FINAL REPORT

# DISTRIBUTION AND ABUNDANCE OF SEABIRDS IN THE NORTHEASTERN CHUKCHI SEA, 2008–2011


ADRIAN E. GALL

ROBERT H. DAY


PREPARED FOR

**CONOCOPHILLIPS COMPANY**
ANCHORAGE, ALASKA

**SHELL EXPLORATION & PRODUCTION COMPANY**
ANCHORAGE, ALASKA

**STATOIL USA E & P, INC**
ANCHORAGE, ALASKA

PREPARED BY


**ABR, INC.–ENVIRONMENTAL RESEARCH & SERVICES**
FAIRBANKS, ALASKA

# DISTRIBUTION AND ABUNDANCE OF SEABIRDS IN THE NORTHEASTERN CHUKCHI SEA, 2008–2011

FINAL REPORT

Prepared for

**ConocoPhillips Company**

P.O. Box 100360

Anchorage, AK 99510-0360

**Shell Exploration & Production Company**

3601 C Street, Suite 1334

Anchorage, AK 99503

**Statoil USA E & P, Inc**

3800 Centerpoint Drive, Suite 920

Anchorage, AK 99503

Prepared by


Adrian E. Gall

Robert H. Day

**ABR, Inc.—Environmental Research & Services**

P.O. Box 80410

Fairbanks, AK 99708-0410


December 2012

*Printed on recycled paper.*

## EXECUTIVE SUMMARY

- In 2008–2011, we collected data on the distribution and abundance of seabirds in the northeastern Chukchi Sea in the vicinity of several oil and gas lease areas. The Greater Hanna Shoal (GHS) study area was ~110–180 km (~60–100 NM) northwest of the village of Wainwright and included 3 study areas known as Klondike, Burger, and Statoil.
- The objectives of this study were to: (1) describe seasonal, spatial, and interannual variation in the distribution and abundance of seabirds; (2) describe seasonal and interannual changes in species-richness and species-composition; and (3) relate the patterns in distribution and abundance within the study areas to the regional pattern seen in the GHS study area as a whole.
- We conducted seabird surveys during 3 seasons that covered the entire open-water period of the northeastern Chukchi Sea: late summer (Jul/Aug), early fall (Aug/Sep), and late fall (Sep/Oct; 2008–2010 only). In 2011, we conducted an extended fall cruise that combined the early and late fall cruises from earlier years.
- In 2008, sampling effort was greater in Klondike than in Burger, especially during the Jul/Aug cruise, because it generally had less ice cover. In 2009–2011, we did not encounter any ice in the study areas during the sampling period. In 2010, we sampled all 3 study areas in Jul/Aug and Aug/Sep but sampled only Burger in Sep/Oct. In 2011, we added sampling in the Greater Hanna Shoal study area and did not sample the lease boxes in Sep/Oct.
- Seabirds were most abundant overall in 2009 and least abundant in 2008. In both 2010 and 2011, total abundance within the study-area boxes was similar but generally was lower than that in 2009 and higher than that in 2008.
- Alcids were the most abundant species-group in 2008, 2010, and 2011 and were the second-most-abundant species-group in 2009. Densities of alcids were significantly higher in Klondike than in Burger during all three seasons in 2008, whereas densities were higher in Burger than in Klondike during Jul/Aug and Aug/Sep but were higher in Klondike than in Burger in Sep/Oct in 2009. In contrast, densities of alcids were similar among all 3 study areas in 2010 and 2011.
- Tubenoses were the second-most-abundant species-group in 2008, 2010, and 2011 and were the most abundant species-group in 2009, primarily because of large flocks of Short-tailed Shearwaters moving through Klondike in Aug/Sep. The maximal density of Short-tailed Shearwaters in 2009 was nearly 16 times the maximal density in any other year.
- Multivariate analyses of the seabird community composition indicated that species-composition varied among seasons and that the dominant pattern of composition differed among study areas. The numerical dominance of alcids in all study areas combined increased from 2008 to 2010. Klondike was numerically dominated by alcids and tubenoses in all years. Burger was numerically dominated by larids and tubenoses in 2008 and by alcids in 2009–2011. Statoil also was numerically dominated by alcids in 2010 and 2011.
- We recorded 11 species on transect in the study areas that are classified as being of conservation concern. One (Spectacled Eider) is listed as a threatened species under the U.S. Endangered Species Act of 1973, as amended (ESA), 2 (Kittlitz's Murrelet and Yellow-billed Loon) are classified as candidate species under the ESA, and 2 (Red-throated Loon and Arctic Tern) are classified as species of conservation concern by the U.S. Fish and Wildlife Service.
- Comparisons among the study-area boxes suggest that the structure and variability of the seabird community reflects the flow of Bering Sea Water (BSW) northward in the Central Channel. The data collected in 2011 from the GHS provide further evidence to support this hypothesis.
- The southeastern half of GHS, including Klondike and the western half of Statoil, appears to be a more pelagically-dominated system with a greater abundance of diving alcids and Short-tailed Shearwaters and higher

biomass of copepods (in 2008–2010) than seen to the north and east. The northeastern half of GHS, including Burger and the eastern half of Statoil, appears to be a benthically-dominated system with a greater abundance of surface-feeding larids and a higher abundance, biomass, and number of benthic taxa than seen to the south and west.

- The distribution of seabirds, particularly the planktivorous species, may be strongly influenced by advective processes that transport oceanic species of zooplankton from the Bering Sea to the Chukchi Sea. This transport apparently differed among years and resulted in a broader northeastward intrusion of BSW in 2009 and 2011 than in other years. Planktivorous seabirds concentrated in areas characterized by BSW, whereas piscivorous and omnivorous seabirds concentrated in areas characterized by cold Meltwater and Winter Water.

## TABLE OF CONTENTS



## LIST OF FIGURES

## LIST OF TABLES

## LIST OF APPENDICES



## ACKNOWLEDGMENTS

ConocoPhillips Company (COP), Shell Exploration & Production Company (Shell), and Statoil USA E &P Inc. (Statoil) funded this research; in addition, COP provided project management and oversight during 2008–2009. We thank Caryn Rea, James Darnall, and Mike Faust of COP; Michael Macrander of Shell; and Karin Berentsen and Steinar Eldøy of Statoil for support and advice during all phases of this study. We also thank John Burns, Jeff Hastings, and Sheyna Wisdom of Olgoonik Fairweather; Tom Mahoney, Blair Paktokak, and Bob Shears of Olgoonik Oilfield Services; and David Aldrich, Abby Faust, Sarah Norberg, and Waverly Thorsen of Aldrich Offshore Services for logistical and operational support in the field. We thank the Captains and crew of the M/V *Bluefin*, M/V *Norseman II*, and the M/V *Westward Wind* for keeping us safe at sea. In addition, we thank the other Principal Investigators and other scientists involved with this project; special thanks go to Thomas Weingartner of the Institute of Marine Sciences (IMS), University of Alaska Fairbanks, for insights into the physical oceanography of the Chukchi Sea, and to Arny Blanchard of IMS for statistical guidance. At ABR, we thank Lauren Attanas, Jennifer Boisvert, Corey Grinnell, Stephen Murphy, Tim Obritschkewitsch, Jonathan Plissner, John Rose, Peter Sanzenbacher, and Tawna Morgan for help with the seabird sampling; Rebecca Baird, Matt Macander, Allison Zusi-Cobb, and Dorte Dissing for help with GIS work; Christopher Swingley for help with data management; Alexander Prichard for statistical advice; Pamela Odom for report production; and Thomas DeLong for project support. Jeffrey Laake of the NMFS National Marine Mammal Laboratory at the Alaska Fisheries Science Center provided very timely assistance with Distance analyses. We thank Caryn Rea of COP, Steinar Eldøy of Statoil, and Michael Macrander and Koen Broker of Shell for review of this report.

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACW | Alaska Coastal Water |
| ADFG | Alaska Department of Fish and Game |
| Aug | August |
| BOEMRE | Bureau of Ocean Energy Management, Regulation, and Enforcement |
| BSW | Bering Sea Water |
| °C | degrees Celsius |
| CSESP | Chukchi Sea Environmental Studies Program |
| CTD | Conductivity, temperature, depth sensor |
| ESA | U.S. Endangered Species Act of 1973 (as amended) |
| GHS | Greater Hanna Shoal |
| GLM | generalized linear model |
| GPS | global positioning system |
| Jul | July |
| km | kilometer |
| MMS | Minerals Management Service |
| MW | Meltwater |
| NEPA | National Environmental Policy Act |
| NOAA | National Oceanic and Atmospheric Administration |
| NM | nautical mile |
| nMDS | Non-metric multidimensional scaling |
| NPPSD | North Pacific Pelagic Seabird Database |
| m | meter |
| OCSEAP | Outer Continental Shelf Environmental Assessment Program |
| Oct | October |
| Sep | September |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| WW | Winter Water |

# INTRODUCTION

The seasonally ice-covered Chukchi Sea shelf is among the largest continental shelves in the world. It also is highly productive, although much of the primary production and zooplankton biomass can be attributed to the northward flow of nutrient-rich oceanic water that originates far to the south, in the basin of the Bering Sea (Springer and McRoy 1993, Grebmeier et al. 2006). This influx of oceanic nutrients and plankton sustains a seabird community that otherwise would have little prey available (Springer et al. 1989). Despite an understanding of the importance of advection to the food web of the Chukchi Sea, questions remain about the spatial and temporal scales of processes that link the Bering and Chukchi ecosystems (Springer et al. 1996). Seasonal and interannual changes in advection may have profound effects on the distribution and abundance of non-breeding, staging, and migratory seabirds that rely on these resources during the open-water season (June to mid-October).

In addition to its rich marine resources, the Chukchi Sea is of great interest for offshore oil development. Exploration for offshore oil began in Arctic Alaska in the 1970s and led to exploratory drilling of 5 wells in 1989 and 1990. Two of these wells, known as Klondike and Burger, are located west of the village of Wainwright. These areas were not pursued beyond exploration at that time, and there was no further activity until February 2008, when nearly 3 million acres in the Chukchi Sea were leased for oil exploration. Studies of marine ecology were conducted in the late 1970s and early 1980s as part of the National Oceanic and Atmospheric Administration's Outer Continental Shelf Environmental Assessment Program (OCSEAP), and there has been resurgence in oceanographic research during the past decade. This study was initiated in 2008 to inform managers and industry about the recent distribution, abundance, and timing of seabirds using the northeastern Chukchi Sea. It forms one component of the Chukchi Sea Environmental Studies Program (CSESP), a multidisciplinary study of the marine ecology of this area.

## STUDY OBJECTIVES

In this study, we explored the distribution and abundance of seabirds in the northeastern Chukchi Sea in 3 areas where ConocoPhillips Company, Shell Exploration & Production Company, and Statoil USA E & P have lease-blocks for offshore oil and gas exploration and development. The objectives of this study were to: (1) describe seasonal, spatial, and interannual variation in the distribution and abundance of seabirds; (2) describe seasonal and interannual changes in species-richness and species-composition; and (3) relate the patterns in distribution and abundance within the lease areas to the regional pattern near Hanna Shoal. A synthesis report (Gall and Day 2011) provides detailed information on spatial, seasonal, and interannual variation in the ecology of seabirds in this area in 2008–2010, and publications (Gall et al., in press; Day et al., in press) summarize this information. This study provides baseline information on the recent distribution and abundance of seabirds in the lease areas and provides spatial and ecological context for the distribution and abundance of seabirds in the northeastern Chukchi Sea in the vicinity of those lease areas. This information will be used for an analysis of potential impacts of offshore exploration and development activities and will be included within a National Environmental Policy Act (NEPA) document required for exploration.

# METHODS

## STUDY AREA

This study was conducted in the northeastern Chukchi Sea, in an area extending ~180 km west of the village of Wainwright, which is located on the northwestern coast of Alaska (Figure 1). The overall survey area is bounded by 2 currents flowing from the Chukchi Sea to the Arctic Ocean: the Central Channel flow, to the west, and the Alaska Coastal Current, to the east (Weingartner et al. 2005, 2008). During 2008–2010, surveys focused on three study-area boxes located ~110–180 km offshore called Klondike, Burger, and Statoil that were sampled during 2–3 research cruises/yr. The Klondike study area is located on the eastern side of the Central Channel and near the inflow of Bering Shelf water, whereas the Burger

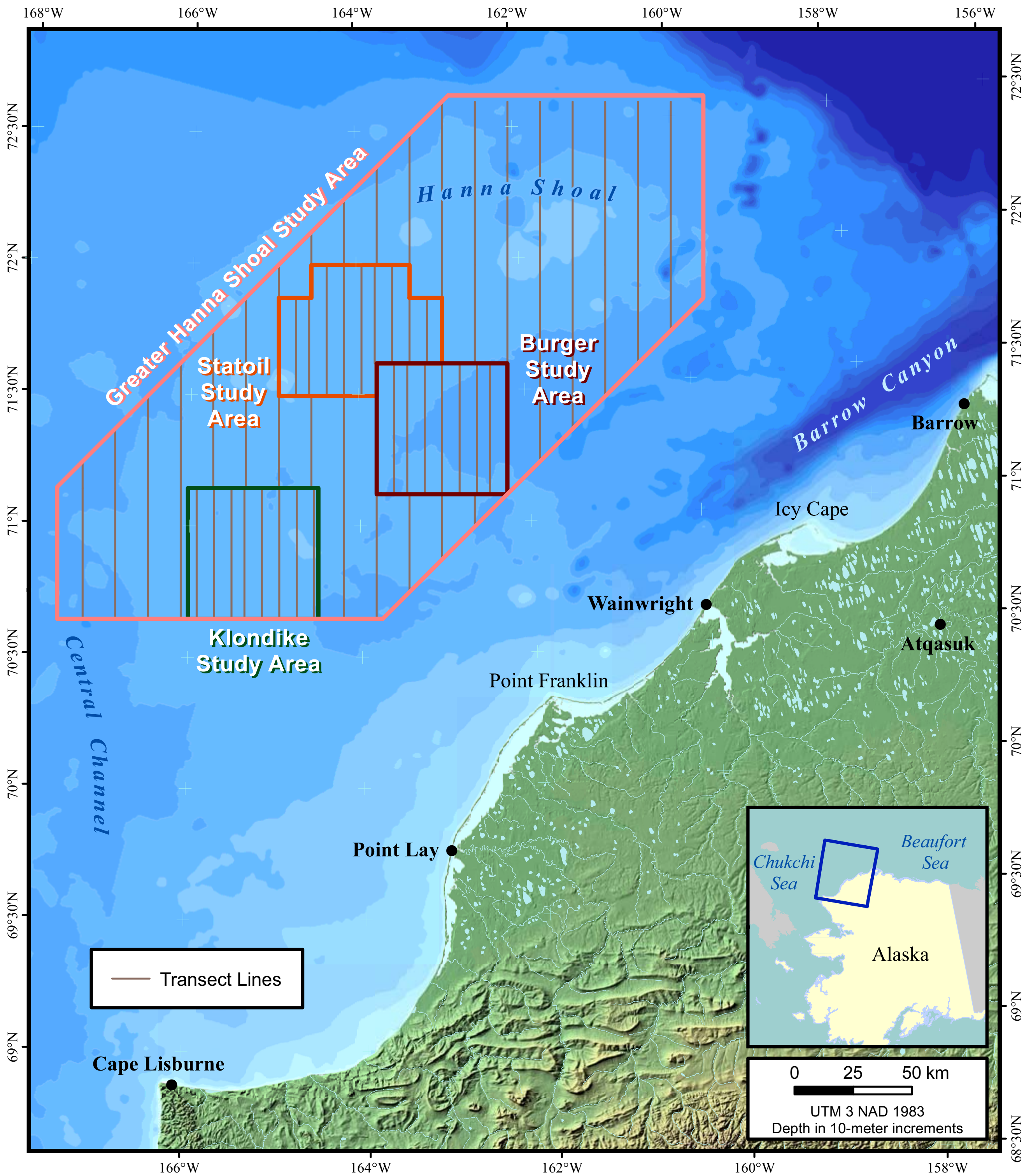


Figure 1. Locations of the Klondike, Burger, Statoil, and Greater Hanna Shoal study areas in the northeastern Chukchi Sea. Also shown are the locations of the survey lines.

study area is located to the northeast of Klondike and on the southern slope of Hanna Shoal. The Statoil study area was added in 2010 and is located to the north of Klondike and northwest of Burger, with its western edge close to the Central Channel and the eastern half on the southern slope of Hanna Shoal. The survey area was expanded again in 2011 to include areas north and west of the 3 study-area boxes; this larger study area is referred to as the Greater Hanna Shoal (GHS) study area. The Alaska Coastal Current flows east of the GHS study area, exiting the region via Barrow Canyon.

Each study-area box consisted of a polygon ~3,000 $km^2$ in area, and observers surveyed seabirds along a series of parallel survey lines spaced 2 NM apart that ran north–south through the 3 study-area boxes. A subsample of these survey lines was included in the survey design for data collection during 2011, which consisted of broad-scale survey lines in the Greater Hanna Shoal (GHS) study area spaced 7.5 NM apart and lines within the study-area boxes that were spaced an average of 3.75 NM apart (Figure 1). In addition to transects within the general study area, we also sampled opportunistically when transiting between Wainwright and the GHS study area.

## DATA COLLECTION

We conducted seabird surveys during 3 seasons covering the entire open-water period of the northeastern Chukchi Sea (Figure 2): late summer (hereafter “Jul/Aug”), early fall (hereafter “Aug/Sep” in earlier years and “Aug–Oct” in 2011), and late fall (hereafter “Sep/Oct”). These surveys were designed to quantify the distribution, abundance, and species-composition of the seabird community within the 3 study-area boxes and across the GHS study area. In 2008–2010, we surveyed only the 3 study-area boxes during each of the 3 seasons. In 2011, we surveyed the study-area boxes during Jul/Aug and part of the GHS study area (including the boxes) during Aug/Sep, and then completed surveys in the northern section of the GHS study area during Sep/Oct.

We conducted the surveys as consecutive 10-min counting periods (hereafter, transects) when the ship was moving along a straight-line course at a minimal velocity of 9.3 km/h (5 kt; Tasker et al. 1984, Gould and Forsell 1989). We collected data 9–12 h/day during daylight hours, weather and ice conditions permitting. Surveys generally were stopped when sea height was Beaufort 6 (seas ~2–3 m [~6–10 ft]) or higher, although we occasionally continued to sample if observation conditions still were good (e.g., if seas were at the lower end of Beaufort 6 and we were traveling with the wind). One observer stationed on the bridge of the vessel recorded all birds seen within a radius of 300 m in a 90° arc from the bow to the beam on one side of the ship (the count zone) and located and identified seabirds with 10 X binoculars. For each bird or group of birds, we recorded:

- species (to lowest possible taxon);
- total number of individuals;
- distance from the observer when sighted (in categories; 0–50 m [0–164 ft], 51–100 m [165–328 ft], 101–150 m [329–492 ft], 151–200 m [493–656 ft], 201–300 m [657–984 ft]);
- radial angle of the observation from the bow of the ship (to the nearest 1°);
- number in each age-class (juvenile, sub-adult, adult, unknown age), if possible;
- habitat (air, water, flotsam/jetsam, ice); and
- behavior (flying, sitting, swimming, feed-ing, comfort behavior, courtship behavior, other).

We counted all birds on the water and in the count zone, taking care to avoid recounting the same individuals. For flying birds, however, we conducted scans for them ~1 time/min (the exact frequency varied with ship’s speed) and recorded an instantaneous count (or “snapshot”) of all birds flying within the count zone. This “snapshot” method reduces the bias of overestimating the density of flying birds (Tasker et al. 1984, Gould and Forsell 1989). We counted only those flying birds that entered the count zone from the sides or front and did not count flying birds that entered from behind the ship (i.e., an area that already had been surveyed), to avoid the possibility of counting ship-following birds.

We entered observations of all birds directly into a computer connected to a global positioning system (GPS) with DLog software (R. G. Ford Consulting, Portland, OR) in 2008 and TigerObserver software (TigerSoft, Las Vegas, NV) in 2009–2011; these programs time-stamped and geo-referenced every observation entered in real time. The primary GPS connected to the data-collection computer occasionally lost communication with satellites, resulting in missing locations for observations and transect cutoff points. To fill these GPS data gaps, we patched the few gaps in the location record (a total of 156 min across the 4 yr) to interpolate the ship's location between known waypoints by using the ship's speed and the time of the observation.

## DATA ANALYSIS

### DENSITY CALCULATIONS AND ANALYSES

We estimated detection-corrected (hereafter, corrected) densities (birds/km²) of birds within each study area by using line-transect sampling analyses and followed analytical methods described by Buckland et al. (2001, 2004). This approach accounts for the decrease in probability of detecting a bird with increased distance from the survey line. The analysis consisted of 3 steps. First, we fitted a detection function for each species to the observed distances of sightings from a line directly ahead of the ship to estimate the probability of detection for each species. Next, we used the observed flock sizes to estimate the mean flock size for each species. Finally, we estimated the corrected density of birds for each transect and study area during each season (cruise) by incorporating the probability of detection, the area surveyed, and the mean flock size.

