHAPTER 4 WALRUS DISTRIBUTION AND ABUNDANCE 4-1
RESULTS 4-1
Walrus Sighting Information 4-1
Annual Variation in Walrus Density and Distribution 4-3
Effects of Environmental Conditions on Detection 4-3
Walrus Density 4-5
Walrus Distribution 4-7
DISCUSSION 4-9
CONCLUSION 4-10
LITERATURE CITED 4-11
ACKNOWLEDGMENTS 4-12

ACRONYMS AND ABBREVIATIONS

~	approximately
°	degree
Δ	delta
%	percent
ADCP	Acoustic Doppler Current Profiler
AIC	Akaike's Information Criterion
ASAMM	Aerial Survey Arctic Marine Mammals
Aug	August
Bf	Beaufort Windforce
BOWFEST	Bowhead Whale Feeding Study
BWASP	Beaufort Sea Aerial Survey Program
CDS	Conventional distance sampling
CHAOZ	Chukchi Acoustic, Oceanographic, and Zooplankton study
CI	Confidence Interval
COMIDA	Chukchi Offshore Monitoring in Development Area
CSESP	Chukchi Sea Environmental Studies Program
e.g.	exempli gratia (for example)
fig.	figure
GHS	Greater Hanna Shoal
i.e.	id est (that is)
ind	individuals
ind h^{-1}	individuals per hour
ind km^{-2}	individuals per square kilometer
g m^{-2}	gram per square meter
km	kilometer
km^{2}	square kilometer
km^{-1}	per kilometer
km h^{-1}	kilometer per hour
m	meter
MCDS	Multiple Covariate Distance Sampling
MRDS	Mark-Recapture Distance Sampling
M/V	Merchant Vessel
n	number (sample size)
N	north (latitude)
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
OCSEAP	Outer Continental Shelf Environmental Assessment Program
Oct	October
R/V	Research Vessel
Sep	September
sight	sightings
SLR	Single Lens Reflex camera
USA	United States of America
W	west (longitude)

EXECUTIVE SUMMARY

The Chukchi Sea Environmental Studies Program (CSESP) is an integrated ecosystem-based survey involving physical and chemical oceanography, plankton, benthos, fish, sea bird, marine mammal, and acoustic study components. The main purpose of this integrated approach has been to increase understanding of how the continental shelf in the northeastern Chukchi Sea functions ecologically. This information will be used 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. The integrated approach provides a more powerful tool for understanding, and therefore predicting, marine ecosystem changes than considering the components separately.

ConocoPhillips initiated and managed the CSESP program in 2008 and 2009, with cofunding and participation of Shell. Since 2010, Statoil joined this initiative, and Olgoonik-Fairweather provided overall management and logistics support on behalf of the three sponsors. The CSESP focused on the companies' respective offshore lease areas in 2008−2010. In 2011 and 2012 the study area was expanded to include Hanna Shoal and areas outside the leased prospects (referred to as the Greater Hanna Shoal [GHS] study area), to provide a broader assessment of previous years' results. The 2012 data completes the fifth year of information collected on marine mammal distribution and abundance in the northeastern Chukchi Sea. This report summarizes and compares the 2012 Chukchi Sea marine mammal data to the results from previous years (2008–2011).

During the 2012 study, we conducted 10,027 km on- and off-transect observation effort in the Chukchi Sea, including transits to and from Wainwright and Nome. We recorded an estimated total of 1,698 marine mammals in the Chukchi Sea, which included 272 cetacean sightings (394 animals), 838 seal sightings (886 animals), 588 walrus (*Odobenus rosmarus*) sightings (4,541 animals), and 14 polar bear (*Ursus maritimus*) sightings (18 animals). In addition, we opportunistically observed 9 whale (28 animals), 14 seal (17 animals), and 15 walrus sightings (168 animals) when there was no dedicated observation effort. We have seen few polar bears in the northeastern Chukchi Sea during the CSESP program, which is not surprising since the study occurs during the open-water season and polar bears are strongly associated with sea ice. The 14 polar bear sightings of 18 animals observed in the Chukchi Sea in 2012 resulted in the highest sighting rate of the 2008−2012 CSESP studies (0.124 ind 100 km^{-1}), very likely due to the presence of scattered sea ice until late September. One bear was seen feeding on top of a floating bowhead whale carcass.

The main conclusions based on the 2012 data compared to results from previous years and other marine mammal studies are as follows:

- Bowhead whale (*Balaena mysticetus*) density in 2012 was the highest of all five years of CSESP surveys (0.004 ind km^{-2}). Unlike previous years, most bowhead whales were sighted regularly throughout September.
- In 2012, the highest bowhead sighting rate (ind 100 km^{-1}) occurred in the GHS. Among the three prospect-specific study areas, we recorded most bowhead whales in the Burger and Statoil study areas, and none in the Klondike study area
- Gray whale (*Eschrichtius robustus*) sighting rates (ind 100 km^{-1}) were higher in 2012 compared to previous years, mostly nearshore as expected. Preliminary quantitative analyses showed a positive relationship between gray whale distribution and amphipod biomass in the study area.

- As in previous years, no beluga whales (*Delphinapterus leucas*) were observed during the summer and early fall, which is to be expected considering their distribution pattern and the timing of our survey (August through mid-October).
- Minke whales (*Balaenoptera acutorostrata*), killer whales (*Orcinus orca*), and harbor porpoises (*Phocoena phocoena*) were again recorded in 2012. Although these species occurred in low numbers, the encounters over the past five years suggest that these species are regular visitors to the northeastern Chukchi Sea.
- We recorded one humpback whale (*Megaptera novaeangliae*) in the Chukchi Sea in 2012 for the first time since the start of the CSESP surveys in 2008. However, this sighting is not unique. Subsistence hunters have spotted humpback whales regularly in low numbers around Barrow and there have been several confirmed sightings of humpback whales in the northeastern Chukchi Sea in recent years.
- The 2012 densities of ringed/spotted[1] (*Phoca hispida/largha*) and bearded seals (*Erignathus barbatus*) in each study area were within the range of densities observed in the previous four years.
- In 2012, consistent with 2010 and 2011, ringed/spotted seal density was highest in the Statoil study area. Unlike previous years, when densities in Klondike tended to be higher than or equal to those in Burger, the 2012 ringed/spotted seal density was higher in Burger than in Klondike.
- Higher ringed/spotted seal densities in the summer versus the fall during heavy-ice years (2008 and 2012) imply that sea ice presence was an important factor influencing the distribution of ringed/spotted seals. During light-ice years (2009–2011) densities were highest in the fall.
- The distribution of bearded seals within the three prospect-specific study areas in 2012 was similar to previous years. Most seals were recorded at Statoil, followed by Burger and Klondike.
- Trophic interactions, i.e., competition for food and walrus predation, might play a role in the distribution pattern of bearded seals across study areas. Although the Burger study area is richer in benthic prey organisms, bearded seals were more abundant in the Statoil study area.
- No seasonal density pattern was apparent for bearded seals in 2012. Seasonal occurrence of bearded seals over the past five years was highly variable. Also, no pattern between heavy (2008 and 2012) and light ice years (2009−2011) was apparent. We therefore conclude that sea ice did not influence the seasonal distribution of bearded seals.
- The number of walrus sightings in 2012 was the highest recorded over the past five years. Most sightings were recorded in September, coinciding with the presence of sea ice and the start of coastal haul-out formation.
- In 2012, walrus densities within the Klondike and Statoil study areas were similar as in previous years. The 2012 densities in the Burger study area were similar to 2011, but higher than 2008–2010.

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[1] 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.

- Consistent with previous years, we observed highest walrus densities in the Burger study area. Surveys in the GHS study area in 2011 and 2012 showed that this concentration extended eastward and northwards toward Hanna Shoal.
- The high concentrations of walruses observed in Burger, extending eastward and northward as observed in 2012 and 2011, coincide with high bivalve biomass, thus indicating the presence of a preferred foraging area.

CHAPTER 1

GENERAL SURVEY INFORMATION

INTRODUCTION

Marine mammal research in the Chukchi Sea has a history spanning over at least 30 years. In 1975, an extensive research program was developed under the Outer Continental Shelf Environmental Assessment Program (OCSEAP)[2] to establish an environmental baseline for the Alaska OCS, including the Beaufort and Chukchi Seas. The OCSEAP objective was to collect sufficient data to predict potential impacts of oil and gas exploration and development activities and to 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). Since 1979, 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 (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 over 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 Aerial Surveys of Arctic Marine Mammals (ASAMM) project is a continuation of the BWASP and COMIDA aerial surveys and has been flown in 2011 and 2012.

The increased focus on Chukchi Sea research is mainly due to a renewed interest in offshore oil and gas activities combined with potential threats to the arctic marine ecosystem from climate change. Marine mammal monitoring and acoustic programs were implemented as part of industrial activities in the Chukchi Sea from 1989 to 1991 and annually since 2006, primarily as mitigation but also to document potential impacts from anthropogenic activities (e.g., Brueggeman et al. 1990, 1991, 1992a, 1992b, 2009a; Funk et al. 2008, 2010; Ireland et al. 2009; Blees et al. 2010). Satellite-tagged bowhead and beluga whales have provided useful information on whale movements and migration patterns (Suydam et al. 2001, 2005; Quakenbush et al. 2010). Similarly, detailed information on seasonal movements, habitat use, and foraging behavior of bearded seals, ringed seals, and walruses has been obtained through the use of satellite tags, radio transmitters, and dive recorders (Lowry et al. 1998; Jay and Hills 2005; Jay et al. 2006, 2010, 2012; 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, contributing greatly to their success. Detection of marine mammal vocalizations by bottom-founded acoustic recorders has revealed interesting information on spatial and temporal migration patterns (e.g., Berchok et al. 2010; Delarue et al. 2011; Martin et al. 2009; Moore et al. 2006).

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[2] OCSEAP was initiated by inter-agency agreement between DOI's Bureau of Land Management (BLM) [now, Bureau of Ocean Energy Management, BOEM] and the Department of Commerce's national Oceanic and Atmospheric Administration (NOAA).

Although the Chukchi Sea research effort has been extensive, most studies were designed and implemented as stand-alone programs, making it difficult to integrate research findings. Exceptions are the Bowhead Whale Feeding Ecology Study (BOWFEST) of 2007−2011 (e.g., Berchok et al. 2010; Goetz etal. 2010; Shelden and Mocklin 2012) and the multi-year 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.

ConocoPhillips initiated and managed a multi-year interdisciplinary research program in 2008 and 2009, with cofunding and participation by Shell. Statoil joined this initiative in 2010 and Olgoonik-Fairweather provided overall management and logistics support on behalf of the three sponsors. This 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. Data collected in three prospect-specific study areas 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. 2013). In 2011 and 2012 the study area was expanded to include Hanna Shoal and areas outside the leased prospects, affording a broader assessment of 2008–2010 results. The 2012 data completes the fifth year of information collected on marine mammal distribution and abundance in the northeastern Chukchi Sea. This report summarizes and compares the 2012 marine mammal data to the results from previous years (2008–2011). The 2012 study area discussed in this report is shown in Figure 1.1.

Purpose and Objectives

The purpose of the CSESP vessel-based marine mammal study during the open-water 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, contribute to 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 CSESP will also be used to develop monitoring plans for future offshore oil and gas exploration and development.

Three objectives have been identified to achieve the purpose of this marine mammal study, as listed below. Objectives 1 and 2 are discussed in this report. Objective 3 requires more detailed analyses and will be addressed in separate publications.

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 study area; and
3. Integrate marine mammal results with other components of the CSESP to increase our understanding of ecological relationships.

Structure of this report

This 2012 marine mammal report follows the structure of the 2011 report that presented marine mammal information in separate chapters. Each chapter summarizes the results of a group of species (whales, seals) or of one species (walrus) focusing on the two first objectives listed above. The chapters of this report and a brief description of their contents are as follows:

CHAPTER 1 (current chapter) introduces the overall program, describes the study area, survey design, data collection protocol, and data analyses approach. In addition, the current chapter summarizes general survey results, including total sampling effort, overall environmental conditions, and total number of marine mammal sightings. The limited polar bear sighting information did not warrant a separate chapter; hence these data are summarized in the results section of this chapter. The data analyses approach and general survey results are relevant to the marine mammal sighting information presented in Chapters 2–4, but are not repeated in those chapters.

CHAPTER 2 summarizes the 2012 CSESP results of cetacean presence and distribution and compares them with past CSESP surveys. We also present some preliminary results on gray whale distribution (as observed during five years of CSESP surveys) in relation to the distribution of their preferred prey, i.e., amphipods.

CHAPTER 3 summarizes the 2012 CSESP results of seal abundance and distribution and also compares them to previous years. We specifically focus on the annual and seasonal abundance of ringed, spotted, and bearded seals and their spatial distribution within the three prospect-specific study areas and in the expanded Greater Hanna Shoal study area.

CHAPTER 4 summarizes the 2012 CSESP results of walrus abundance and distribution and compares them to previous years. We specifically focus on the annual and seasonal abundance and spatial distribution within the three prospect-specific study areas and in the expanded Greater Hanna Shoal study area.

STUDY AREAS

The CSESP study areas have changed over the past five years. In 2008 and 2009, the study areas locations were chosen based on two Chukchi Sea offshore prospects of interest to ConocoPhillips and Shell; 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 size of each of the three study areas is ~3000 km^2. In 2011 and 2012 a larger area was sampled, expanded eastward and westward to encompass the three prospect-specific study areas and northwards to include Hanna Shoal, an area of ecological importance in the northern Chukchi Sea (Fig. 1.1). The larger study area is referred to as “Greater Hanna Shoal (GHS)” and covers an area of about 38,000 km^2. Data were also recorded during transits to and from Wainwright or Nome for crew changes and/or supply delivery, during buoy deployments and retrievals, and during other vessel activities.

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 the mainland of Alaska and the Beaufort Sea. Its size is about 595,000 km2, 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 and Statoil study areas 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. 1.2). The extent of temperature and salinity differences among the three study areas varied from year to year, depending on factors such as sea ice cover and prevailing wind speed and direction. This was also apparent in 2011, when early ice retreat combined with a greater heat flux through the Bering Strait, resulted in warmer water temperatures in the upper 15 m in August compared to previous years

(Weingartner et al. 2012). The different physical characteristics are reflected by contrasting planktonic, benthic, and seabird communities (Blanchard et al. 2013 a, 2013b; Gall et al. 2012, Questel et al. 2012).

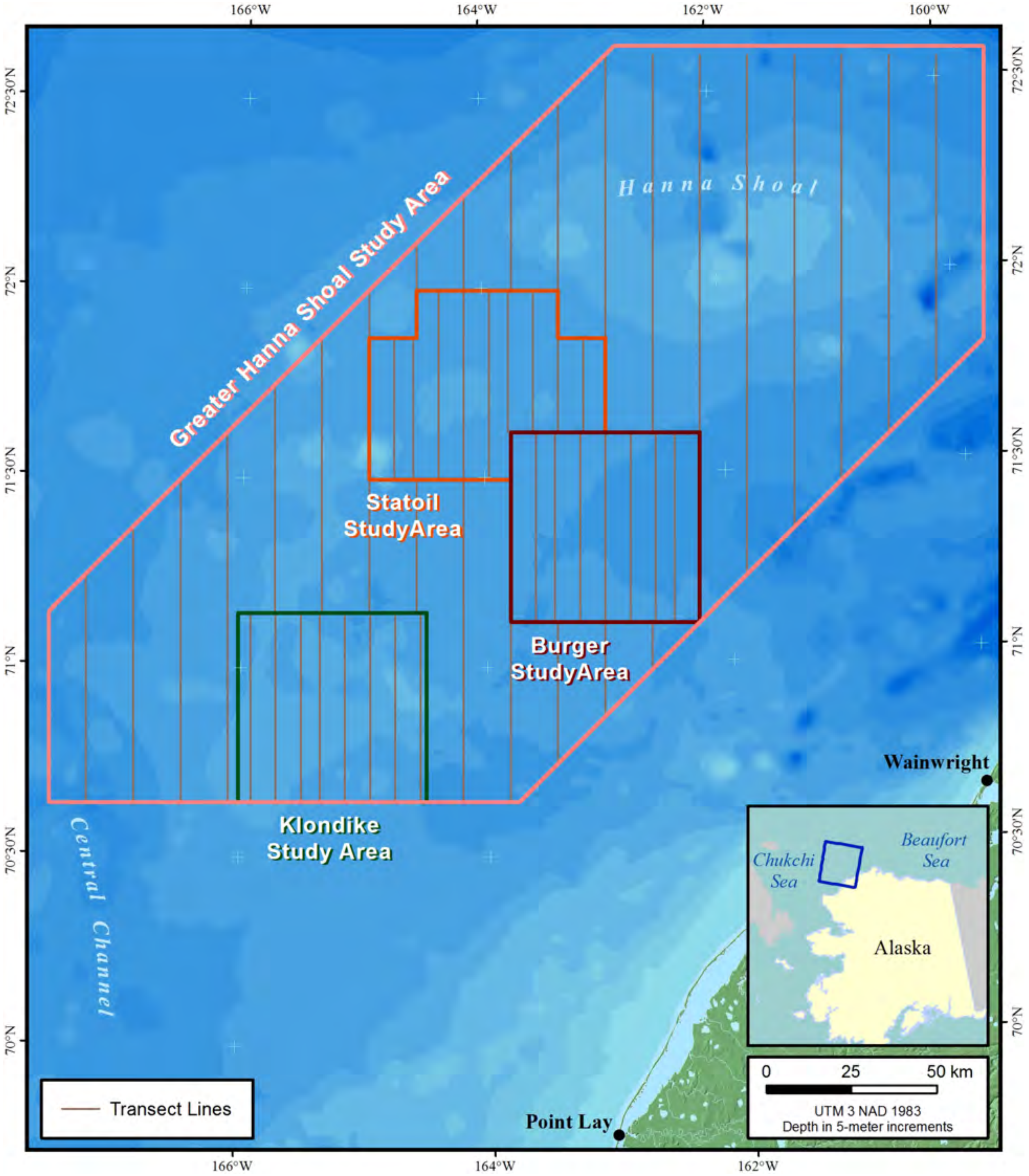


Figure 1.1. GHS study area in the northeastern Chukchi Sea, including the three prospect-specific study areas and transect lines.

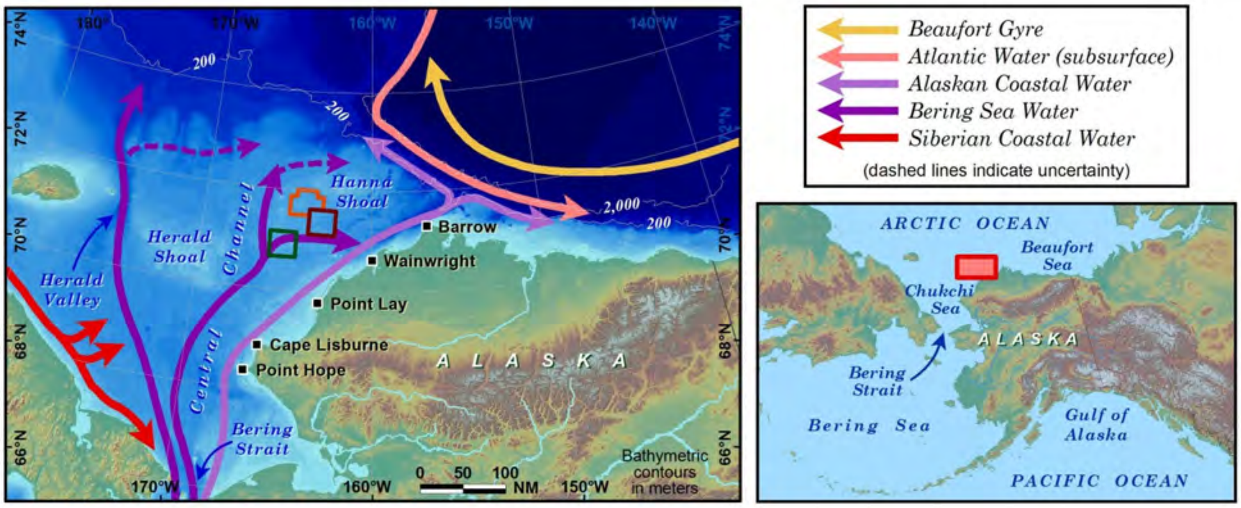


Figure 1.2. Main geographic features and prevailing currents in the Chukchi Sea. The orange, dark red, and green polygons represent the three prospect-specific study areas as shown in Figure 1.1. Currents modified from Weingartner et al. (2008).

METHODS

This section outlines the methods and observation protocol used during the 2012 CSESP marine mammal survey. Generally, the observation protocol is similar to that used in 2008–2011. The *R/V Westward Wind* was used as platform for marine mammal line transect surveys in 2009−2011 and again in 2012. Opportunistic surveys during buoy deployments and retrievals and vessel transits in 2012 were done from both the *Westward Wind* and *R/V Norseman II* (Fig. 1.3). In 2008 the marine mammal observation platform for line-transect surveys was the *M/V Bluefin,* and one line-transect survey in 2010 was conducted from the *R/V Norseman II*.

Survey Design

We recorded data along north-south oriented transect lines in each of the three study areas and in the GHS study area (Fig. 1.1). Transect line spacing in the GHS study area was variable, with lines every 11−13 km outside and 5.6−7 km inside the prospect-specific study areas. The denser sampling grid inside the Klondike, Burger, and Statoil study areas allowed for a better comparison with results from previous years, when line spacing was 3.7 km. Data collection took place during two separate cruises. On the first cruise transect lines were surveyed only in the three prospect-specific study areas. During the second cruise transect lines were surveyed within the entire GHS study area (which includes the prospect-specific study areas). Detailed information on survey dates and effort is provided in the section General Survey Results. Additionally, we collected data on an opportunistic basis during acoustic buoy deployments and retrievals in the Chukchi Sea, during vessel activities for other scientific disciplines, and during transits between the GHS study area and the Beaufort Sea, Wainwright or Nome.

Figure 1.3. The research vessel *R/V Westward Wind* (A) was used both for line-transect and opportunistic surveys, while the *R/V Norseman II* (B) was only used for opportunistic surveys in 2012. Photo credit: CSESP.

