FINAL REPORT

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

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PREPARED FOR

CONOCOPHILLIPS ALASKA, INC.
ANCHORAGE, ALASKA

AND

SHELL EXPLORATION & PRODUCTION COMPANY
ANCHORAGE, ALASKA

PREPARED BY

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

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EXECUTIVE SUMMARY

- In 2008, we collected data on the distribution and abundance of seabirds in the northern Chukchi Sea in the vicinity of two proposed oil prospects. The two study areas lie ~110–180 km (~60–100 NM) northwest of the village of Wainwright and are known as Klondike and Burger.
- The objectives of this study were to: (1) describe the seasonal and spatial variation in abundance and distribution of seabirds; (2) describe seasonal changes in species-richness and species-composition; and (3) compare our results with historical data available in the North Pacific Pelagic Seabird Database.
- We conducted seabird surveys during three seasons that covered the entire open-water period of the northeastern Chukchi Sea: late summer (23 July–18 August), early fall (19 August–21 September), and late fall (22 September–12 October).
- The surveys were conducted as line transects from the bridge of the M/V *Bluefin*.
- The analyses of densities, species-richness, and species-composition used data collected only within the boundaries of the two study-area boxes, whereas data collected opportunistically within ~48 km (26 NM) of each study-area box were used when making comparisons with historical data.
- During the seabird surveys, we sampled a total of 6,037 km (3,260 NM) of transects during 417 h of observation. Sampling effort was greater on Klondike, especially during the late-summer cruise, because it generally had less ice cover than did Burger.
- We recorded a total of 4,646 individuals of 31 species on transect within the two study areas combined during the seabird surveys, of which 4 species were waterfowl, 3 were loons, 2 were tubenoses, 2 were phalaropes, 9 were larids, and 11 were alcids.
- We had sufficient detections to generate reliable estimates of density for eight species. Densities of each of the eight most-abundant species differed significantly among seasons, although different species were most abundant in different seasons. Thick-billed Murres were most abundant in late summer and early fall, whereas Short-tailed Shearwaters, Northern Fulmars, Black-legged Kittiwakes, and Pacific Loons were most abundant in early fall; Glaucous-Gulls and Least Auklets were most abundant in early and late fall; and Crested Auklets were most abundant only in late fall.
- Densities of seven of the eight most-abundant species differed significantly between study areas. In the season in which they were most abundant, Northern Fulmars, Thick-billed Murres, Crested Auklets, and Least Auklets were more common in Klondike, whereas Black-legged Kittiwakes, Glaucous Gulls, and Pacific Loons were more common in Burger; only Short-tailed Shearwaters showed no significant difference in densities between study areas.
- Tubenoses were the most abundant species-group recorded during 2008, primarily because of large flocks of Short-tailed Shearwaters that moved through both study areas in early fall. Larids (gulls, terns, and jaegers) and alcids were the next most-abundant species groups recorded during surveys.
- Total density was highest in early fall when 16 species collectively accounted for 71 birds/km^2 in Klondike and 15 species collectively accounted for 73 birds/km^2 in Burger.
- During late summer and late fall, alcids were the dominant species-groups in Klondike, followed by larids. Conversely, larids were the numerically-dominant species-group in Burger in those seasons, followed by alcids and tubenoses.
- We recorded eight species on transect in Klondike and nine species on transect in Burger that are classified as being of conservation concern. Two (Kittlitz's Murrelet and Yellow-billed Loon) are classified as candidate species under the ESA, and two (Red-throated Loon and Arctic Tern) are classified as species of conservation concern by the USFWS.

- Spatial overlap between the NPPSD historical data set and 2008 data set was greatest in the late summer and, to some extent, in the early fall, but no historical transects were conducted within ~9 km of either study area in late fall. Consequently, comparisons between the two data sets have been made with several caveats.
- Average uncorrected densities (birds/km^2) in the historical data set were higher on transects outside of the study-area boxes than on transects within the boxes. The highest densities in the vicinity of Klondike were recorded west of the study area, whereas the highest densities in the vicinity of Burger were recorded north of the study area. Densities from the historical data collected within the study areas suggest that overall total densities of seabirds in Klondike and Burger were similar between the historical data and in 2008.
- Seasonal and spatial patterns in species-composition were similar between the historical data and the 2008 data, although species richness was higher in the 2008 data.
- We propose here that the structure of the seabird community differs substantially between the two study areas and that these differences reflect what we believe are oceanographic differences between the two study areas.
- The Klondike study area appears to be more of a pelagically-dominated system and the Burger study area appears to be more of a benthically-dominated system. Diving alcids that forage on zooplankton or pelagic fishes dominating in the Klondike area, whereas surface-feeding or near-surface-feeding larids and tubenoses and deep-diving epibenthic- or demersal-feeding seaducks and loons dominated in the Burger area.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

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INTRODUCTION

The Chukchi Sea has one of the highest rates of primary productivity in the world ocean (Grebmeier et al. 2006). This extraordinary productivity supports rich benthic and planktonic communities that, in turn, support large communities of apex predators such as seabirds, seals, and whales. Although the region is ice-covered for much of the year, the ice-free waters and the ice edges become important habitat for non-breeding, staging, and migratory seabirds from mid-July to mid-October. Thick-billed Murres (*Uria lomvia*), Common Murres, (*U. aalge*), and Black-legged Kittiwakes (*Rissa tridactyla*) nest on cliffs along the Chukchi coast and are common offshore during late summer and early fall (Divoky 1987, Divoky and Springer 1988). Species that nest on tundra, such as phalaropes and jaegers, move out to sea in early fall and join millions of migratory Short-tailed Shearwaters foraging in the area (Divoky 1987, Divoky and Springer 1988). Finally, ice-associated gulls such as Ross's Gulls (*Rhodostethia rosea*) and Ivory Gulls (*Pagophila eburnea*) move from high-arctic breeding areas into the Chukchi Sea as the ice advances southward in late fall. As many as 5 million seabirds of at least 22 species may use the Chukchi Sea in a single ice-free season (Divoky 1987).

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 in 1989 and 1990, including at least two wells known as Klondike and Burger that were located ~110–180 km (~60–100 NM) west of the village of Wainwright. These prospects were not developed at that time, and there was little further activity until February of 2008, when nearly 3 million acres in the Chukchi Sea were leased for oil exploration. Although marine-ecology studies were conducted in the late 1970s and early 1980s, there are few recent data on the distribution and abundance of seabirds in the areas proposed for development. Clearly, there is a need for studies that will inform managers and industry about the distribution, abundance, and timing of seabirds using the northeastern Chukchi Sea.

HISTORY OF PREVIOUS RESEARCH

Data on seabirds in the northeastern Chukchi Sea during the open-water season are limited, primarily because of the area's historic inaccessibility. Much of the interest in seabirds in this area has concentrated on mainland seabird colonies and on seabirds at sea in the vicinity of the Hope Basin, which lies immediately north of Bering Strait, in the southern Chukchi. The focus of seabird colony research has been Cape Lisburne, which is part of the Alaska Maritime National Wildlife Refuge; data also have been collected at irregular intervals ~50 miles south of there at Cape Thompson. These colonies have been studied periodically since 1976 by David Roseneau (U.S. Fish and Wildlife Service), who built on earlier work begun on nesting seabirds at Cape Thompson by Swartz (1966).