We selected 8 focal species for statistical analyses from among the 10 most-abundant species in every year. These 8 focal species represented a variety of foraging methods, thereby providing an overview of functional ecological groups of the seabird community. We assigned each of the remaining species to a detection group that included at least one of the 8 focal species based on its similarity in size, color, and/or behavior. For each detection group, we fitted models that used 1 of 2 possible key functions (half-normal or hazard-rate) to the distribution of observation distances to find the model that best estimated the probability of detection (Table 1). We included covariates in the model sets to account for possible differences in detection among observation platforms (i.e., vessel), observers, and sea surface conditions (measured on the Beaufort scale). The fit of each model was assessed with Akaike's Information Criterion (AIC), diagnostic plots, and a Kolmogorov–Smirnov goodness-of-fit test (following Buckland et al. 2004). The one exception was for phalarope spp., in which the detections were concentrated in the first distance interval. Consequently, we fitted only the half-normal model to prevent overfitting the skewed distance distribution (S. T. Buckland, University of St. Andrews, St. Andrews, Scotland, in litt.). Once a model was selected for a detection group, we calculated species-specific corrected density estimates within that group by running a separate analysis that filtered for each species and then applied the detection model to generate the estimates and associated 95% confidence intervals. These corrected density estimates were calculated with the formula:

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

where $\hat{D}$ is the corrected density estimate, *n* is the total number of observations seen on transects, $\hat{E}(s)$ is the mean flock size, *L* is the total length of transects sampled, and $\hat{P}_a$ is the probability of detection estimated by the model (Buckland et al. 2001). The distance analysis was conducted with the statistical package mrds (Thomas et al. 2011) for R. We used R v. 2.15 (http://www.r-project.org) for all analyses.

We calculated mean corrected densities of each species by study area, season, and year. We calculated variances with the delta method and calculated log-normal, *z*-based, two-sided 95% confidence intervals for the estimates of density with equations 3.71–3.74 in Buckland et al. (2001: 77). We used generalized linear models (package MASS; Venables and Ripley 2002) to examine differences among the Klondike, Burger, and Statoil study areas; among seasons; and among years for each species. The models included the

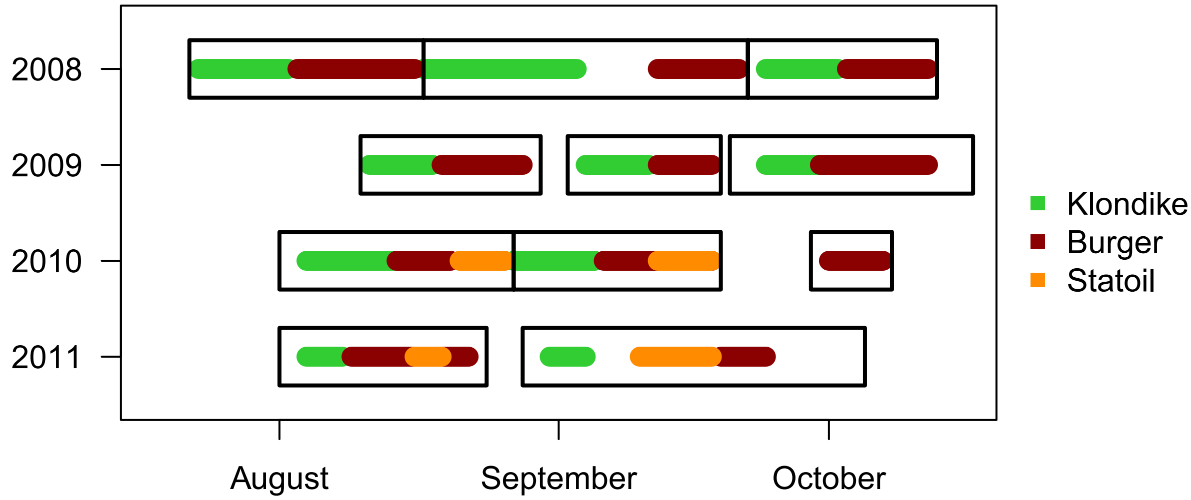


Figure 2. Timing of boat-based surveys for seabirds in the Greater Hanna Shoal study area, 2008–2011.

Table 1. Detection function model parameters used to calculate corrected densities of 8 most abundant taxa of seabirds.

| Species | Function shape | Covariates | Average probability of detecting a flock | CV (%) | Mean flock size |
|---|---|---|---|---|---|
| Crested Auklet | half-normal | observer + vessel + Beaufort | 0.59 | 1.1 | 4.1 |
| Least Auklet | half-normal | observer + Beaufort | 0.54 | 2.6 | 1.8 |
| Black-legged Kittiwake | half-normal | observer | 0.55 | 3.0 | 1.7 |
| Glaucous Gull | | | | | 1.2 |
| Northern Fulmar | | | | | 1.3 |
| Phalarope spp. | half-normal | none | 0.45 | 3.9 | 4.3 |
| Short-tailed Shearwater | half-normal | observer | 0.71 | 1.8 | 5.3 |
| Thick-billed Murre | hazard-rate | none | 0.82 | 1.9 | 1.7 |

years for each species. The models included the additive effects of the factors STUDY AREA, SEASON, and YEAR and the 2-way interactions between STUDY AREA and the temporal variables. We specified SEASON as nested within YEAR as repeated measurements for each study area but found no support for including random effects in the model ($P$ = 0.99 for likelihood-ratio tests). We ran 2 separate analyses because we did not sample in Klondike or Statoil in Sep/Oct 2010 and did not sample any of the study areas in Sep/Oct 2011. In the first analysis, we compared densities between Burger and Klondike in all seasons during 2008–2011. In the second analysis, we compared densities in all three study areas between Jul/Aug and Aug/Sep 2010–2011. In all statistical tests, the level of significance ($\alpha$) was 0.05.

We also used the geo-located observations to generate maps of distribution and abundance for individual species of interest integrated over the GHS study area. First, we standardized transect lengths to 2.5 km and estimated the corrected abundance on each transect following the distance sampling method described above. We then overlaid a overlaid a 3.0×3.0-km grid over the GHS study area and used generalized additive models (package mcgv; Wood 2004) to predict the density surface by using the estimated abundance for each survey transect as a response and the interaction of latitude and longitude as explanatory variables. This analysis produced color maps showing surface models of the density of each of the 8 focal species within the GHS, to create contoured portrayals of the data.

### COMMUNITY ANALYSES

We summarized seabird species-richness and species-composition by study area, season, and year (Magurran 2004). We aggregated individual species into 6 taxonomic species-groups prior to analysis: waterfowl (family Anatidae, including geese, swans, and ducks), loons (family Gaviidae), tubenoses (family Procellariidae, including fulmars and shearwaters), phalaropes (shorebirds of the family Scolopacidae that spend most of their lives in water), larids (families Laridae and Stercorariidae, including gulls, terns, and jaegers), and alcids (family Alcidae, including murres, guillemots, murrelets, auklets, and puffins). Scientific names of all bird species discussed in this report are presented in Appendix A.

We used multivariate analyses and descriptive statistics to explore the changes in structure of the seabird community among seasons, study areas, and years. We grouped the data into sample units by study area, season, and year. The overall similarity in the species-composition of samples is determined by their closeness in the ordination. This approach is useful for detecting patterns in overall community structure and similarities among species assemblages (Blanchard et al. 2010). We used the species-groups to calculate a Bray–Curtis similarity matrix (Bray and Curtis 1957) to which we applied non-metric multidimensional scaling (MDS; Clarke and Green 1988). Finally, we determined the dominant species assemblages composing each sample. The stress coefficient of the ordination was 0.09, indicating a good fit to the data (Clarke and Ainsworth 1993). The MDS analysis was conducted with the package vegan in R (Oksanen et al. 2011).

# RESULTS

## OCEANOGRAPHIC STRUCTURE

We present here a summary of the oceanographic conditions in the sampling region to provide context for interpreting the seabird data. For detail on the sampling and analysis of the physical oceanography data, please see Weingartner et al. (2011). The physical structure of the GHS study area in 2008–2011 may be seen in a series of vertical sections (Figures 3–7) and plan views (Figure 8) of CTD data collected during each of the research cruises. These vertical sections show temperature (°C) and salinity along a series of stations extending from the southwestern corner (far left side of plots) to the northeastern corner (at ~80 km along the X-axis) of the Klondike study area, then from the southwestern corner (at ~100 km along the X-axis) to the northeastern corner (far right side of plots) of the Burger study area; this sampling pattern is true for all cruises except Sep/Oct 2010, which displays data from Burger only because there was no sampling in Klondike or Statoil during that cruise. The plan views show the distribution of temperature and salinity throughout

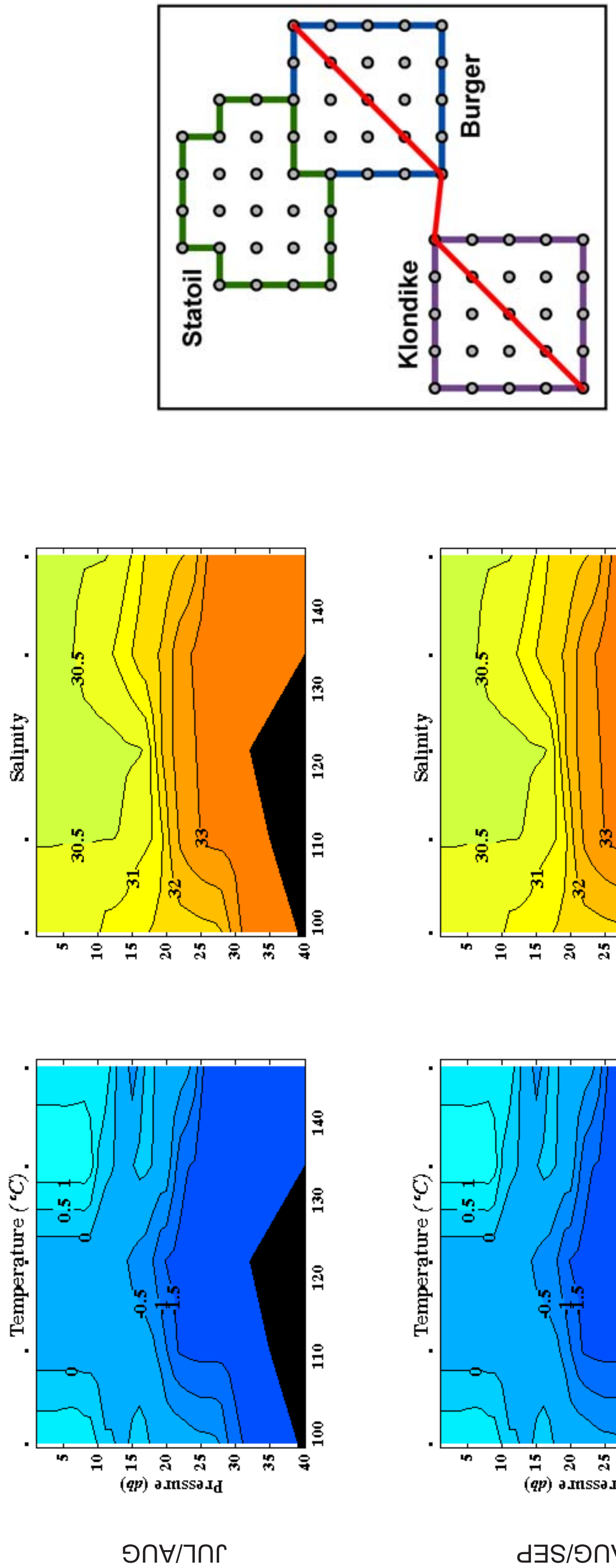


Figure 3. Vertical sections of temperature (°C), and salinity in the Klondike and Burger study areas, 2008 (Weingartner et al. 2011).

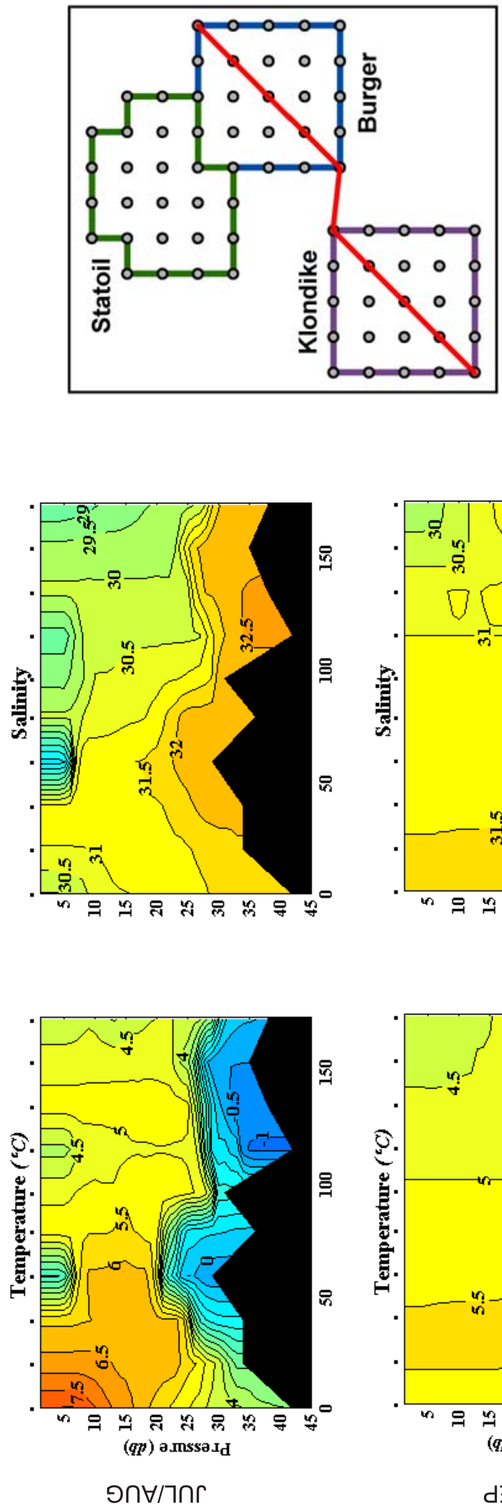


Figure 4. Vertical sections of temperature (°C) and salinity in the Klondike and Burger study areas, 2009 (Weingartner et al. 2011).

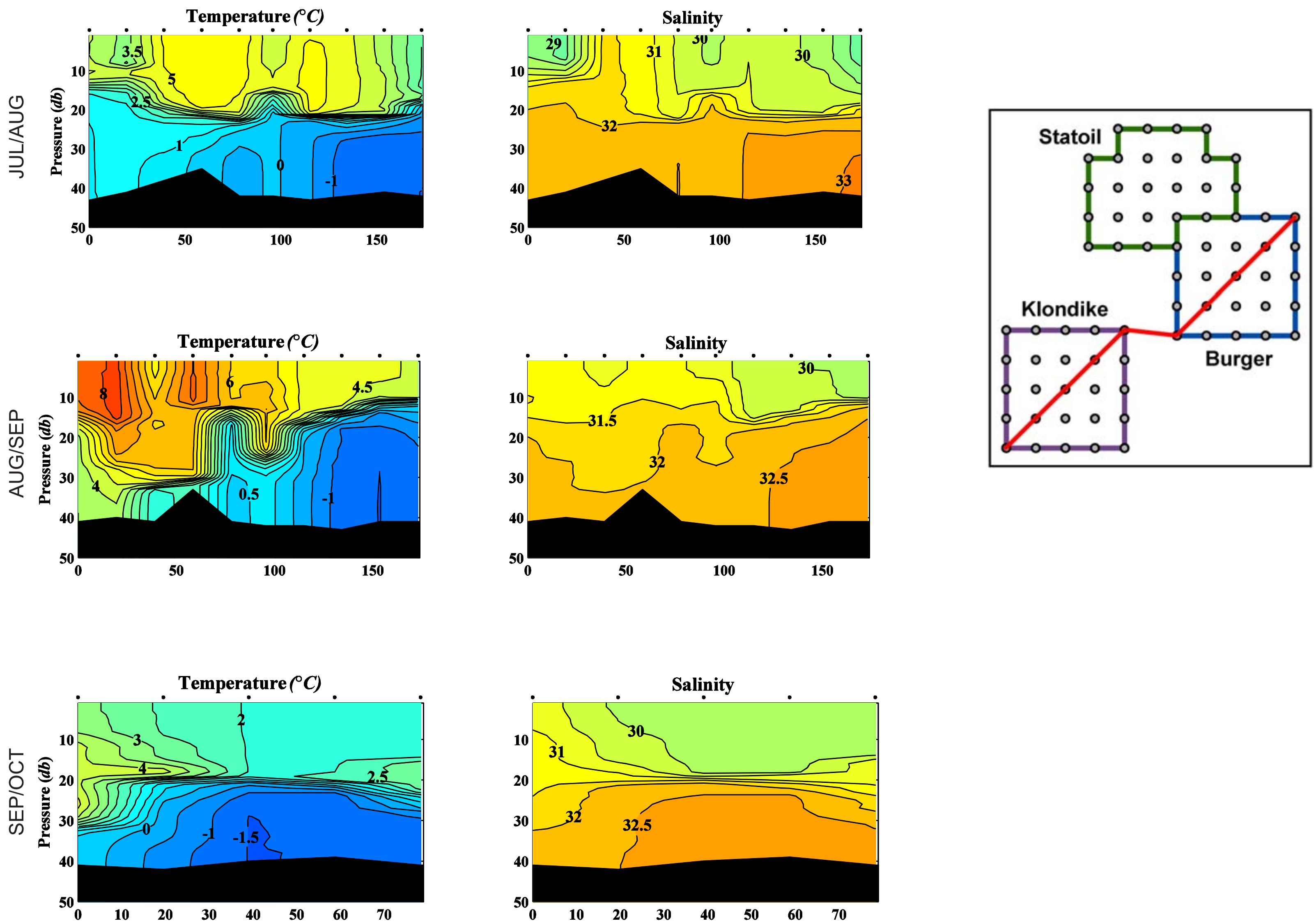


Figure 5. Vertical sections of temperature (°C) and salinity in the Klondike and Burger study areas, 2010 (Weingartner et al. 2011).

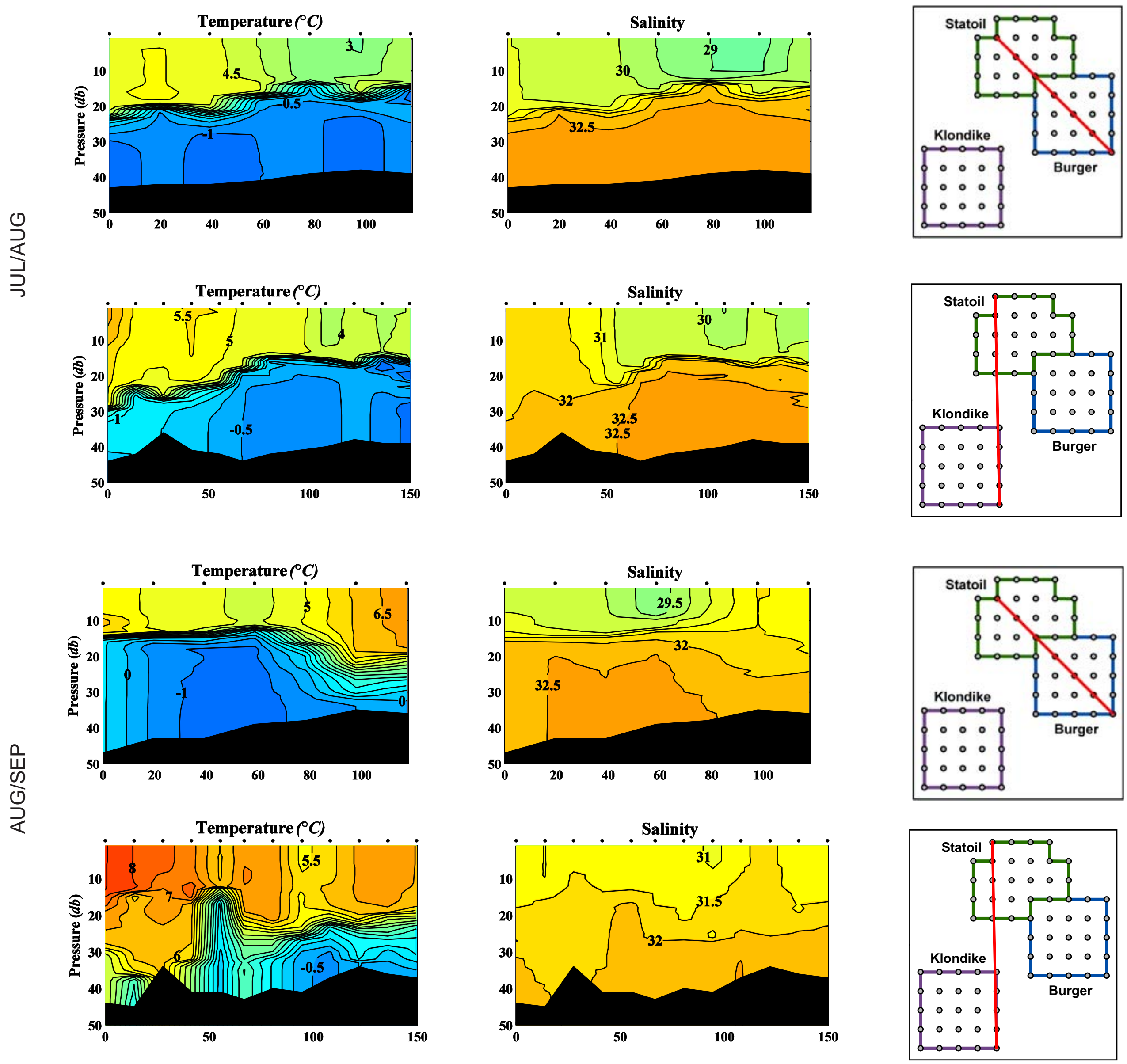


Figure 6. Vertical sections of temperature (°C) and salinity in the Klondike, Burger, and Statoil study areas, 2010 (Weingartner et al. 2011).