Data Collection Protocol

One dedicated observer searched for marine mammals during daylight hours from the bridge or flying bridge of the vessels, with eye height ~5–6.5 m above sea level. The observer systematically scanned an area of 180° centered on the vessel's trackline with the naked eye and Fujinon 7x50 reticle binoculars while the vessel moved at speeds ranging from 5 to 9 knots (~9.3–17 km h^{-1}). Observers alternated watch every 2 hours during daylight. Line transects were surveyed for about 10 to 14 hours per day during, depending on weather conditions, day length, and the schedule of other scientific activities on the vessel. The Inupiat marine mammal observer, located on the bridge, assisted in the monitoring effort and passed on sighting information to the dedicated observer. All sighting data were used in the analyses. 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 species identification.

Recorded data were defined as "on-transect" 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 were defined as "off-transect." Observers resumed "on-transect" effort once the vessel returned to transect course and speed. Data were defined as "non-transect" if the effort was less than 1 km, or in situations when observers were not on dedicated watch (e.g., when the vessel was stationary, circling at one location for buoy deployment and retrieval, or a record was entered just to record a sighting). Non-transect data was not included in the total line km effort.

The on-watch observer entered environmental and sighting information directly onto a Panasonic Toughbook™ computer using TigerObserver™ data acquisition software that was specifically developed for this science program. Navigation based software (TigerNav™) continuously logged vessel information, such as date, time, vessel position, vessel speed, and water depth. Both TigerNav™ and TigerObserver™ were synchronized to a server system on the vessel. Similarly, Acoustic Doppler Current Profiler (ADCP), thermosalinograph, and meteorological equipment recorded and stored air and sea surface temperature, salinity, wind speed, wind heading, and atmospheric pressure data on the server. The relevant navigational and oceanographic data were automatically linked to marine mammal sighting data.

Environmental Data

Environmental conditions 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, with 10 km or more indicating the horizon a clear day), ice cover (in 10% increments, estimate of 360° area within a 2-km radius from the vessel), 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 (non-adults; determined based on size or presence of mother), 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. The vessel did not approach sighted animals to collect this data.

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 far distance. The category "ringed/spotted seal" therefore was used to record seal sightings that could not be confirmed as either a ringed or spotted seal.

We used reticle binoculars (when the horizon was visible) or eye estimates to visually determine distances to marine mammals. 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 (about 500 m or less) from the vessel. The range finder, clinometer, and radar of the vessel were occasionally used for verification of estimated distances when a suitable target (e.g., ice or other vessel) was present.

Visual observations and effort data 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 during better conditions when possible. The visibility criterion was established to match the seabird observation protocol.

Data Analyses

This section describes the data analyses approach of the 2012 marine mammal survey data, starting with a summary of the data structure. The data analyses presented in this Chapter is mainly relevant to the results presented in Chapters 2–4, but are not repeated in those chapters.

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

- On-transect: data recorded when the vessel traveled along the north-south oriented transect lines within the prospect-specific study areas and the GHS study area.
- Off-transect: data recorded when the vessel deviated more than 600 m from the transect line, or when the vessel traveled along other lines than the transect line (for example transect connectors, transits to buoy recorder and retrieval locations, and transits to and from Wainwright and Nome.)
- Non-transect: data recorded opportunistically when no observers where on dedicated watch, for example when the vessel was stationary (e.g., in safe harbor due to storms or on anchor at approximately 1 mile off the coast of Wainwright), at a buoy deployment or retrieval location, or when a record was entered just to record a sighting.

General Survey and Marine Mammal Sighting Information

We used on- and off-transect data to summarize general survey information, consisting of survey environmental conditions and sightings of marine mammals. This chapter presents the results of environmental conditions from the 2012 survey and compares them with 2008−2011 data. This chapter also contains an overview of the polar bear sighting results, since the limited polar bear sighting information did not warrant a separate chapter n polar bears. Results of the cetacean, ice seal, and walrus observation data are included in Chapters 2, 3, and 4, respectively.

Annual Variation in Marine Mammal Density and Distribution

This section summarizes the data analyses approach used to determine the annual variation in density and distribution of cetaceans, ice seals, and walrus. The results of these analyses are presented in Chapters 2−4.

Species densities

We analyzed distribution and abundance patterns for bowhead whales, seals, and walruses by estimating corrected densities (number of individuals [ind] km^{-2}) for each study area and year using distance-sampling methodology (Buckland et al., 2001, 2004). This smethodology 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. As a result, such calculations can be underestimated by these types of detection bias as described below (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.

Information and surface time for bowheads, seals, and walruses during the open water period in the Chukchi Sea does not exist. Thus, availability bias could not be taken into account in this study. Likewise, no information was collected to confirm that all animals on the transect line were detected. Therefore, the assumption of g(0)=1 further underestimates our density data.

We used software program Distance 6.1 Release 1 (Thomas et al., 2010) for modeling a detection function for seal, walrus, and bowhead whale sighting data. The number of other cetacean sightings (on-transect) was too low to model a detection function with confidence (n < 60). The detection function allows for correction of density data due to perception bias. It estimates the proportion of animals missed at different perpendicular distances from the transect line taking into account environmental variables. 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 2008–2012 data, based on the following criteria:

- Only on-transect data were used. These are the observations made while traveling along the north-south oriented 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 is very different than in water. The total number of sightings on-transect and on ice was too low for calculating a separate detection function for on-ice sightings (seal n = 5; walrus n = 11).
  - Combining (i.e., pooling) species of similar size, behavior, and color for datasets with low sample sizes. This resulted in grouping all ringed and spotted seal sighting data (including sightings categorized as ringed/spotted seals), and calculating separate detection functions for bearded seal and walrus.

For each species or species group, we used Conventional Distance Sampling (CDS) and Multiple Covariate Distance Sampling (MCDS) analyses tools to find the model that best fitted the distribution of perpendicular distances. We tested various strategies for truncation and binning of perpendicular distances. We included covariates in the model that, besides distance, also have the potential to affect probability of detection (i.e., sea state, visibility, glare amount, observer, and vessel). We assessed the fit of two different model types (hazard-rate and half-normal) with diagnostic plots, the Kolmogorov goodness-of-fit test, and the Akaike's Information Criterion or AIC (following Buckland et al., 2004). The input parameters of the best-fitted model were entered into the distance-sampling model portion of the Mark Recapture Distance Sampling (MRDS) engine that allowed us to apply the estimated detection function to a subset of the data. To calculate densities for each study area and year, we pooled all data collected throughout the survey season. Likewise, for the calculation of seasonal densities per year we pooled the 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 (i.e., group 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.

Because identifying individual spotted and ringed seals was challenging (i.e., only about 30% positive identification for each species), we pooled all ringed and spotted seal sightings together with the combined ringed/spotted seal category for the density analyses. As an indication for the contribution of ringed and spotted seals to the total combined ringed/spotted seal densities, we estimated the density of confirmed ringed and spotted seal sightings for all five years (2008-2012) combined. We then calculated the ratio between identified ringed and spotted seal densities that could be applied to the combined ringed/spotted seal annual and seasonal densities. We justify this approach by assuming that the challenge of identifying ringed and spotted seals is similar. This assumption seems reasonable considering the similarity in appearance and behavior of these species in offshore waters.

In addition to the lack of information regarding availability bias and the validity of g(0)=1 (see above), the estimated ringed/spotted and bearded seal densities also represent an underestimate due to the large percent of seal sightings classified as unidentified seals. We therefore also calculated densities of unidentified seals as an indication of the underestimation of ringed/spotted and bearded seal densities.

Spatial distribution

To visualize spatial distribution patterns during 2012 we plotted sighting rates (ind km^{-1}) in 5 × 5 nm grid cells within the three prospect-specific and GHS study areas. This was done for bowhead whales, ringed/spotted seals, bearded seals, and walruses. We calculated sighting rates for each 5 × 5 nm grid cells using on- and off-transect data, provided that off-transect efforts were 1 km or more in length. A similar map was developed for the combined 2008–2011 data, to compare the distribution pattern observed in 2012 with previous years.

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. The collective CSESP papers, and specifically the paper "The offshore northeastern Chukchi Sea, Alaska: a complex high-latitude ecosystem" (Day et al. 2013) addresses this relationship qualitatively. A quantitative approach, requiring a larger effort involving multi-variate analyses, has not yet been initiated.

We also performed some preliminary quantitative analyses regarding the relationship between gray whale distribution and prey availability. We calculated and plotted gray whale sighting rates (ind hour^{-1}) in 5 × 5 nm grid cells. We decided to calculate sighting rates on a time-based effort instead of a distance-based effort to include sightings recorded at times that the vessel was stationary. The average duration that observations were made from a stationary vessel was 33 minutes, with a maximum of 137 minutes. We created kriging maps using average amphipod biomass values of the 2008-2011 CSESP benthic data (Blanchard and Knowlton 2013) and historical data (Feder et al. 1994). Kriging is based on the theory that the value at an unknown point should be the average of the known values at its neighbors; weighted by the neighbors' distance to the unknown point. The gray whale distribution pattern based on sighting rates and the benthic biomass maps were then combined to assess the relationship between whale and prey distribution. We intend to conduct additional efforts to integrate visual and acoustic marine mammal data with oceanographic and lower trophic data in a collaborative effort between CSESP and other science programs.

RESULTS

We conducted dedicated vessel-based line-transect surveys off the *Westward Wind* from August 15 to October 4, 2012, split into three separate cruises (Table 1.1). Besides collecting data during line-transect surveys, observers were also onboard the *Westward Wind* and *Norseman II* during buoy deployment and retrieval cruises in the Chukchi Sea (mooring cruises) to record marine mammal observations while the vessel was transiting to and from buoy locations.

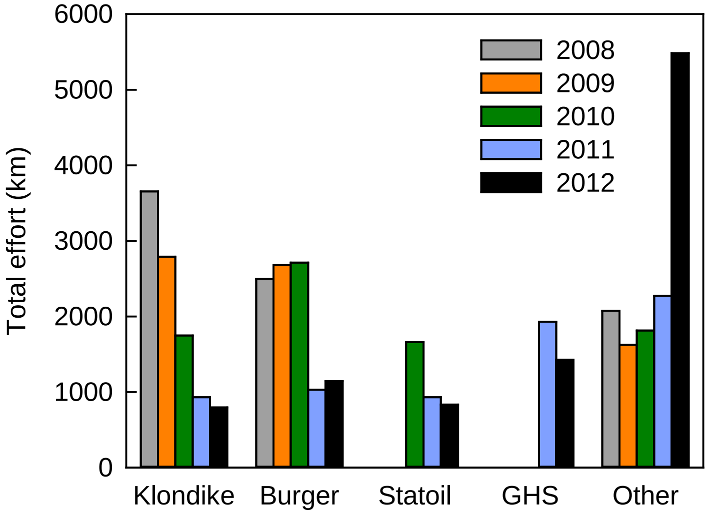
Table 1.1. Start and end dates of 2012 CSESP cruises from the *R/V Westward Wind and R/V Norseman II*.

Westward Wind		Norseman II	
Dates	**Description**	**Dates**	**Description**
Aug 6 - 7	Transit to Chukchi	-	-
Aug 8 - 13	Chukchi Mooring	-	-
Aug 15	Crew Change - Wainwright	-	-
Aug 15 - 26	Cruise 1: Joint Studies	-	-
Aug 29	Crew Change - Wainwright	-	-
Aug 30 - Sep15	Cruise 2: Joint Studies	Sep 8	Crew Change - Wainwright
Sep 16	Crew Change - Wainwright	Sep 8 - 14	Chukchi Mooring
Sep17 - Oct 4	Cruise 3: Joint Studies	Sep 14	Crew change - Wainwright
Oct 4	Crew Change - Wainwright	Oct 10 - 11	Transit to Chukchi
Oct 4 - 15	Chukchi Mooring	Oct 12 - 16	Chukchi Mooring
Oct 14	Transit to Nome	Oct 16	Transit to Nome
Oct 15	Crew Change - Nome	Oct 17	Crew change - Nome

Similar to the 2011 survey, we sampled the three prospect-specific study areas during the first cruise and the GHS study area (including the prospect-specific study areas) during the second and third cruises. The 2012 on-transect effort in the study areas was therefore comparable to the 2011 effort (Fig. 1.4). Due to the wider line spacing in the three prospect-specific study areas in 2011 and 2012, the total amount of linear kilometers surveyed was smaller than in previous years. The presence of dedicated observers on board the vessels during mooring cruises in 2012 increased the off-transect effort compared to previous years (Fig. 1.4, Table 1.2).

In the Chukchi Sea, we conducted 10,027 km of on- and off-transect observation effort, including transits to and from Nome. During this effort, we recorded 272 cetacean sightings (394 animals), 838 seal sightings (886 animals), and 588 walrus sightings (4541 animals). In addition, we opportunistically recorded 9 whale sightings (28 animals), 14 seal sightings (17 animals), and 15 walrus sightings (168 animals). Further details about seal, walrus, and cetacean data are provided in Chapters 2–4.

We have seen few polar bears in the Chukchi Sea during the CSESP program. This is not surprising since the study occurs during the open-water season and polar bears are strongly associated with sea ice. The highest number of polar bear sightings was recorded in 2012 when scattered sea ice was present in the study area until late September (Table 1.3, Fig. 1.5). One bear was seen feeding on top of a floating bowhead whale carcass.



	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	1031	933	1931	2275	7103
2012	**798**	**1144**	**836**	**1430**	**5481**	**9690**
Total	9927	10075	3429	3361	13274	40066

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

Figure 1.4 and Table 1.2. Summary of 2012 effort (in km) in comparison with previous years. The category 'Other' contains all off-transect effort in the Chukchi Sea and transit to and from Nome. Effort during sea states >Bf 5 (241 km) are not included.

Table 1.3. Summary of polar bear sightings in the Chukchi Sea for 2012 and previous years. One polar bear in water was feeding on a bowhead whale carcass. Two polar bear sightings recorded in 2012 without associated effort data were not included in the sighting 100 km^{-1} calculation.

	ON ICE		IN WATER		TOTAL		
Year	Sightings	Individuals	Sightings	Individuals	Sightings	Individuals	Sightings 100 km^{-1}
2008	6	8	1	1	7	9	0.085
2009	3	4	0	0	3	4	0.042
2010	2	2	1	1	3	3	0.038
2011	0	0	0	0	0	0	0.000
2012	**9**	**13**	**5**	**5**	**14**	**18**	**0.124**
TOTAL	20	27	7	7	27	34	0.062

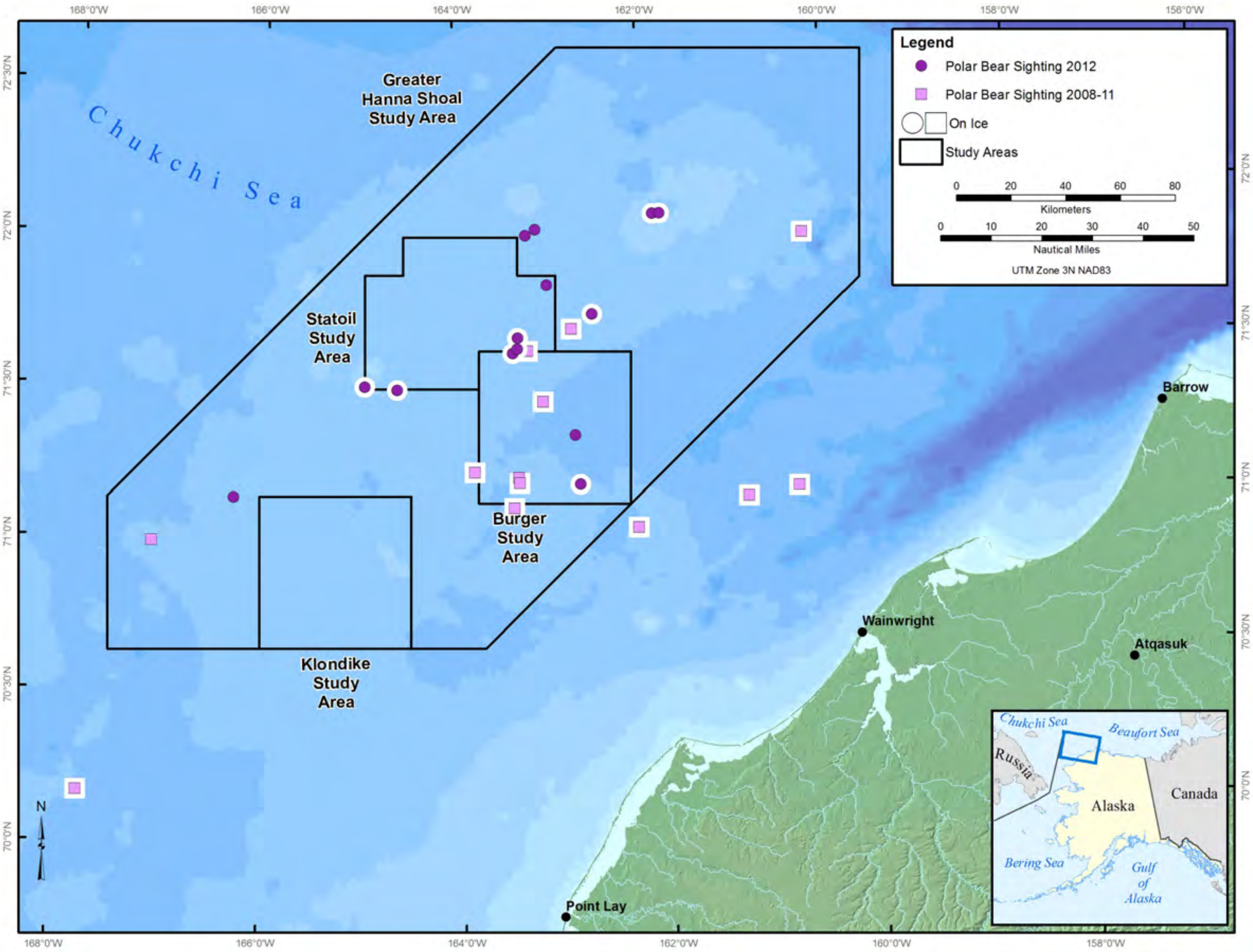
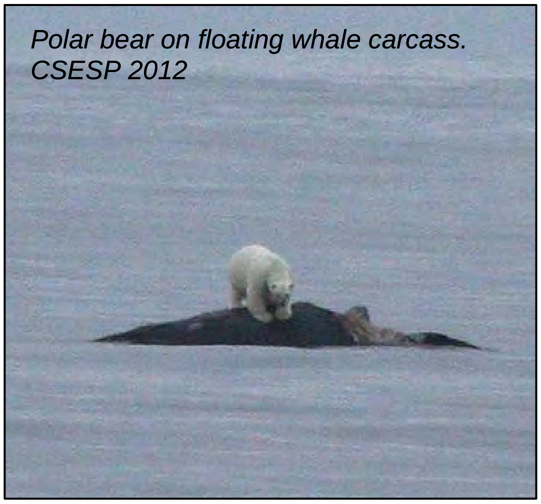


Figure 1.5. Polar bear sightings recorded on- and off-transect in the northeastern Chukchi Sea during August−mid-October 2012 (purple circles) and 2008-2011 (pink squares).

Polar bear on sea ice. CSESP 2012



Polar bear on floating whale carcass. CSESP 2012

Environmental conditions, such as sea state and visibility, influence the effectiveness with which observers are able to detect marine mammals. Average sea state conditions in 2012 were very similar to previous years (Fig. 1.6). However, there was large variation among the three study areas, especially compared to 2008–2010 (Fig. 1.7). The pattern of visibility conditions as recorded during marine mammal efforts in 2012 was similar to previous years. Most effort occurred during visibilities of 8 km or more. The occurrence of visibilities >3.5 to 7 km was the highest of all years (Fig.1.6).

In 2012, sea ice was present in the study areas during August and September. The Klondike study area was ice free early in the season, while floes of sea ice covered the central and northern GHS study area (including Burger and Statoil). Most sea ice retreated out of the study area over the course of the season; however, scattered floes remained in the Burger and Statoil study areas until late September (Fig. 1.8).

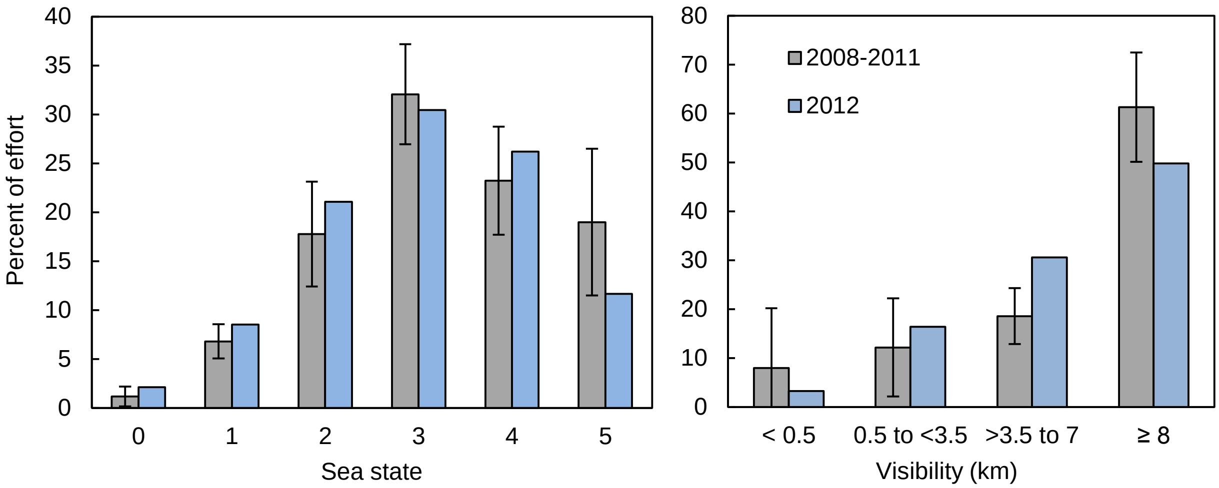


Figure 1.6. Sea state and visibility conditions in 2012 compared to previous years. Sea state is expressed in Beaufort Windforce scale (NOAA) and visibility in kilometers.