Another area of research has been avian use of the coastal-lagoon systems of the northeastern Chukchi Sea. The earlier work by Johnson (1993) and Johnson et al. (1993) described baseline use of the Chukchi lagoon systems by birds, whereas recent work has focused on monitoring population trends of birds in all lagoon systems in northern and northwestern Alaska annually (e.g., Dau and Larned 2004 and related annual reports). There also have been extensive studies of eider migration at Barrow, which has perhaps the highest concentration of migrating waterfowl on this continent (Thompson and Person 1963; Woodby and Divoky 1982; Suydam et al. 1997, 2000a, 2000b; Day et al. 2004), and studies of migrating Ross's Gulls, which concentrate at Barrow in the fall (Divoky et al. 1988). Aerial surveys for and satellite telemetry of migrating and staging Spectacled (*Somateria fischeri*) and Steller's eiders (*Polysticta stelleri*), both of which are protected under the Endangered Species Act, in the Chukchi Sea have indicated that shallow, nearshore waters between Ledyard Bay and Peard Bay form important stopover areas for migrating Spectacled and King eiders in both the summer and fall (Balogh 1997, Oppel et al. 2009).

In contrast to the well-known coastal seabird community, few historical data on the at-sea distribution and abundance of seabirds are available for the northern Chukchi Sea. The first research was conducted by Jacques (1930), who surveyed birds in the Bering Sea and western Chukchi Sea in July–August 1928. Later, Swartz (1967) examined the at-sea distribution of seabirds in the southern and central Chukchi during the environmental studies at Cape Thompson (Swartz 1966) for a short time in 1960. The interest in oil development in arctic Alaska in the 1970s prompted a decade of research on seabirds and other marine organisms in this region. The main seabird studies in areas important for oil development were conducted by (1) Divoky (1970), who studied seabirds in the eastern Chukchi Sea from a USCG icebreaker; (2) Divoky (1979), who described some aspects of the Chukchi Sea open-water and ice-edge avifauna; and (3) Divoky (1987), who studied seabirds throughout the Chukchi Sea in the early 1980s as part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP). The latter report was never released by OCSEAP as part of its "Environmental Assessment of the Alaskan Continental Shelf" publication series, so it is not widely available or widely known. Another source of information on seabirds near this area is found in Divoky and Springer (1988), who provided an overview of the data available on seabirds in the southern Chukchi Sea for an MMS synthesis report.

Although limited historical data exist for the region (Hopcroft et al. 2008), studies conducted during the past five years are filling in the gaps in knowledge about the ecology of the northern Chukchi Sea. Most recently, there has been some ship-of-opportunity sampling of seabirds in the Chukchi Sea conducted primarily by the U.S. Fish and Wildlife Service. These data have not been published yet, but they have been contributed to the North Pacific Pelagic Seabird Database, a publicly available information resource maintained by the U.S. Geological Survey, that is updated periodically. The next version will include data from recent USFWS surveys and is scheduled for release in October 2009. Other ongoing studies that are providing detail on avian use of nearshore and offshore waters include satellite telemetry studies of Long-tailed Ducks (*Clangula hyemalis*) and King Eiders (Dickson and Bowman 2008); and Yellow-billed Loons (*Gavia adamsii*; Rizzolo and Schmutz 2008). The present study conducted in 2008 and continuing in 2009 will provide information on the distribution and abundance of marine birds in the northern Chukchi Sea.

STUDY OBJECTIVES

In this study, we explored the distribution and abundance of seabirds in the northeastern Chukchi Sea, in two areas where ConocoPhillips Alaska, Inc., and Shell Exploration & Production Company have several lease-blocks for offshore oil exploration and development. The objectives of this study were to: (1) describe the seasonal and spatial variation in abundance and distribution of seabirds; (2) describe seasonal changes in species-richness and species-composition; and (3) compare our results with historical data that are publicly available in the North Pacific Pelagic Seabird Database. This research both provides baseline information on the present distribution and abundance of seabirds in the lease areas and summarizes information on the historical distribution and abundance of seabirds in the northeastern Chukchi Sea. This information will be used for an analysis of potential impacts resulting from offshore exploration and development activities and 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 ~110–180 km (~60–100 NM) west of the village of Wainwright, which is located on the northwestern coast of Alaska. The survey area is bounded by two outflows from the Chukchi Sea to the Arctic Ocean: the Central Channel to the west and Barrow Canyon to the east. The survey area included two study areas called "Klondike" and "Burger" (Figure 1). The Klondike study area was located on the eastern side of the Central Channel and was ice-free for most of the study period, whereas the Burger study area was located to the northeast of Klondike and south of Hanna Shoal. Burger did not become ice-free until early September, restricting access and preventing surveys in the northeastern third of that study area until early fall.

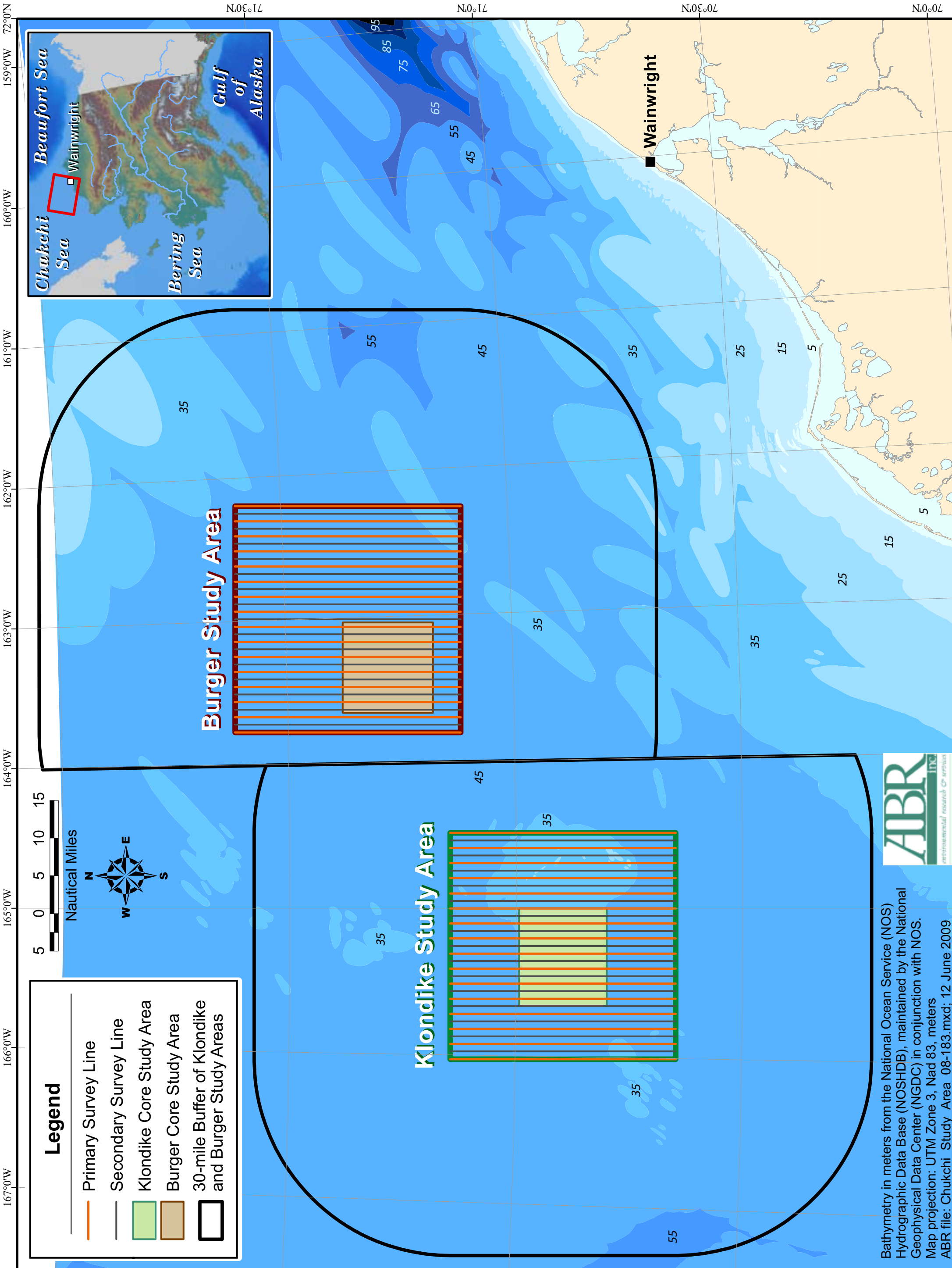


Figure 1. Locations of the Klondike and Burger study areas in the northeastern Chukchi Sea in 2008. Also shown are the locations of the survey lines and the 30-mi buffer zones used for examining the historical data.