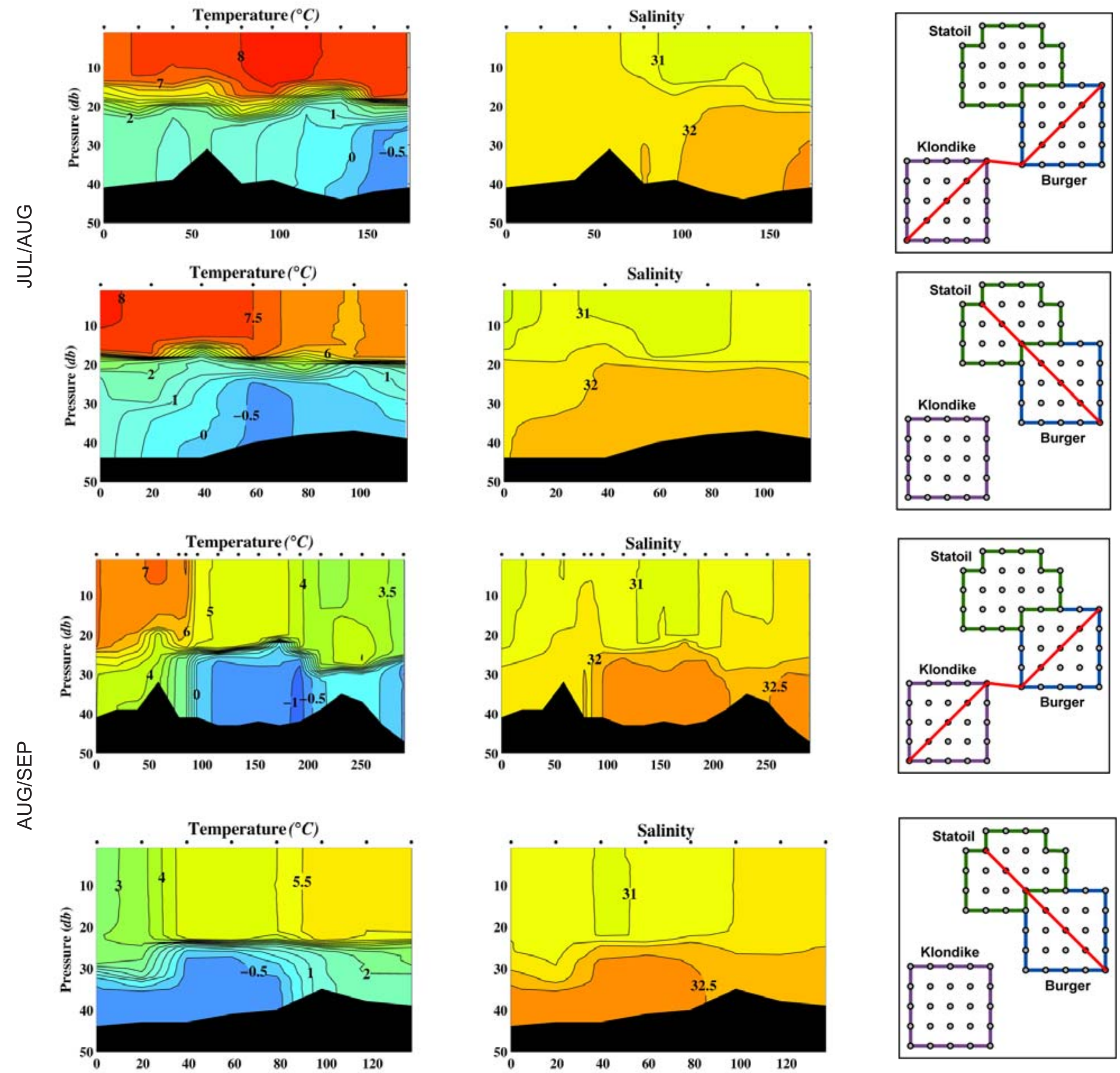


Figure 7. Vertical sections of temperature (°C) and salinity in the Klondike, Burger, and Statoil study areas, 2011 (Weingartner et al. 2012).

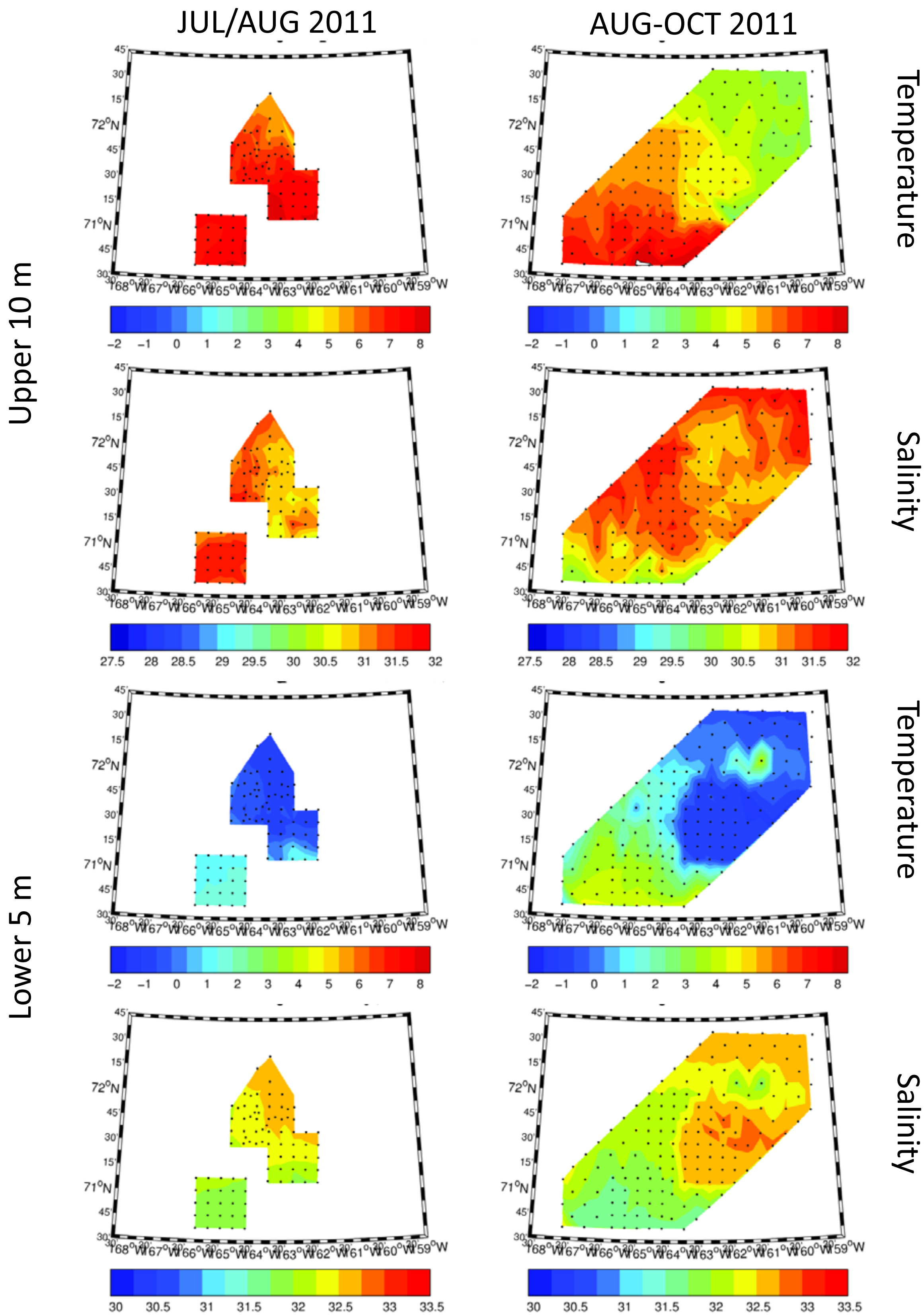


Figure 8. Plan views of temperature (°C) and salinity in the Greater Hanna Shoal study area, 2011 (Weingartner et al. 2012).

the GHS study area in 2011. The physical oceanography of the 3 study-area boxes is described in greater detail by Weingartner et al. (2011, 2012).

In all years, warm, moderately saline Bering Sea Water (BSW) flowed northward into the vicinity of the study-area boxes, gradually replacing the cold, saline Winter Water (WW) formed during the previous winter and sharing the surface layer with cold, fresh Meltwater (MW; Figures 3–7). This WW was representative of the entire water column during the winter and was modified in the upper layer during the spring and summer by ice melt and advection. In all years, the temperature and salinity were higher over Klondike than over Burger, indicating that BSW always was present. In contrast, MW was present over Burger in all years, although its spatial extent varied widely among years: extensive in 2008, restricted to the northeastern corner in 2009 and 2011, and restricted to the northeastern half in 2010. In both 2010 and 2011, BSW occurred over the northwestern and western parts of Statoil, whereas MW occurred over the eastern part of Statoil (Figures 4–7).

Vertical sections of data from Jul/Aug and Aug/Sep indicate that the extent of BSW over the study areas was greatest in 2009 (Figure 4) and 2011 (Figure 7), least in 2008 (Figure 3), and intermediate in 2010 (Figure 5). In Aug/Sep 2008, water generally was cold, although it was warmer and more saline over Klondike than over Burger. Temperatures in the upper mixed layer ranged from 3.5 °C on the western edge of Klondike to 0–2 °C over Burger, with a clearly visible front in the transition between the two study areas (at ~80 km on the X-axis; Figure 3). In Aug/Sep 2009, the mixed layer was nearly homogenous across both study areas, with a slight decrease in temperature from 5.5 °C to 4.5 °C and a gradual decrease in salinity from 31.5 to 30 from the southwestern corner of Klondike to the northeastern corner of Burger (Figure 4). In Aug/Sep 2010, temperatures over Klondike were twice those over Burger (Figure 5); Statoil had BSW over the western half of the study area and MW over the eastern half of the study area (Figure 6). In 2011, the extent of BSW was greatest in Jul/Aug, when temperatures in the upper mixed layer were 7–8 °C and salinity was 30.5–31.5 over the entire area surveyed (Figure 7). This warm water-mass was restricted to Klondike in Aug–Oct 2011, when temperatures approached 9 °C.

The plan-view sections for upper-layer temperature and salinity (Figure 8, top 4 panels) and lower-layer temperature and salinity (Figure 8, bottom 4 panels) in 2011 show the spatial extent of these water-masses during the 2 cruises in 2011 and indicate substantial spatial variation across Hanna Shoal. The upper layer was extremely warm during Jul/Aug, with temperatures ≥7 °C seen everywhere except for a small area sampled north of Statoil, whereas the lower layer indicated cool water (1–2 °C) over Klondike and southern Burger and cold water (–2 to 0 °C) over northern Burger and Statoil. In the Aug–Oct cruise, water in the upper layer remained warm in the southern half of GHS, with warm water extending northward along the western boundary, along the Central Channel. In contrast, cool surface water (down to 2–3 °C) extended over the northeastern half of the GHS and intruded into the study-area boxes: only the southern parts of Klondike were ≥7 °C (Figure 7). The upper-layer temperatures were 1–2 °C cooler in Burger, Statoil, and the northern part of Klondike than they had been in Jul/Aug, indicating surface cooling. Water in the bottom layer warmed over the southern half of the GHS as well, notably in Klondike, western Statoil, and southern Burger but remained cold over northern Burger and eastern Statoil. The salinity plot for the bottom layer showed moderate-salinity water (31.5–32.0; presumably BSW) over the southeastern half of GHS, covering Klondike and western Statoil and high-salinity (32.5–33.5) WW over the northeastern half of GHS. A tongue of warm, moderately saline BSW appears extends eastward over Hanna Shoal, encircling a pool of cold, high-salinity WW over northeastern Burger and eastern Statoil.

## PATTERNS OF ABUNDANCE AND DISTRIBUTION

Seabirds were most abundant overall in 2009 (Table 2) and least abundant in 2008. In both 2010 and 2011, total abundance within the study-area boxes was similar but generally between that in 2009 and that in 2008. Sampling effort was similar

Table 2. Estimated total abundance of seabirds counted during boat-based marine surveys in the northeastern Chukchi Sea, by study area, season, and year. Values in parentheses are 95% confidence intervals.

| | Study area | | |
|---|---|---|---|
| Year/season | Klondike | Burger | Statoil |
| 2008 | | | |
| Jul/Aug | 8,800 | 900 | -- |
| | (6,300–12,200) | (700–1,200) | (--) |
| Aug/Sep | 15,600 | 11,200 | -- |
| | (12,200–19,900) | (8,200–15,500) | (--) |
| Sep/Oct | 32,300 | 6,000 | -- |
| | (24,100–43,200) | (4,000–9,000) | (--) |
| 2009 | | | |
| Jul/Aug | 19,600 | 124,200 | -- |
| | (14,900–26,000) | (98,800–155,900) | (--) |
| Aug/Sep | 260,400 | 114,000 | -- |
| | (195,600–346,700) | (85,700–151,600) | (--) |
| Sep/Oct | 52,700 | 6,900 | -- |
| | (37,800–73,400) | (5,300–9,100) | (--) |
| 2010 | | | |
| Jul/Aug | 26,100 | 23,100 | 20,200 |
| | (17,200–39,800) | (14,200–37,500) | (15,000–27,200) |
| Aug/Sep | 46,300 | 37,500 | 37,900 |
| | (38,900–55,200) | (31,000–45,200) | (31,800–45,300) |
| Sep/Oct | -- | 25,400 | -- |
| | (--) | (19,600–33,000) | (--) |
| 2011 | | | |
| Jul/Aug | 13,100 | 12,600 | 41,100 |
| | (9,400–18,100) | (5,900–26,700) | (21,200–79,600) |
| Aug/Sep | 75,600 | 45,800 | 82,800 |
| | (55,100–103,700) | (25,400–82,700) | (52,300–131,000) |
| Sep/Oct | -- | -- | -- |
| | (--) | (--) | (--) |

among study areas in all years of the study except for 2008, when sea ice during the Jul/Aug cruise prevented complete sampling in Burger (Figure 2).

## ALCIDS

Alcids were the most abundant species-group in 2008, 2010, and 2011 and were the second-most-abundant group in 2009. Densities of alcids in 2008 were significantly higher in Klondike than in Burger during all 3 seasons, whereas densities in 2009 were higher in Klondike than in Burger in Sep/Oct but higher in Burger than in Klondike in Jul/Aug and Aug/Sep (Figure 9, Tables 3–6). In 2010 and 2011, densities of alcids as a group were similar among study areas, although individual species' densities did differ among study areas. Of the 11 species of alcids recorded on transect within the study areas over the 4 years, only Crested Auklets, Least Auklets, and Thick-billed Murres were abundant enough to model trends in distribution and abundance.

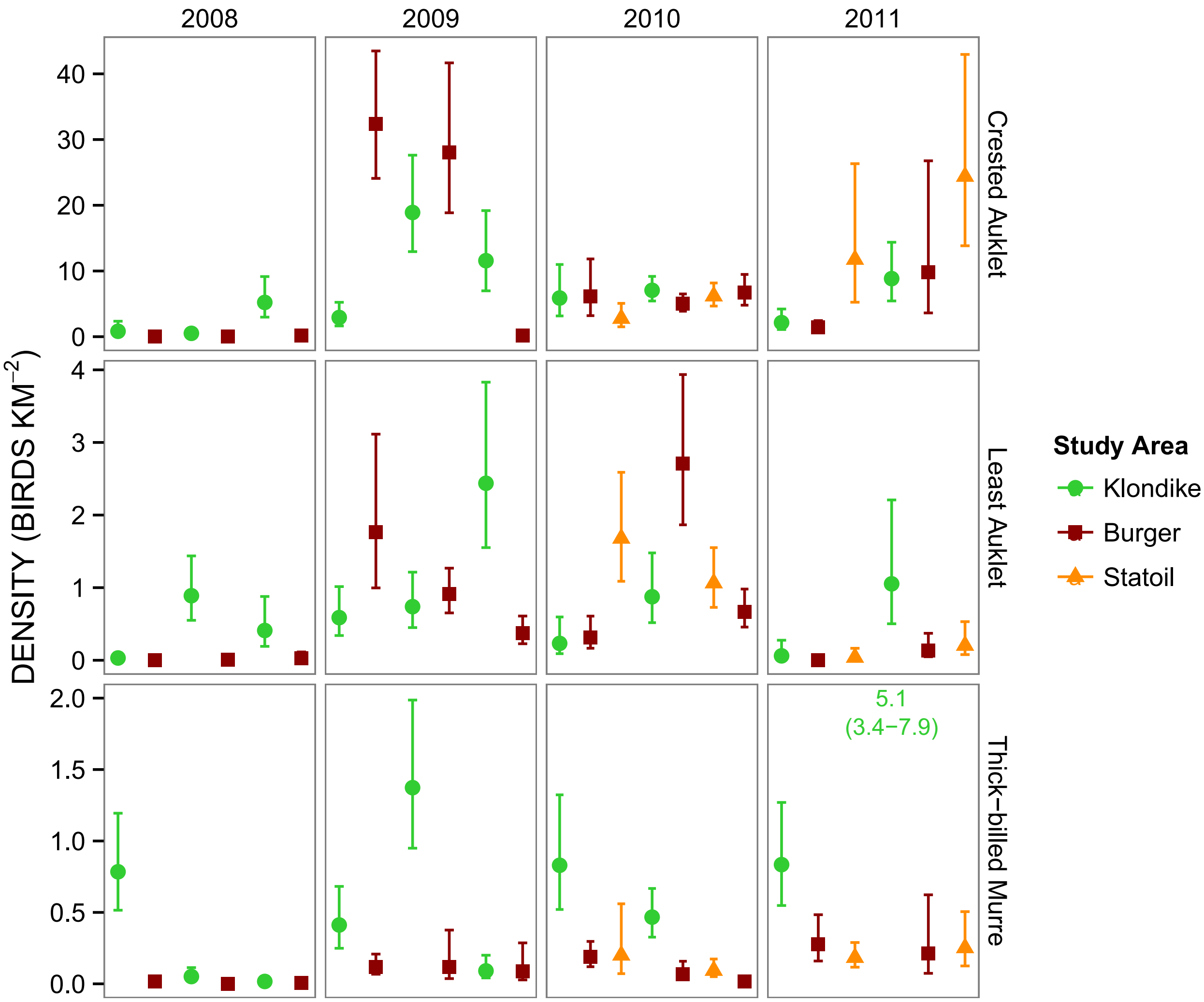


Figure 9. Mean density (birds/km$^2$) of Crested Auklets, Least Auklets, and Thick-billed Murres on transect in the Klondike, Burger, and Statoil study areas in 2008–2011, by study area and season. Error bars represent 95% confidence intervals.

Crested Auklets were the most abundant species recorded in all 4 years of the study (Figure 9, Tables 3–6). Densities differed significantly among seasons in all 4 years ($P < 0.001$ for SEASON*YEAR), with densities the highest in 2009, the lowest in 2008, and intermediate in 2010 and 2012. Crested Auklets occurred throughout the GHS study area in 2011 (Figure 10), with the highest densities located in the northeastern part of Statoil, near an area where sea-surface temperatures dropped quickly (Figure 8), and other locations south (in Burger) and west of Statoil. Densities were low over northern Hanna Shoal and east of Burger.