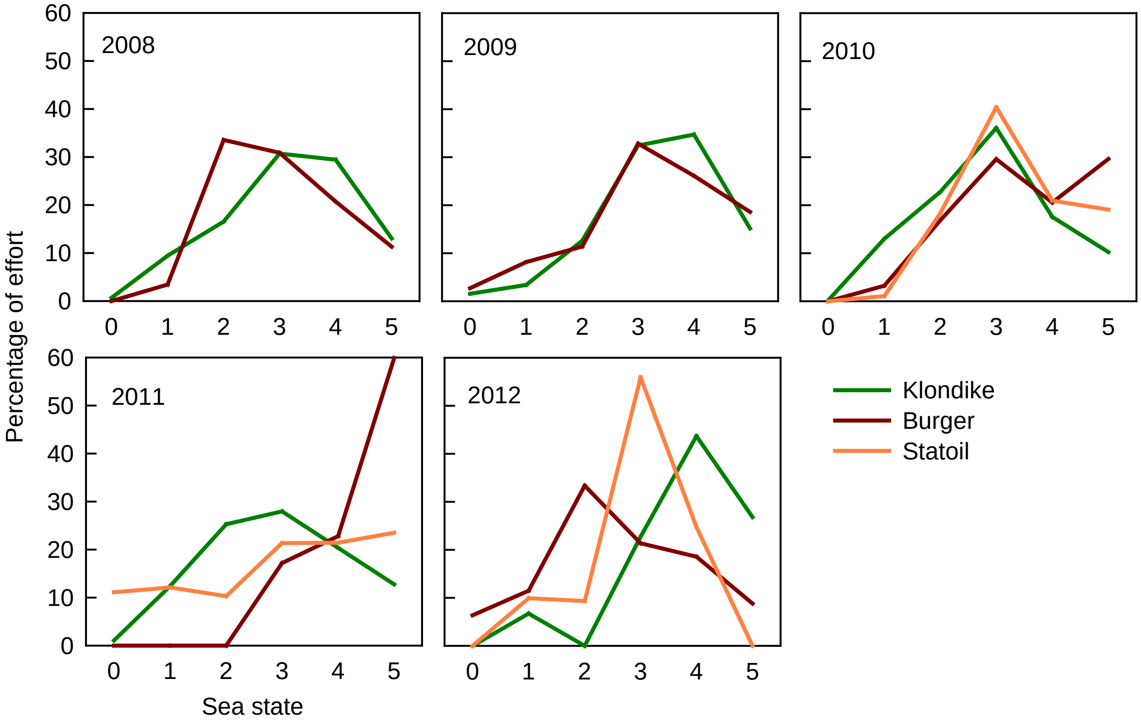
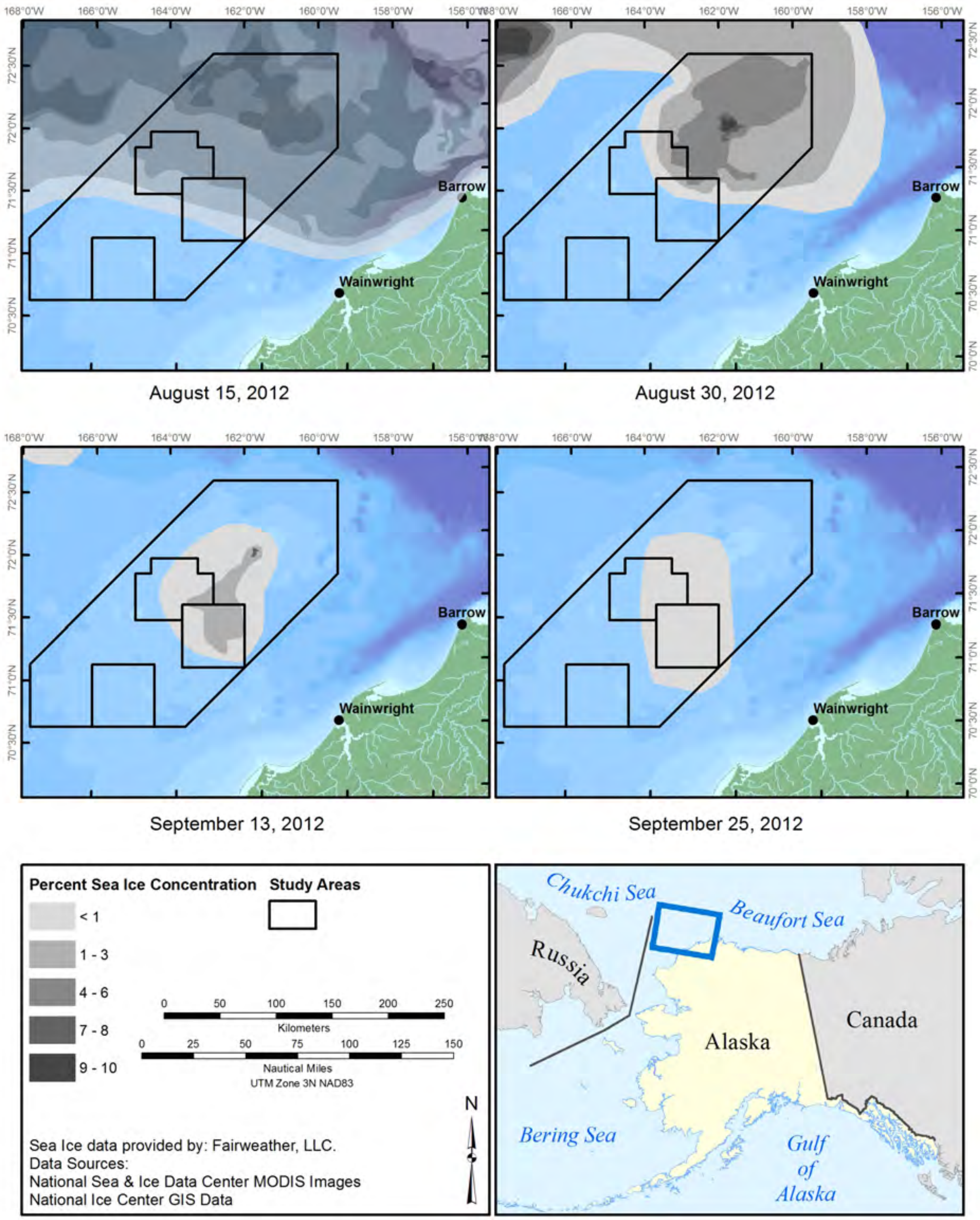


Figure 1.7. Percent of total sampling effort for various sea state conditions for each year and study area. Sea state is expressed in Beaufort Windforce scale (NOAA).


Chukchi Sea ice in September. CSESP 2012


August 15, 2012

August 30, 2012

September 13, 2012

September 25, 2012

Sea Ice data provided by: Fairweather, LLC.
Data Sources:
National Sea & Ice Data Center MODIS Images
National Ice Center GIS Data

Figure 1.8. changes in sea ice concentration in the CSESP study areas during the 2012 season. Marine mammal transect surveys started August 15 and ended August 4.

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CHAPTER 2

CETACEAN DISTRIBUTION AND ABUNDANCE

This chapter summarizes the results of cetacean presence, abundance, and distribution in the northeastern Chukchi Sea from the CSESP vessel-based marine mammal surveys in 2012 and compares them with previous years. We focused in more detail on the annual and seasonal variation in sighting rates of bowhead and gray whales. In addition, we present preliminary results on the distribution of gray whales (as observed during five years of CSESP surveys) relative to the distribution of their preferred prey, i.e., amphipods. Maps showing the sighting locations of fin, humpback, minke, killer, and unidentified whales, and of the harbor porpoise are included in Attachment 1 of this chapter. Information about the survey area and design, observation protocol, and data analyses is provided in the methods section of Chapter 1).

RESULTS

Cetacean Sighting Summary

A total of seven cetacean species were seen in 2012 (Table 2.1). They included bowhead whale (*Balaena mysticetus*), gray whale (*Eschrichtius robustus*), minke whale (*Balaenoptera acutorostrata*), fin whale (*B. physalus*), humpback whale (*Megaptera novaeangliae*), killer whale (*Orcinus orca*), and harbor porpoise (*Phocoena phocoena*). Sighting information of these species in 2012 was as follows:

- The number of bowhead whales was highest in 2012, with 75 confirmed sightings of 105 individuals. A large proportion of the whales recorded as unidentified were likely bowhead whales.
- The number of gray whale sightings was also highest in 2012. As in previous years, we saw gray whales mainly during off-transect effort in nearshore waters.
- During the five years of CSESP surveys observers did not observe any beluga whales (except for one carcass on 10 August 2012 at 71°22'N and 157°93'W).
- In 2012, we saw two minke whales in the Chukchi Sea and one near Nome.
- Observers recorded all six fin whale sightings on 7 August 2012 just north of the Bering Strait, and one humpback whale on 11 August offshore of Barrow.
- The number of killer whale sightings in 2012 was similar to previous years; however the number of individuals was much higher due to a sighting in the Statoil study area on 24 August of a pod estimated to include 30 animals.
- The number of harbor porpoises sighted in the Chukchi Sea in 2012 (six sightings of 13 animals) was higher than in previous years. In addition, there were two sightings of four animals in the Beaufort Sea, at 71°42'N and 71°43'N just northwest of Barrow.

Table 2.1. Number of cetacean sightings, individuals, and sighting rate (Sight 100 km^{-1}) recorded in 2008–2012 for each study area and year. Sighting rate information allows comparison among areas and years. The category "Other" contains off-transect data for which effort information was not always available and sighting rate could therefore not be calculated.

	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
2012																
Bowhead whale	0	0	0	13	14	1.136	5	8	0.598	20	24	1.291	37	59	75	105
Fin whale	0	0	0	0	0	0	0	0	0	0	0	0	6	11	6	11
Gray whale	0	0	0	1	1	0.087	1	1	0.120	0	0	0	77	118	79	120
Humpback whale	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Minke whale	0	0	0	1	1	0.087	0	0	0	0	0	0	2	2	3	3
Unid. whale	0	0	0	11	13	0.961	3	6	0.359	54	58	3.486	40	51	108	128
Killer whale	0	0	0	0	0	0	0	0	0	0	0	0	3	41	3	41
Harbor porpoise	0	0	0	0	0	0	0	0	0	0	0	0	6	13	6	13
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	0.059	41	55	0.385	6	10	0.173	20	24	0.559	57	89	130	185
Fin whale	0	0	0	0	0	0	0	0	0	0	0	0	7	14	7	14
Gray whale	2	3	0.020	4	5	0.038	1	1	0.029	1	2	0.028	150	256	158	267
Humpback whale	0	0	0	0	0	0	0	0	0	0	0	0	6	12	6	12
Minke whale	2	2	0.020	1	1	0.009	0	0	0	0	0	0	7	9	10	12
Unid. whale	2	2	0.020	16	19	0.150	3	6	0.086	55	59	1.538	53	67	129	153
Killer whale	6	13	0.059	0	0	0	0	0	0	0	0	0	5	44	11	57
Harbor porpoise	3	7	0.030	0	0	0	1	2	0.029	0	0	0	10	20	14	29
Dall's porpoise	0	0	0	0	0	0	0	0	0	0	0	0	3	6	3	6

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

Annual Variation of Bowhead and Gray Whale Abundance and Distribution

Effects of Environmental Conditions on Detection

Environmental parameters influence the effectiveness with which observers are able to detect cetaceans. Figure 2.1 shows cetacean sighting rates (number of sightings per 100 km) for each sea state and visibility category. Similar patterns were found when using mysticete data only thus these figures are not displayed. Except for the high sighting rate in 2012 at Beaufort sea state category 0, there was no clear pattern between cetacean sightings rate and sea state category. However, as in 2008–2011, the combined sighting rates in sea states 0-2 was generally higher than for sea states 3-6. Both during 2012 and 2008-2011, cetacean sighting rates were highest when visibility was greater. This is likely due to difficulty of detecting their most common sighting cues, i.e., blow, fluke, or (if present) dorsal fin, in low visibility conditions.

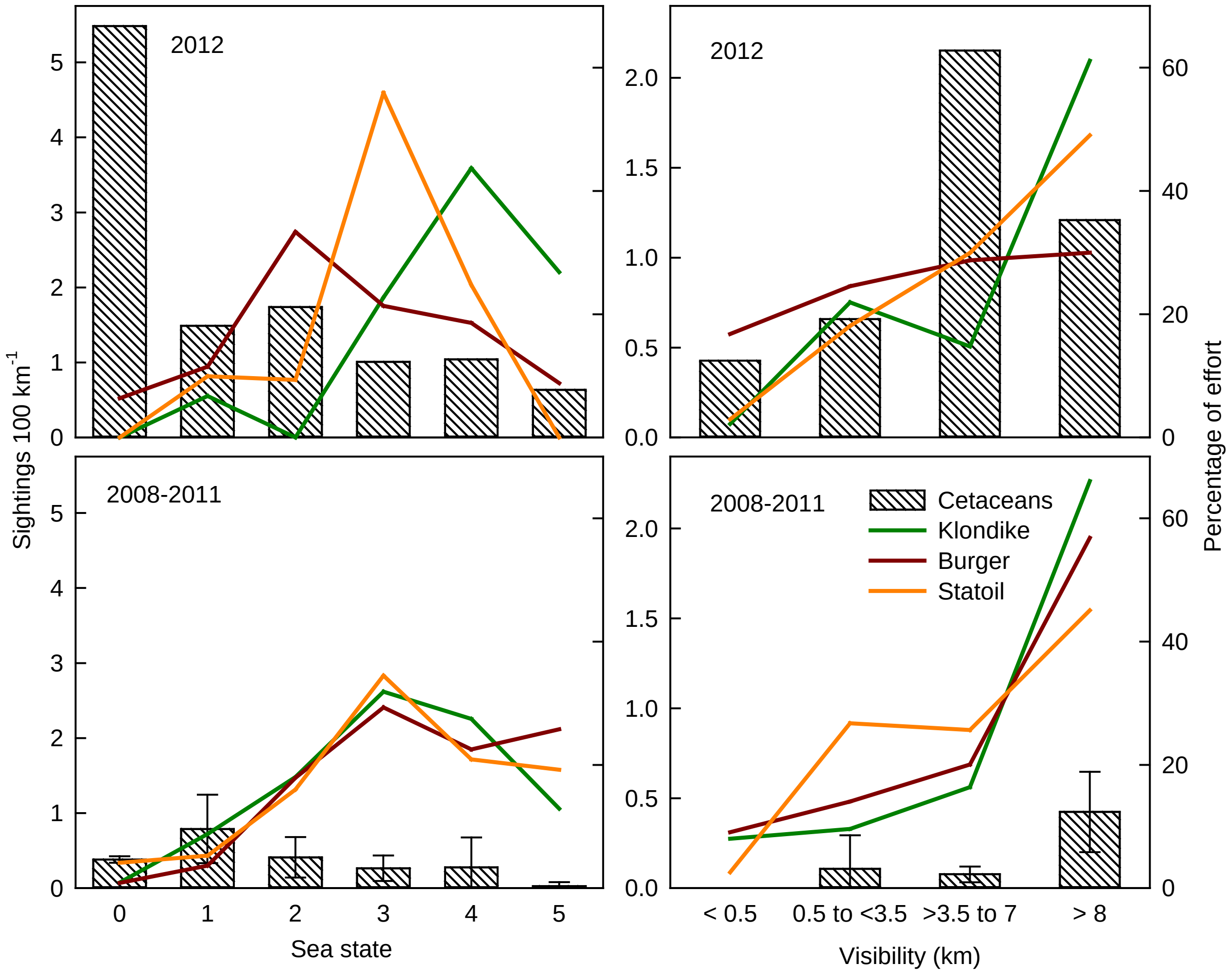

Figure 2.1. Cetacean sighting rate (sightings 100 km^{-1}) of 2012 and 2008-2011 on-transect data in the three prospect-specific study areas for each sea state (Beaufort Windforce scale; left) and visibility category (right). Error bars represent standard deviations. Lines show the amount of effort during different categories of sea state and visibility in each prospect-specific study area, expressed as percent of total effort.

Bowhead Whales

The number of on-transect bowhead whale sightings of the 2008–2012 database was large enough (n=73) for determining a reliable detection function. The best-fit model for the detection function of bowhead whales was the hazard rate model with visibility as covariate. The best results were obtained with no truncation distance, binning of data in 625 m intervals, and visibility data grouped into three categories (poor = ≤1 km; medium = 2-7 km; good = 8-10 km). We calculated annual densities, with 95% confidence intervals, using the estimated f(0) from the MRDS detection function, pooling study area and seasonal data. We also calculated seasonal densities, with July/August representing summer and September/October representing fall, pooling study areas and annual data. The bowhead density was clearly highest in 2012 (Table 2.2). This bowhead density was very likely an underestimate, because we had many records of unidentified (mysticete) whales (0.006 ind km^{-2}; 95% CI 0.003-0.011) in 2012. The high upper confidence interval of the 2008 density was likely caused by a low sample size (n=2), in combination with clustered occurrence of these sightings. Seasonal bowhead densities were about two times higher in the fall than in the summer (Table 2.2).

In addition to estimating densities, we calculated annual sighting rates (ind 100 km^{-1}) of bowhead whales for each study area and season (Fig. 2.2). The maximum sighting rate was 1.38 ind 100 km^{-1}, observed in the GHS study area. Among the three prospect-specific study areas, we recorded most bowhead whales in the Burger and Statoil study areas, and none in the Klondike study area (Figs. 2.2A, 2.3). In 2012, unlike previous years, we regularly saw bowhead whales in September. We recorded our first sighting on August 15, 2012. In 2011, most sightings occurred in August (first one on August 6), none in September, and only two in October. In 2008−2010, we saw all bowhead whales in October, with the exception of one sighting of two animals mid-September (Fig. 2.2B).

Table 2.2. Summary of estimated annual and seasonal bowhead whale densities (ind km^{-2}). UCL = upper confidence limit, LCL = lower confidence limit.

Year	IND KM^{-2}	UCL	LCL
2012	**0.004**	**0.008**	**0.002**
2011	0.001	0.003	0.000
2010	0.001	0.000	0.004
2009	0.000	0.001	0.000
2008	0.000	1.769	0.000
Season	IND KM^{-2}	UCL	LCL
Summer	0.001	0.002	0.000
Fall	0.002	0.003	0.001

Bowhead whale (Balaena mysticetus). CSESP 2012

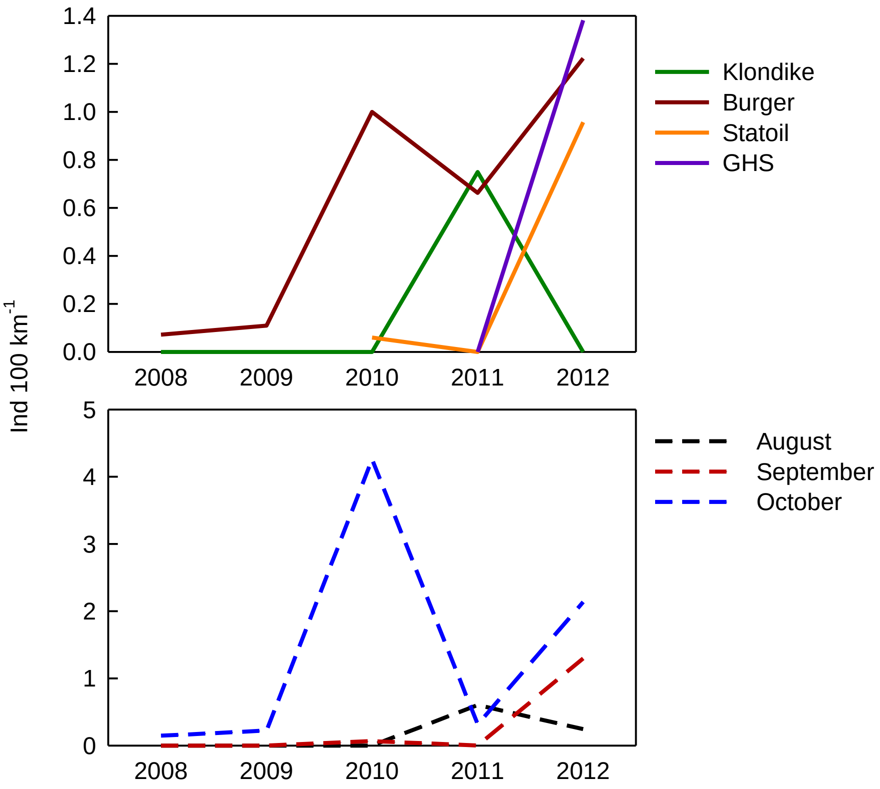

Figure 2.2. (A) Annual variation of bowhead whale sighting rate (ind 100 km^{-1}) within the three prospect-specific study areas and the Greater Hanna Shoal (GHS) study area, based on on-transect data. The GHS study area was surveyed in the fall (September and October) and includes the observations from the prospect-specific study areas recorded during that period. (B) Seasonal variation of bowhead whale sighting rate during the 2008-2012 survey periods, based on on- and off-transect data.