Each study area consisted of a core area of greatest interest for exploration that was ~27 km (~15 NM) on a side within a larger study-area box that was ~55 km (30 NM) on a side. The larger study-area box included a buffer zone around proposed exploration activity for marine mammals and provided spatial context for all the disciplines. These ~3,087-km^2 (900-NM^2) study-area boxes were the focus of all sampling. We surveyed along a series of parallel survey lines that ran north–south through these 900-NM^2 boxes. The primary sampling grid included lines on the eastern and western boundaries of each study area and lines spaced ~3.6 km (2 NM) apart within each study area (Figure 1), creating a set of 16 parallel survey lines that each were 30 NM (55.6 km) long. A secondary sampling grid of lines was offset from the primary lines by ~1.8 km (1 NM; Figure 1) and was sampled as time allowed or when the primary lines were obstructed by ice. In addition to transects within the study areas, we also sampled opportunistically near both study areas (primarily when ice prevented us from sampling within the study areas themselves) and when transiting between Wainwright and the study areas. Some of these additional data are included in the comparison with the historical data set.

OCEANOGRAPHIC STRUCTURE

The Chukchi Sea is a shallow (~50 m deep) shelf sea north of Bering Strait. The primary inflow of nutrient-rich water comes from the south through Bering Strait and has three main outflows to the Arctic Ocean (Weingartner et al. 2005, Woodgate et al. 2005, Grebmeier et al. 2006). The physical structure of the study areas in 2008 may be seen in a series of vertical sections of CTD data collected during each of the three research cruises (Figures 2–4). These vertical sections show temperature (°C), salinity (psu), density (σ_t), and fluorescence (*V*; an indication of the standing stock of phytoplankton) 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.

On the late-summer cruise (24 July–18 August 2008), there was an apparent east–west division in the water masses. Water in the western edge of the Klondike study area (0 to ~30 km along the X-axis) was warmer, more saline, and less stratified than was water in the eastern half of Klondike and in Burger (Figure 2). The presence of warm, salty water indicates the edge of the Central Channel current (Weingartner et al. 2005, Woodgate et al. 2005, Grebmeier et al. 2006). On the early-fall cruise (18 August–20 September 2008), the surface layers had more-complex temperature and salinity structure than in the summer (Figure 3). Warm water was still present on the western edge of the Klondike study area (0 to ~30 km along the X-axis), whereas the surface layer over the northeastern corner of Klondike and most of Burger (~50 km to ~180 km along the X-axis) consisted of very cold, low-salinity surface water likely indicating melting sea ice separated by warmer and saltier filaments. On the late-fall cruise (20 September–12 October 2008), the hydrography was similar to the earlier cruises (Figure 4). Warm, higher-salinity waters of the Central Channel current remained over most of the Klondike study area (0 to ~60 km along the X-axis), whereas the cold, lower-salinity water occupied most of the upper water column from the northeastern corner of the Klondike study area to the northeastern corner of the Burger study area (~70 km to ~180 m along the X-axis).

DATA COLLECTION

We conducted seabird surveys during three seasons that covered the entire open-water period of the northeastern Chukchi Sea: late summer (23 July–18 August), early fall (19 August–21 September), and late fall (22 September–12 October). These surveys were designed to quantify the distribution, abundance, and species-composition of the seabird community within the prospects.

The surveys were conducted as consecutive10-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, weather and ice conditions permitting. Surveys generally were stopped when sea height was greater than Beaufort 5 (seas to ~2 m [~6 ft]), although we occasionally exceeded that level slightly if observation

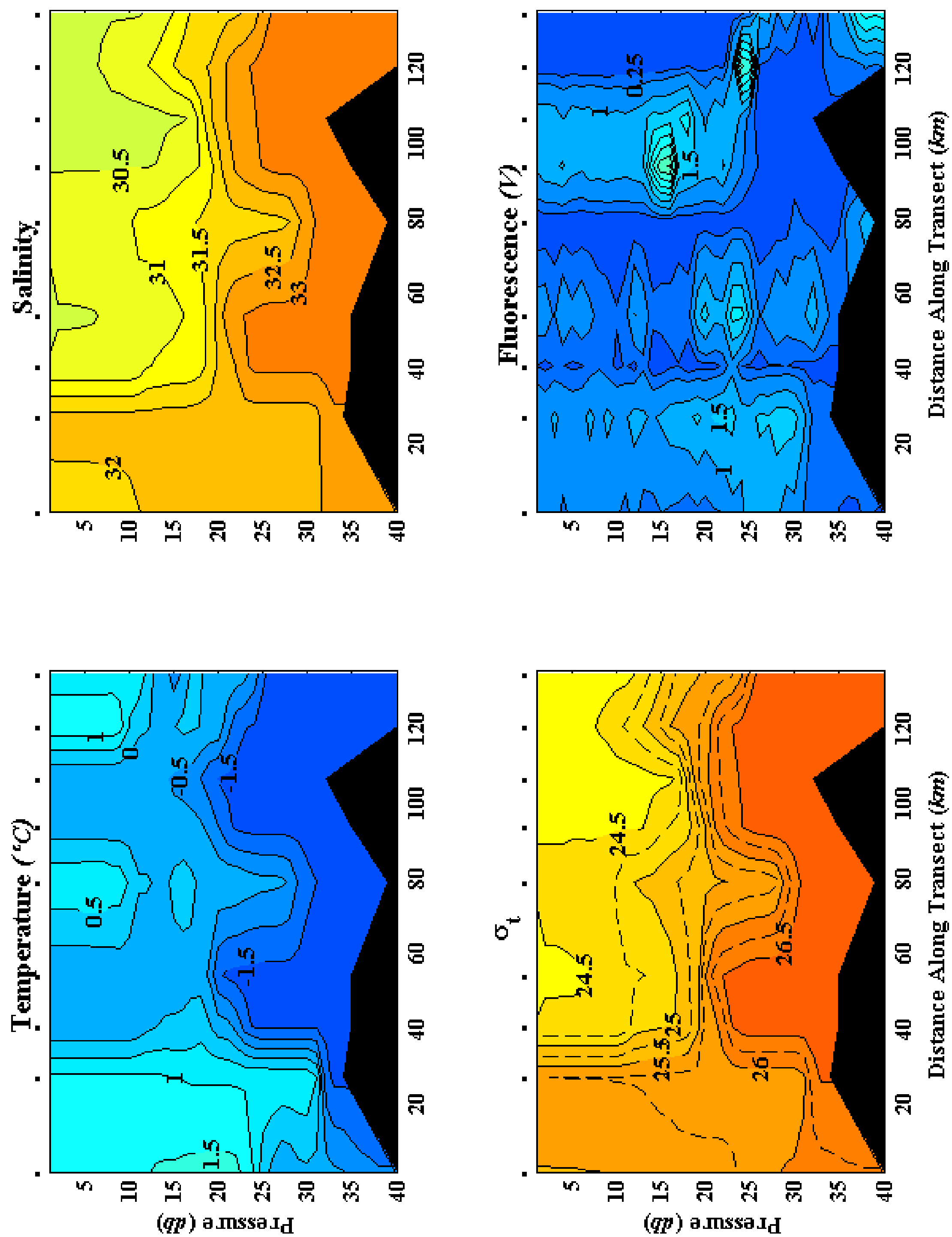


Figure 2. Vertical sections of temperature (°C), salinity (psu), density (σ_t), and chlorophyll fluorescence (*V*) in the Klondike and Burger study areas, late summer 2008.