Least Auklet densities differed significantly among study areas, seasons, and years ($P < 0.001$ for STUDY AREA*SEASON*YEAR). In 2008 and 2011, densities of Least Auklets were low overall but were higher in Klondike than the other study areas (Figure 9, Tables 3–6). In 2009 and 2010, densities were high overall, and the spatial patterns of abundance differed among seasons (Figure 9, Tables 3–6). In 2011, Least Auklets were concentrated in Klondike and northwest of Statoil

Table 3. Estimated densities (birds/km$^2$) of the 8 focal species of seabirds counted during boat-based marine surveys in the northeastern Chukchi Sea, by study area and season, 2008. Values in parentheses are 95% confidence intervals.

| | Study area/season | | | | | |
|---|---|---|---|---|---|---|
| | Klondike | | | Burger | | |
| Species-group/species | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct |
| ALCIDS | | | | | | |
| Thick–billed Murre | 0.784 | 0.051 | 0.017 | 0.018 | 0.0 | 0.007 |
| | (0.515–1.194) | (0.023 –0.113) | (0.006–0.052) | (0.007–0.048) | (0) | (0.001–0.043) |
| Least Auklet | 0.032 | 0.890 | 0.410 | 0.0 | 0.007 | 0.028 |
| | (0.010–0.101) | (0.551–1.437) | (0.192–0.878) | (0) | (0.001–0.042) | (0.007–0.115) |
| Crested Auklet | 0.827 | 0.516 | 5.219 | 0.0 | 0.006 | 0.163 |
| | (0.290–2.356) | (0.285–0.932) | (2.977–9.150) | (0) | (0.001–0.037) | (0.060–0.440) |
| TUBENOSES | | | | | | |
| Northern Fulmar | 0.266 | 0.665 | 0.267 | 0.045 | 0.043 | 0.049 |
| | (0.159–0.443) | (0.468–0.946) | (0.113–0.631) | (0.020–0.103) | (0.015–0.124) | (0.019–0.124) |
| Short–tailed Shearwater | 0.012 | 1.241 | 1.343 | 0.0 | 1.017 | 0.258 |
| | (0.003–0.051) | (0.601–2.560) | (0.654–2.756) | (0) | (0.389–2.658) | (0.126–0.529) |
| PHALAROPES | 0.022 | 0.584 | 0.706 | 0.0 | 0.866 | 0.0 |
| | (0.005–0.103) | (0.208–1.644) | (0.299–1.667) | (0) | (0.422–1.778) | (0) |
| LARIDS | | | | | | |
| Black–legged Kittiwake | 0.403 | 0.221 | 0.786 | 0.107 | 0.745 | 0.088 |
| | (0.268–0.605) | (0.123–0.399) | (0.504–1.224) | (0.056–0.206) | (0.451–1.229) | (0.038–0.204) |
| Glaucous Gull | 0.045 | 0.062 | 0.486 | 0.046 | 0.196 | 0.107 |
| | (0.018–0.114) | (0.032–0.122) | (0.359–0.658) | (0.019–0.112) | (0.126–0.304) | (0.044–0.260) |

Table 4. Estimated densities (birds/km$^2$) of the 8 focal species of seabirds counted during boat-based marine surveys in the northeastern Chukchi Sea, by study area and season, 2009. Values in parentheses are 95% confidence intervals.

| Species-group/species | Study area/season | | | | | |
|---|---|---|---|---|---|---|
| | Klondike | | | Burger | | |
| | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct |
| ALCIDS | | | | | | |
| Thick–billed Murre | 0.412 | 1.373 | 0.091 | 0.118 | 0.118 | 0.089 |
| | (0.249–0.682) | (0.949–1.986) | (0.041–0.200) | (0.067–0.208) | (0.037–0.376) | (0.027–0.287) |
| Least Auklet | 0.588 | 0.739 | 2.438 | 1.762 | 0.910 | 0.372 |
| | (0.341–1.015) | (0.450–1.213) | (1.552–3.830) | (0.996–3.114) | (0.652–1.268) | (0.227–0.609) |
| Crested Auklet | 2.927 | 18.906 | 11.571 | 32.365 | 28.028 | 0.149 |
| | (1.637–5.234) | (12.941–27.621) | (6.979–19.185) | (24.092–43.479) | (18.854–41.666) | (0.055–0.401) |
| TUBENOSES | | | | | | |
| Northern Fulmar | 1.158 | 0.321 | 0.032 | 1.257 | 0.218 | 0.139 |
| | (0.664–2.019) | (0.171–0.600) | (0.012–0.086) | (0.715–2.208) | (0.142–0.334) | (0.043–0.445) |
| Short–tailed Shearwater | 0.164 | 59.760 | 1.452 | 1.673 | 1.855 | 0.295 |
| | (0.081–0.332) | (39.062–91.427) | (0.560–3.763) | (0.387–7.235) | (1.034–3.329) | (0.134–0.650) |
| PHALAROPES | 0.856 | 0.080 | 0.116 | 2.578 | 1.686 | 0.080 |
| | (0.415–1.766) | (0.046–0.138) | (0.022–0.602) | (1.580–4.207) | (0.973–2.921) | (0.029–0.219) |
| LARIDS | | | | | | |
| Black–legged Kittiwake | 0.103 | 1.711 | 0.643 | 0.156 | 1.820 | 0.139 |
| | (0.038–0.278) | (1.132–2.585) | (0.410–1.008) | (0.065–0.374) | (1.292–2.565) | (0.047–0.408) |
| Glaucous Gull | 0.0 | 0.142 | 0.312 | 0.082 | 0.421 | 0.328 |
| | (0) | (0.047–0.434) | (0.148–0.655) | (0.027–0.250) | (0.291–0.609) | (0.187–0.574) |

Table 5. Estimated densities (birds/km$^2$) of the 8 focal species of seabirds counted during boat-based marine surveys in the northeastern Chukchi Sea, by study area and season, 2010. Values in parentheses are 95% confidence intervals.

| | Study area/season | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Klondike | | | Burger | | | Statoil | | |
| Species-group/species | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct |
| ALCIDS | | | | | | | | | |
| Thick–billed Murre | 0.830 (0.521–1.323) | 0.467 (0.327–0.668) | – | 0.189 (0.120–0.297) | 0.068 (0.029–0.158) | 0.016 (0.005–0.048) | 0.200 (0.071–0.560) | 0.093 (0.050–0.174) | – |
| Least Auklet | 0.233 (0.091–0.596) | 0.875 (0.518–1.478) | – | 0.317 (0.165–0.608) | 2.709 (1.865–3.935) | 0.669 (0.457–0.981) | 1.679 (1.088–2.589) | 1.063 (0.729–1.551) | – |
| Crested Auklet | 5.892 (3.160–10.986) | 7.062 (5.434–9.179) | – | 6.157 (3.204–11.834) | 5.026 (3.882–6.506) | 6.742 (4.796–9.476) | 2.764 (1.505–5.075) | 6.172 (4.661–8.174) | – |
| TUBENOSES | | | | | | | | | |
| Northern Fulmar | 0.185 (0.086–0.397) | 0.214 (0.124–0.371) | – | 0.249 (0.142–0.438) | 0.067 (0.030–0.150) | 0.007 (0.001–0.044) | 0.107 (0.063–0.183) | 0.159 (0.087–0.287) | – |
| Short–tailed Shearwater | 0.074 (0.021–0.260) | 2.227 (1.154–4.298) | – | 0.053 (0.012–0.234) | 2.466 (1.262-4.818) | 0.025 (0.009–0.066) | 1.153 (0.554–2.399) | 2.041 (1.259–3.308) | – |
| PHALAROPES | 0.586 (0.175–1.960) | 2.394 (1.352–4.239) | – | 0.051 (0.011–0.244) | 0.907 (0.413–1.994) | 0.046 (0.021–0.101) | 0.203 (0.067–0.618) | 1.716 (0.944–3.117) | – |
| LARIDS | | | | | | | | | |
| Black–legged Kittiwake | 0.268 (0.115–0.621) | 0.883 (0.562–1.389) | – | 0.166 (0.078–0.352) | 0.303 (0.184–0.500) | 0.0 (0) | 0.166 (0.055–0.503) | 0.541 (0.355–0.825) | – |
| Glaucous Gull | 0.027 (0.007–0.102) | 0.73 (0.025–0.208) | – | 0.061 (0.024–0.153) | 0.081 (0.042–0.154) | 0.099 (0.052–0.190) | 0.037 (0.010–0.142) | 0.076 (0.034–0.168) | – |

Table 6. Estimated densities (birds/km²) of the 8 focal species of seabirds counted during boat-based marine surveys in the northeastern Chukchi Sea, by study area and season, 2011. Values in parentheses are 95% confidence intervals.

| | Study area/season | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Klondike | | | Burger | | | Statoil | | |
| Species-group/species | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct |
| ALCIDS | | | | | | | | | |
| Thick–billed Murre | 0.834 (0.548–1.270) | 5.146 (3.354–7.895) | – | 0.278 (0.160–0.484) | 0.214 (0.074–0.623) | – | 0.184 (0.117–0.289) | 0.252 (0.125–0.505) | – |
| Least Auklet | 0.061 (0.014–0.276) | 1.053 (0.502–2.208) | – | 0.0 (0) | 0.134 (0.049–0.372) | – | 0.039 (0.009–0.165) | 0.204 (0.078–0.532) | – |
| Crested Auklet | 2.145 (1.092–4.215) | 8.843 (5.442–14.369) | – | 1.454 (0.863–2.451) | 9.841 (3.618–26.763) | – | 11.750 (5.245–26.325) | 24.378 (13.836–42.952) | – |
| TUBENOSES | | | | | | | | | |
| Northern Fulmar | 0.450 (0.231–0.877) | 0.120 (0.050–0.285) | – | 0.249 (0.131–0.471) | 0.0 (0) | – | 0.199 (0.088–0.448) | 0.081 (0.032–0.202) | – |
| Short–tailed Shearwater | 0.162 (0.057–0.461) | 7.807 (2.947–20.680) | – | 1.557 (0.234–10.361) | 1.697 (0.795-3.622) | – | 0.024 (0.006–0.099) | 0.977 (0.485–1.969) | – |
| PHALAROPES | 0.077 (0.012–0.501) | 0.216 (0.075–0.626) | – | 0.422 (0.153–1.169) | 0.287 (0.092–0.893) | 0.939 (0.005–0.006) | 0.939 (0.119–7.414) | 0.065 (0.020–0.212) | – |
| LARIDS | | | | | | | | | |
| Black–legged Kittiwake | 0.023 (0.003–0.149) | 0.224 (0.109–0.463) | – | 0.069 (0.024–0.200) | 1.191 (0.630–2.251) | – | 0.073 (0.018–0.298) | 0.323 (0.207–0.503) | – |
| Glaucous Gull | 0.0 (0) | 0.060 (0.018–0.195) | – | 0.013 (0.002–0.087) | 0.106 (0.041–0.277) | – | 0.028 (0.004–0.183) | 0.134 (0.064–0.283) | – |

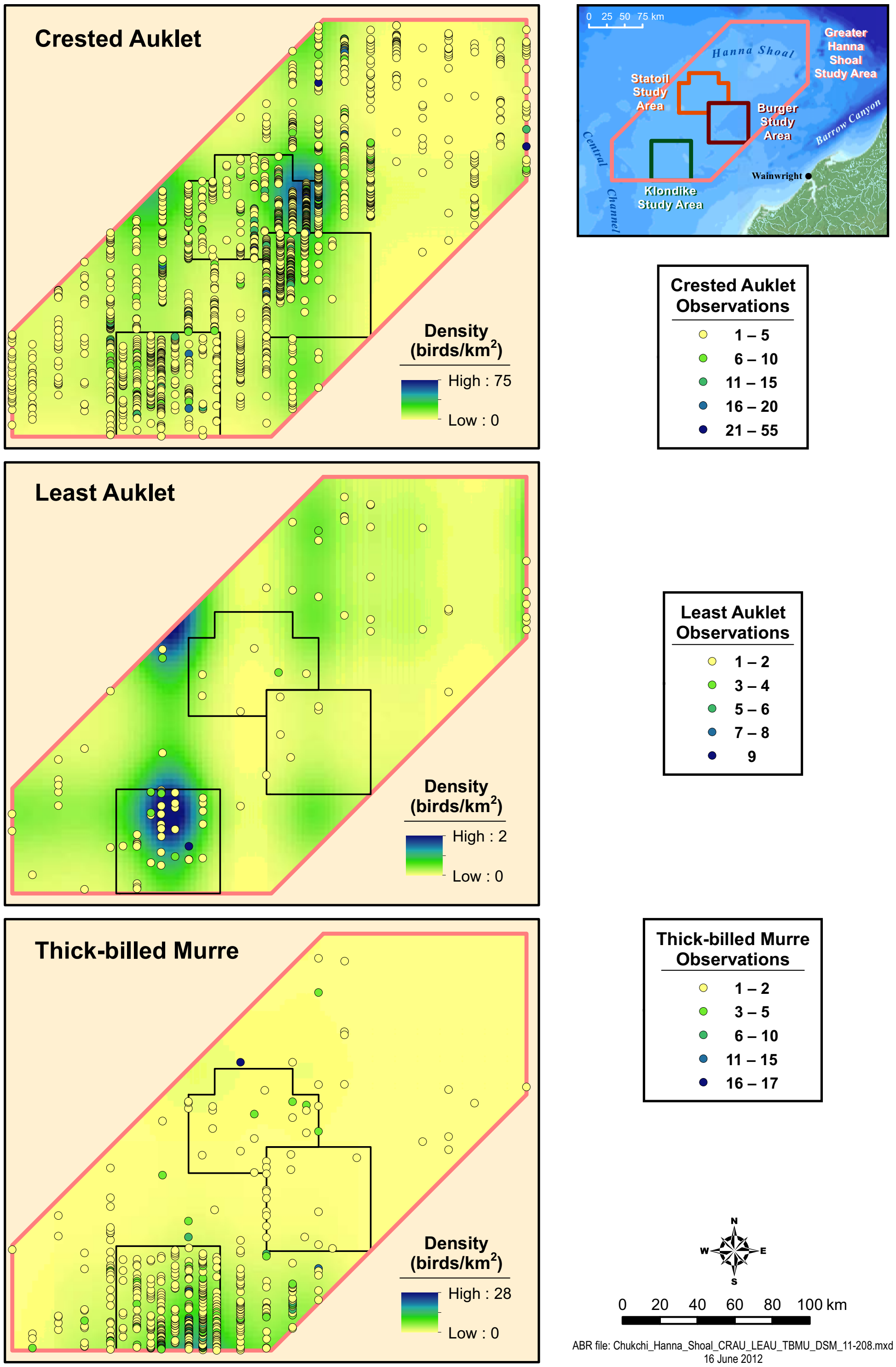


Figure 10. Distribution and abundance (birds/km$^2$) of Crested Auklets, Least Auklets, and Thick-billed Murres recorded on transect in the Greater Hanna Shoal study area in 2011.

in an area where Crested Auklet densities also were high (Figure 10); the high densities in Klondike appeared to be associated with an area of salinity fronts. As was seen for Crested Auklets, densities were low over northern Hanna Shoal and east of Burger.

Thick-billed Murre densities were consistently higher in Klondike than in Burger or Statoil and were lowest in Sep/Oct in all years ($P < 0.001$ for STUDY AREA*SEASON). The highest mean density in any season or year was recorded in Klondike in Aug–Oct 2011 (Figure 9, Tables 3–6.Thick-billed Murres were concentrated along the southern edge of the GHS study area in 2011, in an area where warm, low-salinity water appeared to be intruding (Figure 10), with mostly small groups recorded throughout the northwestern half of the GHS. Mean densities approached zero over most of Hanna Shoal.

Of the other 9 species of alcids recorded, Ancient Murrelets were the most abundant and occurred only on the Aug/Sep and Sep/Oct cruises of 2010 and 2011 (Appendix B). They were present in all 3 study areas in Aug/Sep and were recorded most often in and near Statoil. Parakeet Auklets were seen in low numbers every year, and primarily in Klondike, although the highest density was recorded in Burger in Sep/Oct 2008. In all 4 years, Tufted Puffins and Horned Puffins were seen primarily in Klondike in Jul/Aug. Kittlitz's Murrelets were rare in the first 3 years and occurred in Klondike in Sep/Oct 2008 (we believe that the 5 unidentified murrelets were of this species), Aug/Sep 2009, and Jul/Aug and Aug/Sep 2010; and in Burger in Sep/Oct 2009 and Sep/Oct 2010. They were most abundant in 2011, when they were recorded in Klondike in Jul/Aug and in all 3 study areas and the northern section of GHS in Aug–Oct. Black Guillemots and Dovekies were seen in all 3 study-area boxes and in the northern section of the GHS but were seen only in low numbers and in all years except 2009. Pigeon Guillemots were seen in both study areas and only in Jul/Aug 2008.

## TUBENOSES

Tubenoses were the second-most-abundant species-group in 2008, 2010, and 2011 and the most abundant species-group in 2009, primarily because of large flocks of Short-tailed Shearwaters moving through Klondike in Aug/Sep (Figure 11). This species-group includes both non-breeding seasonal migrants and Northern Hemisphere residents. For example, Short-tailed Shearwaters migrate to the Bering and Chukchi seas from the Southern Hemisphere to feed during their non-breeding season, whereas Northern Fulmars are Northern Hemisphere breeders that nest in the northern Bering Sea and visit the study area during the open-water season.

Short-tailed Shearwaters were the second most abundant species in all 4 years of the study. Their densities differed significantly among study areas, seasons, and years ($P < 0.001$ for STUDY AREA*SEASON*YEAR). Densities generally were higher in Klondike than in Burger in 2008, 2009, and 2011 but were not significantly different among study areas in 2010 (Figure 11, Tables 3–6). In all years, Short-tailed Shearwaters were most abundant in Aug/Sep (Aug–Oct in 2011). Short-tailed Shearwaters were concentrated in the southern half of the GHS study area in 2011 (Figure 12), with small groups recorded throughout the northwestern half of the GHS and a near-absence over northern Hanna Shoal.

Northern Fulmar densities differed among seasons and years but not consistently among study areas ($P < 0.001$ for SEASON*YEAR). In general, their seasonal abundance declined from Jul/Aug to Sep/Oct, with the exception of Klondike in 2008, when they were most abundant in Aug/Sep. Densities were lowest in Sep/Oct of all 4 years (Figure 11, Tables 3–6). Northern Fulmars were significantly more abundant in Klondike than in Burger in 2008 (Figure 11), whereas densities did not differ significantly between study areas in 2009, 2010, or 2011. Northern Fulmars occurred in low densities throughout the GHS study area in 2011, although they were least common over eastern Burger and eastern Statoil (Figure 12).

## PHALAROPES

Phalaropes were seen in patchily distributed feeding flocks, primarily in Jul/Aug and Aug/Sep of all years; densities did not differ among study areas, seasons, or years ($P > 0.05$; Figure 11). Phalaropes were rare during the Aug–Oct cruise in 2011, with small flocks located at the northwestern corner of the GHS, in an area that did not appear to

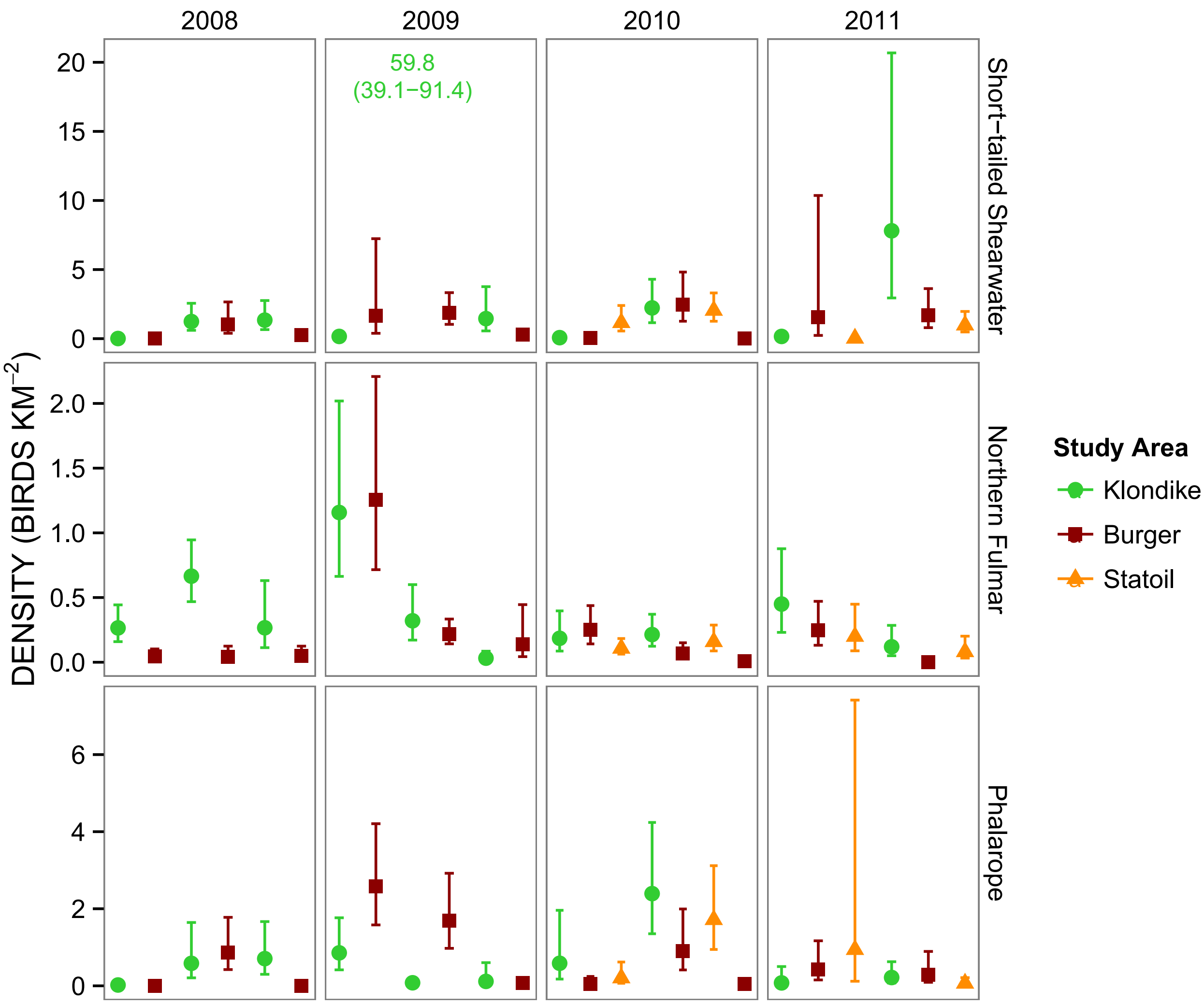


Figure 11. Mean density (birds/km$^2$) of Short-tailed Shearwaters, Northern Fulmars, and phalaropes on transect in the Klondike, Burger, and Statoil study areas in 2008–2011, by study area and season. Error bars represent 95% confidence intervals.

have distinct oceanographic structures, and in Burger (Figure 12).

LARIDS

Larids were the third-most-abundant species group recorded during surveys. This group included gulls, terns, and jaegers. Of the 11 species of larids recorded on transect, Black-legged Kittiwakes and Glaucous Gulls were abundant enough in every year to examine patterns in distribution and abundance.

Black-legged Kittiwake densities differed significantly among years and among seasons ($P < 0.001$ for YEAR*SEASON). They were distributed widely, occurring in all study areas and in all 3 seasons during the 4 years of the study (Figure 13, Tables 3–6). Black-legged Kittiwakes occurred in low densities throughout the GHS study area in 2011 (Figure 14), with concentrations occurring over the shallowest part of Hanna Shoal and in southern Burger, an area with what appears to be a thermohaline front.