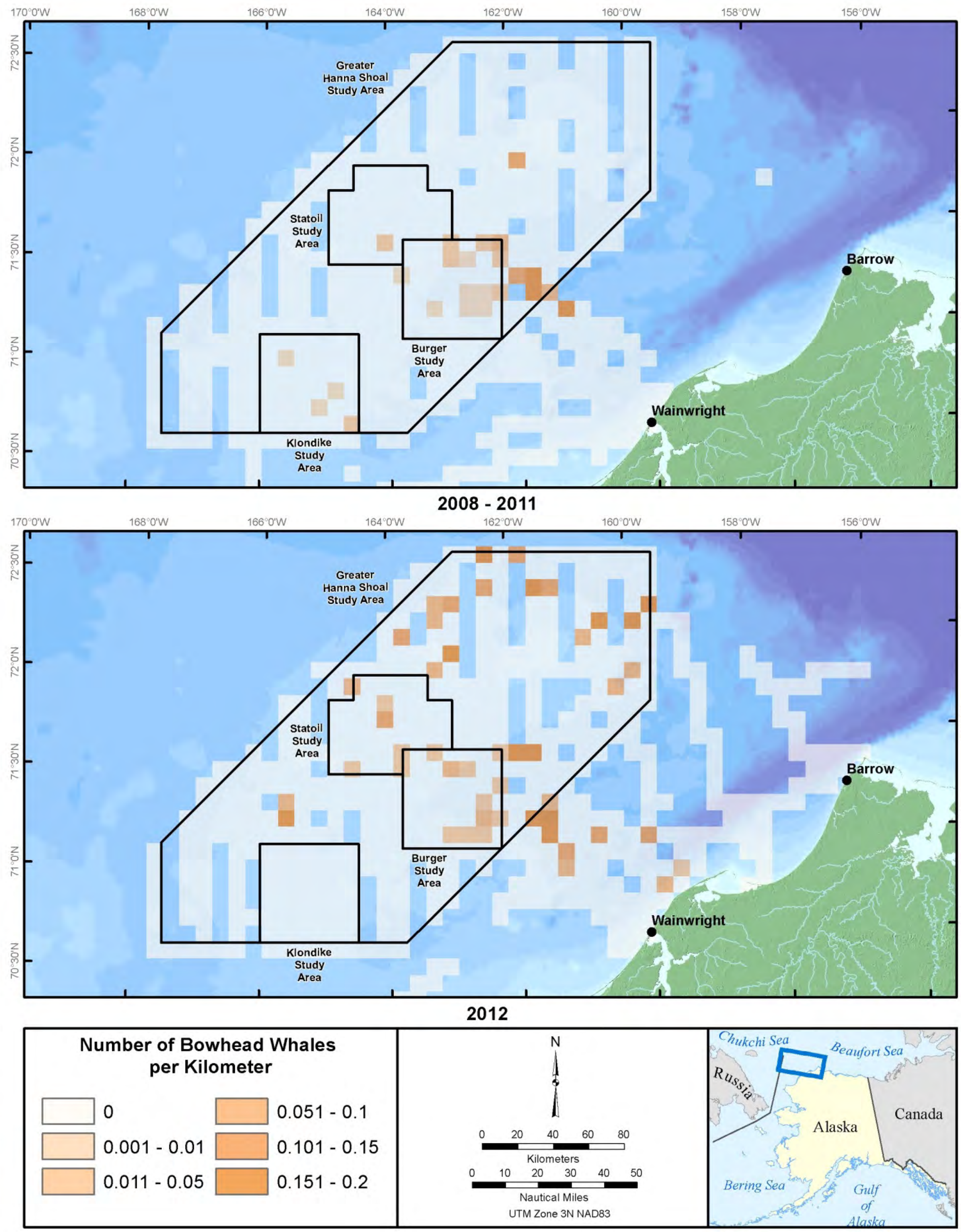

Figure 2.3. Bowhead distribution in the northeastern Chukchi Sea from August to mid-October based on sighting rates (individuals per km) calculated for 5×5 nm grid cells using on- and off-transect data of 2008−2011 (upper graph) and 2012 (lower graph).

Gray Whales

On-transect sighting rates of gray whales were highest in 2012 compared to previous years, with a maximum sighting rate of 0.12 ind 100 km^{-1} in the Statoil study area. No gray whales were sighted in the Klondike study area during our transect surveys in 2012 (Fig. 2.4A). Gray whales were only observed in the Klondike study area in 2008, with 0.08 ind 100 km^{-1}. In 2012 and previous years, gray whale sightings in the offshore study areas have been rare; we sighted about 90% of all gray whales (n=158) nearshore. The most northern offshore gray whale recorded during the five years of this study was at 72°31'N and 159°74'W, about 130 km northwest of Barrow (Fig. 2.5). From 2008–2012, most gray whales were observed in August, with the exception of the 2008 survey year (Fig. 2.4B).

In 2012, we evaluated the relationship between gray whale distribution and biomass of amphipod prey. We quantified gray whale sighting rates (ind h^{-1}) from about 2,770 hours of visual observations recorded during 2008–2012 on- and off-transect effort. We calculated sighting rates on a time-based effort instead of a distance-based effort to include off-transect sightings recorded at times that the vessel was stationary (see Chapter 1 – methods). The average gray whale sighting rate in the nearshore area was higher than in the offshore area (0.59 ± 10.77 and 0.004 ± 0.078 ind h^{-1}, respectively). Kriging maps showing the distribution of amphipod biomass (in g m^{-2}), a preferred food of gray whales, overlain with gray whale distribution based on visual observations revealed that gray whale presence coincided with amphipod biomass of ~70–180 g m^{-2} (Fig. 2.5).

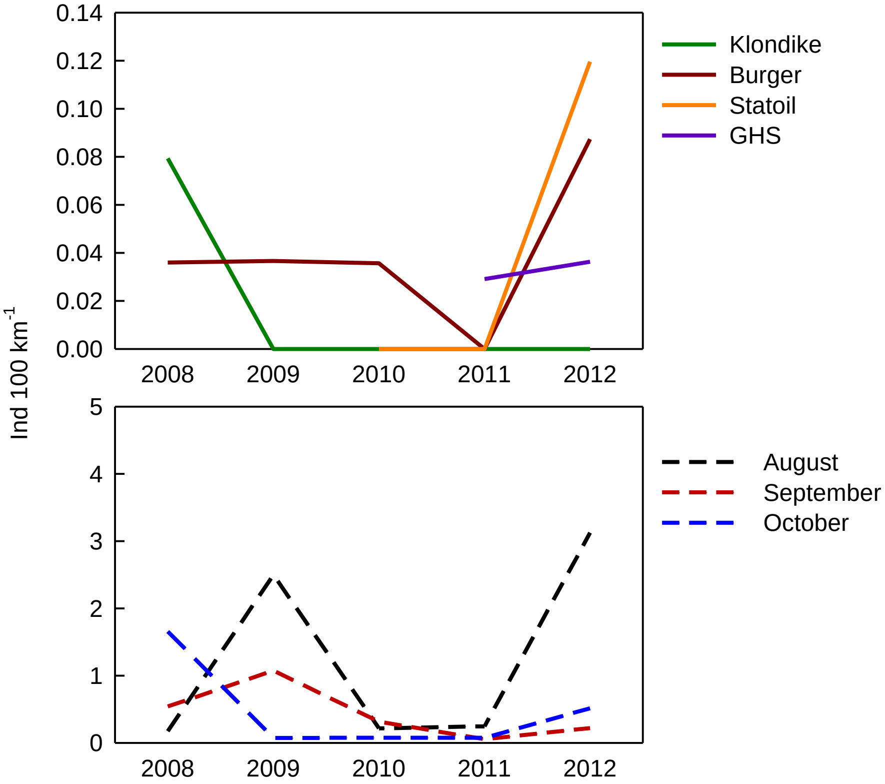

Figure 2.4. (A) Annual variation of gray whale sighting rate (ind 100 km^{-1}) within the three prospect-specific study areas and the GHS study area, based on on-transect data. The GHS study area was surveyed in the fall (September, October) and includes the observations from the prospect-specific study areas recorded during that period. (B) Seasonal variation of gray whale sighting rate, based on on- and off-transect data.

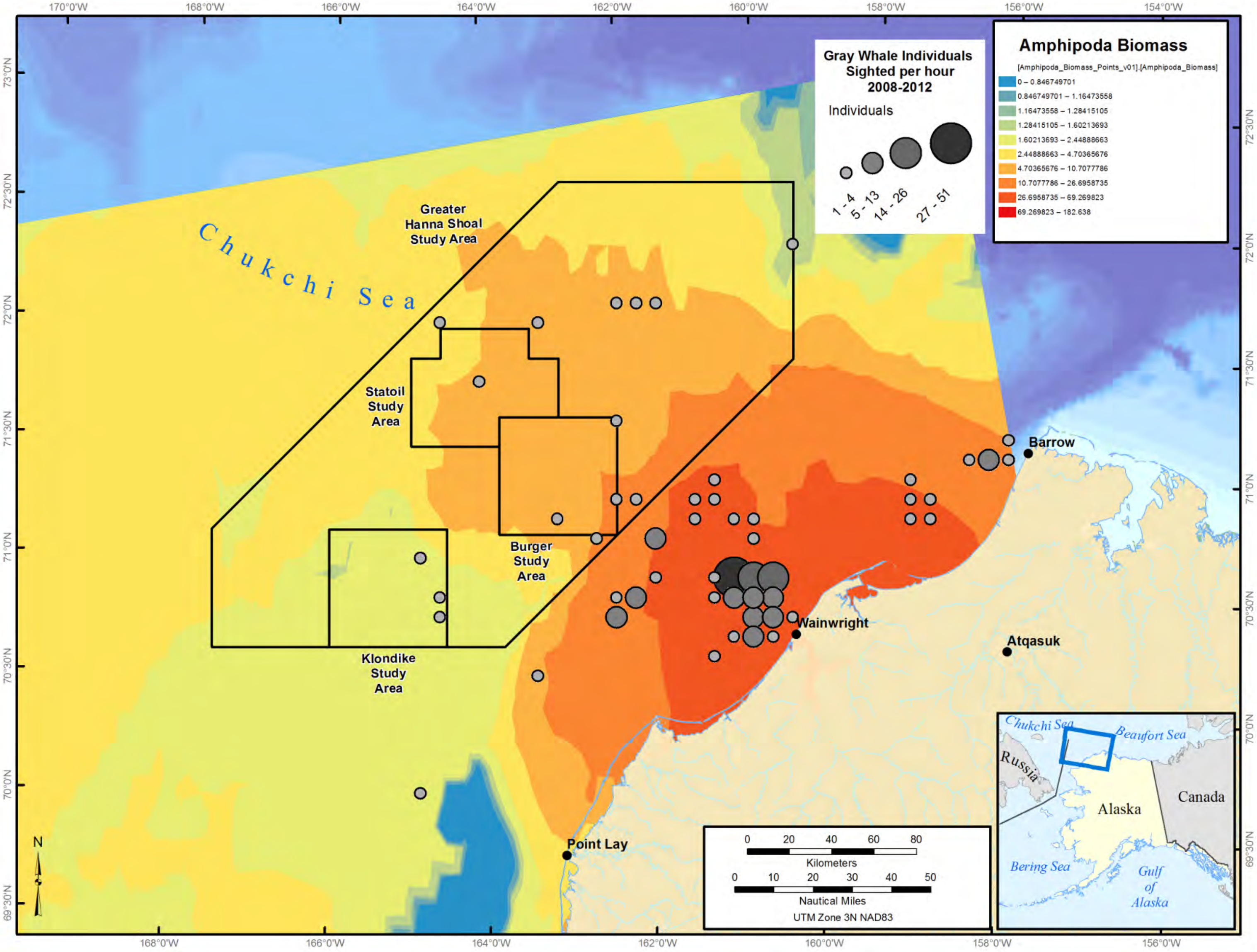

Figure 2.5. Gray whale sighting rates (ind h^{-1}) based on 2008-2012 vessel-based on- and off-transect data and amphipod biomass in the northeastern Chukchi Sea (source Blanchard and Knowlton 2013, Feder et al. 1994).

DISCUSSION

Most bowheads migrate north through the Chukchi Sea starting in early April. The majority has passed Point Barrow by late July. Therefore bowhead whale sightings are usually not common in the northern Chukchi Sea in August and early September (Aerts et al. 2013; Clarke et al. 2011, 2012, 2013). In 2011, we observed bowhead whales in the northeastern Chukchi Sea throughout August, but not in September and few in October. The low sighting rate of bowhead whales in the fall of 2011 was likely indicative of a late fall migration. An unusually late fall migration west 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). The sighting rate of bowhead whales throughout September and early October of 2012 was highest of all five years of our study. Observers from the ASAMM aerial survey also recorded a greater number of bowhead whales in the northeastern Chukchi Sea in September and October 2012 (Clarke et al. 2013). Bowhead whale call count data recorded in the Chukchi Sea in 2012 also showed the highest detection numbers during September and October. Similar to our 2012 visual data, there were few call detections south of 71^{o}N (Delarue et al. 2013), which supports satellite tagging data showing that most bowhead whales migrate north of 71^{o}N during the fall (Quakenbush et al. 2010).

During 2008–2012, we saw most gray whales in the nearshore area off Wainwright (within 50 km), where benthic sampling revealed a high biomass of amphipods (Feder et al. 1994; Blanchard and Knowlton 2013). This distribution pattern was also apparent from detections of their vocalizations on bottom-founded acoustic recorders (Delarue et al. 2012, 2013). During 1982-1991, gray whales were commonly observed around Hanna Shoal (Moore 2000). However, none were sighted there during the aerial surveys from 2008–2011 (Clarke et al. 2012) and only two in 2012 (Clarke et al. 2013). During our 2011 survey we saw three sightings of four gray whales close to Hanna Shoal (Aerts et al. 2012). The few whales in the Hanna Shoal area in 2011 and 2012 are of interest due to the rarity of occurrence in recent years. Generally, amphipod biomass is lower at Hanna Shoal than in nearshore areas (Blanchard and Knowlton 2013, Feder et al. 1994), although dense prey aggregations have been observed in the Hanna Shoal area (Nelson et al. 1994). Overall, gray whale distribution appeared to be strongly related to amphipod biomass distribution. Positive correlations between gray whale presence and prey availability were also reported for western North Pacific gray whales (Fadeev 2011). Although these findings seem obvious, relationships between food availability and marine mammal abundance are not always detectable. Many factors influence marine mammal distribution, but the relative immobility of gray whales' preferred prey may be a key parameter.

No beluga whales have been sighted in the northeastern Chukchi Sea during the five years of CSESP vessel-based marine mammal surveys. We observed one carcass on 10 August 2012 that was already in a state of decomposition. Two stocks of beluga whales migrate through the northeastern Chukchi Sea; the Beaufort and eastern Chukchi Sea stocks. Animals of the Beaufort Sea stock migrate north through open leads in April or May, although some may arrive in the Beaufort Sea as early as March or as late as July (Braham et al. 1977). Belugas of the eastern Chukchi Sea stock are common in Kotzebue Sound and near Kasegaluk Lagoon in early summer until about mid-to late July (Frost and Lowry 1990). Satellite tagging data shows that most of these beluga whales move farther north in July, mainly residing at high latitudes along the continental shelf break between Point Barrow and the Canadian border (Suydam et al. 2001, 2005). In the fall, the Chukchi and Beaufort stocks of belugas both return to their wintering grounds in the Bering Sea, following a deepwater route along the continental shelf break or routes farther offshore (Allen and Angliss 2010). The area and timing of our vessel survey likely limits the probability of encountering beluga whales of either stock. Consistent with known migration patterns of both stocks, beluga whale call detections and observations form aerial surveys have been recorded in the northern Chukchi Sea mainly in spring from early April to early or mid-July (Delarue et al. 2011; Clarke et al. 2012, 2013). Few beluga whales have been sighted in September in the CSESP study area during ASAMM/COMIDA aerial surveys that usually occur from late June to late October; sighting rates were highest in October (Clarke et al. 2012, 2013). Beluga vocalization data also showed that most belugas migrate past Barrow into the Chukchi Sea in October and November (Delarue et al. 2011).

Minke whales are common in the Bering Sea and southern Chukchi Sea. During the five years of this study, they have been sighted in low numbers, all south of 71.3^{o}N. Aerial survey results of 1982-1991 (Moore and Clarke 1992) and 2008-2010 (Clarke et al. 2011) did not report any minke whales in the northeastern Chukchi Sea. In 2011, aerial survey observers recorded five confirmed sightings of six minke whales, including one sighting at 71.89°N; this is likely the farthest north confirmed minke whale recorded in the Chukchi Sea (Clarke et al. 2012). Similar numbers were recorded in 2012, mostly nearshore (Clarke et al. 2013). Minke whale vocalizations during the open-water season were detected for the first time in 2011 (Delarue et al. 2012) and again in 2012, with most sightings off Cape Lisburne and Point Lay.

Humpback whales have mainly been recorded southwest of St. Lawrence Island, in the southeastern Bering Sea, and north of the central Aleutian Islands (Moore et al. 2002). No humpback whales were observed north of Point Hope during the 2008-2011 CSESP marine mammal surveys (Aerts et al. 2012). However, in 2012 we had one confirmed humpback whale sighting near Barrow. Although uncommon, our sighting in 2012 is not unique. Subsistence hunters have spotted humpback whales regularly in low numbers around Barrow. There is one record of a cow and calf humpback whale in the Beaufort Sea, 54 miles east of Point Barrow (Hashagen et al. 2009). No additional humpback whale sightings have been documented in the Beaufort Sea since 2009. Recently, there have been several confirmed sightings of humpback whales in the northeastern Chukchi Sea. During marine mammal surveys there, conducted as part of seismic survey mitigation and monitoring plans, three sightings of five humpback whales were recorded in 2007 and one animal in 2008 (Haley et al. 2010). One humpback was observed in July 2009 during the COMIDA aerial surveys that were flown each year from 2008−2011 (Clarke et al. 2011, 2012). In 2012, aerial observers recorded 29 humpback whales, mostly west of Point Hope but also some nearshore between Icy Cape and Barrow (Clarke et al. 2013).

Subsistence hunters have seen few killer whales each year during July and August in the Point Barrow region (George et al. 1994). During the five years of CSESP surveys we observed an estimated total of 57 killer whales in 11 sightings in 2008, 2011, and 2012. Killer whales had never been observed during the COMIDA/ASAMM aerial surveys from 1982–1991 and 2008–2011. However, in August 2012, 13 killer whales were sighted about 6 miles northeast of Barrow and five were sighted west of Point Hope (Clarke et al. 2013). 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. In 2012, killer whale call detections during summer were widespread in time and space, although concentrations were observed in the Burger study area, and off Cape Lisburne and Point Lay (Delarue et al. 2013).

Harbor porpoises are seen occasionally in the northern Chukchi Sea. Suydam and George (1992) reported nine records in the Barrow area in 1985–1991. More recently, during the summer and fall of 2006–2008, observers recorded harbor porpoises in the Chukchi Sea (Haley et al. 2010). In this study, we sighted 28 harbor porpoises during 2008–2012. Four animals were seen in the Beaufort Sea northwest of Barrow, 28 animals in the northeastern Chukchi Sea, and 10 animals 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

- Bowhead whale (*Balaena mysticetus*) density in 2012 was the highest of all five years of CSESP surveys (0.004 ind km^{-2}). Unlike previous years, most bowhead whales were sighted regularly throughout September.
- In 2012, the highest bowhead whale sighting rate (ind 100 km^{-1}) occurred in the GHS. Among the three prospect-specific study areas, we recorded most bowhead whales in the Burger and Statoil study areas, and none in the Klondike study area
- Gray whale (*Eschrichtius robustus*) sighting rates (ind 100 km^{-1}) were higher in 2012 compared to previous years, mostly nearshore as expected. Preliminary quantitative analyses showed a positive relationship between gray whale distribution and amphipod biomass in the study area.
- As in previous years, no beluga whales were observed during the summer and early fall. This is to be expected considering their seasonal distribution pattern relative to the timing of our survey.
- Minke whales, killer whales, and harbor porpoises were again recorded in 2012. Although these species occur in low numbers, encounters over the past five years suggest that these species are regular visitors to the northeastern Chukchi Sea.
- We recorded one humpback whale in the northeastern Chukchi Sea in 2012; the first time since the start of the CSESP surveys in 2008. However, this sighting is not unique. Subsistence hunters have spotted humpback whales regularly in low numbers around Barrow and there have been several confirmed sightings in the northeastern Chukchi Sea in recent years.

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ATTACHMENT A

Figures of cetacean sightings recorded in 2012 and 2008-2011 in the CSESP study areas of the northeastern Chukchi Sea and in the southern Chukchi and Bering Seas during transits between Nome and the CSESP study areas.

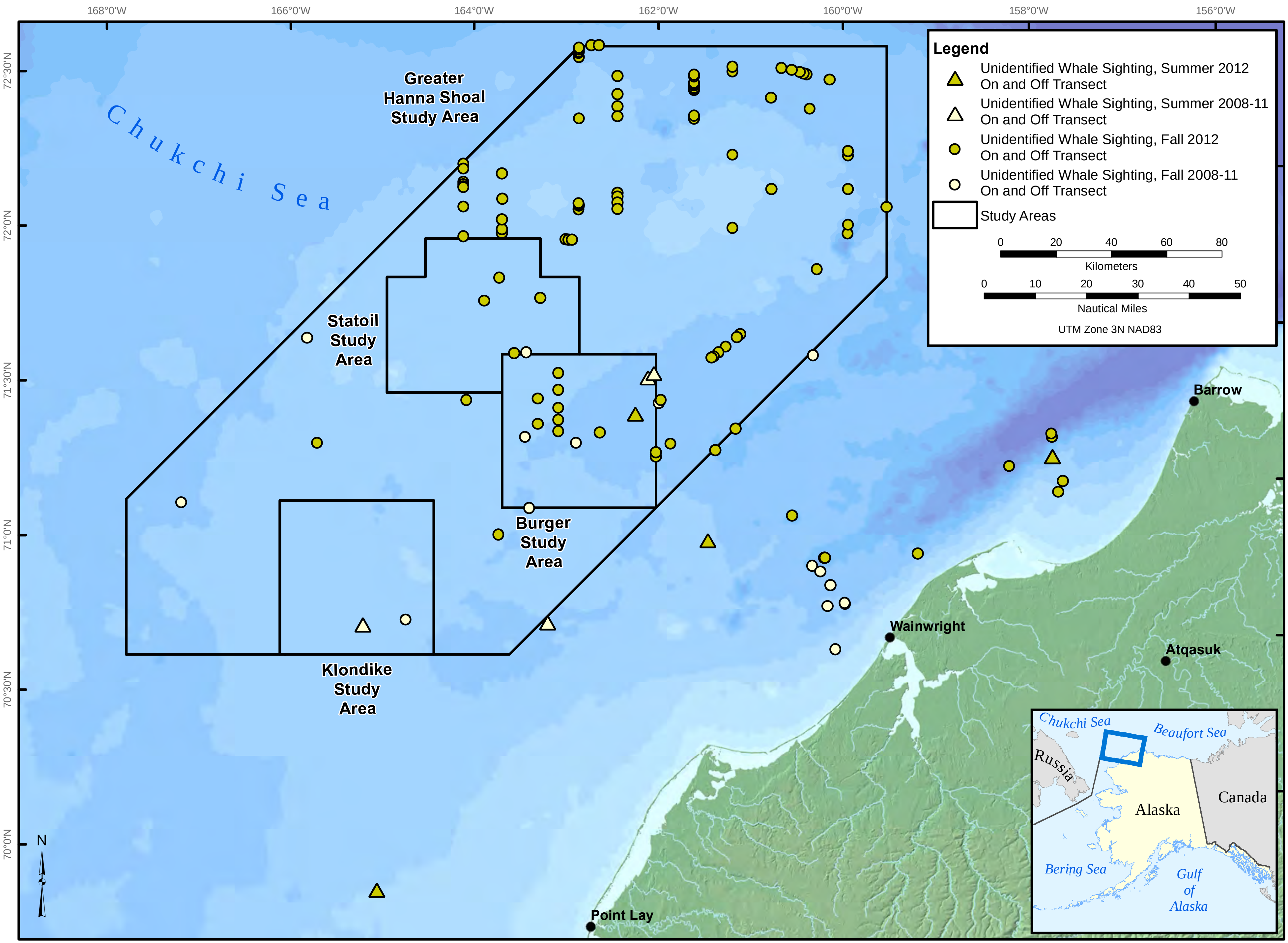


Figure A-1. Sightings of unidentified whales in 2012 and 2008–2011 in the CSESP study areas of the northeastern Chukchi Sea.