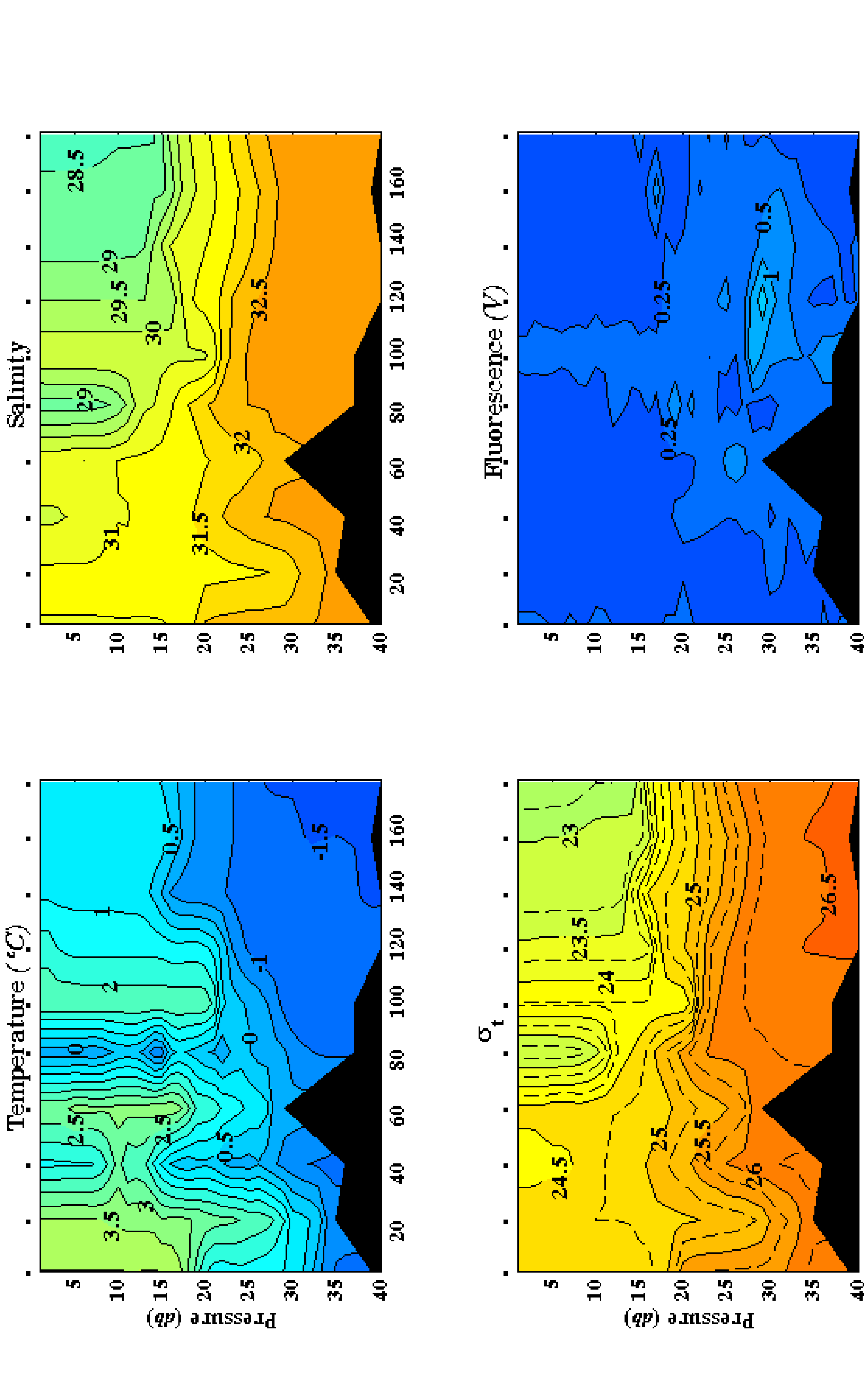


Figure 3. Vertical sections of temperature (°C), salinity (psu), density (σ_t), and chlorophyll fluorescence (V) in the Klondike and Burger study areas, early fall 2008.

conditions still were good (e.g., if seas were rough but 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× 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 5°);
- number in each age-class (juvenile, sub-adult, adult, unknown age), if possible;
- habitat (air, water, flotsam/jetsam, ice); and
- behavior (sitting, swimming, feeding, comfort behavior, courtship behavior, other).

For birds on the water, all birds seen within the count zone were counted. For flying birds, however, observers conducted scans for them ~1 time/min (exact frequency varied with ship's speed) and recorded an instantaneous ("snapshot") count of all birds flying within the count zone (Tasker et al. 1984, Gould and Forsell 1989). This "snapshot" method reduces the bias of overestimating the density of flying birds (Tasker et al. 1984, Gould and Forsell 1989). Flying birds that entered the count zone only from the sides or front were counted, whereas flying birds that entered from behind the ship (i.e., an area that already had been surveyed) were not counted to avoid the possibility of counting ship-following birds.

Observations of all birds were entered directly into a computer connected to a global positioning system (GPS) with DLog software (R.G. Ford Consulting, Portland, OR), which time-stamped and geo-referenced every observation. The primary GPS connected to the data-collection computer lost communication with satellites on three occasions (1334–1355 and 1530–1557 on 23 July and 1539–1605 on 29 August), resulting in missing locations for observations and transect cutoff points. We used the position track from the ship's meteorological station, which used a different GPS, to patch the gaps in the observation record by linking positions using the time stamp of the observations.

DATA ANALYSIS

The analyses of densities, species-richness, and species-composition used data collected only within the boundaries of the two study-area boxes (Figure 1). Because the historical data set covered a much larger area, we included data collected opportunistically within ~48 km (26 NM) of each study area to increase our sampling area (Figure 1) when making comparisons with historical data. Data collected when traveling outside of the study-area boxes were recorded following the same sampling protocol as sampling within the study area.

DENSITY CALCULATIONS AND ANALYSES

We estimated corrected densities (birds/km^2) of birds within each study area by using distance-sampling analyses available in the program DISTANCE (Thomas et al. 2006) and followed analytical methods described by Buckland et al. (2001, 2004). The analysis consisted of three steps. First, we fitted a detection function for each species to the observed distances of sightings from that edge of the transect zone 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.