Glaucous Gulls also were widespread, occurring in all study areas and in all seasons surveyed except for Klondike in Jul/Aug 2009 and Jul/Aug 2011 (Figure 13, Tables 3–6). Their densities differed significantly among seasons in all years and between study areas in 2008 and 2009

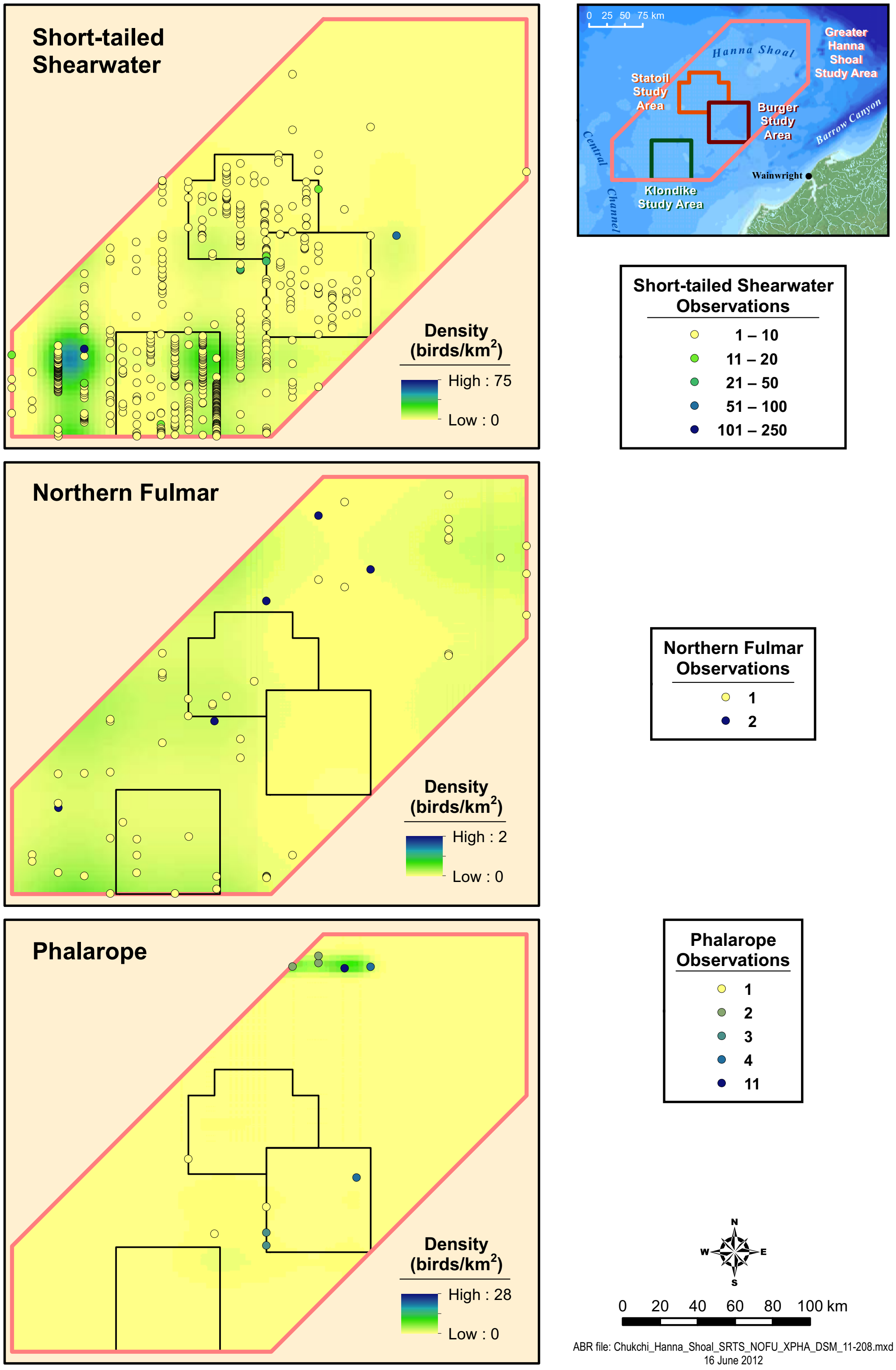


Figure 12. Distribution and abundance (birds/km$^2$) of Short-tailed Shearwaters, Northern Fulmars, and phalaropes recorded on transect in the Greater Hanna Shoal study area in 2011.

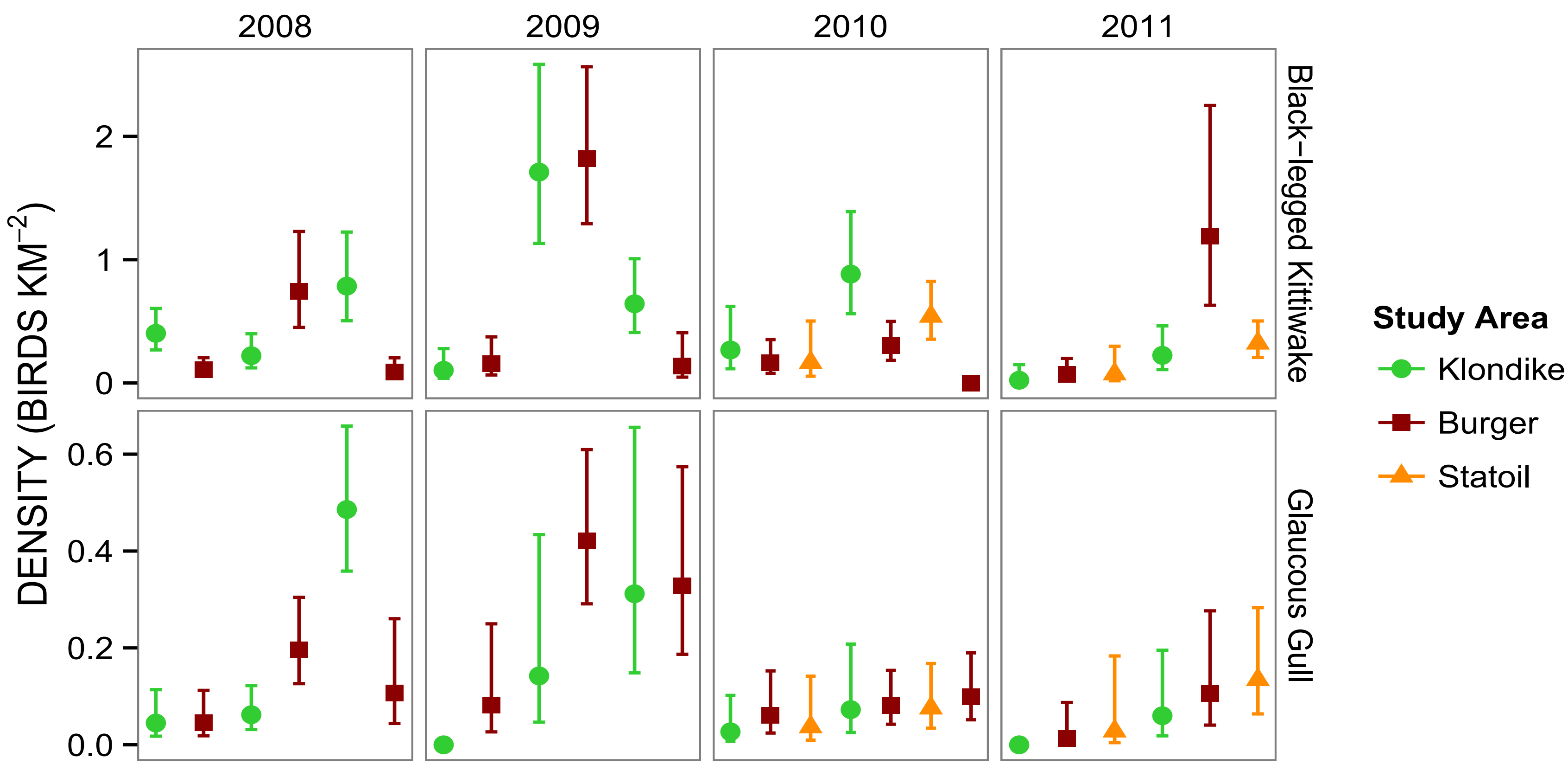


Figure 13. Mean density (birds/km$^2$) of Black-legged Kittiwakes and Glaucous Gulls on transect in the Klondike, Burger, and Statoil study areas in 2008–2011, by study area and season. Error bars represent 95% confidence intervals.

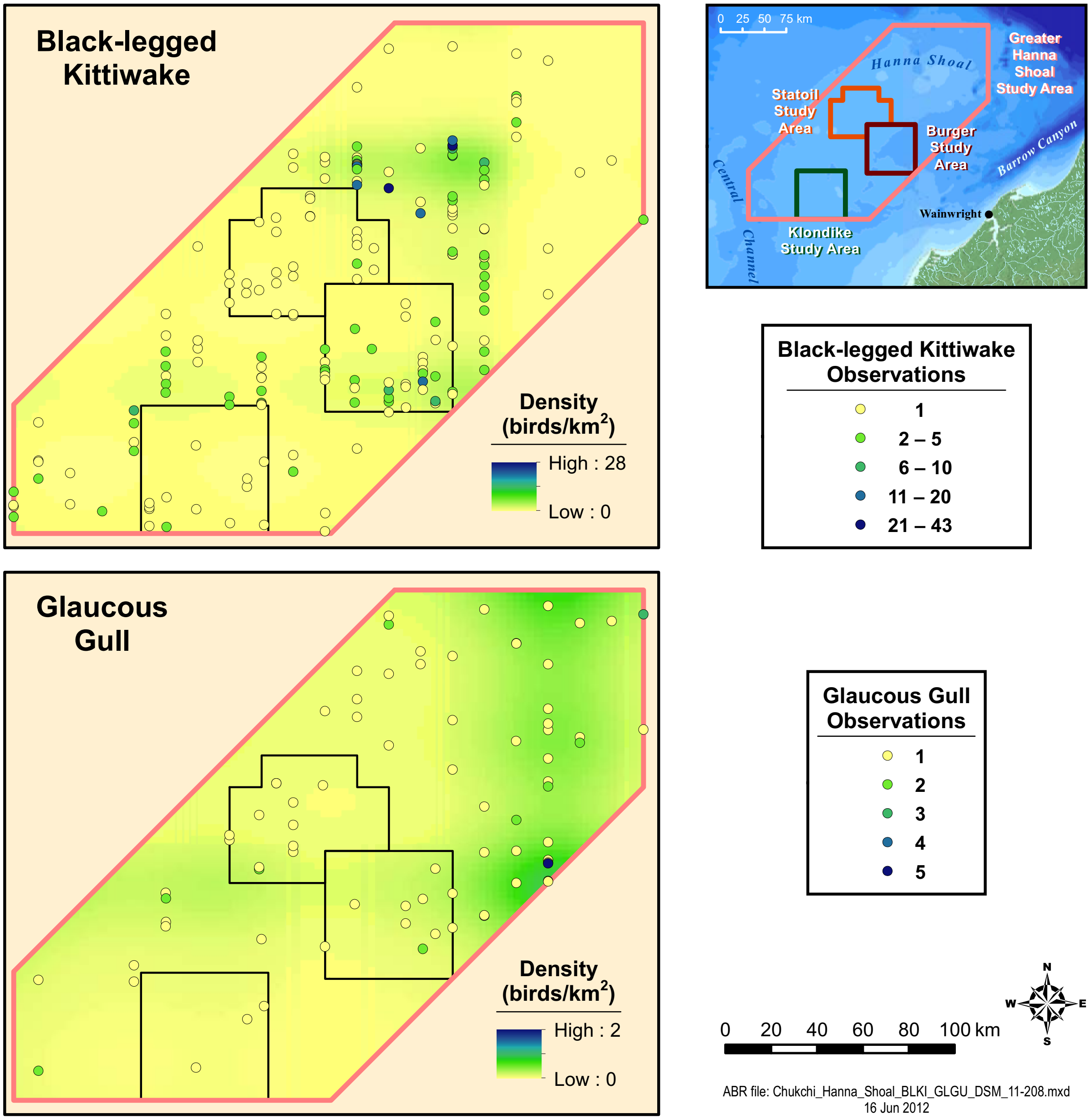


Figure 14. Distribution of estimated densities (birds/km$^2$) of Black-legged Kittiwakes and Glaucous Gulls recorded on transect in the Greater Hanna Shoal study area in 2011.

($P \leq 0.001$ for STUDY AREA*SEASON*YEAR). In all 4 years, densities of Glaucous Gulls in Klondike, Burger, and Statoil (in 2010 and 2011) increased from Jul/Aug to Aug/Sep (Figure 13). Densities continued to increase from Aug/Sep to Sep/Oct in all years, except for a decline in Burger during that period in 2008. Glaucous Gulls occurred in low densities throughout the GHS study area in 2011 (Figure 14), with the highest concentration located east of Burger.

Of the other 9 species of larids, Sabine's Gulls, Arctic Terns, Pomarine Jaegers, and Parasitic Jaegers were recorded most commonly in Aug/Sep, Ross's Gulls were recorded primarily in Burger and over Hanna Shoal and only in Sep/Oct, and Herring Gulls occurred primarily in Aug/Sep and Sep/Oct (Appendix B). Sabine's Gulls and jaegers occurred primarily in Klondike, whereas Arctic Terns occurred in Klondike in 2008, in Burger in 2009, in both study areas in 2010, and in Statoil and GHS only in 2011. Long-tailed Jaegers were seen off-transect in Klondike and Burger in Aug/Sep 2008 and on-transect in Klondike and Burger in 2009 and 2010. Ivory Gulls occurred only in Burger and over northern Hanna Shoal, similar to the pattern seen for Ross's Gulls, and only in Sep/Oct 2008 and 2011. A single Glaucous-winged Gull was seen only off-transect in Klondike and only in Jul/Aug 2008, after a storm with strong southerly winds.

LOONS

In all 4 years, loons were completely absent from the study areas in Jul/Aug and were recorded in both Aug/Sep and Sep/Oct (Appendix B), when they were migrating through the Chukchi Sea on their way to wintering areas. Pacific Loons occurred in all 3 study areas, but only in Aug/Sep and Sep/Oct. Of the other 2 species of loons, Yellow-billed Loons occurred in all years except 2010, whereas Red-throated Loons occurred in all years except 2009. Yellow-billed Loons were rare in 2008 and 2011 but were more common in 2009 (Appendix B). Red-throated Loons were rare during these surveys and were seen only in Aug/Sep: we saw 1 in Burger in 2008, none in 2009, 1 in Statoil in 2010, and 4 in and near Burger in 2011.

WATERFOWL

Waterfowl were seen in low densities in all seasons and in all 3 study areas and generally were more common in 2008 than in subsequent years (Tables 7–8, Appendix B). Of the 5 species of waterfowl recorded, none was abundant enough to provide reliable estimates of density. In all years except 2011, Long-tailed Ducks were the most abundant waterfowl species; they were seen in both study areas and in all seasons in 2008 and primarily in Aug/Sep in 2009 and 2010. Waterfowl species seen only in 2008 and 2010 included King Eiders, which were seen flying singly or in pairs on all 3 cruises, and single flocks of Common Eiders recorded in Burger in Sep/Oct. We recorded a single flock of White-winged Scoters in Burger in Sep/Oct 2008, a single Spectacled Eider in Klondike on 8 September 2009, and a single Spectacled Eider off transect in Burger on 16 September 2009. We saw only 1 species of waterfowl, a Common Eider, in 2011.

## COMMUNITY STRUCTURE

Multivariate analyses of the seabird community indicated that species-composition varied primarily among years and showed a consistent pattern of seasonal change. The MDS ordination separated into 2 groups, with some overlap (misclassification) of study areas by season (Figure 15). When the points in the MDS ordination were grouped by season, community composition shifted from Jul/Aug to Aug/Sep, then shifted back toward the Jul/Aug composition in Sep/Oct (Figure 15). Much of this pattern was driven by seasonal changes in species-composition in Burger in 2008, and subsequent years have provided support for the classification. Samples do not separate into distinct groups when identified by year, indicating that overall composition is similar among study areas and years.

The patterns in species-composition identified in the multivariate analyses were reflected in changes in the relative abundance of each of the 6 species-groups among study areas, seasons, and years (Figure 16). Most notably, the relative abundance of alcids in all study areas combined increased from 2008 to 2010 and remained high in 2011. Klondike was dominated numerically by alcids (primarily Crested Auklets) and tubenoses

Table 7. Species of seabirds identified during boat-based surveys in the northeastern Chukchi Sea, in the Klondike and Burger study areas by season. Species identified on-transect within the study area are designated as “X8”, “X9”, “X10”, and/or X11 for 2008, 2009, 2010, and 2011, respectively. Species identified only off-transect in a given year are designated as “OT8”, “OT9”, and, “OT10” for 2008, 2009, and 2010 respectively. Species seen only on-transect and only within the 30-NM buffer zone (used in the historical comparisons) are designated as “B8”, “B9”, “B10”, for 2008, 2009, and 2010 respectively. Species identified in the historical dataset within the study area or buffer zone, available from the North Pacific Pelagic Seabird Database, are designated as “H.”

| | Study area/season | | | | | |
|---|---|---|---|---|---|---|
| | Klondike | | | Burger | | |
| Species-group/species | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct |
| WATERFOWL | | | | | | |
| Spectacled Eider | – | X9 | – | – | OT9 | OT10 |
| King Eider | X8 | – | X8 | – | X8, OT10 | X8, X10 |
| Common Eider | – | – | – | – | X8 | X10 |
| White-winged Scoter | – | – | OT8 | – | – | X8, OT10 |
| Long-tailed Duck | X8 | X9, H | X8, X9, B10 | B9, H | X8, X9, X10, H | X8, B9, X10, H |
| LOONS | | | | | | |
| Red-throated Loon | – | – | – | – | X8, X11 | – |
| Pacific Loon | – | X8, X9, X10 | X8, X9 | – | X8, X9, X10, X11 | X8, X9, OT10 |
| Arctic Loon | H | – | H | – | H | – |
| Common Loon | – | H | – | – | – | – |
| Yellow-billed Loon | – | X8, X9 | X8, X9 | – | X8, X9, X11, OT10 | OT9 |
| TUBENOSES | | | | | | |
| Northern Fulmar | X8, X9, X10, X11 | X8, X9, X10, X11, H | X8, X9 | X8, X9, X10, X11 | X8, X9, X10 | X8, X9, X10 |
| Short-tailed Shearwater | X8, X9, X10, X11 | X8, X9, X10, X11, H | X8, X9, B10, H | X9, X10, X11 | X8, X9, X10, X11, H | X8, X9, X10 |
| PHALAROPES | | | | | | |
| Red-necked Phalarope | X9, X10 | X8, X9, X10, X11 | X8, X9 | X9, X10, X11 | X8, X9, X10, X11 | X9 |
| Red Phalarope | X8, X9, X10, H | X8, X10, H | X8, X9 | X9, X11, OT10, H | X8, X9, X10, H | X9, X10 |
| LARIDS | | | | | | |
| Black-legged Kittiwake | X8, X9, X10, X11, H | X8, X9, X10, X11, H | X8, X9, B10, H | X8, X9, X10, X11, H | X8, X9, X10, X11, H | X8, X9, OT10, H |
| Ivory Gull | H | – | – | H | H | X8, H |
| Sabine's Gull | X8, OT9, X10, H | X8, X9, X10, H | X8, X9 | X8, OT9, X10, X11, H | OT8, X10 | X9 |
| Ross's Gull | – | – | – | H | OT9, X11, H | X8, X9, X10, H |

Table 7. Continued.

| | Study area/season | | | | | |
|---|---|---|---|---|---|---|
| | Klondike | | | Burger | | |
| Species-group/species | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct |
| LARIDS (continued) | | | | | | |
| Herring Gull | X8, H | X9, H | X8 | X9, H | X9, X10 | X8 |
| Glaucous-winged Gull | OT8 | – | – | – | – | – |
| Glaucous Gull | X8, X10, H | X8, X9, X10, X11, H | X8, X9, B10 | X8, X9, X10, X11, H | X8, X9, X10, X11, H | X8, X9, X10, H |
| Arctic Tern | B8, H | X8, X10 | – | X9, X10, B8 | OT8, X9 | – |
| Pomarine Jaeger | X8, X9, X10, H | X8, X9, X10, X11, H | X8, X9 | X8, X9, X10, X11, H | X8, X9, X10, X11 | – |
| Long-tailed Jaeger | X9, X10, H | OT8, OT10, H | – | X9, H | OT8, X10 | – |
| Parasitic Jaeger | X8, H | X8, X11, OT10, H | – | X8, H | X10, B8, H | – |
| ALCIDS | | | | | | |
| Dovekie | X8 | – | X8 | – | H | X8, X10 |
| Common Murre | X8, X11, B10, H | X9, X10, X11, H | X8, X9 | X11, B10, H | X9, X10, X11 | X9 |
| Thick-billed Murre | X8, X9, X10, X11, H | X8, X9, X10, X11, H | X8, X9, H | X8, X9, X10, X11, H | X9, X10, X11, B8 | X8, X9, X10 |
| Black Guillemot | X8, X10, H | – | – | X8, X10, X11, H | B8, H | X8, OT10 |
| Pigeon Guillemot | X8 | – | – | X8 | – | – |
| Kittlitz's Murrelet | X10, X11, H | X9, X10, X11, H | X8, B9 | – | X10, X11, B9 | X9 |
| Ancient Murrelet | – | X10 | OT10 | – | X10, X11 | X10 |
| Parakeet Auklet | X10, H | X8, X9, X10, X11, H | – | – | X10, H | X8, X10 |
| Least Auklet | X8, X9, X10, X11 | X8, X9, X10, X11, H | X8, X9, B10, H | X9, X10, X11, H | X8, X9, X10, X11 | X8, X9, X10 |
| Crested Auklet | X8, X9, X10, X11 | X8, X9, X10, X11, H | X8, X9, B10, H | X9, X10, X11 | X8, X9, X10, X11, H | X8, X9, X10 |
| Horned Puffin | X8, X9, X10, X11, H | X9 | – | X8, X10, OT9 | X10 | – |
| Tufted Puffin | X8, X9, X10, H | OT9 | X8 | – | X10 | – |