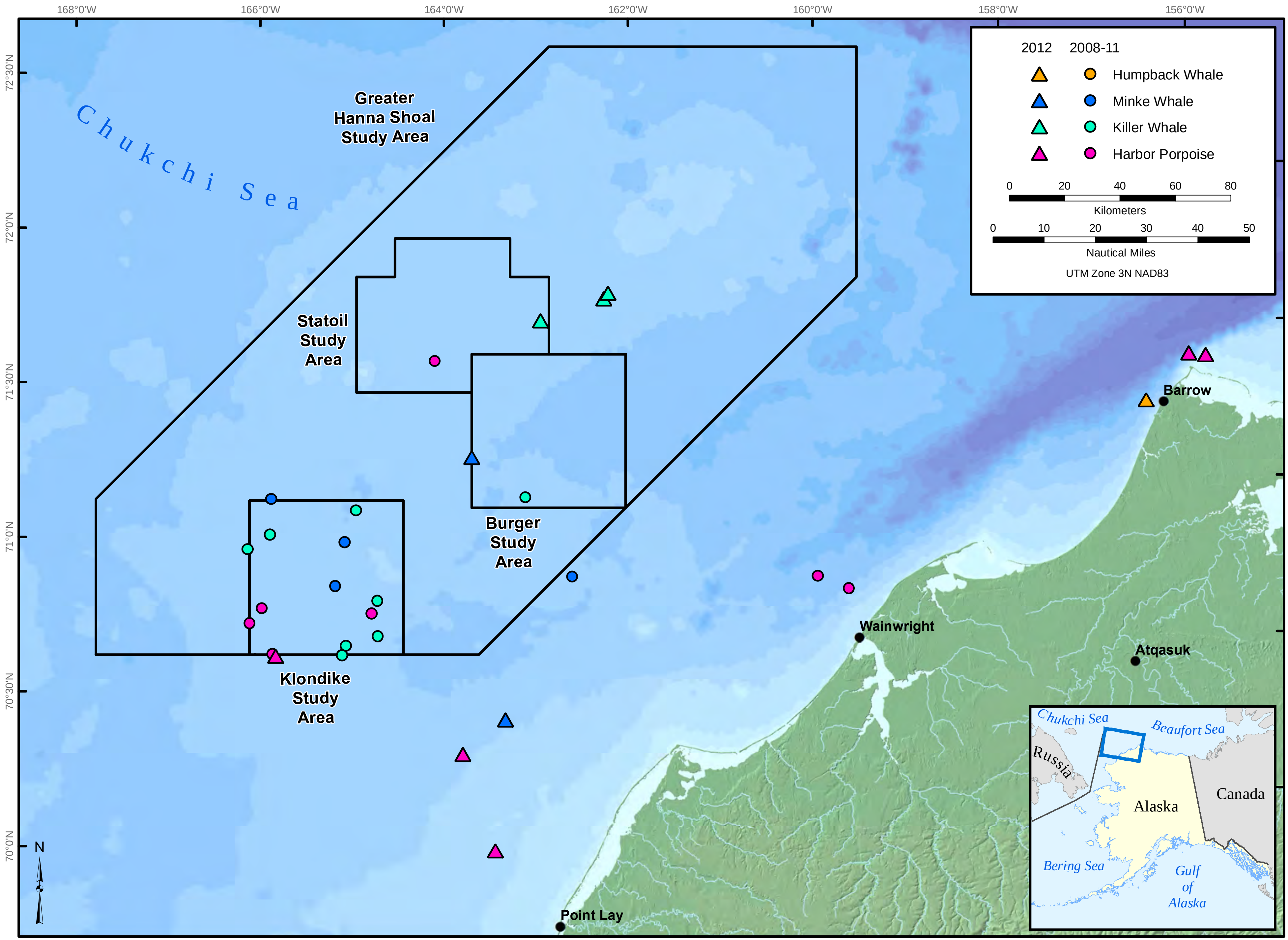


Figure A-2. Cetacean sightings, excluding bowhead and gray whales, seen in 2012 and 2008–2011 in the CSESP study areas of the northeastern Chukchi Sea.

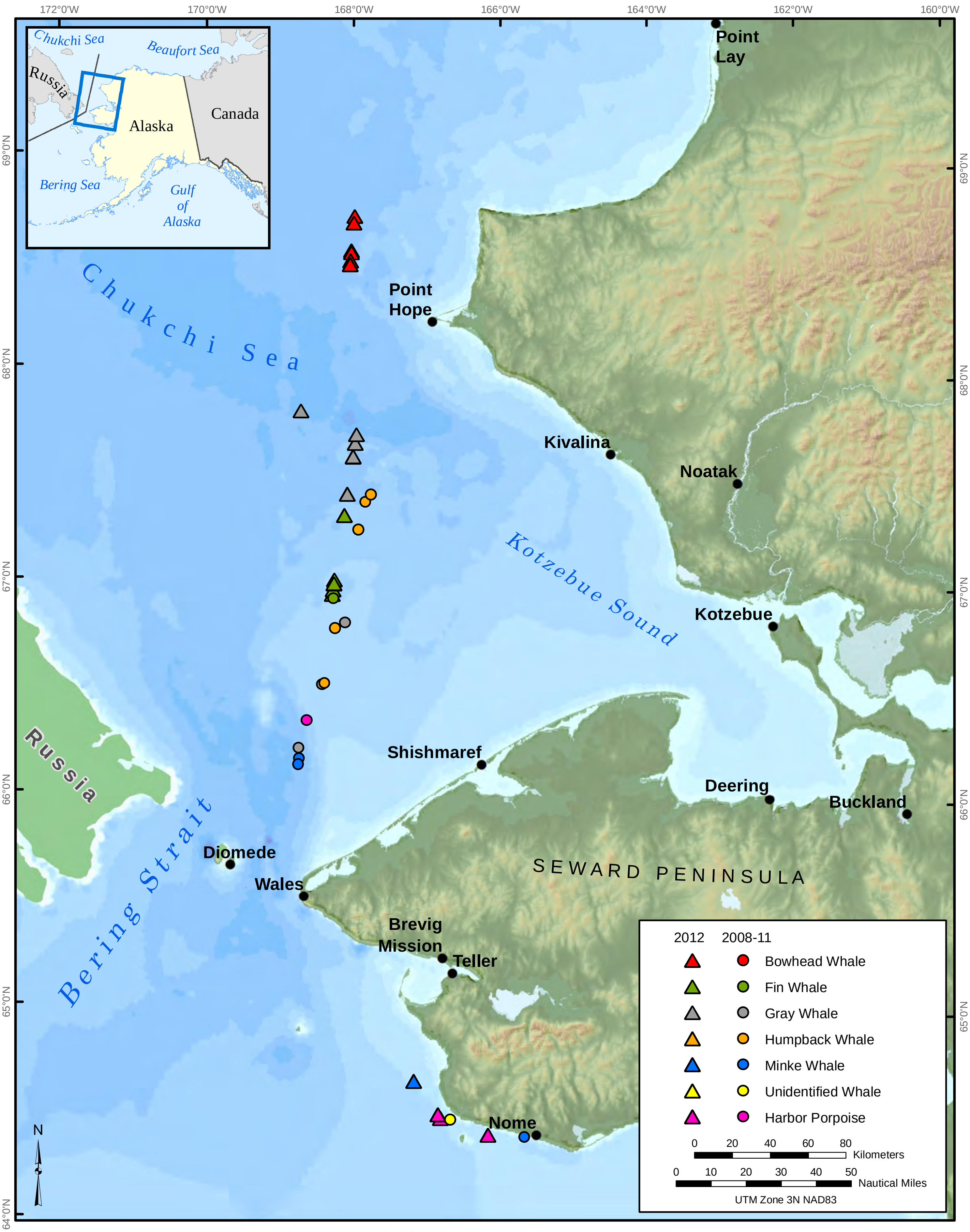


Figure A-3. Cetacean sightings recorded in the southern Chukchi and Bering Seas in 2012 and 2008-2011 during vessel transits between Nome and the CSESP study areas.

CHAPTER 3

SEAL DISTRIBUTION AND ABUNDANCE

In 2012, marine mammal observations in the northeastern Chukchi Sea were recorded along transect lines in the three prospect-specific study areas in August, whereas in September/October data were recorded in the GHS study area (which encompasses the prospect-specific study areas Klondike, Burger, and Statoil). In addition, observers recorded marine mammal sightings on transits to acoustic recorder and mooring locations and to Wainwright and Nome (see Chapter 1 for further details). Information about the survey area and design, observation protocol, and data analyses is provided in the methods section of Chapter 1). In this chapter, we present the results of seal sighting data in three different sections, as follows:

1. Seal sighting information, which summarizes on- and off-transect data from 2012 and compares it with similar data from 2008–2011;
2. Annual variation of seal density and distribution, comparing the 2012 seal sightings with data from 2008-2011, using only on-transect data; and
3. Seal distribution and abundance in 2012 and 2008−2011, using on- and off-transect data converted into effort-corrected sighting rates (individuals [ind] km^{-1}).

RESULTS

Seal Sighting Information

Ringed and spotted seals (*Pusa hispida* and *Phoca largha*, respectively) were the most commonly sighted seal species in 2012 (62% of 666 identified seal sightings), similar to most previous years. Only in 2010 did we record more bearded seal (*Erignathus barbatus*) sightings than ringed and spotted seals. Because positive identification of ringed and spotted seal is challenging, we introduced the category ringed/spotted seals in 2008 (Table 3.1). Of the five years of CSESP surveys, the total number of ringed/spotted and bearded seal sightings was highest in 2012, due to the increased off-transect effort (category OTHER). Taking effort into account, we recorded the highest number of seals in 2011. We did not see any ribbon seals (*Histriophoca fasciata*) in 2012. We recorded three solitary seals on sea ice in 2012: two bearded seals and one ringed/spotted seal. Swimming, looking, and unknown were the most common initial behaviors of seals (85%) and dive, sink, and unknown were the most common secondary behaviors (78%). The distances relative to the vessel at which we sighted seal species in 2012 ranged from 5–2,085 m, with most sightings occurring between 100 and 500 m (Fig. 3.1). Compared to previous years, we recorded fewer sightings close to the vessel (<100 m) and more sightings farther away (>500 m).

Table 3.1. Summary of seal sighting data from 2008–2012 for each study area and year. The category OTHER contains off-transect data for which effort in km was not always available. On-ice sightings are excluded (2008 – 11 sightings of ~150 seals; 2009 – 2 solitary seals; 2012 – 3 solitary seals).

	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
2012																
Ringed seal	0	0	0	12	12	0.010	9	11	0.011	4	4	0.003	51	61	76	88
Spotted seal	2	2	0.002	3	3	0.003	3	3	0.004	6	6	0.004	39	48	53	62
Ringed/Spotted	7	7	0.008	26	27	0.023	24	25	0.029	2	2	0.001	221	238	280	299
Bearded seal	9	9	0.011	41	41	0.036	41	42	0.049	20	21	0.013	146	150	257	263
Unid. seal	5	5	0.006	38	38	0.033	14	14	0.017	13	13	0.008	116	121	186	191
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	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	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	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	0.007							12	12	49	49

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

Table 3.1 continued

	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
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	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	0.006	33	33	0.003	31	33	0.009	39	39	0.011	116	133	284	311
Spotted seal	34	35	0.003	26	27	0.002	11	12	0.003	26	26	0.007	104	117	201	217
Ringed/Spotted	153	168	0.015	91	93	0.009	72	74	0.021	44	44	0.012	342	377	702	756
Bearded seal	70	72	0.007	151	153	0.014	153	157	0.044	52	53	0.015	272	279	698	714
Ribbon seal	5	5	0.002	2	2	0.001	1	1	0.00102	0	0	0	0	0	8	8
Unid. seal	230	325	0.023	131	132	0.012	42	44	0.012	70	74	0.020	301	347	774	922

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

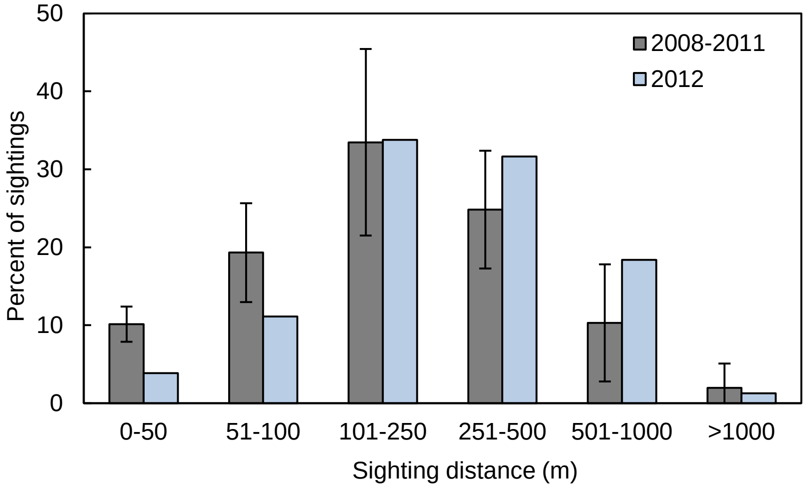
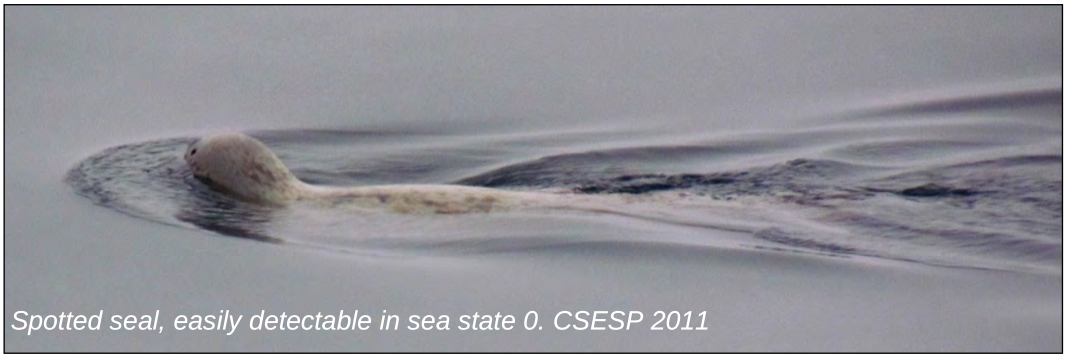


Figure 3.1. Radial sighting distance (in m) from the vessel at which seals were sighted shown as a percentage of total number of sightings (n = 1056 for 2008-2011; n = 234 for 2012). Error bars represent standard deviations.

Annual Variation in Seal Density and Distribution

Effects of Environmental Conditions on Detection

Seals can be difficult to detect, especially if environmental conditions are poor. Figure 3.2 shows that in 2012, as in 2008–2011, most seals were sighted when the sea state (Beaufort Windforce) was low, with the sighting rate decreasing with increasing sea states. When comparing seal sighting rates among study areas, the effect of sea state on detectability should therefore be considered. For example, in 2012, sea state conditions were on average more favorable in the Burger study area then in the Klondike and Statoil study areas. Although variable from year to year, the average sea state in the study areas of all four previous years combined showed a consistent pattern (Fig. 3.2). Comparison of seal sighting data averaged over more than one year will therefore be less biased for sea state. A clear pattern between seal sighting rate and visibility was not apparent in 2012 and 2008–2011 (Fig.3.2). Since most seals were sighted at distances of less than 500 m from the vessel, the absence of a relationship between seal sighting rate and visibility is to be expected.


Spotted seal, easily detectable in sea state 0. CSESP 2011

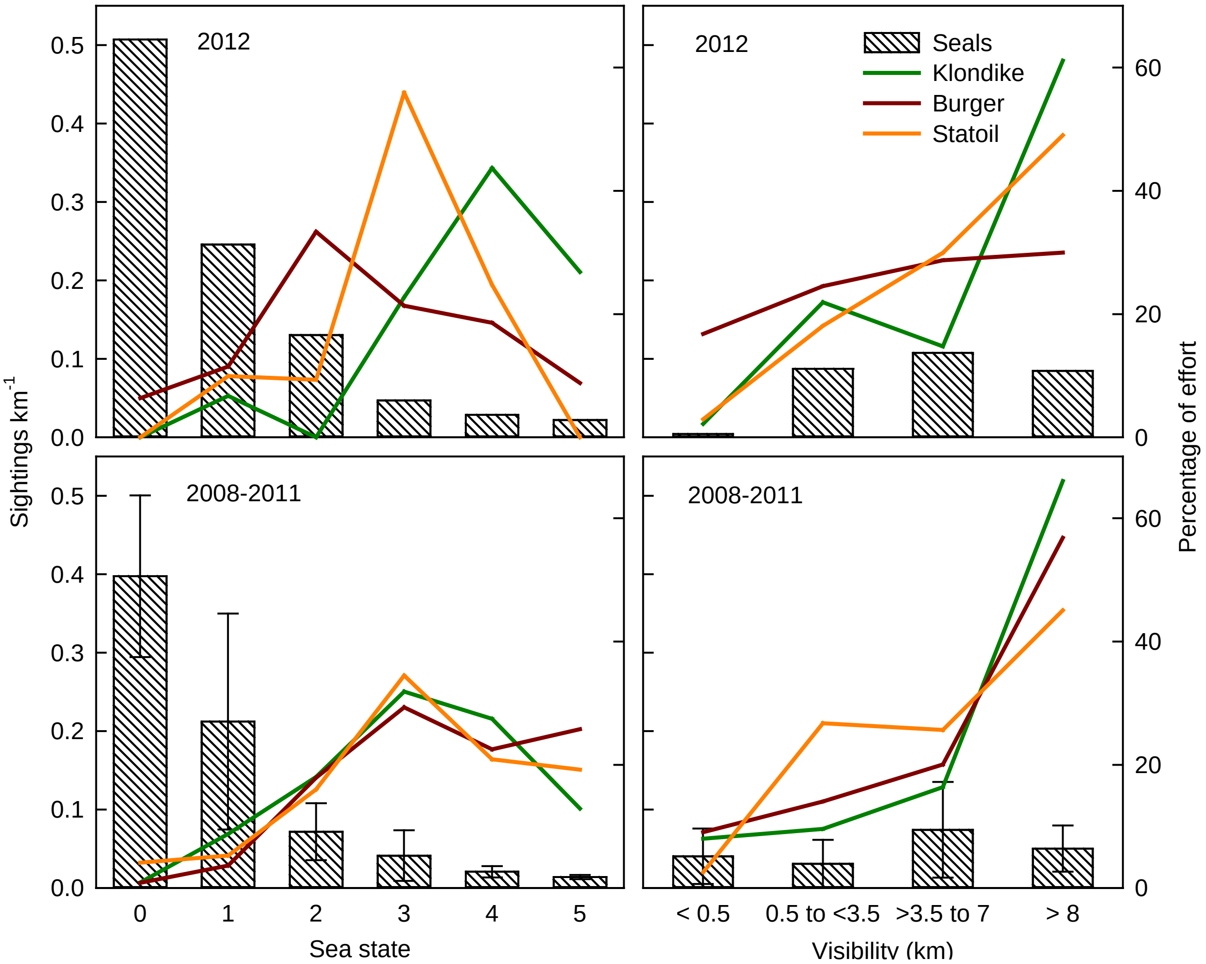


Figure 3.2. Seal sighting rate (sightings km^{-1}) of 2012 and 2008-2011 on-transect data in the three prospect-specific study areas for each sea state (Beaufort Windforce scale; left) and visibility category (right). Error bars represent standard deviations. The lines indicate the amount of effort (in percent of total effort) that occurred in each prospect-specific study area during each sea state and visibility category.

Seal Density

We used Program Distance (Thomas et al. 2010) to calculate ringed/spotted and bearded seal densities (see Chapter 1 for details). The 2008–2012 database contained large sample sizes for determining reliable detection functions (n=594 ringed/spotted and n=396 bearded seals). To estimate annual densities for each study area and season, we pooled ringed and spotted seal sighting data together with the category ringed/spotted seals. We did this because there were relatively few confirmed ringed and spotted seal sightings and their densities would otherwise be underestimated. 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). The best-fit model for the detection function of ringed/spotted seals using the 2008–2012 data was the hazard rate model with sea state, vessel, and observer as covariates. For bearded seals the best-fit model was the hazard-rate model, with sea state and vessel as covariates. However, the model fits with different covariates were all very close with Δ AIC 2.5–46.0 and p-values of the Kolmogorov-Smirnov goodness of fit tests around 0.03 for ringed/spotted and 0.050 for bearded seals. We calculated densities, with 95% confidence intervals, for ringed/spotted and bearded seals for each study area and year, using the estimated f(0) from the MRDS detection function from all on-transect data. We also calculated densities for each season and year, with data from July/August representing summer and data from September/October representing fall. Large confidence intervals were mainly caused by the occurrence of sightings in clusters, sometimes in combination with low sample sizes.