Of the 31 species recorded on transect in this study in 2008, only 8 were common enough (i.e., there were ≥60 observations) to fit detection functions for each one with confidence. For the other 23 species, we grouped them with similar species or species of similar size and color to create 8 detection groups. For each detection group, we fit

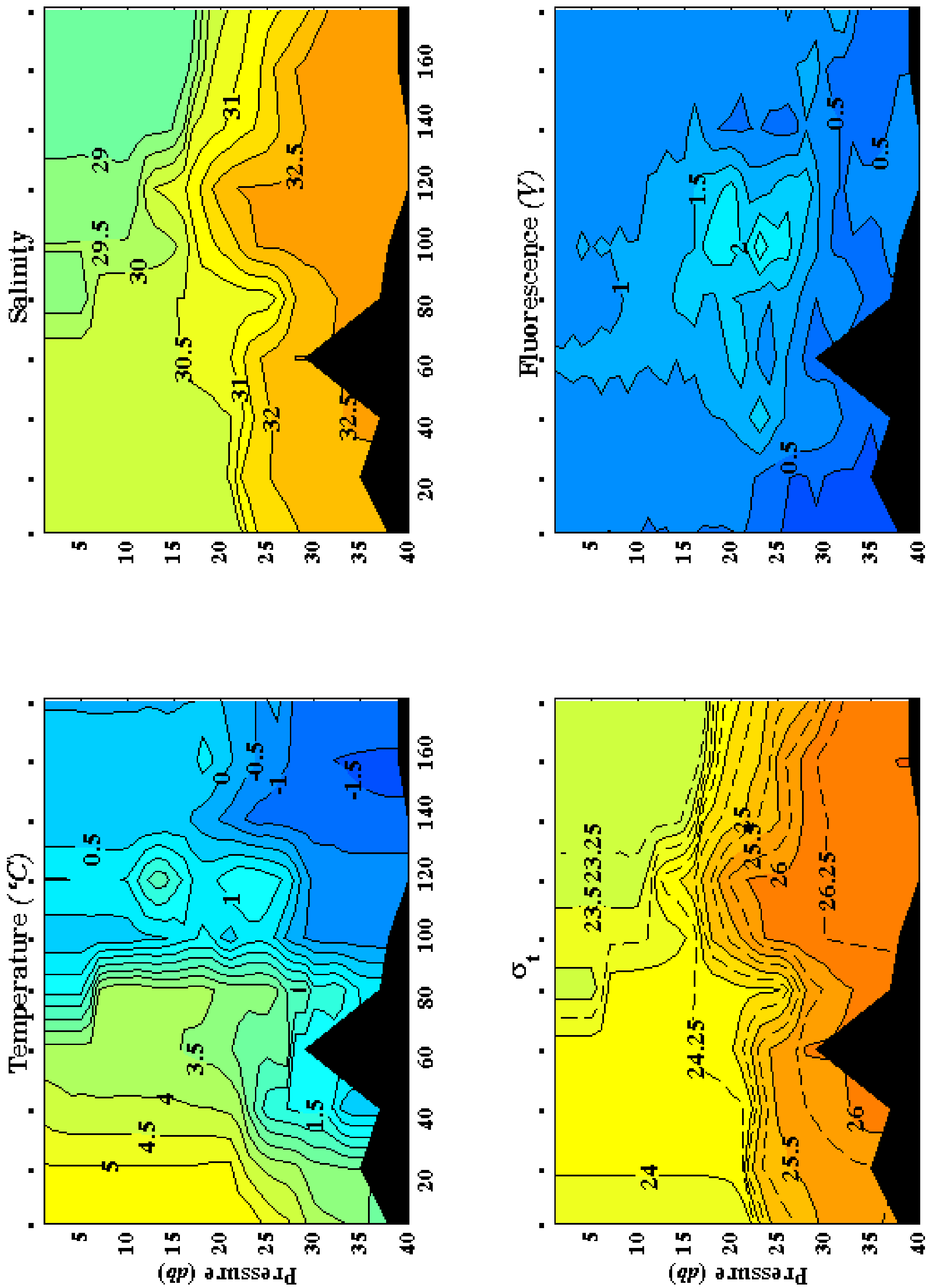


Figure 4. Vertical sections of temperature (°C), salinity (psu), density (σ_t), and chlorophyll fluorescence (*V*) in the Klondike and Burger study areas, late fall 2008.

six models to the distribution of observation distances to find the model that best estimated the probability of detection. These models used one of two possible key functions (half-normal or hazard-rate) to describe the shape of the detection function and included additive effects of season and study area to account for differences in species detections among cruises and between study areas. We selected the model with the lowest Akaike Information Criterion (AIC) to be the one that best fit the data. The fit of the models was assessed with diagnostic plots and a Kolmogorov–Smirnov goodness-of-fit test (Buckland et al. 2004). Once a model was selected for a detection group, we calculated species-specific estimates within that group by running a separate analysis that filtered for each species and then applied the common detection model to generate the estimates and associated 95% confidence intervals. These density estimates were calculated with the formula:

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

where n is the total number of observations seen on transects, $\hat{E}(s)$ is the mean flock size of the species, 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).

We calculated mean corrected densities of each species by study area and season. 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). We focused statistical analyses of trends in seasonal and spatial abundance on the eight most-common species, which had the most reliable estimates of density.

We used a weighted GLM procedure in SPSS (2007) to examine differences between study areas and among seasons. The model included the additive effects of study area and season and an interaction between these main effects. Survey effort varied among seasons, primarily due to heavy ice cover during late summer; therefore, we weighted the analyses by survey effort. We compared density estimates between study areas within each season using multiple contrasts. In all statistical tests, the level of significance (α) was 0.05. We also used the geo-located observations to generate maps of distribution and abundance for all birds combined and for individual species of interest.

COMMUNITY ANALYSES

We summarized species-richness and species-composition of all birds by study area and season to examine temporal patterns in these community-level attributes (Magurran 1988). For ease of summarizing the species-composition information and for ease of presenting information of this large number of species, we often aggregated species into taxonomic species-groups. These six species-groups included waterfowl (members of the Anatidae and including geese, swans, and ducks), loons (members of the Gaviidae and including loons), tubenoses (members of the Procellariidae and including fulmars and shearwaters), phalaropes (members of the Scolopacidae and representing unusual shorebirds known as phalaropes that spend most of their lives in water), larids (members of the Laridae and Stercorariidae and including gulls, terns, and jaegers), and alcids (members of the Alcidae and a diverse species-group including murres, guillemots, murrelets, auklets, and puffins).

COMPARISON WITH HISTORICAL DATA

We compared our data with historical data from the same area collected in 1975−1981. These data were collected from a variety of ships by numerous observers. The data are stored in the USGS "North Pacific Pelagic Seabird Database" (NPPSD), which is publicly available (USGS 2005). Across all years, most transects were 10–15 min in duration (~3–4.5 km [1.6–2.4 NM] in length), and other important attributes of the sampling (e.g., transect width, exclusion of ship-following birds) were similar to methods used in this study. We used GIS to overlay the transect data on a map of the two study areas and extracted all transects that occurred either in each study-area box or a ~48-km (26-NM) buffer around it (Figure 1), so that we had enough data for a comparison between historical data and data from this study. To make the comparison as similar as possible, we recalculated densities from our 2008 data as uncorrected densities. We also compared historical species-richness and species-composition in each study area with the 2008 data.

RESULTS

During the seabird surveys, we sampled a total of 6,037 km (3,260 NM) of transects during 417 h of observation. In Klondike, we sampled 545 transects totaling 1,329 km (718 NM) in late summer, 521 transects totaling 1,254 km (677 NM) in early fall, and 344 transects totaling 846 km (457 NM) in late fall. In Burger, we sampled 301 transects totaling 716 km (387 NM) in late summer, 446 transects totaling 1,071 km (578 NM) in early fall, and 341 transects totaling 821 km (443 NM) in late fall. Sampling effort was greater in Klondike, especially during the late-summer cruise, because it generally had less ice cover than did Burger.

PATTERNS OF DISTRIBUTION AND ABUNDANCE

We recorded a total of 4,646 individuals of 31 species on transect within the two study areas combined; we also recorded 2 other species only off-transect (Table 1). Of the 31 species recorded on transect, 4 were waterfowl (all seaducks), 3 were loons, 2 were tubenoses, 2 were phalaropes, 9 were larids (7 gulls/terns and 2 jaegers), and 11 were alcids.