Table 8. Species of seabirds identified during boat-based surveys in the northeastern Chukchi Sea, in the Statoil and Greater Hanna Shoal (outside of the three study-area boxes) study areas by season. Species identified on-transect within the study area are designated as “X10”, and/or “X11” for 2010 and 2011, respectively. Species identified only off-transect are designated as “OT10” for 2010. Species identified in the historical dataset within the study area or buffer zone, available from the North Pacific Pelagic Seabird Database, are designated as “H.”

| | Study area/season | | | |
|---|---|---|---|---|
| | Statoil | | | Greater Hanna Shoal |
| Species-group/species | Jul/Aug | Aug/Sep | Sep/Oct | Aug–Oct |
| WATERFOWL | | | | |
| Spectacled Eider | – | – | – | – |
| King Eider | – | – | – | X11 |
| Common Eider | – | OT10, X11 | – | X11 |
| White-winged Scoter | – | – | – | – |
| Long-tailed Duck | X10, H | X10, H | H | – |
| LOONS | | | | |
| Red-throated Loon | – | X10 | – | X11 |
| Pacific Loon | – | X10, X11 | – | X11 |
| Arctic Loon | – | H | – | – |
| Common Loon | – | – | – | – |
| Yellow-billed Loon | – | – | – | X11 |
| TUBENOSES | | | | |
| Northern Fulmar | X10, X11 | X10, X11 | – | X11 |
| Short-tailed Shearwater | X10, X11 | X10, X11, H | – | X11 |
| PHALAROPES | | | | |
| Red-necked Phalarope | X10, X11 | X10, X11 | – | X11 |
| Red Phalarope | OT, H | X10 | – | X11 |
| LARIDS | | | | |
| Black-legged Kittiwake | X10, X11, H | X10, X11, H | – | X11 |
| Ivory Gull | – | H | – | X11 |
| Sabine's Gull | X10 | – | – | X11 |
| Ross's Gull | H | H | OT10, H | X11 |
| Herring Gull | H | X10 | – | X11 |
| Glaucous-winged Gull | – | – | – | |
| Glaucous Gull | X10, X11, H | X10, X11, H | H | X11 |
| Arctic Tern | – | – | – | X11 |
| Pomarine Jaeger | X10, H | X10, X11 | – | X11 |
| Long-tailed Jaeger | H | – | – | – |
| Parasitic Jaeger | X11, H | H | – | X11 |
| ALCIDS | | | | |
| Dovekie | – | X10, H | – | X11 |
| Common Murre | X11, H | X10, X11 | – | X11 |
| Thick-billed Murre | X10, X11, H | X10, X11 | – | X11 |
| Black Guillemot | X10, H | H | – | X11 |
| Pigeon Guillemot | – | – | – | – |
| Kittlitz's Murrelet | X10 | X11 | – | X11 |
| Ancient Murrelet | – | X10, X11 | – | X11 |
| Parakeet Auklet | X10 | X10, X11 | – | X11 |
| Least Auklet | X10, X11, H | X10, X11 | OT10 | X11 |

Table 8. Continued.

| | Study area/season | | | |
|---|---|---|---|---|
| | Statoil | | | Greater Hanna Shoal |
| Species-group/species | Jul/Aug | Aug/Sep | Sep/Oct | Aug–Oct |
| ALCIDS (continued) | | | | |
| Crested Auklet | X10, X11 | X10, X11, H | – | X11 |
| Horned Puffin | X10, X11 | X10, X11 | – | X11 |
| Tufted Puffin | X10, X11 | – | – | – |

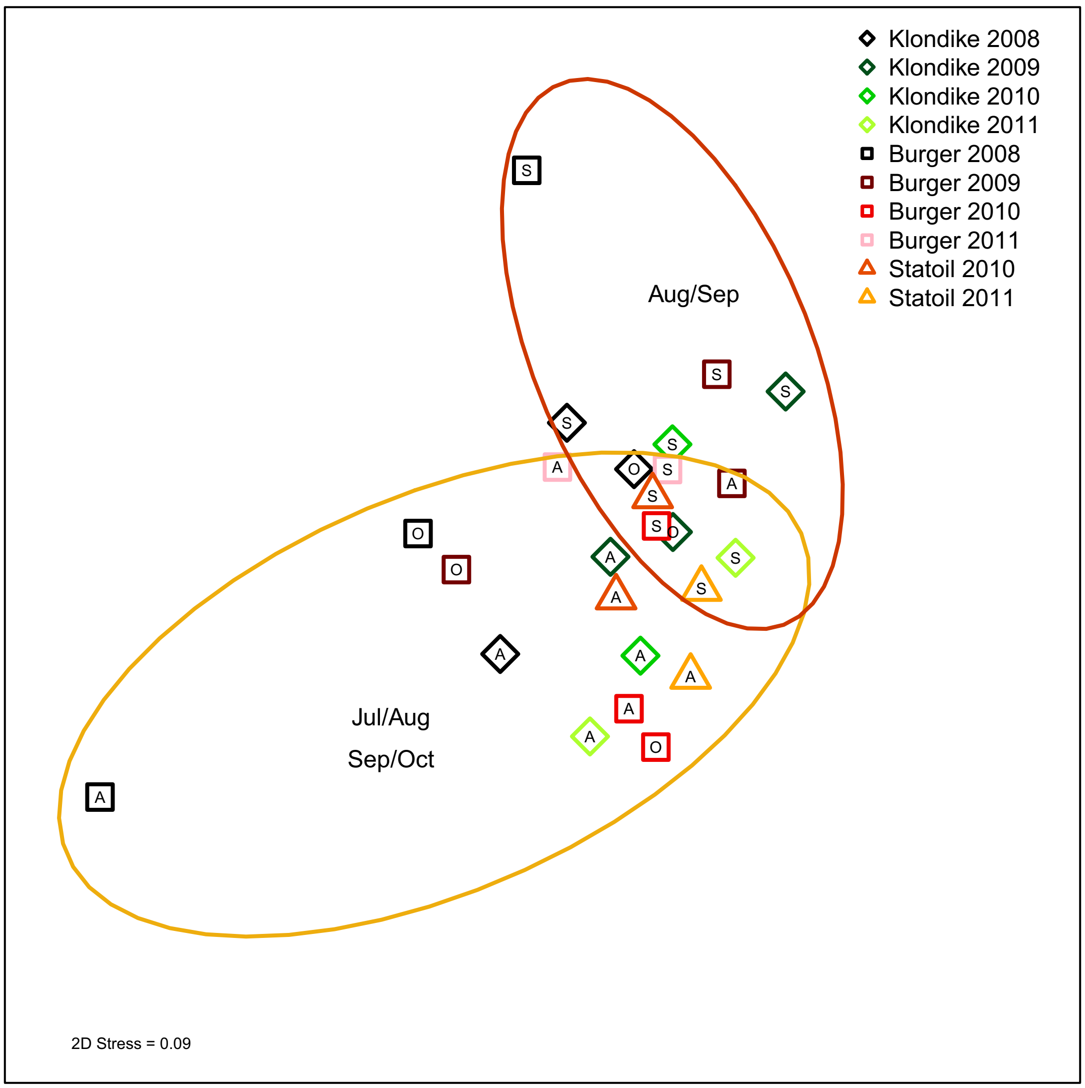


Figure 15. Non-metric multidimensional scaling ordination plot of Bray-Curtis similarities for *ln*(x+1)-transformed density of seabirds recorded in the northeastern Chukchi Sea during 2008–2011. Samples are grouped by season.

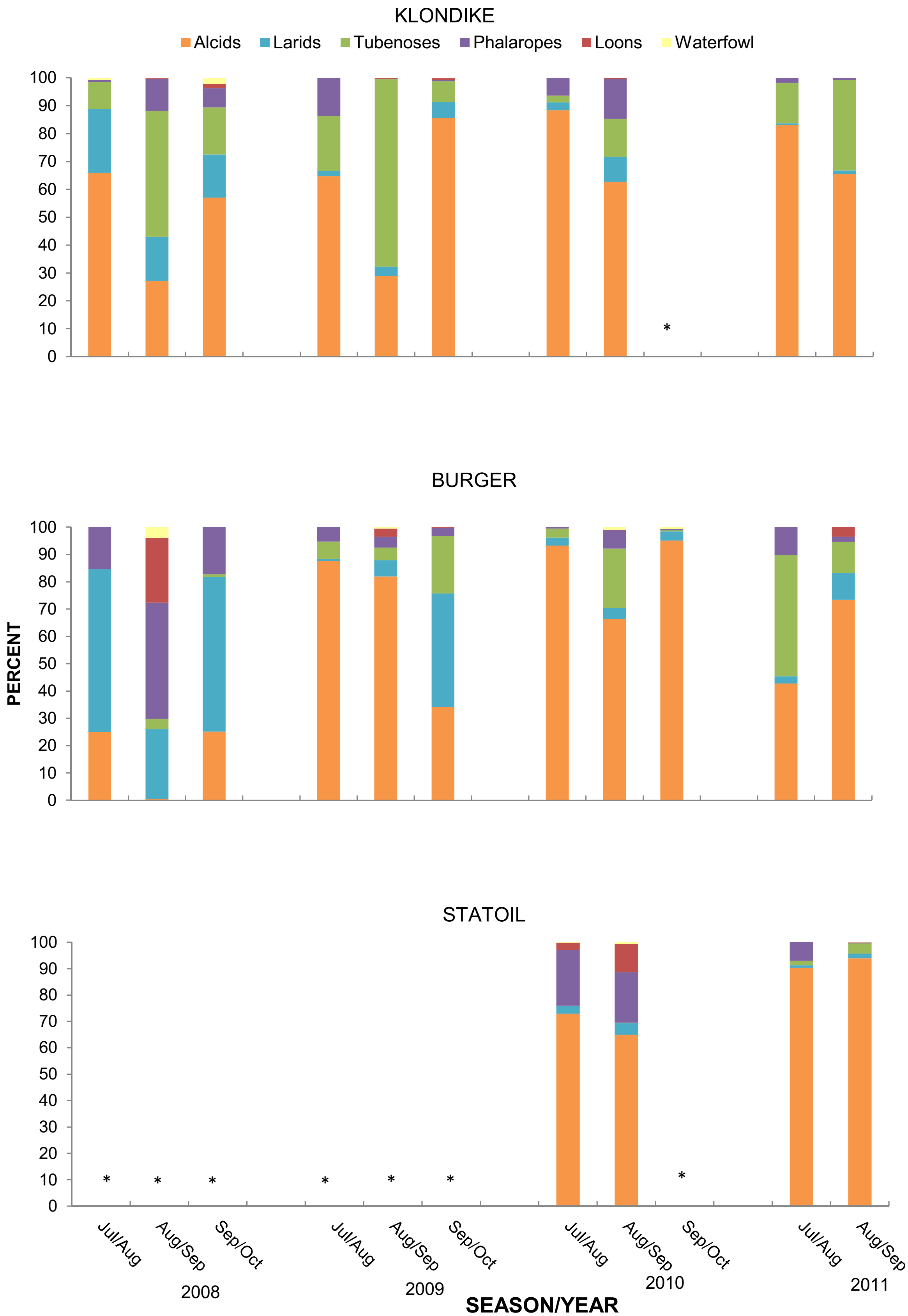


Figure 16. Species-composition of the seabird community on transect in the Klondike, Burger, and Statoil study areas, by season and year. Asterisks indicate no data.

(primarily Short-tailed Shearwaters) in all years. Burger was dominated numerically by larids (primarily Black-legged Kittiwakes) and tubenoses in 2008, but alcids were most abundant in 2009–2011. In Statoil, alcids were the most abundant species-group in 2010–2011. Waterfowl and loons were the least common species-groups and consisted primarily of flocks of Long-tailed Ducks and Pacific Loons, respectively.

## CONSERVATION STATUS

During the surveys of 2008–2011, we recorded 11 species on transect in the study areas that are classified as being of conservation concern (Table 9). All of these species occurred on at least 2 of the 5 lists. Of these 11 species, 1 (Spectacled Eider) is listed as threatened under the ESA, 2 (Kittlitz's Murrelet and Yellow-billed Loon) are classified as candidate species under the ESA, and 2 (Red-throated Loon and Arctic Tern) are classified as species of conservation concern by the USFWS. The Bureau of Land Management considers all 4 species listed by the USFWS, plus 2 others, to be sensitive species. The Alaska Department of Fish and Game (ADFG) does not list any of the USFWS-listed species as species of special concern; instead, that state agency classifies 8 of the 11 species as featured for management in the State of Alaska's Comprehensive Wildlife Conservation Strategy. The non-governmental organization Audubon Alaska classifies 7 of the 11 species as being of conservation concern. Finally, the quasi-governmental organization Alaska Natural Heritage Program classifies 6 of the 11 species as being of conservation concern.

Of the 11 species of conservation concern, 4 (King Eider, Spectacled Eider, Yellow-billed Loon, and Kittlitz's Murrelet) occurred on all 5 lists, and Red-throated Loon occurred on 4 of the 5 lists, indicating that there is a high level of concern about the long-term fate of these 5 species in many organizations. Only Arctic Tern occurred on 3 of the 5 lists, including both the USFWS and ADFG, so there is a substantial concern about them. The other 5 species occurred on 2 of the 5 lists, indicating concern—but not widespread alarm—about population trends of those species.

We saw a total of 7 Yellow-billed Loons in 2008, 48 birds in 2009, and 8 birds in 2011; most were seen in Burger, although a few were seen in Klondike.

Of the 5 species of waterfowl that are of conservation concern, only the Long-tailed Duck was recorded and widely distributed in 2008–2010; it was not recorded in 2011. Waterfowl species recorded in 2008 and 2010 but not in 2009 included King Eiders in both Klondike and Burger, Common Eiders only in Burger, and White-winged Scoters only in Klondike in 2008 and in Burger in 2010. Spectacled Eiders were seen in Sep/Oct 2009 (1 in Klondike and 1 in Burger) and in Sep/Oct 2010 (1 in Statoil). A single Common Eider seen in Statoil and 2 seen in the GHS were the only waterfowl recorded on transect in 2011.

Arctic Terns occurred primarily in Klondike in Aug/Sep 2008 and Aug/Sep 2010, whereas the 2 observations in 2009 both occurred in Burger and the single observation in 2011 occurred near Statoil. The other 4 species of conservation concern were rare, with ≤21 observations per species in all seasons/years combined. A single Red-throated Loon was seen in Burger in Aug/Sep 2008, and 2 were seen in Statoil in Aug/Sep 2010. Dovekies were seen in Klondike in Jul/Aug and Sep/Oct 2008, in Burger in Sep/Oct 2008, and in Statoil in Sep/Oct 2010; all were single birds. Black Guillemots were recorded in both study areas throughout 2008, but they primarily were associated with sea ice; as a result, none were seen in 2009, and we saw only 1 in each of the 3 study areas in Jul/Aug 2010. Finally, Kittlitz's Murrelets were rare, with the highest abundance recorded in 2011.

# DISCUSSION

## INFLUENCE OF PHYSICAL OCEANOGRAPHY IN THE REGION

We propose here that the oceanography differs throughout the GHS study area seasonally and interannually and that these differences create spatial and temporal differences in the structure of the seabird community in the northeastern Chukchi Sea. The movement of oceanic water northward from the Gulf of Anadyr through the Bering Strait influences the patterns of productivity throughout

Table 9. Bird species in the northeastern Chukchi Sea that are of conservation concern.

| | Listing organization | | | | |
|---|---|---|---|---|---|
| Species[a] | USFWS[b] | BLM[c] | ADFG[d] | Audubon Alaska[e] | Alaska Natural Heritage Program[f] |
| Spectacled Eider | threatened species under the ESA | threatened species under the ESA | species of special concern | nationwide species of conservation concern | species of conservation concern |
| King Eider | – | sensitive species | featured species | state species of conservation concern | species of conservation concern |
| Common Eider | – | – | featured species | state species of conservation concern | – |
| White-winged Scoter | – | – | featured species | – | – |
| Long-tailed Duck | – | sensitive species | featured species | – | – |
| Red-throated Loon | species of conservation concern | sensitive species | featured species | state species of conservation concern | – |
| Yellow-billed Loon | candidate species under the ESA | sensitive species | featured species | nationwide species of conservation concern | species of conservation concern |
| Arctic Tern | species of conservation concern | – | featured species | – | – |
| Dovekie | – | sensitive species | – | – | species of conservation concern |
| Black Guillemot | – | sensitive species | – | – | species of conservation concern |
| Kittlitz's Murrelet | candidate species under the ESA | sensitive species | featured species | nationwide species of conservation concern | species of conservation concern |

a. Only species with low population levels or similar concerns (e.g., rapidly declining populations; highly restricted breeding, staging, and/or wintering areas) are listed.
b. U.S. Fish and Wildlife Service, List of endangered, threatened, proposed, candidate, and delisted species in Alaska (USFWS 2009), and birds of conservation concern (USFWS 2008).
c. Bureau of Land Management, Special status species list for Alaska 2005 (http://www.blm.gov/pgdata/etc/medialib/blm/ak/aktest/ims.Par.13157.File.dat/im_ak_2006_003.pdf)
d. Alaska Department of Fish and Game, Division of Wildlife Conservation, Endangered Species in Alaska (http://www.adfg.state.ak.us/special/esa/esa_home.php), Alaska Species of Special Concern (http://www.adfg.state.ak.us/special/esa/species_concern.php), and State of Alaska's Comprehensive Wildlife Conservation Strategy (http://www.sf.adfg.state.ak.us/statewide/ngplan/).
e. The Audubon Alaska Watchlist 2010 (Kirchoff and Padula 2010).
f. Alaska Natural Heritage Program, Environmental and Natural Resources Institute, University of Alaska, Anchorage, AK; AKNHP Vertebrate Species Tracking List, November 2008 (http://aknhp.uaa.alaska.edu/zoology/Zoology_Birds_track08.htm). Species of conservation concern are categorized by status (critically imperiled, imperiled, vulnerable), geographic scale (global, national, sub-national), and breeding status in the region of concern (breeding, non-breeding, migrant).

the Chukchi Sea (Grebmeier et al. 2006). In the southern Chukchi Sea, an oceanographic front between Bering Sea Water (BSW) and Alaskan Coastal Water (ACW) is the defining feature that separates distinct benthic communities (Grebmeier et al 2006, Bluhm et al. 2009), with higher biomass and bivalve abundance under BSW and lower biomass under ACW. In our study areas, communities also are structured to some extent by processes associated with fronts, but the water masses involved are modified from those found farther south. Despite the shallow bathymetry, the GHS study area straddles a region that resembles the interface found at a shelf-break, in that there is a transition from a stream of oceanic water entrained in the Central Channel to a 2-layer water-column having little transport trapped over Hanna Shoal.

In terms of the fate of primary production, the southwestern half of the GHS appears to be more of a pelagic-dominated system and the northeastern half appears to be more of a benthic-dominated system, with a transition between the 2 systems occurring between Klondike and Burger. This transition zone is seen in Statoil, which was added to the study in 2010 and spans the longitudes between Klondike and Burger. The boundary between these two main water-masses is seen in surface temperatures and in bottom temperatures and salinities in the plan-view maps.

Observations from 2008–2010 focused on 3 study areas that offered a fragmented look at the fronts that develop each summer between BSW intruding from the south and MW and WW that are formed on the Chukchi shelf during the winter and spring. Comparisons among the study-area boxes suggested that the structure and variability of the seabird community reflects the flow of BSW northward in the Central Channel, and the data collected in 2011 from the GHS provide further evidence to support this hypothesis. Species associated with BSW in the study-area boxes such as Least Auklets, Short-tailed Shearwaters, Thick-billed Murres, and Northern Fulmars were concentrated in the southwestern half of the GHS. These patterns closely resembled the distribution of warm, salty water in the upper 10 m of the water column (i.e., BSW). Crested Auklets also were abundant near the Central Channel but appeared to concentrate near the front between the water-masses, which was strongest in Statoil in 2011.

For species that occurred in low densities, such as Glaucous Gulls and Black-legged Kittiwakes, the larger study area helped clarify the patterns of distribution. These two species had high densities in the northeastern half of the GHS, an area that appeared to be avoided by birds associated with BSW that that instead had the 2-layer system consisting of MW at the surface and WW on the bottom. In addition to the species that were common in the study-area boxes in all 4 years, we also found the Ross's Gulls that had become rare in the boxes. In 2011, this ice-associated species occurred almost exclusively northeast of the areas that we had surveyed in 2008–2010, migrating across the cooler area in northern Hanna Shoal that was covered by MW.

## BASELINE SPECIES DISTRIBUTION AND ABUNDANCE

The distribution of seabirds, particularly the planktivorous species, is influenced in the northeastern Chukchi Sea by advective processes that transport oceanic species of zooplankton from the Bering Sea. Because planktivorous seabirds are most abundant in areas where their prey is concentrated within 20 m of the ocean's surface (Haney 1991, Piatt and Springer 2003), they are responsive to conditions that make their prey both abundant and accessible. Total seabird abundance was highest in 2009, lowest in 2008, and intermediate in 2010 and 2011. This interannual variation reflected changes in the location and strength of the boundary between BSW and MW, although the connections to zooplankton populations appeared less clear (Questel et al. 2012). The year of lowest total seabird abundance (2008) was associated with the coldest overall water temperatures, weak stratification, late inflow of BSW that did not develop until Sep/Oct, and the lowest biomass of large zooplankton seen in 2008–2011. The year of highest total seabird abundance (2009) was associated with the extensive and early intrusion of warm BSW into the study region, but it was accompanied by only intermediate biomass of large zooplankton. The warm BSW established vertical stratification of the water-column at 25–35 m depth in Jul/Aug that persisted until Sep/Oct. The years of intermediate seabird abundance (2010 and 2011) also were associated with strong intrusions of BSW but had shallower and weaker stratification (20 m) than 2009. This stratification remained weak during Sep in Klondike but persisted in Burger and the eastern edge of Statoil as MW/WW moved back into the study-area boxes from the northeast. This habitat heterogeneity was reflected in the persistence of substantial numbers of seabirds in the eastern GHS study area. We unfortunately lack information on the vertical distribution of prey to explore these interactions further; consequently, we can only speculate on the mechanisms for these interannual and spatial variations.