The ringed/spotted and bearded seal densities, as summarized in the sections below, do not take into account the seal sightings recorded as unidentified and thus underestimate the actual densities. We therefore also estimated unidentified seal densities using the 2008-2012 data (n=429). The best-fit model was the hazard rate model with sea state as covariate. The annual unidentified seal density within the study areas ranged from 0.012 to 0.152 ind km^{-2}. The seasonal density ranged from 0.004 to 0.171 ind km^{-2} (Table 3.2). The contribution of ringed/spotted and bearded seals to these unidentified seal densities is unknown. The ratio between ringed/spotted and bearded seal densities for each study area and season as summarized in Table 3.3 and 3.4 could provide an indication. However, we recognize that this might overestimate the densities of the more-identifiable bearded seal and underestimate the densities of ringed/spotted seals.

Table 3.2. Summary of estimated annual unidentified seal densities (ind km^{-2}) for each study area and season.

	KLONDIKE	BURGER	STATOIL	GHS	SUMMER	FALL
2012	**0.019**	**0.062**	**0.038**	**0.032**	**0.042**	**0.032**
2011	0.015	0.033	0.041	0.066	0.015	0.066
2010	0.017	0.023	0.014	-	0.004	0.032
2009	0.012	0.014	-	-	0.010	0.014
2008	0.152	0.049	-	-	0.171	0.035

Ringed/spotted seals

Average ringed/spotted seal densities of on-transect data appears to be highly variable among years and study areas. Densities recorded in 2008−2012 ranged from 0.011 to 0.112 ind km^{-2} (Table 3.3, Fig. 3.3). The lowest density was in the Burger study area in 2010 and the highest density in the Klondike study area in 2008. The 2012 density recorded in the Klondike study area was within the range of 2009−2011 densities, but was lower than the 2008 density (Fig. 3.3). The 2012 densities in the Burger and Statoil study areas were similar to previous years. There was no consistent pattern of abundance among the three prospect-specific study areas. The overall ringed/spotted seal density in the GHS study area in 2012 was lower than in 2011. We sampled the GHS study area (which includes the three prospect-specific study areas) in the fall of 2011 and 2012. The densities of the GHS study area shown in Figure 3.3 are therefore identical to the fall densities in Figure 3.4.

Average seasonal densities of ringed/spotted seals ranged among years from 0.004 to 0.127 ind km^{-2} (for summer 2009 and 2008, respectively) (Fig. 3.4). Densities were higher in fall than summer during three (2009−2011) of the five study years (though likely not statistically significant in 2011). In the other two years (2008, 2012) we recorded lower densities in the fall than the summer (though likely not statistically significant in 2012). The two years with higher densities in the summer were characterized by the presence of sea ice in the study areas until mid-September. During light-ice years, ringed/spotted seal densities were generally lower in the summer.

Using confirmed ringed and spotted seal densities, calculated from 2008-2012 data and the combined ringed/spotted seal detection function, we determined that the ratio between ringed and spotted seals was about 2:1. This ratio could be applied to the combined annual ringed/spotted seal densities for each study area and season summarized in Table 3.3 to obtain an indication of the contribution of these two species to the combined ringed/spotted seal densities.

Table 3.3. Summary of estimated annual ringed/spotted seal densities (ind km^{-2}) for each study area and season. UCL = upper confidence limit, LCL = lower confidence limit.

		KLONDIKE	BURGER	STATOIL	GHS	SUMMER	FALL
2012	**ind km^{-2}**	**0.019**	**0.051**	**0.075**	**0.022**	**0.057**	**0.022**
	UCL	**0.048**	**0.117**	**0.163**	**0.035**	**0.117**	**0.035**
	LCL	**0.008**	**0.023**	**0.035**	**0.014**	**0.028**	**0.014**
2011	ind km^{-2}	0.030	0.013	0.088	0.063	0.046	0.063
	UCL	0.068	0.026	0.152	0.094	0.084	0.094
	LCL	0.013	0.007	0.051	0.042	0.025	0.042
2010	ind km^{-2}	0.018	0.011	0.028	not surveyed	0.008	0.026
	UCL	0.030	0.024	0.054		0.016	0.040
	LCL	0.011	0.005	0.015		0.004	0.017
2009	ind km^{-2}	0.018	0.023	not surveyed	not surveyed	0.004	0.028
	UCL	0.046	0.039			0.010	0.049
	LCL	0.007	0.013			0.002	0.016
2008	ind km^{-2}	0.112	0.042	not surveyed	not surveyed	0.127	0.029
	UCL	0.193	0.062			0.210	0.048
	LCL	0.065	0.028			0.077	0.018

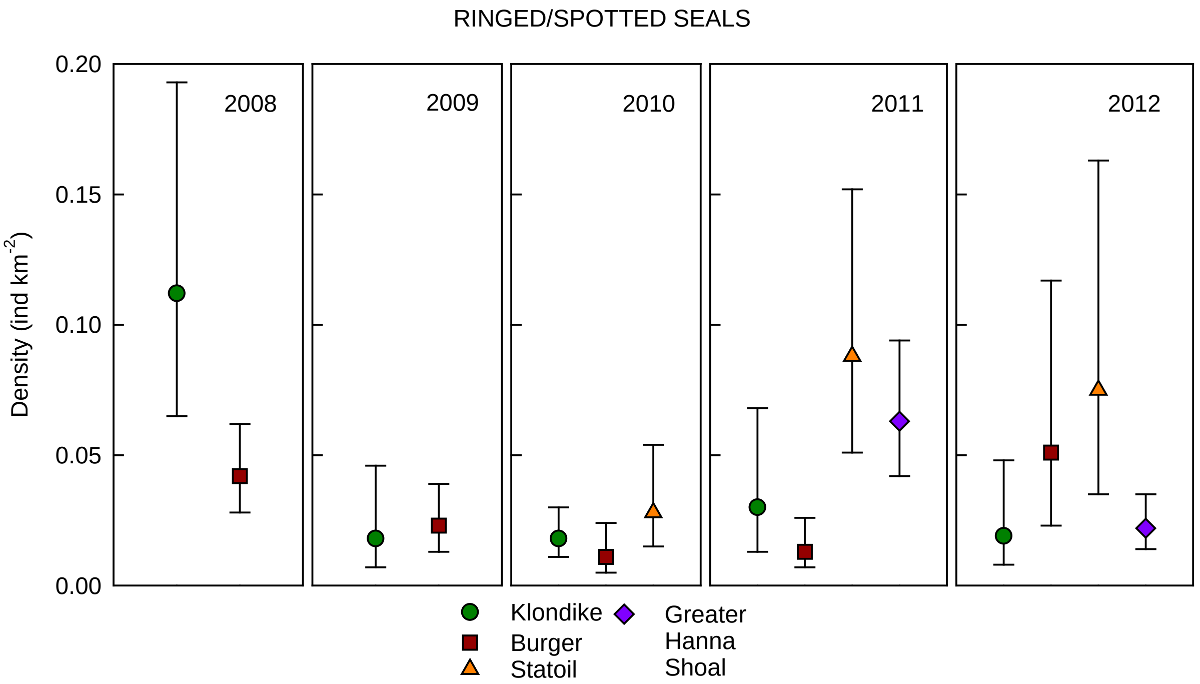


Figure 3.3. Ringed/spotted seal densities (with 95% Confidence Intervals) for 2008−2012 in each prospect-specific study area.

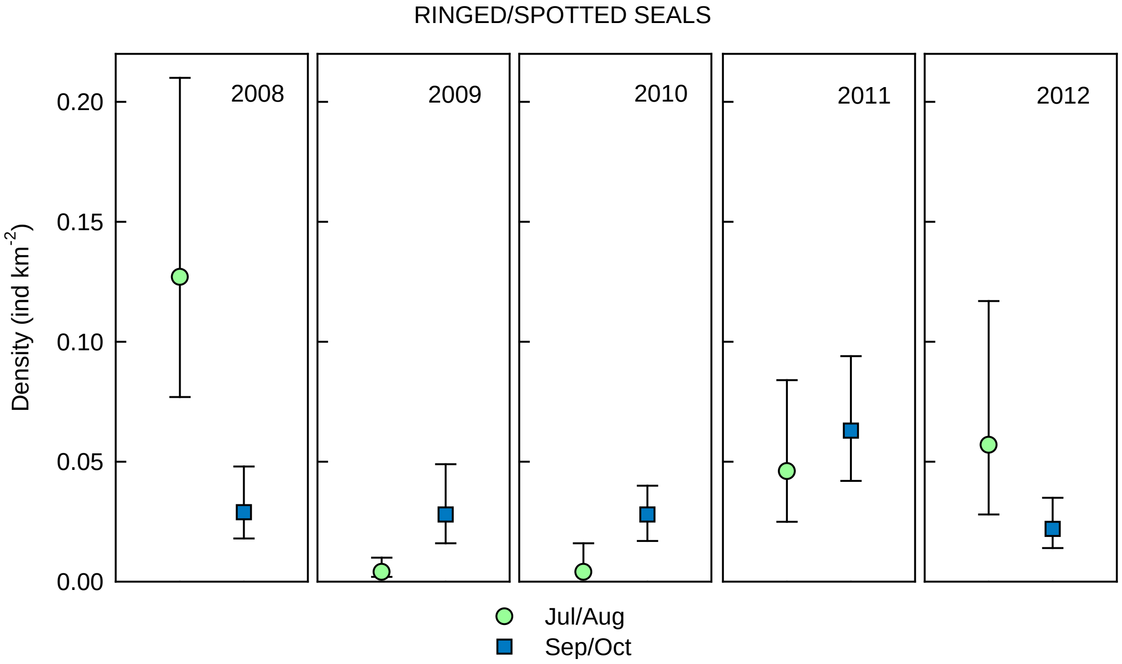


Figure 3.4. Ringed/spotted seal densities (with 95% Confidence Intervals) for 2008−2012 in the summer (July/August) and fall (September/October).

Bearded seals

Average bearded seal densities of on-transect data for each year and study area from 2008–2012 ranged from 0.004 to 0.074 ind km^{-2} (Table 3.3, Fig. 3.5) The lowest density occurred in the Klondike study area in 2009, while the highest density occurred in the Statoil study area in 2012. The bearded seal density in the Statoil study area, sampled in 2010-2012, was comparable among years. Bearded seal densities in the Klondike and Burger study areas were also within the range of densities recorded in previous years (Fig. 3.5). Among study areas, we recorded higher bearded seal densities in Statoil than in Klondike (2010 and 2012) and Burger (2011). Except for 2011, the bearded seal density was generally lower in the Klondike study area than in the Burger study area (although not always statistically significant).

Average seasonal bearded seal densities ranged among years from 0.004 to 0.049 ind km^{-2}. The lowest density occurred in summer 2009 and the highest density in summer 2011. Unlike for ringed/spotted seals, no pattern in seasonal density, possibly related to the presence or absence of sea ice, was apparent for bearded seals. Summer and fall densities in 2012 were similar and within the range of densities recorded for previous years (Table 3.3, Fig. 3.6).

Because bearded seals are more easily identifiable than ringed and spotted seals, the amount of bearded seals missed due to classification as unidentified is assumed to be less than for ringed/spotted seals. The actual bearded seal densities recorded in 2008-2012 are therefore closer to the average density, whereas actual densities for ringed/spotted seals are likely closer to the upper confidence level.

Table 3.4. Summary of estimated annual bearded seal densities (ind km^{-2}) for each study area and season. UCL = upper confidence limit, LCL = lower confidence limit.

		KLONDIKE	BURGER	STATOIL	GHS	SUMMER	FALL
2012	**ind km^{-2}**	**0.018**	**0.042**	**0.074**	**0.039**	**0.032**	**0.039**
	UCL	**0.037**	**0.079**	**0.124**	**0.056**	**0.058**	**0.056**
	LCL	**0.009**	**0.022**	**0.044**	**0.027**	**0.017**	**0.027**
2011	ind km^{-2}	0.03	0.013	0.072	0.020	0.049	0.020
	UCL	0.065	0.021	0.138	0.031	0.086	0.031
	LCL	0.013	0.008	0.037	0.013	0.028	0.013
2010	ind km^{-2}	0.007	0.022	0.058	not surveyed	0.007	0.044
	UCL	0.016	0.039	0.100		0.013	0.068
	LCL	0.003	0.012	0.033		0.004	0.028
2009	ind km^{-2}	0.004	0.010	not surveyed	not surveyed	0.004	0.009
	UCL	0.010	0.020			0.012	0.017
	LCL	0.001	0.005			0.001	0.005
2008	ind km^{-2}	0.016	0.026	not surveyed	not surveyed	0.032	0.013
	UCL	0.029	0.040			0.051	0.022
	LCL	0.009	0.016			0.019	0.008

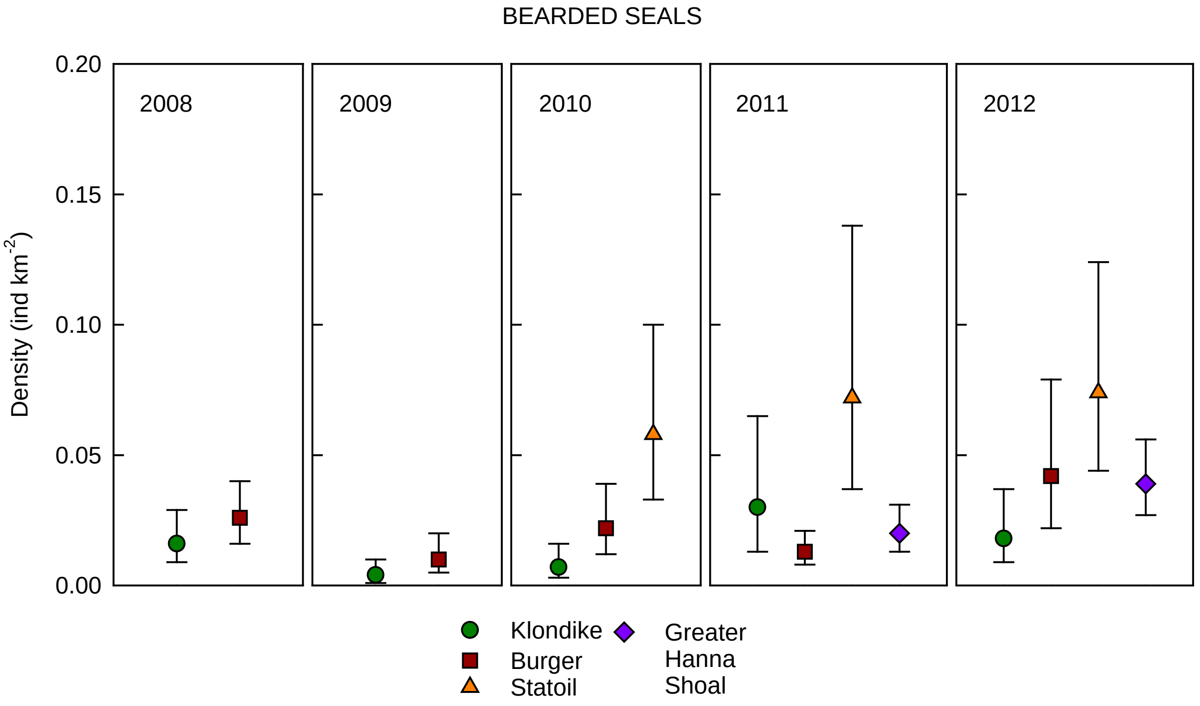


Figure 3.5. Bearded seal densities (with 95% Confidence Intervals) for 2008−2012 in each prospect-specific study area.

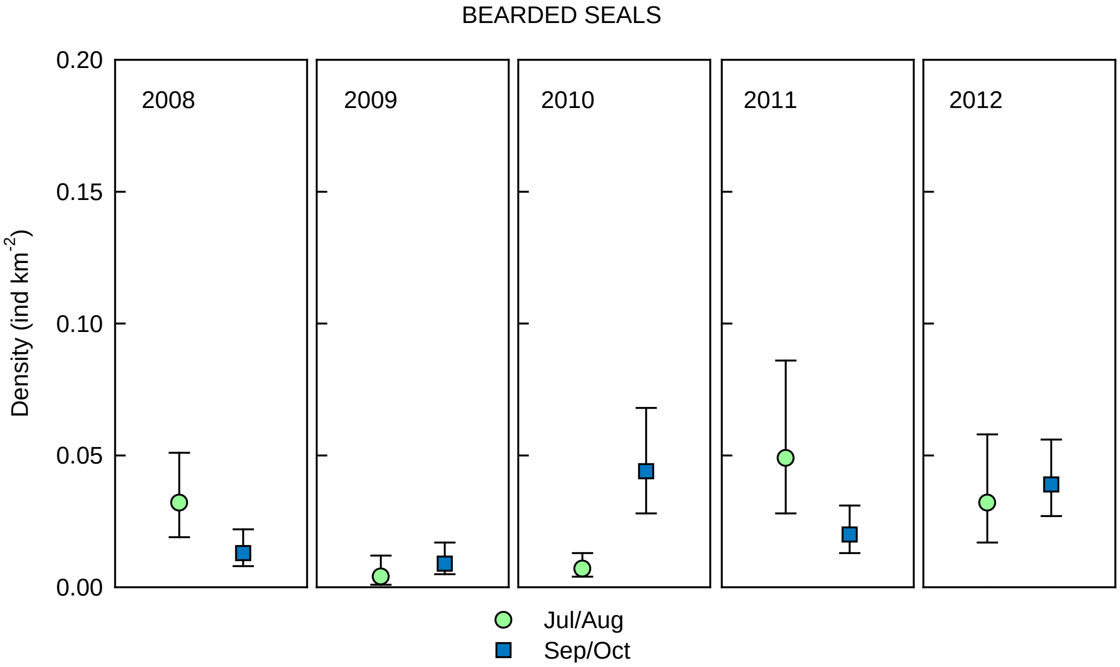


Figure 3.6. Bearded seal densities (with 95% Confidence Intervals) for 2008−2012 in the summer (July/August) and fall (September/October).

Seal Distribution

We created maps displaying ringed/spotted and bearded seal distribution based on effort-corrected sighting rates (ind km^{-1}) of on- and off-transect data (Figs. 3.7, 3.8). In 2012, the distribution of ringed/spotted seals was mainly concentrated in the central part of the GHS study area. In contrast, in 2008−2011, the ringed/spotted seal distribution showed a more northerly distribution in the GHS study area. The 2012 distribution among the three prospect-specific study areas showed more ringed/spotted seals in Burger than in Klondike. This differed from the distribution pattern in 2008–2011. In all five years of this study, we frequently saw ringed/spotted seals near shore of the study area (Fig. 3.7).

The bearded seal distribution pattern in 2012 was similar to that of the ringed/spotted seals. The 2012 bearded seal distribution was mainly concentrated in the central part of the GHS study area, whereas the 2008–2011 data showed a more northerly distribution. Distribution among the three prospect-specific study areas showed a more consistent pattern across all years, with highest densities in the Statoil study area. Like ringed/spotted seals, bearded seals also occurred frequently near shore of the study area (Fig. 3.8).

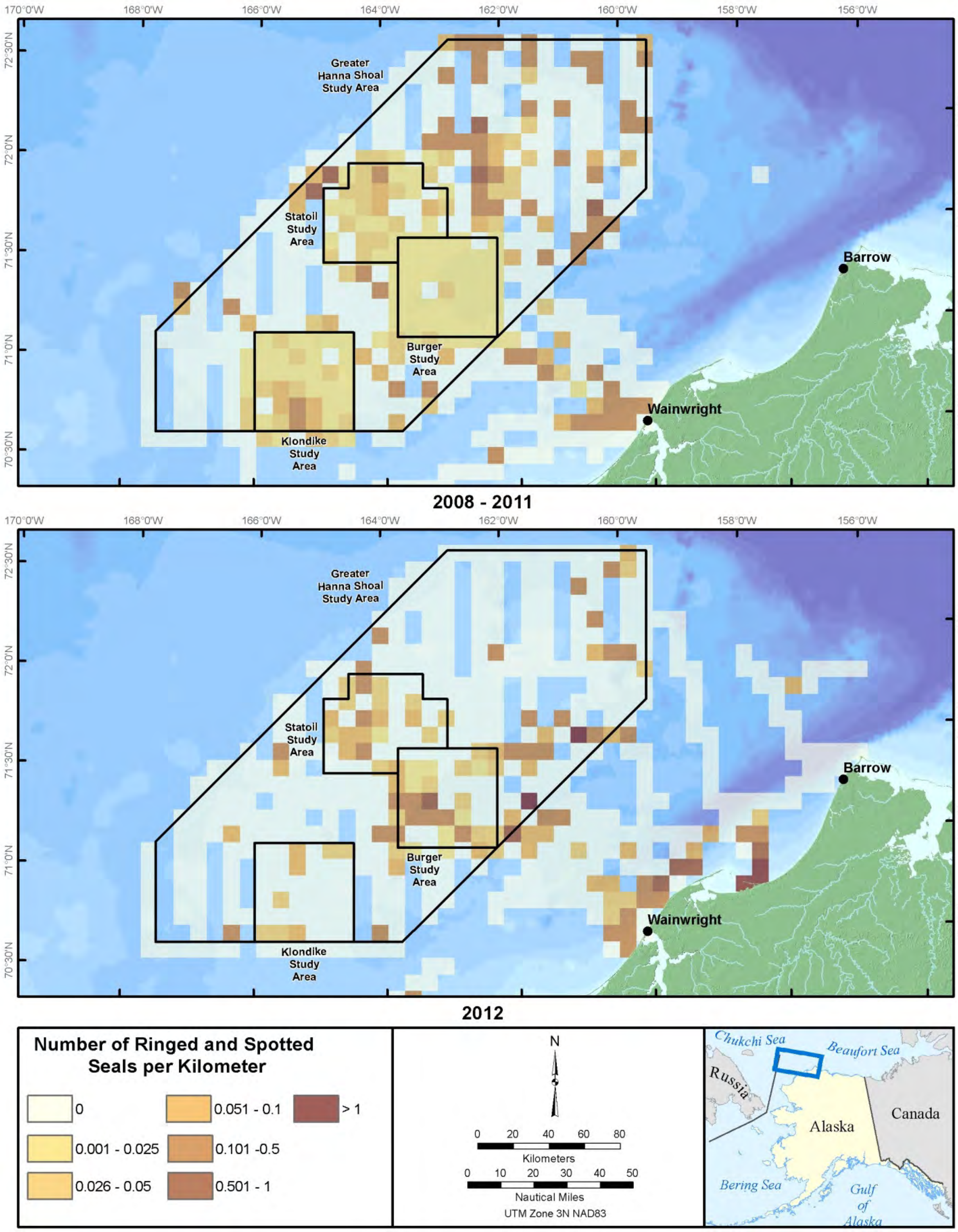


Figure 3.7. Ringed and spotted seal distribution based on sighting rates (ind per km) calculated for 5 × 5 nm grid cells using on- and off-transect data of 2008-2011 (upper graph) and 2012 (lower graph).