Of the 31 species recorded on transect within the two study areas, we had sufficient detections to generate reliable estimates of density for 8 species (Table 2). Densities of each of the 8 most-abundant species differed significantly among seasons (P < 0.001 for all models); however, seasonal patterns of abundance differed by species. Thick-billed Murres were most abundant in late summer and early fall, whereas Short-tailed Shearwaters, Northern Fulmars, Black-legged Kittiwakes, and Pacific Loons all were most abundant in early fall, Glaucous-Gulls and Least Auklets were most abundant in both early and late fall, and Crested Auklets were most abundant only in late fall.

Densities of seven of the eight most-abundant species differed significantly between study areas, with only Short-tailed Shearwaters showing no significant difference in densities between study areas (P = 0.968; Table 2). In the season in which they were most abundant, Northern Fulmars, Thick-billed Murres, Crested Auklets, and Least Auklets were more common in Klondike, whereas Black-legged Kittiwakes, Glaucous Gulls, and Pacific Loons were more common in Burger.

TUBENOSES

Tubenoses were the most abundant species-group recorded during 2008, primarily because of large flocks of Short-tailed Shearwaters moving through both study areas in early fall (Figure 5, Table 2). Densities of Short-tailed Shearwaters and Northern Fulmars were at least twice as high as the density of alcids, the next most abundant species group, in early fall. This species-group represents both seasonal non-breeding 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 and reside in the area year-round.

Short-tailed Shearwaters occurred in both study areas and in all three seasons except for Burger in late summer (Table 2). Densities differed significantly among seasons but did not differ significantly between study areas (P = 0.769 for effect of study area). Densities were lowest in late summer, intermediate in late fall, and highest in early fall, which is when they are moving from summer feeding areas back to breeding areas in the Southern Hemisphere (Figure 5, Table 2). Although densities in late fall were higher than in late summer, the difference was not significant (P = 0.832), presumably because of high variability in the data. Short-tailed Shearwaters were abundant in both study areas and tended to occur in the eastern half of Klondike and the western half of Burger (Figure 6).

Northern Fulmars occurred in both study areas and in all three seasons (Table 2, Figure 7). The significant interaction term (P < 0.001) indicated different patterns in seasonal variation between study areas. In Klondike, densities were low in both late summer and late fall but high in early fall (Figure 5, Table 2). In Burger, the seasonal difference in densities among seasons was not significant (P > 0.700 for both comparisons). Northern Fulmars were more abundant in Klondike than in Burger in early fall (difference = 32.2 birds/km^2; 95% CI 25.7–38.7 birds/km^2;

Table 1. Species of seabirds identified during boat–based surveys in the northeastern Chukchi Sea, by study area and season. Species identified in 2008, are designated as "X." Species seen only off-transect are designated as "OT," species seen only within the 30-mi buffer zone used in the historical comparisons are designated as "B," and species identified in the historical dataset available from the North Pacific Pelagic Seabird Database are designated as "H."

		Study area/season					
		Klondike			Burger		
Species-group/species	Scientific name	Late summer	Early fall	Late fall	Late summer	Early fall	Late fall
WATERFOWL							
King Eider	*Somateria spectabilis*	X	–	X	–	X	X
Common Eider	*S. mollissima*	–	–	–	–	X	–
White-winged Scoter	*Melanitta fusca*	–	–	OT	–	–	X
Long-tailed Duck	*Clangula hyemalis*	X	H	X, H	B	X, H	X, H
LOONS							
Red-throated Loon	*Gavia stellata*	–	–	–	–	X	–
Pacific Loon	*G. pacifica*	–	X	X	–	X	X
Arctic Loon	*G. arctica*	–	–	–	–	H	–
Common Loon	*G. immer*	–	H	–	–	H	–
Yellow-billed Loon	*G. adamsii*	–	X	X	–	X	–
TUBENOSES							
Northern Fulmar	*Fulmarus glacialis*	X	X, H	X	X	X	X
Short-tailed Shearwater	*Puffinus tenuirostris*	B	X, H	X	B	X	X
PHALAROPES							
Red-necked Phalarope	*Phalaropus lobatus*	–	X	X	–	X	–
Red Phalarope	*P. fulicarius*	X	X, H	X	–	X, H	–
LARIDS							
Black-legged Kittiwake	*Rissa tridactyla*	X, H	X, H	X, H	X, H	X, H	X, H
Ivory Gull	*Pagophila eburnea*	–	–	–	H	H	X, H
Sabine's Gull	*Xema sabini*	X, H	X, H	X	X, H	OT	–
Ross's Gull	*Rhodostethia rosea*	–	–	–	H	H	X, H
Herring Gull	*Larus argentatus*	X	H	X	–	–	X

Table 1. Continued.

		Study area/season					
		Klondike			Burger		
Species-group/species	Scientific name	Late summer	Early fall	Late fall	Late summer	Early fall	Late fall
LARIDS (cont'd.)							
Glaucous-winged Gull	*L. glaucescens*	OT	–	–	–	–	–
Glaucous Gull	*L. hyperboreus*	X, H	X, H	X	X, H	X, H	X, H
Arctic Tern	*Sterna paradisaea*	H	X	–	B	OT	–
Pomarine Jaeger	*Stercorarius pomarinus*	X, H	X, H	X	X, H	X	–
Long-tailed Jaeger	*S. longicaudus*	H	OT, H	–	H	OT, H	–
Parasitic Jaeger	*S. parasiticus*	X, H	X, H	–	X, H	B, H	H
ALCIDS							
Dovekie	*Alle alle*	X	–	X	–	H	X
Common Murre	*Uria aalge*	X, H	–	X	H	–	–
Thick-billed Murre	*U. lomvia*	X, H	X, H	X, H	X, H	B	X
Black Guillemot	*Cepphus grylle*	X, H	H	–	X, H	B, H	X
Pigeon Guillemot	*C. columba*	X	–	–	X	–	–
Kittlitz's Murrelet	*Brachyramphus brevirostris*	H	–	X	–	–	–
Parakeet Auklet	*Aethia psittacula*	–	X, H	–	–	H	X
Least Auklet	*A. pusilla*	X	X, H	X, H	–	X	X
Crested Auklet	*A. cristatella*	X	X, H	X, H	–	X, H	X
Horned Puffin	*Fratercula corniculata*	X, H	–	–	X	–	–
Tufted Puffin	*F. cirrhata*	X, H	–	X	–	–	–

Table 2. Estimated corrected densities (birds/km^2) of the eight most-common species of seabirds counted during boat-based marine surveys in the central Chukchi Sea, by study area and season, 2008. Values in parentheses are 95% confidence intervals.