In addition to changes in total abundance, the relative abundance of 8 seabird taxa changed among seasons and years. This seasonal shift is dictated partially by the development of open water. As the ice retreats and foraging habitat becomes available, species move in from foraging areas to the south and from terrestrial breeding areas. Of the colonial seabirds, Thick-billed Murres, Common Murres, and Black-legged Kittiwakes nest in large numbers on cliffs along the eastern Chukchi coast as far north as Cape Lisburne and are common offshore during Jul/Aug and Aug/Sep (Divoky 1987). Species that nest on the tundra, such as phalaropes and jaegers, move out to sea in Aug/Sep and join millions of Short-tailed Shearwaters that migrate from their breeding grounds in Australia to forage in the Northern Hemisphere during the austral winter (Divoky 1987). Finally, ice-associated gulls such as Ross's Gulls and Ivory Gulls migrate from high-arctic breeding areas in Russia and Canada into the Chukchi and Beaufort seas to forage before the ice-edge moves southward again in the October–November (Divoky et al. 1988).

The seasonal pattern in species-composition was similar from year to year, with the numerical dominance shifting from primarily alcids in Jul/Aug (except for Burger in 2008) to a mix of alcids, shearwaters, and phalaropes (all of which are zooplankton-feeders) in Aug/Sep, then shifting back toward the initial species-composition in Sep/Oct. The most remarkable difference in species-composition among years occurred in the cold year of 2008 (and especially the Burger study area), primarily because of the low densities of alcids in that year and the numerical importance of larids in Burger. Densities of diving species such as alcids and Short-tailed Shearwaters fluctuated by 4 orders of magnitude among years, whereas the variation in the density of surface-feeding larids among years was only 1 order of magnitude. This fairly consistent contribution from larids among years indicates that most of the variation in the seabird community can be attributed to planktivorous seabirds.

## PLANKTIVOROUS SEABIRDS

The distribution and abundance of individual species of planktivorous seabirds demonstrates the relationship between foraging strategy and foraging habitat, as defined by physical oceanography. For example, Crested Auklets are diving seabirds that mostly consume euphausiids (e.g., *Thysanoessa* spp.) and large copepods (e.g., *Neocalanus cristatus*, *N. plumchrus*) characteristic of oceanic water from the North Pacific and Bering seas (Bédard 1969, Kitaysky and Golubova 2000, Gall et al. 2006). Areas of high Crested Auklet density tended to coincide with upper-layer water temperatures of 4–5 °C and salinity >30, regardless of stratification conditions, season, or study area. These conditions may have been ideal for the presence and availability of their preferred prey. In contrast, Least Auklets consume both oceanic (e.g., *N. plumchrus*) and shelf copepods (e.g., *Calanus marshallae*), and do not dive as deeply as Crested Auklets do because of their smaller body size (Hunt et al. 1998); therefore, they should concentrate in areas with shallow pycnoclines. Like Crested Auklets, areas of high Least Auklet density coincided with BSW, but they also tended to occur where and when pycnoclines were strongest and only 10–20 m from the surface or when the water-column was well-mixed, a characteristic that may have enhanced the availability of prey close to the surface.

The distribution and abundance of planktivorous species that feed at the surface also reflected their respective foraging strategies. Phalaropes have the most restricted foraging habitat of the planktivorous species we studied in detail because they are small shorebirds that forage only on the surface and typically are associated with microscale upwelling and convergence fronts that concentrate prey within ~0.2 m of the surface (Brown and Gaskin 1988). Like Least Auklets, areas of high phalarope density tended to occur over strong, shallow pycnoclines or well-mixed water. Additionally, their distribution was highly clumped, and they were particularly abundant when and where there were filaments of cold water at or near the surface (e.g., Klondike in Aug/Sep 2008).

OMNIVOROUS SEABIRDS

The distribution of Short-tailed Shearwaters did not appear tightly coupled with particular features of the water-column. Short-tailed shearwaters are fairly large seabirds that consume a variety of large zooplankton, in addition to fish and squid (Hunt et al. 2002; Jahncke et al., 2005) and can dive as deep as 70 m to forage (Weimerskirch and Cherel, 1998). The magnitude of interannual variation in the abundance of Short-tailed Shearwaters during this study was similar to that of primarily planktivorous seabirds, but their seasonal pattern of abundance was consistent among years (i.e., always highest in Aug/Sep), suggesting that they are responding to oceanographic structure at a broader spatial scale than what was sampled in this study.

The distribution and abundance of other omnivorous species, as characterized by Northern Fulmars and Glaucous Gulls, reflected their flexibility in foraging behavior. Both species were present in low densities in all 4 years—densities considerably lower than the large and variable densities of planktivorous species—and both were most abundant in 2009, least abundant in 2010 and 2011, and intermediate in abundance in 2008. Northern Fulmars had consistent seasonal patterns among years: their abundance declined from Jul/Aug to Sep/Oct, perhaps indicating their greater reliance on prey associated with BSW than the generalist Glaucous Gulls. Glaucous Gulls were the least abundant of the 8 focal species in our study and showed a consistent seasonal pattern of increasing abundance from Jul/Aug to Sep/Aug in all years.

PISCIVOROUS SEABIRDS

The variation in distribution and abundance of piscivorous species, as indicated by Black-legged Kittiwakes and Thick-billed Murres, is probably related to the difference in foraging strategies between these two species. Despite being classified as piscivorous (Piatt and Springer 2003), Black-legged Kittiwakes are surface-feeding gulls that will consume both fishes and larger zooplankton (Hobson 1993, Jodice et al. 2006, Iverson et al. 2007), and Thick-billed Murres are diving alcids that will consume both fishes and larger invertebrates (Woo et al. 2008). Thick-billed Murres occurred almost exclusively in Klondike in all years and disappeared by Sep/Oct of each year, suggesting that they had very restricted foraging habitat that was located primarily in BSW. Black-legged Kittiwakes had a consistent seasonal pattern of abundance in Burger in all years, but densities in Klondike tended to be highest when BSW occupied more of Klondike than it did of Burger, suggesting that Black-legged Kittiwakes were foraging on prey species associated with BSW but may be less restricted in their foraging requirements than are Thick-billed Murres. These results are consistent with patterns observed in the southeastern Bering Sea, where Black-legged Kittiwakes were found to be widespread foragers, whereas Thick-billed Murres foraged close to their breeding colonies (Sigler et al. 2012).

## RARE SPECIES

The presence and absence of species among years also demonstrates the influence of physical oceanography on seabird community structure. In 2008, when water temperatures remained cold until late in the open-water season, we saw ice-associated species such as Ivory Gulls, Dovekies, and Black Guillemots. In 2009 and 2011, when water temperatures were warm for most of the open-water season, we did not see the ice-associated species, migrating waterfowl and waterbirds such as King Eiders, Common Eiders, and Red-throated Loons, or species that would be considered at the edges of their range (e.g., Pigeon Guillemots); these species were spotted only in 2008 and/or 2010.

Perhaps the most curious presence of a rare species outside of its range was the appearance of Ancient Murrelets in all 3 study areas in Aug/Sep 2010 and 2011 and lingering in Burger into Sep/Oct 2010. The closest known breeding populations of this small, nocturnal alcid are in the

Aleutian Islands, ~1,600 km south of the Chukchi Sea, and its winter range is largely unknown (Gaston and Shoji 2010). There are no records of Ancient Murrelets in the northern Chukchi Sea in the North Pacific Pelagic Seabird Database (USGS 2010) in the ~35 years of data prior to 2007, and there are few records of these birds north of Bering Strait (Kessel 1989). Surveys conducted by the USFWS recorded 68 Ancient Murrelets in the Chukchi Sea in Sep/Oct 2007 (USGS 2010), however, suggesting that this species is an occasional visitor to the region and is common in years when it is present.

## SPECIES OF CONSERVATION CONCERN

During these surveys, we recorded 11 species of seabirds that are of conservation concern: 5 species of waterfowl (all seaducks), 2 species of loon, 1 species of tern, and 3 species of alcids. With the exception of Yellow-billed Loons in 2009 and Long-tailed Ducks in 2008 and 2009, however, none of the species occurred in substantial numbers. The highest-profile species are the Spectacled Eider, which is listed as threatened under the ESA, and the Yellow-billed Loon and the Kittlitz's Murrelet, both of which are candidate species for listing under the ESA. The Kittlitz's Murrelet is undergoing a listing evaluation at this time, with a Draft Decision due by the end of September 2013.

## CONCLUSIONS

The GHS study area in the northeastern Chukchi Sea has a diverse seabird community of more than 30 species and a maximal abundance of >60 birds km$^2$ within a study-area box during some seasons. There is extensive seasonal and interannual variation in the abundance of the seabirds in this area that is attributable almost entirely to planktivorous species. The greatest number of birds generally occurs in Aug/Sep (~25 August to ~ 20 September), presumably reflecting a variety of factors that may include the timing of melt of sea ice, seasonal changes in the oceanography of the area, bird migration, nesting phenology and breeding success of birds in the Arctic. Despite this general seasonal trend, the interannual variation in the timing of species-specific maximal abundance is related to the strength and timing of inflow of BSW from south of Bering Strait. Planktivorous seabird species generally are more abundant close to the Central Channel (southwestern half of GHS study area) and in BSW, and piscivorous species generally are more abundant in the northeastern half of the GHS study area and in two-layered MW/WW.

The scientific community is moving beyond describing this system to quantifying the spatial and temporal scales of processes in this region. We demonstrate that differences in the seabird community reflect the shifting distributions of BSW throughout the GHS study area. Several other components of this multidisciplinary study also suggest a similar structuring of the ecosystem (Blanchard et al. in press; Questel in press). Our growing understanding of those factors that influence interannual variability is informing the development of long-term plans to monitor the seabird community in this region of active oil and gas exploration.

## LITERATURE CITED


Alaska Department of Fish and Game (ADFG). 2009. Lists of endangered species and species of special concern in Alaska. Alaska Department of Fish and Game, Division of Wildlife Conservation, Anchorage, AK. [http://www.adfg.state.ak.us/special/esa/esa_home.php] Date of use: 25 March 2010.

ADFG. 2006. Our wealth maintained: a strategy for conserving Alaska's diverse wildlife and fish resources. Alaska Department of Fish and Game, Juneau, AK. 824 pp. [http://www.sf.adfg.state.ak.us/statewide/ngplan/NG_outline.cfm] Date of use: 25 March 2010.

Alaska Natural Heritage Program. 2008. AKNHP vertebrate species tracking list, November 2008. Environmental and Natural Resources Institute, University of Alaska, Anchorage, AK. 16 pp. [http://aknhp.uaa.alaska.edu/zoology/pdfs/tracking_lists/2008_VertebrateSpeciesTrackingList.pdf] Date of use: 25 March 2010.

Bédard, J. 1969. Feeding of the Least, Crested, and Parakeet auklets around St. Lawrence Island. Canadian Journal of Zoology 47: 1,025–1,050.

Blanchard, A. L., H. Nichols, and C. Parris. 2010. 2009 Environmental Studies Program in the northeastern Chukchi Sea: benthic ecology of the Burger and Klondike survey areas. Report for ConocoPhillips Alaska, Inc., and Shell Exploration and Production Company, Anchorage, AK, by the Institute of Marine Sciences, University of Alaska, Fairbanks, AK. 86 pp.

Blanchard, A.L., C. L. Parris, A. L. Knowlton, and N. R. Wade. In press. Macrofaunal community structure in the northeastern Chukchi Sea and its association with environmental characteristics. Continental Shelf Research.

Bluhm, B., K. Iken, S. Mincks Hardy, B. Sirenko, and B. Holladay. 2009. Community structure of epibenthic megafauna in the Chukchi Sea. Aquatic Biology 7: 269–293.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, United Kingdom. 432 pp.

Buckland, S.T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2004. Advanced distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, United Kingdom. 416 pp.

Bureau of Land Management (BLM). 2005. Special status species list for Alaska 2005. Instruction Memorandum No. AK 2006-003. Bureau of Land Management, Anchorage, AK. 3 pp. [http://www.blm.gov/pgdata/etc/medialib/blm/ak/aktest/ims.Par.13157.File.dat/im_ak_2006_003.pdf] Date of use: 25 March 2010.

Bray, J. R., and J. Y. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27: 235–249.

Brown, R. G. B., and D. E. Gaskin. 1988. The pelagic ecology of the Grey and Red-necked phalaropes *Phalaropus fulicarius* and *P. lobatus* in the Bay of Fundy, eastern Canada. Ibis 130: 234–250.

Clarke, K. R., and M. Ainsworth. 1993. A method of linking multivariate community structure to environmental variables. Marine Ecology Progress Series 92: 205–219.

Clarke, K. R., and R. H. Green. 1988. Statistical design and analysis for a 'biological effects' study. Marine Ecology Progress Series 46: 213–226.

Day, R.H., T. J. Weingartner, R. R. Hopcroft, L. A. Aerts, A. Blanchard, A. E. Gall, B. J. Galloway, D. E. Hannay, B. A Holladay, J. T. Mathis, B. L. Norcross, J. M. Questel, and S. S. Wisdom. In press. The offshore northeastern Chukchi Sea: a complex high-latitude ecosystem. Continental Shelf Research.

Divoky, G. J. 1987. The distribution and abundance of birds in the eastern Chukchi Sea in late summer and early fall. Report for National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program (NOAA/OCSEAP), Arctic Environmental Information and Data Center, Anchorage, AK, by College of the Atlantic, Bar Harbor, ME. 96 pp.

Divoky, G. J., G. A. Sanger, S. A. Hatch, and J. C. Haney. 1988. Fall migration of Ross's Gull (*Rhodostethia rosea*) in Alaskan Chukchi and Beaufort seas. Report for Minerals Management Service, Outer Continental Shelf Study 88-0023 by U. S. Fish and Wildlife Service, Anchorage, AK. 120 pp.

Gall, A. E., D. D. Roby, D. B. Irons, and I. C. Rose. 2006. Differential response in chick survival to diet in Least and Crested auklets. Marine Ecology Progress Series 308: 279–291.

Gall, A. E., and R. H. Day. 2011. Distribution and abundance of seabirds in the northeastern Chukchi Sea, 2008–2010. Report for ConocoPhillips Alaska, Inc., and Shell Exploration and Production Company, Anchorage, AK, by ABR, Inc.—Environmental Research & Services, Fairbanks, AK. 74 pp.

Gall, A. E., R. H. Day, and T. J. Weingartner. In press. Structure and variability of the marine-bird community in the northeastern Chukchi Sea. Continental Shelf Research.

Gaston, A. J., and A. Shoji. 2010. Ancient Murrelet (*Synthliboramphus antiquus*). *In*: The Birds of North America Online (A. Poole, ed.). Ithaca: Cornell Lab of Ornithology. [http://bna.birds.cornell.edu/bna/species/132] Date of use: 15 May 2011.

Gould, P. J., and D. J. Forsell. 1989. Techniques for shipboard surveys of marine birds. U.S. Fish and Wildlife Service, Technical Report No. 25. 22 pp.

Grebmeier, J. M., L. W. Cooper, H. M. Feder, and B. I. Sirenko. 2006. Ecosystem dynamics of the Pacific-influenced northern Bering and Chukchi seas in the Amerasian Arctic. Progress in Oceanography 71: 331–361.

Haney, J. 1991. Influence of pycnocline topography and water-column structure on marine distributions of alcids (Aves: Alcidae) in Anadyr Strait, Northern Bering Sea, Alaska. Marine Biology 110: 419–435.

Hobson, K.A. 1993. Trophic relationships among high arctic seabirds: insights from tissue-dependent stable-isotope models. Marine Ecology Progress Series 95: 7–18.

Hunt, G. L., C. Baduini, and J. Jahncke. 2002. Diets of Short-tailed Shearwaters in the southeastern Bering Sea. Deep Sea Research Part II: Topical studies in oceanography 49: 6147–6156.

Hunt, G., R. W. Russell, K.O. Coyle, and T. Weingartner. 1998. Comparative foraging ecology of planktivorous auklets in relation to ocean physics and prey availability. Marine Ecology Progress Series 167: 241–259.

Iverson, S., A. Springer, and A. Kitaysky. 2007. Seabirds as indicators of food web structure and ecosystem variability: qualitative and quantitative diet analyses using fatty acids. Marine Ecology Progress Series 352: 235–244.

Jahncke, J., K. O. Coyle, and G. L. Hunt. 2005. Seabird Distribution, Abundance and Diets in the Eastern and Central Aleutian Islands. Fisheries Oceanography 14: 160–177.

Jodice, P. G. R., D. D. Roby, K. R. Turco, R. M. Suryan, D. B. Irons, J. F. Piatt, M. T. Schultz, D. G. Roseneau, A. B. Kettle, and J. A. Anthony. 2006. Assessing the nutritional stress hypothesis: relative influence of diet quantity and quality on seabird productivity. Marine Ecology Progress Series 325: 267–279.

Kessel, B. 1989. Birds of the Seward Peninsula, Alaska. University of Alaska Press, Fairbanks, AK. 330 pp.

Kirchhoff, M., and V. Padula. 2010. The Audubon Alaska WatchList 2010. Audubon Alaska, Anchorage AK. 8 pp. [http://ak.audubon.org/sites/default/files/documents/ak-watchlist-2010.pdf] Date of use: 26 October 2010.

Kitaysky, A. S., and E. G. Golubova. 2000. Climate change causes contrasting trends in reproductive performance of planktivorous and piscivorous alcids. Journal of Animal Ecology 69: 248–262.

Magurran, A. E. 2004. Measuring biological diversity. Blackwell Publishing, Malden, MA. 256 pp.

Oksanen, J., F. Guillaume Blanchet, R. Kindt, P. Legendre, R. B. O'Hara, G. L. Simpson, P. Solymos, M. Henry, H. Stevens, and H. Wagner. 2011. Vegan: community ecology package. R package version 1.17-9. [http://CRAN.R-project.org/package=vegan] Date of use: 26 April 2011.

Piatt, J. F., and A. M. Springer. 2003. Advection, pelagic food webs, and the biogeography of seabirds in Beringia. Marine Ornithology 31: 141–154.

Questel, J.M., C. Clarke, and R. R. Hopcroft. In press. Seasonal and interannual variation in the planktonic communities of the northeastern Chukchi Sea. Continental Shelf Research.

Sigler, M. F., K. J. Kuletz, P. H. Ressler, N. A. Friday, C. D. Wilson, and A. N. Zerbini. 2012. Marine predators and persistent prey in the southeast Bering Sea. Deep-Sea Research (Part II) 65-70: 292–303.

Springer, A., C. P. McRoy, and K. R. Turco. 1989. The paradox of pelagic food webs in the northern Bering Sea—II. Zooplankton communities. Continental Shelf Research 9: 359–386.

Springer, A. M., and C. P. McRoy. 1993. The paradox of pelagic food webs in the northern Bering Sea—III. Patterns of primary production. Continental Shelf Research 13: 575–599.

Springer, A. M., C. P. McRoy, and M. V. Flint. 1996. The Bering Sea Green Belt: shelf-edge processes and ecosystem production. Fisheries Oceanography 5: 205–223.

Tasker, M. L., P. H. Jones, T. J. Dixon, and B. F. Blake.1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101: 567–577.

Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5–14.

USFWS (U.S. Fish and Wildlife Service). 2009. Lists of endangered, threatened, proposed, candidate, and delisted species in Alaska. U. S. Fish and Wildlife Service, Anchorage, AK. [http://alaska.fws.gov/fisheries/endangered/species.htm] Date of use: 25 March 2010.

USGS (U.S. Geological Survey). 2010. North Pacific Pelagic Seabird Database (NPPSD v2.0). U.S. Geological Survey, Anchorage, AK. [http://www.absc.usgs.gov/research/NPPSD/index.htm] Date of use: 2 February 2010.

Venables, W. N., and B. D. Ripley. 2002. Modern applied statistics with S, 4th edition. Springer, New York, NY. 495 pp.

Weimerskirch, H, and Y. Cherel. 1998. Feeding ecology of Short-tailed Shearwaters: breeding in Tasmania and foraging in the Antarctic? Marine Ecology Progress Series 167: 261–274.

Weingartner, T., S. Danielson, L. Dobbins, and R. Potter. 2011. Physical oceanographic measurements in the Klondike and Burger survey areas of the Chukchi Sea: 2008–2010. Report for ConocoPhillips Alaska, Inc., and Shell Exploration and Production Company, Anchorage, AK, by the Institute of Marine Sciences, University of Alaska, Fairbanks, AK. 89 pp.

Weingartner, T., S. Danielson, L. Dobbins, and R. Potter. 2012. Physical oceanographic measurements in the northeastern Chukchi Sea: 2011. Report for ConocoPhillips Alaska, Inc., and Shell Exploration and Production Company, Anchorage, AK, by the Institute of Marine Sciences, University of Alaska, Fairbanks, AK. 38 pp.

Weingartner, T. J., K. Aagard, R. Woodgate, S. Danielson, Y. Sasaki, and D. Cavalieri. 2005. Circulation on the north central Chukchi Sea shelf. Deep-Sea Research (Part II) 52: 3,150–3,174.