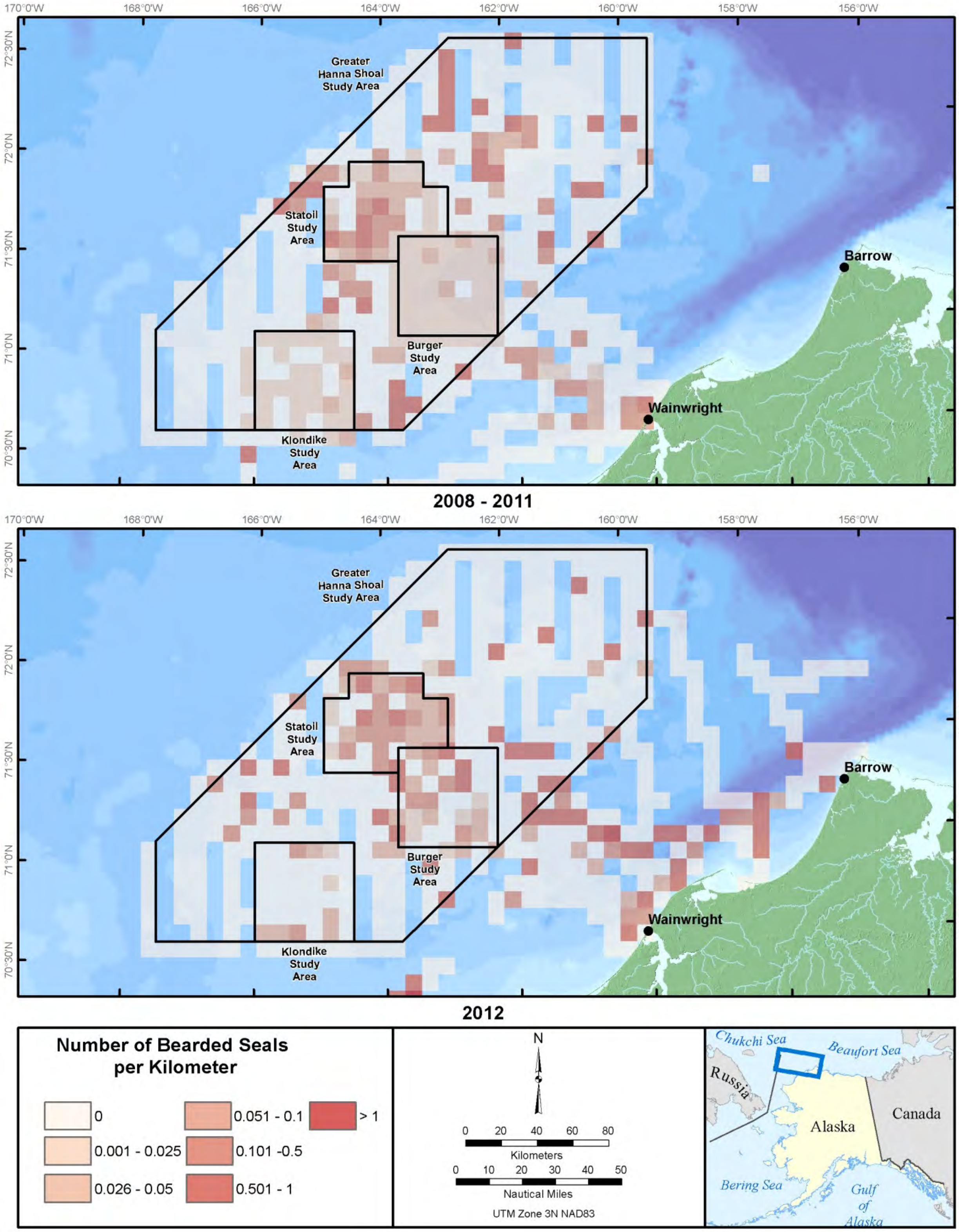


Figure 3.8. Bearded seal distribution based on sighting rates (ind per km) calculated for 5 × 5 nm grid cells using on- and off-transect data of 2008-2011 (upper graph) and 2012 (lower graph).

DISCUSSION

Four species of phocid seals inhabit the northeastern Chukchi Sea either seasonally or year-round; the ringed seal, spotted seal, bearded seal, and ribbon seal. During the five years of CSESP marine mammal surveys, the most commonly observed species were ringed, spotted, and bearded seals. We have only recorded eight solitary ribbon seals (six in 2008 and two in 2011), indicating that this species is of rare occurrence in the northeastern Chukchi Sea during the open-water season.

Based on 2008−2010 data we suggested that inter-annual variability in ringed/spotted seal abundance observed during our surveys was mainly related to food availability, reflecting the influence of oceanographic conditions (Aerts et al. 2013). The diet of ringed seals is flexible and seasonally variable. Crustaceans (mostly shrimp, amphipods, and mysids) are the main food source in spring and summer (Burns and Eley, 1978; Lowry et al., 1980a). Spotted seals also have a flexible diet and can feed on whatever prey items are available and abundant (Kato, 1982; Bukhtiyarov et al., 1984). However, they mainly target schooling fish (specifically Arctic cod) and shrimp.

The Klondike and Statoil study areas are affected by Bering Sea Water from the Central Channel and thus have a stronger pelagic component than the Burger study area (Day et al. 2013). As a result, the biomass of zooplankton species, such as copepods and euphausiids, is generally higher in the Klondike than in the Burger study area. However, this difference has not been apparent every year (Questel et al. 2012). In comparison, the Burger study area is considered a benthic-dominated system (Day et al. 2013). We continue to believe that these differences in ecological conditions, together with other factors, influence the density and distribution of seals in the study areas.

Based on the stronger pelagic component in the Klondike and Statoil areas, we anticipate higher ringed/spotted seal densities there. However, in 2012, the density in the benthic-dominated Burger area was higher than in the Klondike area. We assume that the presence of sea ice that persisted in the Burger area for the majority of the survey season influenced the local ringed/spotted seal density. In 2008, sea-ice conditions and ringed/spotted seal density in Burger were similar to 2012. Also, the seasonal density pattern (higher density in summer than in fall) was similar between these two heavy ice years, supporting the assumption. Although arctic seals are closely associated with sea ice during the breeding and molting seasons, ringed seals exhibit a pelagic lifestyle during the open-water period and use the Chukchi Sea mainly for foraging (Kelly et al. 2010a, 2010b). Spotted seals make foraging trips from coastal haulouts (Lowry et al., 1998, 2000) and do not use sea ice as a foraging platform. Though not required for foraging, the presence of sea ice may improve foraging conditions. Detailed analyses looking into seal distribution and food availability are pending.

In 2008–2012, bearded seal densities showed a consistent pattern in annual and spatial abundance and distribution. In four of the five years a density gradient was evident across study areas. Highest densities occurred at Statoil, intermediate densities at Burger, and lowest densities at Klondike. Bearded seal vocalizations during our survey period, as detected on acoustic recorders in the northern Chukchi Sea, were also concentrated around the Statoil study (Delarue et al. 2013). We assume that ecological variables influenced this observed spatial pattern. The difference in bearded seal densities among study areas is consistent with benthic studies indicating that the density and biomass of potential food sources was higher at Burger and Statoil than at Klondike (Blanchard et al., 2013). However, the bearded seal density at Burger was lower than expected based on the abundance and biomass of potential prey organisms. These lower densities could be related to the presence of large numbers of walruses in Burger (see Chapter 4) that might have decreased food availability for bearded seals through interspecific competition. Trophic interactions between walrus and bearded seals in the Chukchi Sea have been reported previously (Lowry et al. 1980b). Another factor influencing local bearded seal distribution is predation pressure of walruses. Seal-eating walruses are rather common, especially during restrictive ice conditions that can cause a greater overlap in seal and walrus distributions (Lowry and Fay 1984). Stomach contents of walruses taken in the summer of 1960's and 1983 in the Chukchi Sea, where ranges of walruses and seals overlap broadly, have indicated that about 9-11% of the walruses were seal eaters.

Bearded seal density and occurrence did not appear to show a seasonal pattern (i.e., presence in summer vs. fall). In 2008–2012 seasonal occurrence of bearded seals was highly variable. Also, unlike ringed/spotted seal densities, there was no apparent relationship between heavy (2008 and 2012) and light ice years (2009−2011). We therefore conclude that sea ice did not determine the seasonal distribution of bearded seals. However, seasonal variation in bearded seal abundance does exist on a larger spatial and temporal scale. Bearded seal vocalizations in the Chukchi Sea were most numerous in spring (from about April through June) and almost absent during summer, fall, and early winter. Call detections increased again starting in January (Delarue et al. 2013). We acknowledge that abundance patterns based on vocalizations are partly influenced by (seasonal) differences in call behavior (Aerts et al. 2011).

CONCLUSION

- The 2012 densities of ringed/spotted and bearded seals of each study area were within the range of densities observed in the previous four years.
- In 2012, consistent with 2010 and 2011, ringed/spotted seal density was highest in the Statoil study area. Unlike previous years, when densities in Klondike tended to be higher than or equal to those in Burger, the 2012 ringed/spotted seal density was higher in Burger than in Klondike.
- Higher ringed/spotted seal densities in the summer versus the fall during heavy-ice years (2008 and 2012), imply that sea ice presence was an important factor influencing the distribution of ringed/spotted seals. During light-ice years (2009–2011) densities were highest in the fall.
- The distribution of bearded seals within the three prospect-specific study areas in 2012 was similar to previous years. Most seals were recorded at Statoil, followed by Burger and Klondike.
- Trophic interactions, i.e., competition for food or predation, between walruses and bearded seals might play a role in the distribution pattern of bearded seals across study areas. Although the Burger study area is richer in benthic prey organisms, bearded seals were more abundant in the Statoil study area.
- No seasonal density pattern was apparent for bearded seals in 2012. Seasonal occurrence of bearded seals over the past five years was highly variable. Also, no pattern between heavy (2008 and 2012) and light ice years (2009−2011) was apparent. We therefore conclude that sea ice did not influence the seasonal distribution of bearded seals.

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CHAPTER 4

WALRUS DISTRIBUTION AND ABUNDANCE

In 2012, similar to 2008–2011, marine mammal observations were recorded in the northeastern Chukchi Sea during line-transect surveys. The three prospect-specific study areas (Klondike, Burger, and Statoil) were surveyed in August, whereas in September/October data were recorded in the GHS area (which encompasses the three prospect-specific study areas). In addition, observers recorded marine mammal sightings during transits to acoustic recorder and mooring locations and to Wainwright and Nome. Information about the survey area and design, observation protocol, and data analyses is provided in the methods section of Chapter 1. In this chapter, we present the results of Pacific walrus (*Odobenus rosmarus divergens*) data in three different sections as summarized here.

1. Walrus sighting information, which summarizes on- and off-transect data from 2012 and, for comparison, also from 2008–2010;
2. Annual variation of walrus density and distribution, comparing the 2012 walrus sightings with data from 2008-2011, using only on-transect data; and
3. Walrus distribution in 2012 and 2008−2011, using on- and off-transect data converted into effort-corrected sighting rates.

RESULTS

Walrus Sighting Information

In 2012, we recorded a total of 4,541 walruses in 588 sightings along 10,027 km of transects in the Chukchi Sea, including transits to and from Nome. As in previous years, most walruses were sighted in the Burger study area. No walruses were observed in Klondike in 2012.

Sea ice was present in the central and northern GHS study area (including Burger and Statoil) during the start of our survey in August. The Klondike study area was ice-free during the entire survey period. Most sea ice retreated northward over the course of the survey season. However, scattered ice floes remained in the Burger and Statoil study areas until late September (see Figure 1.8 of Chapter 1). As is shown in Table 4.1, observers did not encounter many walruses on ice during on-transect surveys in the study areas (4 sightings of 34 animals), because, for safety reasons, surveys were planned as much as possible away from extensive ice concentrations. Thus, we recorded most on-ice walruses off-transect (category “other”): a total of 55 sightings of 2,368 animals (including repeat sightings). On-ice walrus sightings and individuals accounted for 10% and 50% of the total number, respectively. Sea ice was also present during 2008, until mid-September in the Burger study area. During that year, almost twice as many walruses were observed on ice (18% and 90% of the total sightings and individuals, respectively). In 2009, when ice was largely absent from the study areas, 8 on-ice sightings of 45 walruses were recorded during the deployment of acoustic recorders in early August, which is about 6% and 14% of the total number of sightings and individuals. We did not encounter any walruses on sea ice during August and September of 2010 and 2011, due to sea ice absence.

Table 4.1. Summary of walrus sightings as recorded in 2008-2012 for each survey area and year. The category OTHER includes all off-transect data and also data collected opportunistically for which no effort was recorded (we therefore did not include sighting rate information).

	2012		2011		2010		2009		2008		TOTAL	
	WATER	ICE	WATER	ICE	WATER	ICE	WATER	ICE	WATER	ICE	WATER	ICE
KLONDIKE												
Sightings	0	0	0	0	4	0	5	0	5	0	14	0
Individuals	0	0	0	0	7	0	7	0	19	0	33	0
Sight km^{-1}	0	0	0	-	0.002	-	0.002	-	0.001	-	0.002	-
Ind km^{-1}	0	0	0	-	0.004	-	0.002	-	0.005	-	0.004	-
BURGER												
Sightings	125	0	98	0	22	0	33	0	24	7	302	7
Individuals	315	0	202	0	40	0	60	0	45	174	662	174
Sight km^{-1}	0.109	0	0.081	-	0.008	-	0.012	-	0.009	0.003	0.019	0.001
Ind km^{-1}	0.275	0	0.216	-	0.014	-	0.022	-	0.016	0.063	0.036	0.016
STATOIL												
Sightings	4	1	17	0	11	0	Not Surveyed				32	1
Individuals	9	20	30	0	19	0					58	20
Sight km^{-1}	0.005	0.001	0.017	-	0.007	-					0.011	0.000
Ind km^{-1}	0.011	0.024	0.031	-	0.011	-					0.019	0.006
GREATER HANNA SHOAL*												
Sightings	123	3	22	0	Not Surveyed						145	3
Individuals	289	14	34	0							323	14
Sight km^{-1}	0.079	0.002	0.011	-							0.011	0.001
Ind km^{-1}	0.187	0.009	0.017	-							0.017	0.004
OTHER												
Sightings	292	55	16	0	19	0	82	8	13	2	422	65
Individuals	1728	2334	23	0	67	0	202	45	28	701	2048	3080
TOTAL												
Sightings	544	59	153	0	56	0	120	8	42	9	915	76
Individuals	2341	2368	289	0	133	0	269	45	92	875	3124	3288

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

In 2012, the distance of walrus sightings from the vessel ranged from ~5 to 3,000 m, with 71% of the sightings occurring at distances of 500 m or less (Fig. 4.1). In previous years (2008–2011), the percent of sightings at 500 m or less was somewhat higher at 80%. In 2012, when more ice was present, observers recorded more walruses at greater distances. Walruses are easier to detect on ice and can thus be seen at greater distances. The presence of ice possibly also alerted observers to watch for walruses.

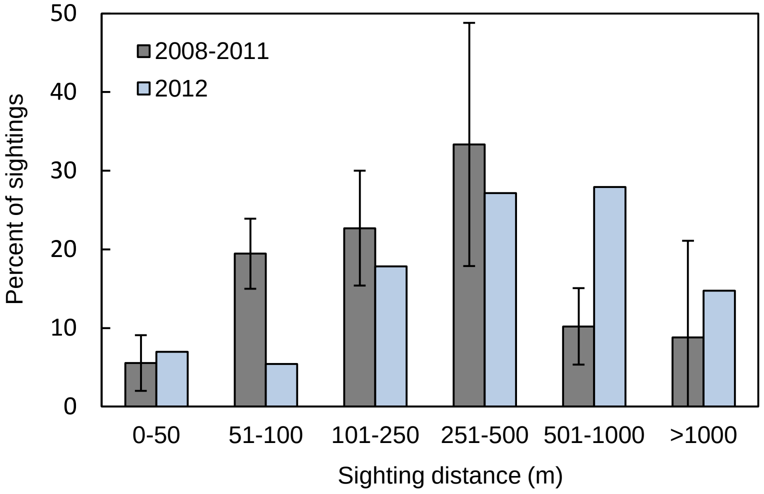

Figure 4.1. Radial distance (in m) from the vessel at which walruses in water were sighted as a percent of total number of on-transect sightings. Error bars represent the standard deviation.

Annual Variation in Walrus Density and Distribution

Effects of Environmental Conditions on Detection

Environmental conditions influence the probability of detecting animals. Based on 2008–2011 data, there was no apparent influence of sea state conditions on the detection of walruses (Fig. 4.2). We attribute this to the fact that walruses are relatively big, have large tusks, occur often in groups, and generally remain longer at the surface than seals. Walruses also noticeable roil the water (see photo). In 2012, a decreasing trend in sightings per km with increasing sea states was also not apparent. However, a large number of walruses were sighted during sea state condition 2 (0.22 sightings per km), which was more than recorded in previous years. There was also no apparent correlation between visibility conditions and walrus sighting rate in 2012 or 2008−2011 (Fig. 4.2). The later is to be expected since the majority of walruses (71%) were sighted at distances of 500 m or less (Fig. 4.1).

Walrus group in Chukchi Sea. CSESP 2012

Group of walruses active at water surface. CSESP 2012

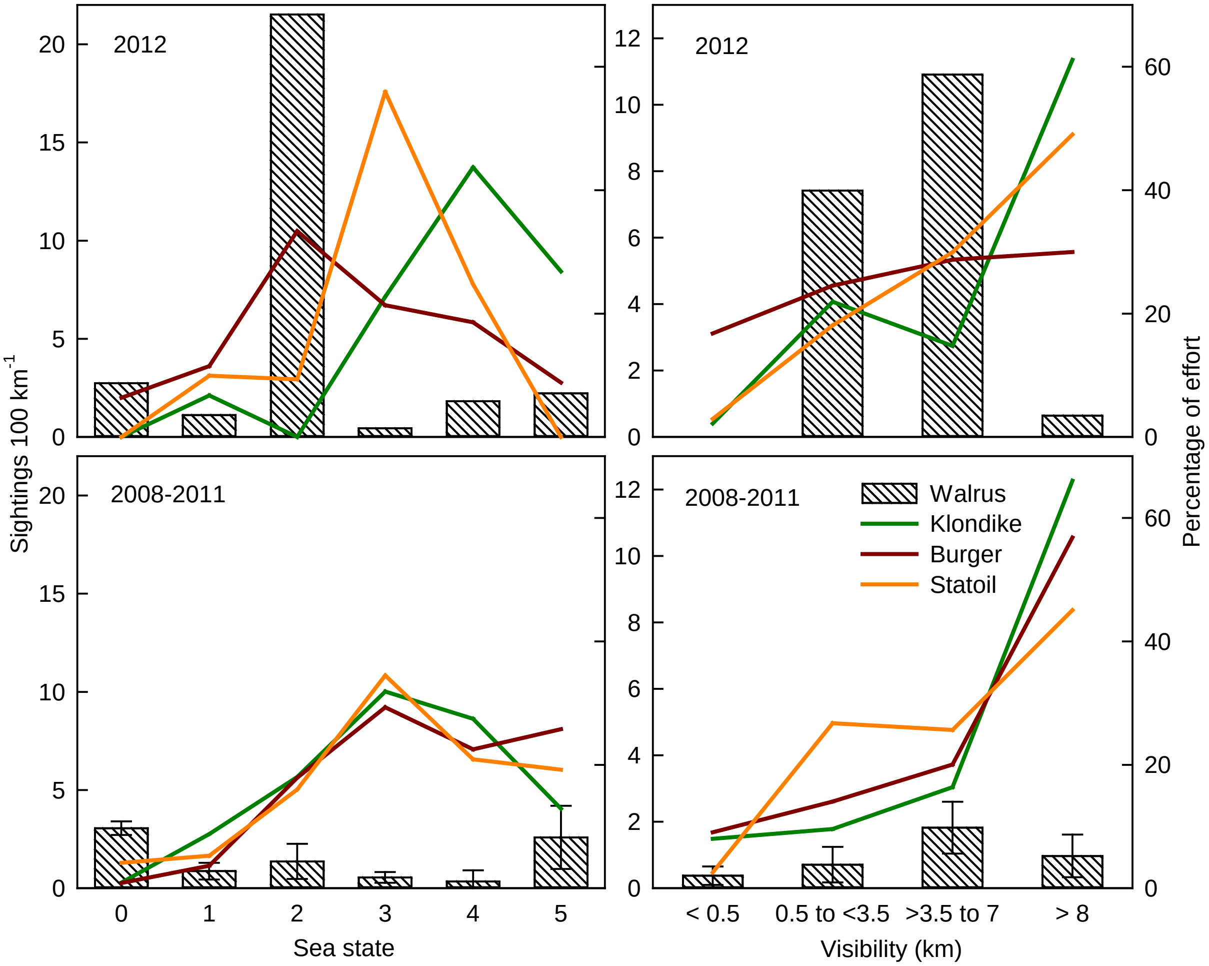

Figure 4.2. Walrus sighting rate (sightings per 100 km) based on 2012 and 2008-2011 on-transect data in the three prospect-specific study areas for each sea state (Beaufort Windforce scale; left) and visibility category (right). On-ice sightings are not included. Error bars represent standard deviations. The lines show survey effort (in percent of total effort) that occurred during each sea state and visibility category.