	Study area/season					
	Klondike			Burger		
Species-group/species	Late summer	Early fall	Late fall	Late summer	Early fall	Late fall
LOONS						
Pacific Loon	0.0 (0)	0.1 (0.0–0.7)	0.1 (0.1–0.2)	0.0 (0)	4.9 (1.8–13.1)	<0.1 (<0.1–<0.1)
TUBENOSES						
Northern Fulmar	0.6 (0.4–0.9)	17.0 (11.3–25.7)	0.3 (0.1–0.6)	0.1 (<0.1–0.2)	1.1 (0.4–3.0)	0.1 (<0.1–0.2)
Short–tailed Shearwater	<0.1 (<0.1–<0.1)	40.4 (25.2–64.7)	1.4 (0.7–2.6)	0.0 (0)	31.6 (16.5–60.7)	0.3 (0.2–0.5)
LARIDS						
Black–legged Kittiwake	0.8 (0.5–1.3)	5.3 (3.2–8.6)	2.0 (1.3–3.1)	0.2 (0.1–0.4)	17.7 (11.7–26.7)	0.3 (0.1–0.6)
Glaucous Gull	0.1 (<0.1–0.2)	1.4 (0.8–2.6)	1.2 (0.8–1.8)	0.1 (<0.1–0.2)	4.2 (2.6–6.8)	0.3 (0.2–0.6)
ALCIDS						
Thick–billed Murre	2.0 (1.4–2.8)	1.7 (0.8–3.4)	<0.1 (<0.1–0.1)	0.1 (<0.1–0.1)	0.0 (0)	<0.1 (<0.1–<0.1)
Least Auklet	<0.1 (<0.1–0.2)	1.6 (0.5–5.3)	0.7 (0.2–2.6)	0 (0)	<0.1 (<0.1–<0.1)	0.1 (<0.1–0.3)
Crested Auklet	0.8 (0.3–1.9)	0.6 (0.4–1.0)	6.9 (4.9–9.6)	0 (0)	<0.1 (<0.1–<0.1)	0.3 (0.2–0.6)

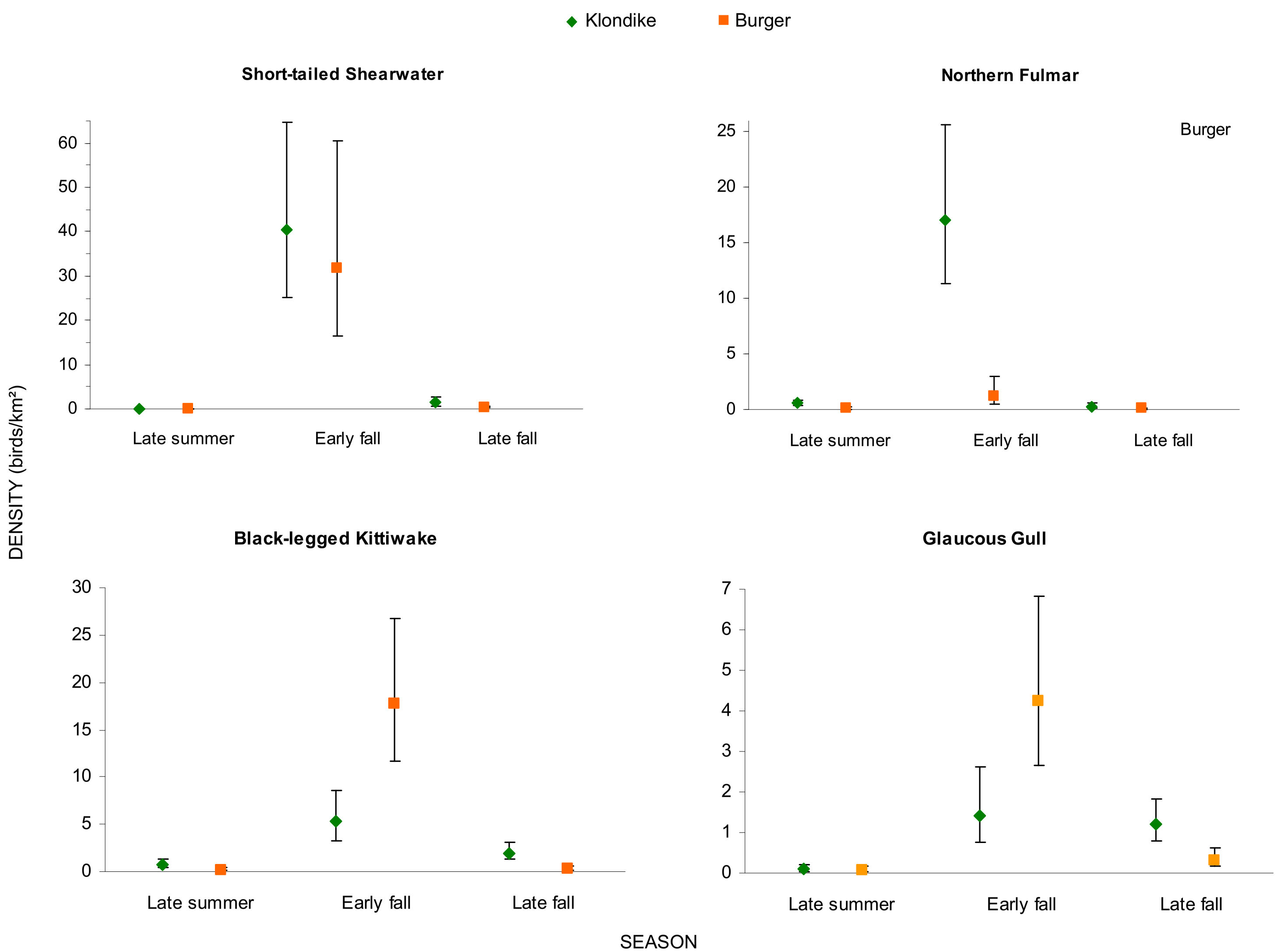
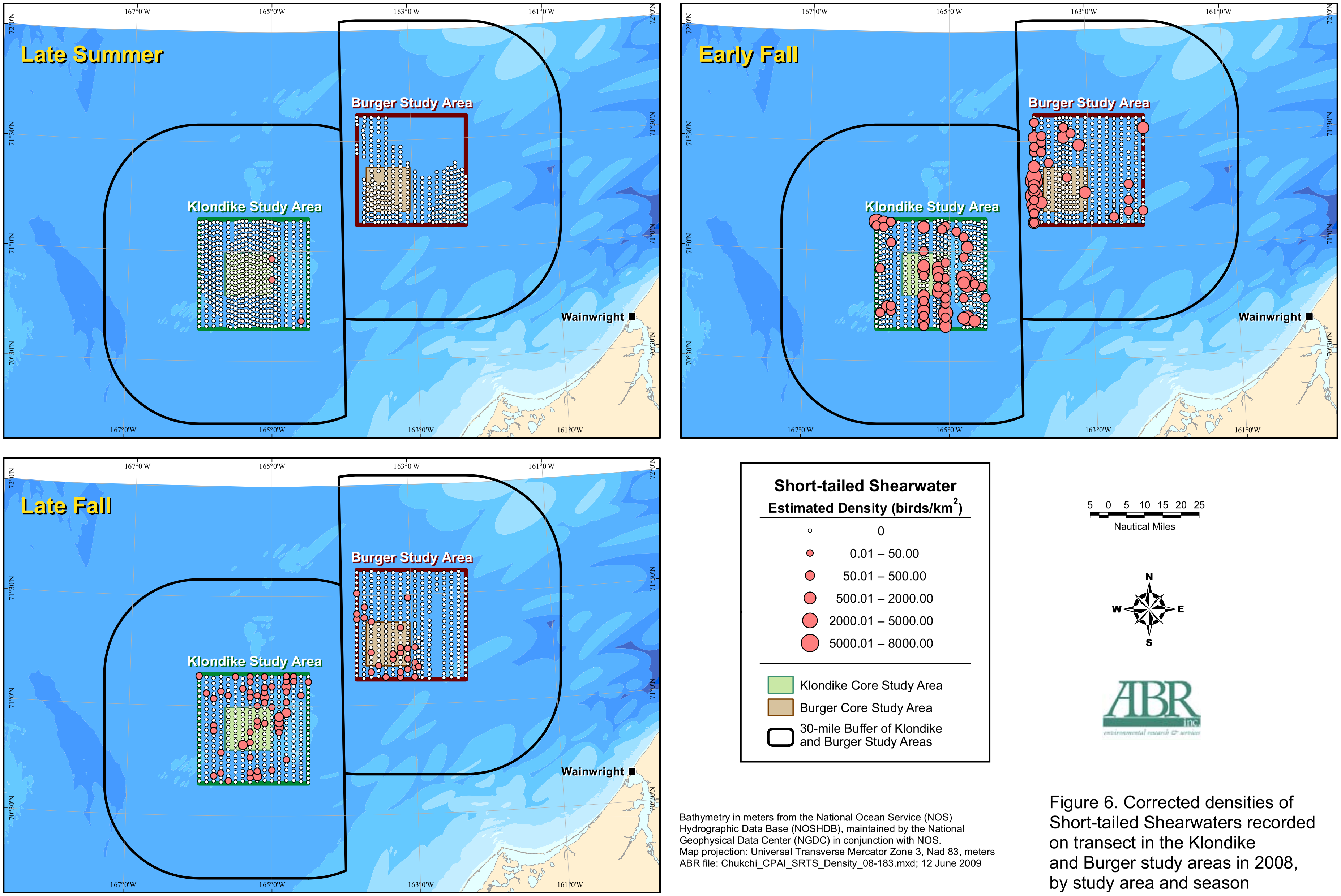