Weingartner, T., K. Shimada, F. McLaughlin, and A. Proshutinsky. 2008. Physical oceanography. Pp. 6–17 *in* Arctic Ocean synthesis: analysis of climate change impacts in the Chukchi and Beaufort seas, with strategies for future research (R. Hopcroft, B. Bluhm, and R. Gradinger, eds.). Report to the North Pacific Research Board, Anchorage, AK, by the Institute of Marine Sciences, University of Alaska, Fairbanks, AK.

Woo, K. J., K. H. Elliott, M. Davidson, A. J. Gaston, and G. K. Davoren. 2008. Individual specialization in diet by a generalist marine predator reflects specialization in foraging behaviour. Journal of Animal Ecology 77: 1082–1091.

Wood, S. N. 2004. Stable and efficient multiple smoothing parameter estimation for generalized additive models. Journal of the American Statistical Association 99: 673–686.

Appendix A. List of all bird species recorded during boat-based marine surveys in the northeastern Chukchi Sea, 2008–2011. Iñupiaq names are provided when known.

| Species-group/species | Scientific name | Iñupiaq name |
|---|---|---|
| WATERFOWL | | |
| Spectacled Eider | *Somateria fischeri* | qavaasuk |
| King Eider | *S. spectabilis* | qiŋalik |
| Common Eider | *S. mollissima* | amauligruaq |
| White-winged Scoter | *Melanitta fusca* | killalik |
| Long-tailed Duck | *Clangula hyemalis* | aahaaliq |
| LOONS | | |
| Red-throated Loon | *Gavia stellata* | qaksrauq |
| Pacific Loon | *G. pacifica* | malġi |
| Yellow-billed Loon | *G. adamsii* | tuutlik |
| TUBENOSES | | |
| Northern Fulmar | *Fulmarus glacialis* | |
| Short-tailed Shearwater | *Puffinus tenuirostris* | |
| SHOREBIRDS | | |
| Pectoral Sandpiper | *Calidris melanotos* | puviaqtuuq |
| Long-billed Dowitcher | *Limnodromus scolopaceus* | siiyukpalik |
| Red-necked Phalarope | *Phalaropus lobatus* | qayyiuġun |
| Red Phalarope | *P. fulicarius* | auksruaq |
| LARIDS | | |
| Black-legged Kittiwake | *Rissa tridactyla* | |
| Ivory Gull | *Pagophila eburnea* | |
| Sabine's Gull | *Xema sabini* | aqargigiaq |
| Ross's Gull | *Rhodostethia rosea* | |
| Herring Gull | *Larus argentatus* | nauyatchiaq |
| Glaucous Gull | *L. hyperboreus* | nauyavasrugruk |
| Arctic Tern | *Sterna paradisaea* | mitqutaiḷḷaq |
| Pomarine Jaeger | *Stercorarius pomarinus* | isuŋŋaġluk |
| Parasitic Jaeger | *S. parasiticus* | miġiaqsaayuk |
| Long-tailed Jaeger | *S. longicaudus* | isuŋŋaq |
| ALCIDS | | |
| Dovekie | *Alle alle* | |
| Common Murre | *Uria aalge* | aqpaq |

Appendix A. Continued.

| Species-group/species | Scientific name | Iñupiaq name |
| --- | --- | --- |
| Thick-billed Murre | *U. lomvia* | |
| Black Guillemot | *Cepphus grylle* | iŋaġiq |
| Pigeon Guillemot | *C. columba* | |
| Kittlitz's Murrelet | *Brachyramphus brevirostris* | |
| Ancient Murrelet | *Synthliboramphus antiquus* | |
| Parakeet Auklet | *Aethia psittacula* | |
| Least Auklet | *A. pusilla* | |
| Crested Auklet | *A. cristatella* | |
| Horned Puffin | *Fratercula corniculata* | |
| Tufted Puffin | *F. cirrhata* | Qiḷaŋaq |
| OWLS | | |
| Short-eared Owl | *Asio flammeus* | nipaiḷuktaq |
| PASSERINES | | |
| American Pipit | *Anthus rubescens* | |
| Snow Bunting | *Plectrophenax nivalis* | amaułigaaluk |

Appendix B. Counts of all birds recorded on transect during boat-based marine surveys in the central Chukchi Sea, by study area and season, 2008–2011.

| | | Study area/season | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | | Statoil | | | Hanna Shoal |
| Species-group/ species | Period/ year | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Aug–Oct |
| WATERFOWL | | | | | | | | | | | |
| Spectacled Eider | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 1 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| King Eider | 2008 | 1 | 0 | 2 | 0 | 1 | 2 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 2 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 8 |
| Common Eider | 2008 | 0 | 0 | 0 | 0 | 5 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 3 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 1 | – | 3 |
| Unidentified eider | 2008 | 0 | 10 | 5 | 0 | 9 | 0 | – | – | – | – |
| | 2009 | 0 | 15 | 1 | 0 | 2 | 5 | – | – | – | – |
| | 2010 | 0 | 0 | – | 7 | 0 | 7 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 7 |
| White-winged Scoter | 2008 | 0 | 0 | 0 | 0 | 0 | 3 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Long-tailed Duck | 2008 | 44 | 0 | 37 | 0 | 68 | 2 | – | – | – | – |
| | 2009 | 0 | 19 | 3 | 0 | 41 | 0 | – | – | – | – |

Appendix B. Continued.

| Species-group/ species | Period/ year | Klondike Jul/Aug | Klondike Aug/Sep | Klondike Sep/Oct | Burger Jul/Aug | Burger Aug/Sep | Burger Sep/Oct | Statoil Jul/Aug | Statoil Aug/Sep | Statoil Sep/Oct | Hanna Shoal Aug–Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Long-tailed Duck (cont.) | 2010 | 0 | 0 | – | 0 | 16 | 7 | 1 | 12 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Unidentified diving duck | 2008 | 0 | 0 | 1 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 2 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| LOONS | | | | | | | | | | | |
| Red-throated Loon | 2008 | 0 | 0 | 0 | 0 | 1 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 1 | – | – |
| | 2011 | 0 | 0 | – | 0 | 2 | – | 0 | 0 | – | 4 |
| Pacific Loon | 2008 | 0 | 1 | 27 | 0 | 33 | 3 | – | – | – | – |
| | 2009 | 0 | 24 | 22 | 0 | 181 | 1 | – | – | – | – |
| | 2010 | 0 | 11 | – | 0 | 6 | 0 | 0 | 2 | – | – |
| | 2011 | 0 | 0 | – | 0 | 24 | – | 0 | 1 | – | 30 |
| Yellow-billed Loon | 2008 | 0 | 3 | 1 | 0 | 2 | 0 | – | – | – | – |
| | 2009 | 0 | 9 | 1 | 0 | 24 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 8 | – | 0 | 0 | – | 8 |
| Unidentified loon | 2008 | 0 | 0 | 1 | 0 | 22 | 0 | – | – | – | – |
| | 2009 | 0 | 6 | 5 | 0 | 30 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 4 | – | – |
| | 2011 | 0 | 0 | – | 0 | 17 | – | 0 | 0 | – | 19 |

Appendix B. Continued.

| Species-group/ species | Period/ year | Klondike Jul/Aug | Klondike Aug/Sep | Klondike Sep/Oct | Burger Jul/Aug | Burger Aug/Sep | Burger Sep/Oct | Statoil Jul/Aug | Statoil Aug/Sep | Statoil Sep/Oct | Hanna Shoal Aug–Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TUBENOSES | | | | | | | | | | | |
| Northern Fulmar | 2008 | 65 | 141 | 38 | 6 | 8 | 8 | – | – | – | – |
| | 2009 | 115 | 52 | 5 | 141 | 34 | 22 | – | – | – | – |
| | 2010 | 17 | 28 | – | 29 | 10 | 1 | 10 | 22 | – | – |
| | 2011 | 30 | 8 | – | 14 | 0 | – | 9 | 6 | – | 15 |
| Short-tailed Shearwater | 2008 | 4 | 286 | 271 | 0 | 199 | 54 | – | – | – | – |
| | 2009 | 22 | 11,946 | 313 | 252 | 331 | 66 | – | – | – | – |
| | 2010 | 8 | 393 | – | 8 | 426 | 5 | 150 | 341 | – | – |
| | 2011 | 13 | 704 | – | 132 | 164 | – | 2 | 155 | – | 1,817 |
| Unidentified procellariid | 2008 | 0 | 0 | 25 | 0 | 0 | 1 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| SHOREBIRDS | | | | | | | | | | | |
| Unidentified (*Pluvialis*) plover | 2008 | 0 | 2 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Pectoral Sandpiper | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 3 | 0 | 3 | 5 | 0 | – | – | – | – |
| | 2010 | 4 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 1 | – | 4 | 0 | – | 9 | 0 | – | 1 |

Appendix B. Continued.

| Species-group/ species | Period/ year | Klondike Jul/Aug | Klondike Aug/Sep | Klondike Sep/Oct | Burger Jul/Aug | Burger Aug/Sep | Burger Sep/Oct | Statoil Jul/Aug | Statoil Aug/Sep | Statoil Sep/Oct | Hanna Shoal Aug–Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Long-billed Dowitcher | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 1 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Red-necked Phalarope | 2008 | 0 | 20 | 69 | 0 | 59 | 0 | – | – | – | – |
| | 2009 | 37 | 10 | 2 | 201 | 106 | 4 | – | – | – | – |
| | 2010 | 1 | 90 | – | 4 | 31 | 0 | 12 | 91 | – | – |
| | 2011 | 0 | 12 | – | 16 | 9 | – | 57 | 4 | – | 47 |
| Red Phalarope | 2008 | 5 | 5 | 1 | 0 | 1 | 0 | – | – | – | – |
| | 2009 | 3 | 0 | 2 | 15 | 32 | 1 | – | – | – | – |
| | 2010 | 21 | 5 | – | 0 | 32 | 5 | 0 | 42 | – | – |
| | 2011 | 0 | 0 | – | 9 | 0 | – | 0 | 0 | – | 1 |
| Unidentified phalarope | 2008 | 0 | 74 | 10 | 0 | 85 | 0 | – | – | – | – |
| | 2009 | 55 | 0 | 9 | 72 | 51 | 4 | – | – | – | – |
| | 2010 | 30 | 169 | – | 1 | 30 | 0 | 10 | 42 | – | – |
| | 2011 | 5 | 0 | – | 3 | 9 | – | 0 | 1 | – | 25 |
| Unidentified shorebird—small | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 1 | 2 | 0 | 0 | 17 | 0 | – | – | – | – |
| | 2010 | 6 | 1 | – | 0 | 0 | 0 | 3 | 0 | – | – |
| | 2011 | 3 | 6 | – | 2 | 0 | – | 5 | 3 | – | 18 |
| Unid. shorebird—medium | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 1 | 0 | 0 | 10 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | 0 | – |

Appendix B. Continued.

| Species-group/ species | Period/ year | Klondike Jul/Aug | Klondike Aug/Sep | Klondike Sep/Oct | Burger Jul/Aug | Burger Aug/Sep | Burger Sep/Oct | Statoil Jul/Aug | Statoil Aug/Sep | Statoil Sep/Oct | Hanna Shoal Aug–Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Unid. shorebird—medium | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| LARIDS & JAEGERS | | | | | | | | | | | |
| Black-legged Kittiwake | 2008 | 99 | 47 | 117 | 14 | 129 | 17 | – | – | – | – |
| | 2009 | 9 | 296 | 101 | 16 | 266 | 22 | – | – | – | – |
| | 2010 | 17 | 135 | – | 13 | 56 | 0 | 13 | 76 | – | – |
| | 2011 | 1 | 15 | – | 3 | 90 | – | 3 | 30 | – | 384 |
| Ivory Gull | 2008 | 0 | 0 | 0 | 0 | 0 | 2 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 1 |
| Sabine's Gull | 2008 | 9 | 92 | 5 | 2 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 1 | 2 | 0 | 0 | 2 | – | – | – | – |
| | 2010 | 1 | 21 | – | 1 | 1 | 0 | 5 | 0 | – | – |
| | 2011 | 0 | 0 | – | 1 | 0 | – | 0 | 0 | – | 1 |
| Ross's Gull | 2008 | 0 | 0 | 0 | 0 | 0 | 127 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 48 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 28 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 20 | – | 0 | 0 | – | 135 |
| Herring Gull | 2008 | 1 | 0 | 18 | 0 | 0 | 1 | – | – | – | – |
| | 2009 | 0 | 10 | 0 | 4 | 2 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 1 | 0 | 0 | 1 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 5 |

Appendix B. Continued.

| Species-group/ species | Period/ year | Study area/season | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | | Statoil | | | Hanna Shoal |
| | | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Aug–Oct |
| Glaucous Gull | 2008 | 11 | 13 | 70 | 6 | 33 | 19 | – | – | – | – |
| | 2009 | 0 | 23 | 49 | 7 | 65 | 54 | – | – | – | – |
| | 2010 | 2 | 11 | – | 4 | 12 | 15 | 3 | 11 | – | – |
| | 2011 | 0 | 4 | – | 1 | 8 | – | 2 | 13 | – | 86 |
| Unidentified gull—small | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 3 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Unidentified gull—large | 2008 | 0 | 0 | 0 | 0 | 1 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Unidentified gull | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 2 | 0 | 3 | 0 | 1 | 11 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Arctic Tern | 2008 | 0 | 24 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 1 | 2 | 0 | – | – | – | – |
| | 2010 | 0 | 29 | – | 1 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 1 |
| Pomarine Jaeger | 2008 | 32 | 12 | 1 | 3 | 3 | 0 | – | – | – | – |
| | 2009 | 6 | 23 | 0 | 10 | 1 | 0 | – | – | – | – |
| | 2010 | 1 | 14 | – | 5 | 1 | 0 | 2 | 3 | – | – |
| | 2011 | 0 | 1 | – | 1 | 2 | – | 0 | 1 | – | 7 |

Appendix B. Continued.

| Species-group/ species | Period/ year | Klondike Jul/Aug | Klondike Aug/Sep | Klondike Sep/Oct | Burger Jul/Aug | Burger Aug/Sep | Burger Sep/Oct | Statoil Jul/Aug | Statoil Aug/Sep | Statoil Sep/Oct | Hanna Shoal Aug–Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Parasitic Jaeger | 2008 | 4 | 2 | 0 | 1 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 1 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 1 | – | 0 | 0 | – | 2 | 0 | – | 1 |
| Long-tailed Jaeger | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 1 | 0 | 0 | 2 | 0 | 0 | – | – | – | – |
| | 2010 | 2 | 0 | – | 0 | 1 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Unidentified jaeger | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 1 | 0 | 0 | 1 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| ALCIDS | | | | | | | | | | | |
| Dovekie | 2008 | 2 | 0 | 1 | 0 | 0 | 2 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 1 | 0 | 1 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 1 |
| Common Murre | 2008 | 13 | 0 | 11 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 8 | 3 | 0 | 3 | 14 | – | – | – | – |
| | 2010 | 0 | 7 | – | 0 | 2 | 0 | 0 | 1 | – | – |
| | 2011 | 8 | 44 | – | 1 | 11 | – | 1 | 8 | – | 79 |
| Thick-billed Murre | 2008 | 228 | 14 | 3 | 3 | 0 | 1 | – | – | – | – |
| | 2009 | 64 | 338 | 16 | 17 | 27 | 15 | – | – | – | – |
| | 2010 | 115 | 97 | – | 24 | 16 | 3 | 25 | 22 | – | – |

Appendix B. Continued.

| Species-group/ species | Period/ year | Study area/season | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | | Statoil | | | Hanna Shoal |
| | | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Aug–Oct |
| Thick-billed Murre (Cont.) | 2011 | 87 | 538 | – | 30 | 22 | – | 16 | 31 | – | 839 |
| Unidentified murre | 2008 | 1 | 9 | 4 | 0 | 2 | 14 | – | – | – | – |
| | 2009 | 0 | 35 | 7 | 0 | 8 | 1 | – | – | – | – |
| | 2010 | 0 | 3 | – | 0 | 3 | 0 | 1 | 1 | – | – |
| | 2011 | 19 | 29 | – | 1 | 7 | – | 1 | 6 | – | 61 |
| Black Guillemot | 2008 | 9 | 0 | 0 | 2 | 0 | 6 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 1 | 0 | 0 | 1 | 0 | – | – |
| | 2011 | 0 | 0 | – | 1 | 0 | – | 0 | 0 | – | 4 |
| Pigeon Guillemot | 2008 | 4 | 0 | 0 | 1 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Unidentified guillemot | 2008 | 0 | 0 | 0 | 0 | 0 | 1 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Kittlitz's Murrelet | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 1 | 0 | 0 | 0 | 6 | – | – | – | – |
| | 2010 | 2 | 1 | – | 0 | 1 | 0 | 1 | 0 | – | – |
| | 2011 | 1 | 5 | – | 0 | 14 | – | 0 | 5 | – | 35 |
| Ancient Murrelet | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |

Appendix B. Continued.

| Species-group/ species | Period/ year | Klondike Jul/Aug | Klondike Aug/Sep | Klondike Sep/Oct | Burger Jul/Aug | Burger Aug/Sep | Burger Sep/Oct | Statoil Jul/Aug | Statoil Aug/Sep | Statoil Sep/Oct | Hanna Shoal Aug–Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ancient Murrelet (cont.) | 2010 | 0 | 18 | – | 0 | 16 | 28 | 0 | 41 | – | – |
| | 2011 | 0 | 0 | – | 0 | 4 | – | 0 | 4 | – | 12 |
| Unidentified murrelet | 2008 | 0 | 0 | 5 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 4 | 3 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 10 | – | 0 | 0 | – | 21 |
| Parakeet Auklet | 2008 | 0 | 7 | 0 | 0 | 0 | 44 | – | – | – | – |
| | 2009 | 0 | 21 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 1 | 8 | – | 0 | 15 | 17 | 10 | 2 | – | – |
| | 2011 | 0 | 8 | – | 0 | 0 | – | 0 | 8 | – | 5 |
| Least Auklet | 2008 | 4 | 139 | 55 | 0 | 1 | 4 | – | – | – | – |
| | 2009 | 63 | 115 | 257 | 201 | 143 | 39 | – | – | – | – |
| | 2010 | 29 | 148 | – | 29 | 474 | 103 | 163 | 184 | – | – |
| | 2011 | 4 | 76 | – | 1 | 8 | – | 3 | 12 | – | 158 |
| Crested Auklet | 2008 | 179 | 128 | 959 | 0 | 1 | 34 | – | – | – | – |
| | 2009 | 394 | 3,139 | 1,455 | 4,566 | 5,082 | 16 | – | – | – | – |
| | 2010 | 639 | 1,380 | – | 806 | 976 | 1,011 | 383 | 1,243 | – | – |
| | 2011 | 182 | 595 | – | 145 | 729 | – | 1,062 | 1,786 | – | 4,865 |
| Unidentified auklet | 2008 | 1 | 22 | 66 | 0 | 0 | 1 | – | – | – | – |
| | 2009 | 8 | 52 | 11 | 11 | 26 | 0 | – | – | – | – |
| | 2010 | 8 | 18 | – | 1 | 40 | 1 | 3 | 2 | – | – |
| | 2011 | 5 | 10 | – | 0 | 3 | – | 0 | 3 | – | 42 |
| Horned Puffin | 2008 | 2 | 0 | 0 | 2 | 0 | 0 | – | – | – | – |
| | 2009 | 4 | 2 | 0 | 0 | 0 | 0 | – | – | – | – |

Appendix B. Continued.

| Species-group/ species | Period/ year | Klondike Jul/Aug | Klondike Aug/Sep | Klondike Sep/Oct | Burger Jul/Aug | Burger Aug/Sep | Burger Sep/Oct | Statoil Jul/Aug | Statoil Aug/Sep | Statoil Sep/Oct | Hanna Shoal Aug–Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Horned Puffin (cont.) | 2010 | 4 | 0 | – | 3 | 1 | 0 | 1 | 1 | – | – |
| | 2011 | 4 | 0 | – | 0 | 0 | – | 2 | 1 | – | 4 |
| Tufted Puffin | 2008 | 8 | 0 | 1 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 1 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 1 | 0 | – | 0 | 1 | 0 | 2 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 1 | – | – | 0 |
| Unidentified puffin | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 1 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Unidentified alcid – small | 2008 | 0 | 0 | 1 | 0 | 0 | 6 | – | – | – | – |
| | 2009 | 0 | 0 | 10 | 0 | 0 | 14 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 11 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 4 | – | 0 | 2 | – | 8 |
| Unidentified alcid | 2008 | 0 | 2 | 8 | 0 | 6 | 1 | – | – | – | – |
| | 2009 | 0 | 18 | 0 | 0 | 11 | 0 | – | – | – | – |
| | 2010 | 19 | 7 | – | 0 | 3 | 0 | 1 | 2 | – | – |
| | 2011 | 0 | 1 | – | 0 | 1 | – | 0 | 0 | – | 5 |
| OWLS | | | | | | | | | | | |
| Short-eared Owl | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 1 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |

Appendix B. Continued.

| Species-group/ species | Period/ year | Study area/season | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | | Statoil | | | Hanna Shoal |
| | | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Jul/Aug | Aug/Sep | Sep/Oct | Aug–Oct |
| Short-eared Owl (cont.) | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| PASSERINES | | | | | | | | | | | |
| American Pipit | 2008 | 0 | 0 | 0 | 0 | 1 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 2 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 0 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 0 |
| Snow Bunting | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | – | – | – | – |
| | 2010 | 0 | 0 | – | 0 | 0 | 0 | 0 | 1 | – | – |
| | 2011 | 0 | 0 | – | 0 | 0 | – | 0 | 0 | – | 4 |