Walrus Density

We calculated walrus density with Program Distance (Thomas et al. 2010a). As explained in Chapter 1, we only used sightings with similar sighting cues, and thus equal detection probability, which resulted in exclusion of on-ice walrus sightings. Five years of data provided an adequate sample size of on-transect walrus sightings (n=498) to determine a reliable walrus detection function. Based on the 2008-2012 dataset, the best-fit model was the Hazard rate model, with sea state and visibility as covariates. 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). The visibility covariate did not make it into the model in previous years. This can be explained by the large contribution of 2012 data (about 50%) that included sightings observed at greater distances from the vessel than in 2008−2011. We calculated walrus densities, with 95% confidence intervals for each study area and year, using the estimated f(0) from the MRDS detection function from all on-transect walrus data (Table 4.2, Fig. 4.3). We also calculated seasonal walrus densities for the summer (July/August) and fall (September/October) of each year pooling study area data (Table 4.2, Fig. 4.4).

Average walrus densities using on-transect data for each year and study area ranged from 0 ind km^{-2} in the Klondike study area in 2012 and 2011 to 0.272 ind km^{-2} in the Burger study area in 2012. Seasonal walrus densities ranged from 0.001 to 0.292 ind km^{-2}, with the lowest density in summer 2008 and the highest in the fall of 2012 (Fig 4.4). The 2012 fall density was similar to the density of the GHS study area that was only surveyed in its entirety in the fall. The large confidence intervals were caused by the occurrence of sightings in clusters and large groups. In the Klondike study area, no walruses were encountered in 2012 and 2011 and the 2008–2010 walrus densities were low (0.008 ind km^{-2} in 2008 and 0.004 ind km^{-2} in 2009 and 2010). In the Burger study area, walrus density in 2012 was similar to the density observed in 2011, but higher than any density recorded in 2008−2010 (Fig. 4.3). We did not find a consistent seasonal pattern in walrus densities, although in three of the five years densities were higher in fall than in summer (2008, 2011, and 2012) (Fig. 4.4). There was no seasonal difference in walrus density in 2010. In 2009, density was highest in summer.

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

		KLONDIKE	BURGER	STATOIL	GHS	SUMMER	FALL
2012	**ind km^{-2}**	**0**	**0.272**	**0.016**	**0.292**	**0.006**	**0.292**
	UCL	**0**	**0.799**	**0.059**	**0.608**	**0.020**	**0.608**
	LCL	**0**	**0.092**	**0.004**	**0.140**	**0.002**	**0.140**
2011	ind km^{-2}	0	0.250	0.025	0.103	0.021	0.103
	UCL	0	0.593	0.056	0.225	0.037	0.225
	LCL	0	0.105	0.011	0.047	0.012	0.047
2010	ind km^{-2}	0.004	0.018	0.020	not surveyed	0.011	0.016
	UCL	0.013	0.030	0.040		0.019	0.025
	LCL	0.001	0.011	0.010		0.007	0.010
2009	ind km^{-2}	0.004	0.029	not surveyed	not surveyed	0.040	0.004
	UCL	0.008	0.053			0.078	0.009
	LCL	0.001	0.016			0.021	0.002
2008	ind km^{-2}	0.008	0.013	not surveyed	not surveyed	0.001	0.021
	UCL	0.022	0.035			0.005	0.044
	LCL	0.003	0.005			0.000	0.010

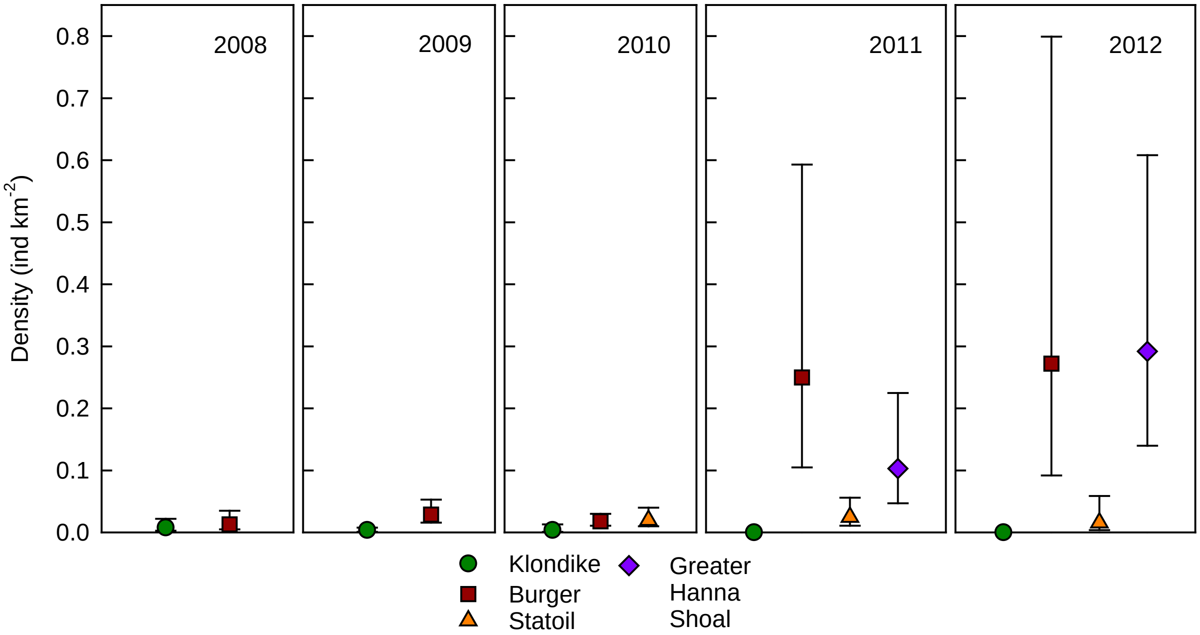

Figure 4.3. Walrus densities (with 95% Confidence Intervals) for 2008−2012 in each prospect-specific study area.

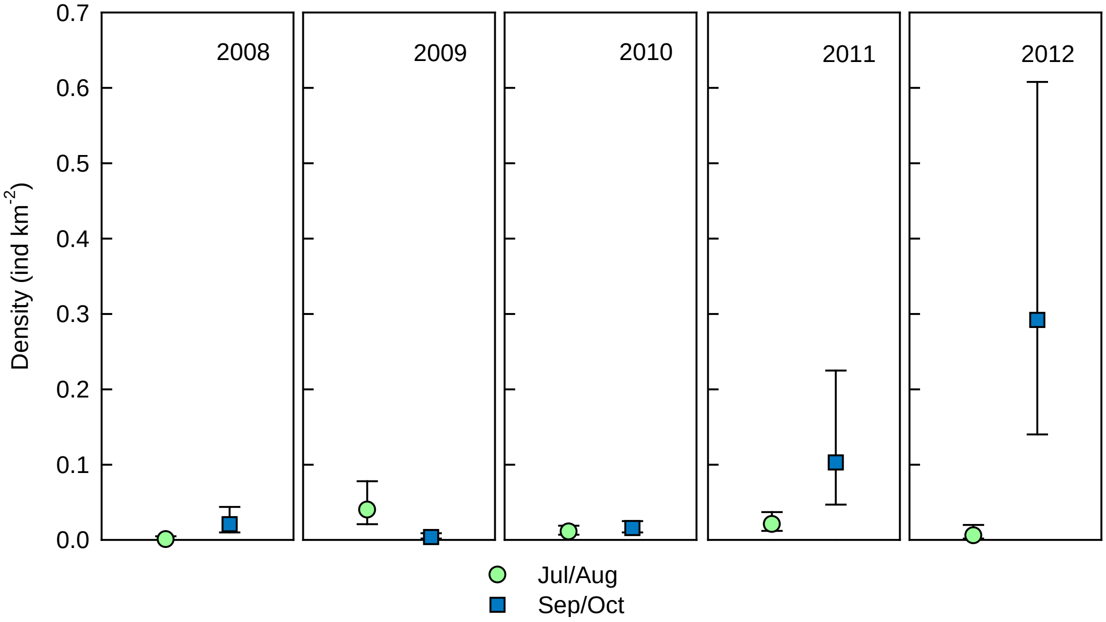

Figure 4.4. Walrus densities (with 95% Confidence Intervals) for 2008−2012 in the summer (July/August) and fall (September/October).

In 2012, the average group size of walruses observed in water was 4.4 animals ±14.5, with a maximum estimate of 150 animals in one group. The group size recorded in 2012 was higher and more variable than in 2008−2011 (average of 2.4 animals ±2.9, with a maximum group size estimate of 50), This difference in groups size was partly due to numerous sightings occurring simultaneously, forcing observers to record multiple groups as one. In 2012, 29% of walrus sightings in water were solitary individuals, while 62% were groups of 2 to 5 animals. This was similar to previous years where 29−45% of in-water sightings were solitary animals, while 53−64% consisted of 2 to 5 animals. For walrus on ice, the average group size in 2012 was 40 animals ±71.2, with a maximum estimate of 400 animals in one group. In 2008, the average on-ice group size was about twice as high (97.2 animals ±228.3, with a maximum estimate of 700 animals), but more variable due to a smaller number of on-ice sightings.

Walruses were not seen regularly during the summer and fall season, but rather occurred in pulses. In 2012, observers recorded the majority of walruses over a three-week period (September 4 and 24) (Fig. 4.5). Similar spikes in numbers were observed in previous years, though the main spike in 2012 was more pronounced and prolonged. 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 and 2008, we recorded no obvious spikes.

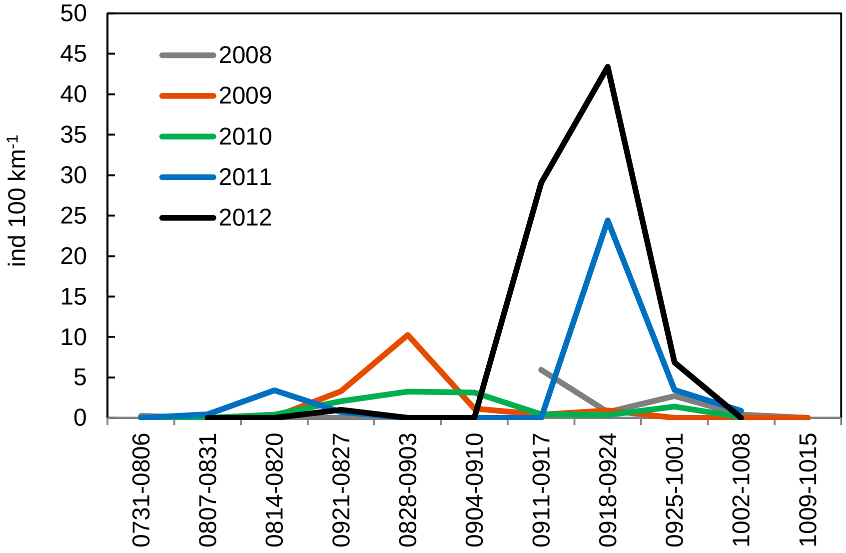

Figure 4.5. Seasonal observations of walruses (ind 100 km^{-1}) in the northeastern Chukchi Sea during 2008−2012. Data are based on on-transect effort and do not include walruses sighted on ice (174 and 34 individuals in 2008 and 2012, respectively).

Walrus Distribution

We plotted effort-corrected sighting rates (ind km^{-1}) using on- and off-transect data to display walrus distribution (Fig. 4.6). Many sightings were recorded along off-transect lines, so inclusion of these data provided a more complete picture. The walrus distribution showed a consistent pattern across years, with concentrations in the northeastern part of the Burger study area. This was particularly apparent in 2012. Surveys in the GHS study area showed that this concentration extended eastwards towards shore (2011 and 2012) and northwards towards Hanna Shoal (2012). In 2012, the spatial distribution of walruses overlaps with the highest concentrations of sea ice as recorded in mid-September (see Fig. 1.8 of Chapter 1). This is also the period during which most walrus were observed (September 4−24; Fig. 4.5).

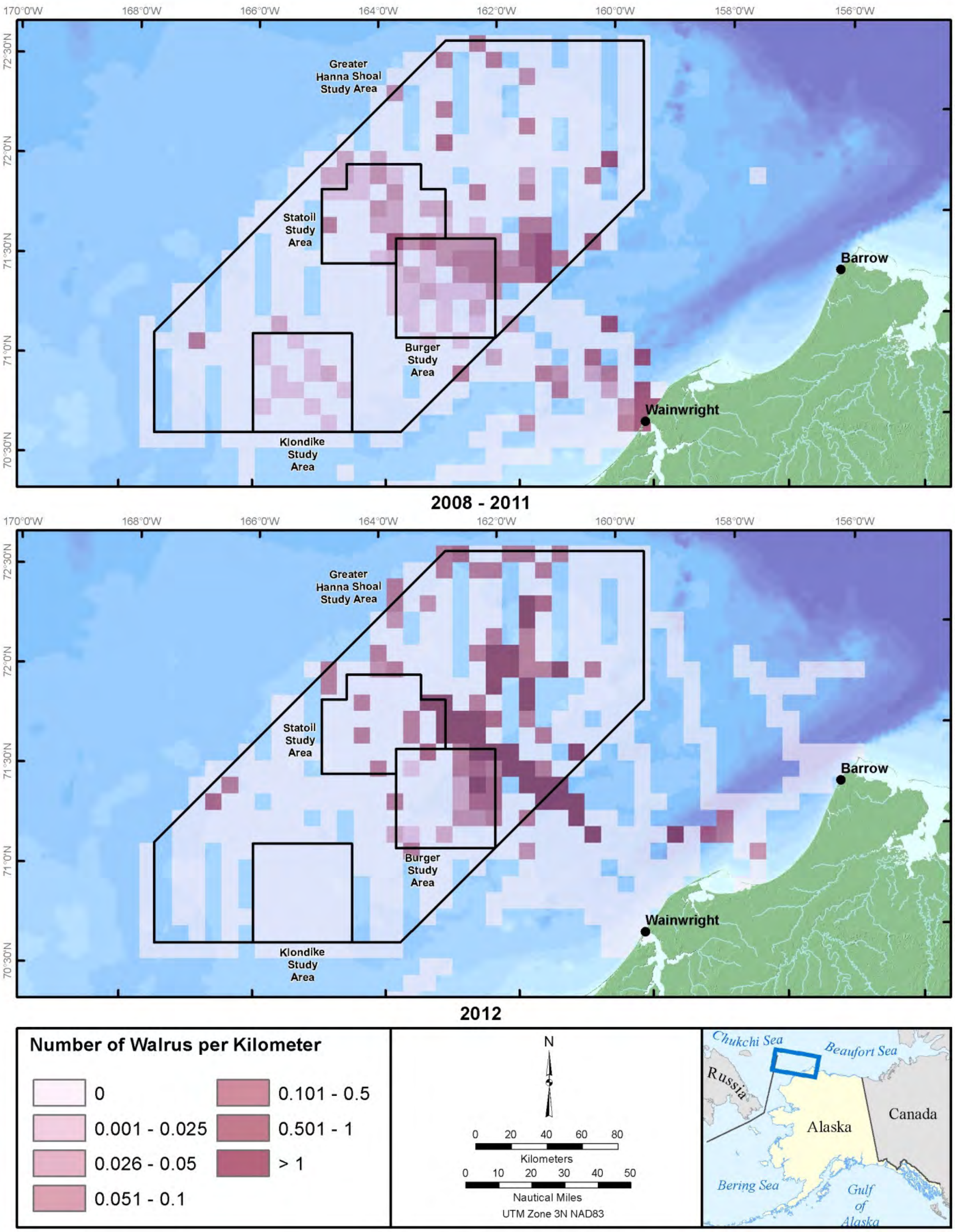

Figure 4.6. Walrus distribution based on sighting rates (ind per km) calculated for 5 × 5 nm grid cells using on- and off-transect data of 2008-2011 (upper graph) and 2012 (lower graph).

DISCUSSION

Five years of data on walrus distribution and abundance in the offshore northeastern Chukchi Sea during the open-water season of 2008–2012 showed the following main trends: (1) walrus abundance varied annually, mostly apparent in the Burger study area; (2) the ratio between walruses observed in water and on ice corresponded with the amount of sea ice in the study areas and timing of terrestrial haul-out formation; (3) relative annual distribution was fairly consistent among the three prospect-specific study areas, with highest densities consistently occurring in Burger; and (4) Burger appears to be an important foraging area for walruses. These four observations are further discussed below.

Over the five-year study, walrus abundance varied between years, with the highest overall numbers recorded in 2012. In addition, we observed annual differences in the proportion of walruses observed in water vs. on ice. These inter-annual variations were most likely related to a combination of differences in the extent and proximity of sea ice habitat and associated utilization of coastal haul-out sites. The distribution of walruses in the Chukchi Sea during summer is closely associated with the distribution and extent of sea ice (Fay et al. 1984, Garlich-Miller 2011). When broken ice is abundant during summer, walruses are typically found in patchy aggregations on the ice from which they access foraging areas and on which they rest. In years when sea-ice retreats beyond the continental shelf, walruses congregate in large numbers at terrestrial haulouts. Since 2007, terrestrial walrus congregations have been observed along the coast of Alaska at Icy Cape and Point Lay during light-ice years (Thomas et al. 2010b, Fishbach et al. 2009). The formation of these onshore congregations has also been confirmed through detections of walrus vocalizations (Delarue et al. 2012, 2013). Walruses that are using sea-ice as a foraging platform tend to make more frequent but shorter trips, both in duration and distance, than walruses using terrestrial haulouts (Udevitz et al. 2009). The probability of detecting walruses is thus dependent on the amount and proximity of sea ice in our study area and the chance of encountering walruses in water during their migration to terrestrial haul outs. Over the five-year study, we had two heavy-ice years (2008 and 2012), one intermediate year with regard to water temperature and sea ice melt (2010), one year characterized by an early ice retreat but intermediate water temperatures (2011), and one year where the influence of warm Bering Sea water resulted in warm, ice-free waters early in the season (2009). Coastal haul outs of large aggregations of walruses were not observed in 2008 (Garlich-Miller 2011; Thomas et al. 2010b) when sea ice in the northeastern Chukchi Sea provided a platform from which walruses were foraging during the entire survey period. Consequently, we observed the highest ratio between in-water and on-ice sightings during this year, though the total walrus density was similar as in 2009 and 2010 (both light-ice years). The higher than expected density during the latter two years is due to the peak in sightings that occurred during the formation of coastal haul-outs end of August. In 2012, another heavy-ice year, coastal haul-outs started to form after mid-September, when most of the sea ice had melted. The timing of migration to coastal haul outs during 2012 was based on detections of walrus vocalizations (Delarue et al. 2013). The ratio between on-ice and in-water walrus sightings in 2012 was half of those recorded in 2008. The majority of walrus sightings coincided with the three-week period (September 4−24) when ice was disappearing and walruses were transferring to terrestrial haul-outs. Numerous walruses were observed in water close to the remaining ice floes as well as on those floes. Detections of walrus vocalizations were also highest during that three-week period (Delarue et al. 2013). The variation in abundance observed among light-ice years (2009–2011) was influenced by the timing of coastal haul-out formation in combination with the location of line-transect survey, as evidenced by the spike in walrus observations each year. The peaks in walrus sightings at the end of August 2009 and 2010 and mid-August 2011 coincided with the formation of coastal haulouts (Fischbach et al. 2009; Garlich-Miller et al. 2011; Clarke et al. 2012). However, the extent of these peaks varied each year. In 2011, there was an additional peak in walrus sightings during the third week of September; about one month after the coastal haul out was formed that year. We were sampling transect lines in Burger and Statoil (just north of Burger) during that week, which likely coincided with presence of concentrations of foraging walruses or walruses traveling between coastal haul outs and foraging areas. Walrus call detections also showed a peak during the same week (Delarue et al. 2012).

Each year we found highest walrus densities in the Burger study area (particularly pronounced in 2011 and 2012), followed by the Statoil and Klondike study areas. There was little inter-annual variation in this general gradient. We assume that the high concentrations of walruses observed in Burger each year, extending eastward and northward as observed in 2012 and 2011, indicated the presence of a preferred foraging area. The overall high benthic biomass and abundance in Burger compared to the Klondike and Statoil study areas (Blanchard et al. 2013a, 2013b) and the high bivalve biomass concentration in the area where we observed most walruses (Fig. 4.7) confirm this assumption. Telemetry data collected in 2008–2011 also indicated that areas of heavy foraging by walrus in the Chukchi Sea corresponded to areas of reported high benthic biomass (Jay et al. 2012), confirming our assumption that the availability of food influences walrus distribution. We plan to conduct more detailed analyses investigating the relationship between walrus distribution and prey availability.

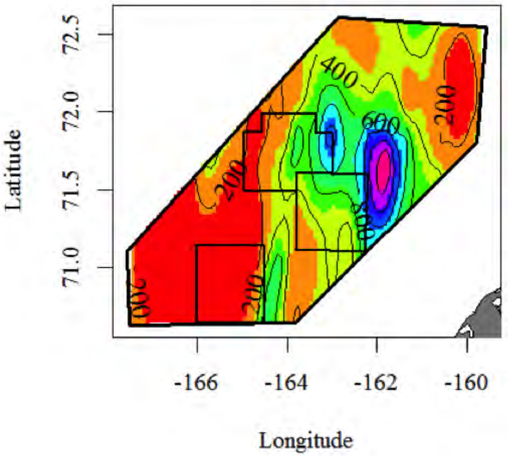

Figure 4.7. Bivalve biomass (g m^{-2}) in the GHS study area based on geostatistical models. Source: Figure 2.8 in Blanchard et al. 2013c.

CONCLUSION

- The number of walrus sightings in 2012 was the highest recorded over the past five years. Most sightings were recorded in September, coinciding with the presence of sea ice and the start of coastal haul-out formation.
- In 2012, walrus densities within the Klondike and Statoil study areas were similar as in previous years. The 2012 densities in the Burger study area were similar to 2011, but higher than 2008–2010.
- Consistent with previous years, we observed highest walrus densities in the Burger study area. Surveys in the GHS study area in 2011 and 2012 showed that this concentration extended eastward and northwards toward Hanna Shoal.
- The high concentrations of walruses observed in Burger, extending eastward and northward as observed in 2012 and 2011, coincide with high bivalve biomass, thus indicating the presence of a preferred foraging area.

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