Figure 5. Mean corrected density (birds/km^2) of Short-tailed Shearwaters, Northern Fulmars, Black-legged Kittiwakes, and Glaucous Gulls on transect in the Klondike and Burger study areas in 2008, by study area and season. Error bars represent 95% confidence intervals.



Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CPAI_SRTS_Density_08-183.mxd; 12 June 2009

Figure 6. Corrected densities of Short-tailed Shearwaters recorded on transect in the Klondike and Burger study areas in 2008, by study area and season

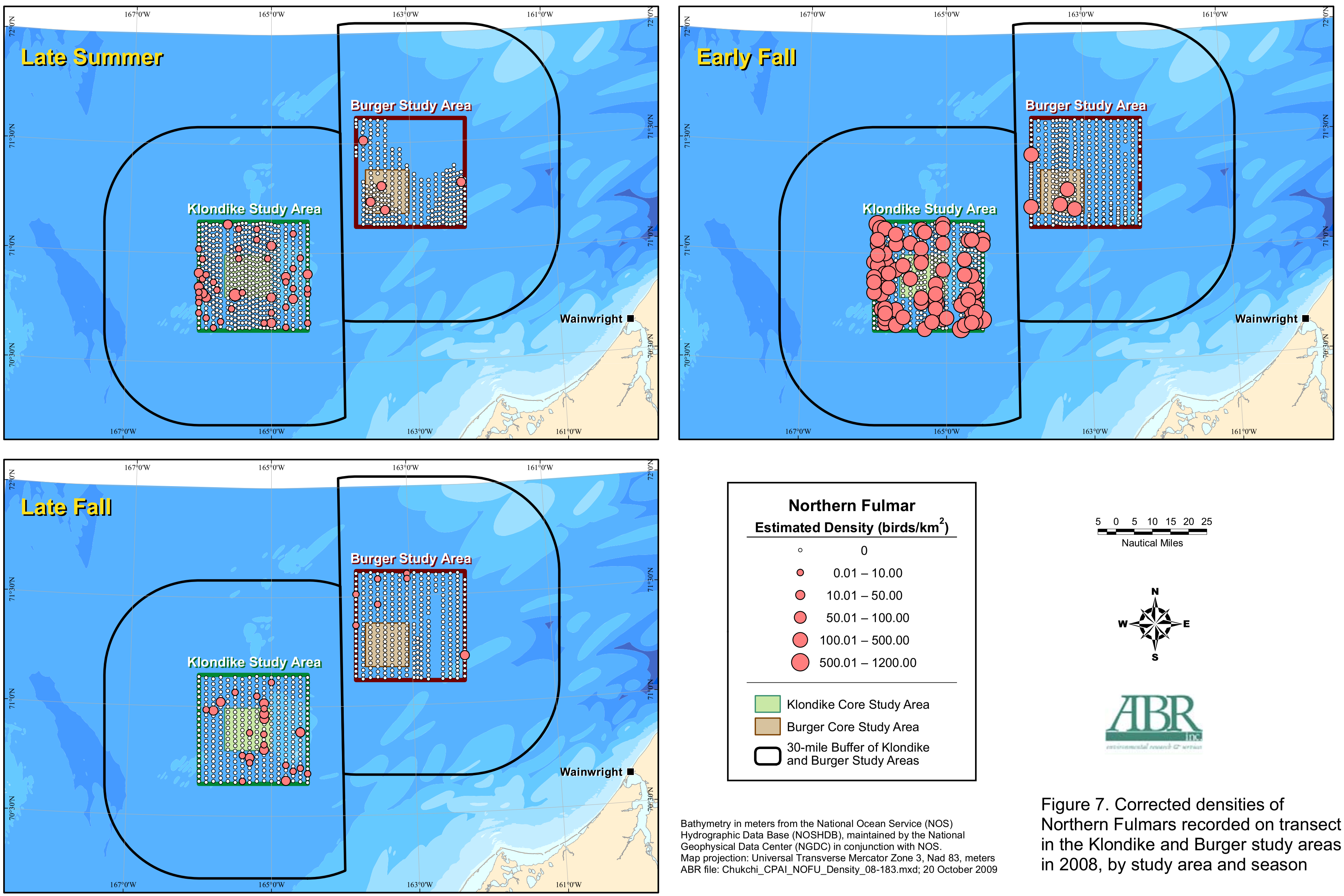


Figure 7. Corrected densities of Northern Fulmars recorded on transect in the Klondike and Burger study areas in 2008, by study area and season

$P < 0.001$), whereas there was no difference in abundance between study areas in late summer ($P = 0.840$) or late fall ($P = 0.863$). Northern Fulmars were distributed across the entire Klondike study area but, within Burger, tended to occur primarily in the western half (Figure 7).

LARIDS

Larids, or gulls and gull-like birds, were the second-most-abundant species group recorded during surveys. Unlike most other seabird species, densities of gulls were generally higher in Burger than they were in Klondike. Of the nine species of larids recorded on transect, only Black-legged Kittiwakes and Glaucous Gulls were abundant enough to generate estimates of density after accounting for detection probability.

Black-legged Kittiwakes occurred in both study areas and in all three seasons (Table 2). The significant interaction term ($P < 0.001$) indicated different patterns among seasons in spatial use. In both Klondike and Burger, densities of Black-legged Kittiwakes were low in late summer and late fall but high in early fall (Figure 5, Table 2). Although densities were similar between study areas in late summer ($P = 0.865$) and late fall ($P = 0.281$), densities of Black-legged Kittiwakes were 38 birds/km^2 higher in Burger than in Klondike in early fall (95% CI 28.6–47.3 birds/km^2; $P < 0.001$). There was little evidence of a spatial pattern in the distribution of Black-legged Kittiwakes within the study areas in any season (Figure 8).

Glaucous Gulls occurred in both study areas and in all three seasons (Table 2). As seen in Black-legged Kittiwakes, the significant interaction term ($P < 0.001$) indicated different patterns among seasons in spatial use. In both Klondike and Burger, densities of Glaucous Gulls were lowest in late summer, intermediate in late fall, and highest in early fall (Figure 5, Table 2). Densities were higher in Burger than in Klondike (difference: 8.8 birds/km^2, 95% CI 5.7–11.8 birds/km^2; $P < 0.001$) in early fall but were higher in Klondike than in Burger in late fall; however, the difference was not statistically significant (difference = 3.1 birds/km^2; 95% CI –0.5–6.7 birds/km^2; $P = 0.090$). There was little evidence of a spatial pattern in the distribution of Glaucous Gulls within the study areas in any season (Figure 9).

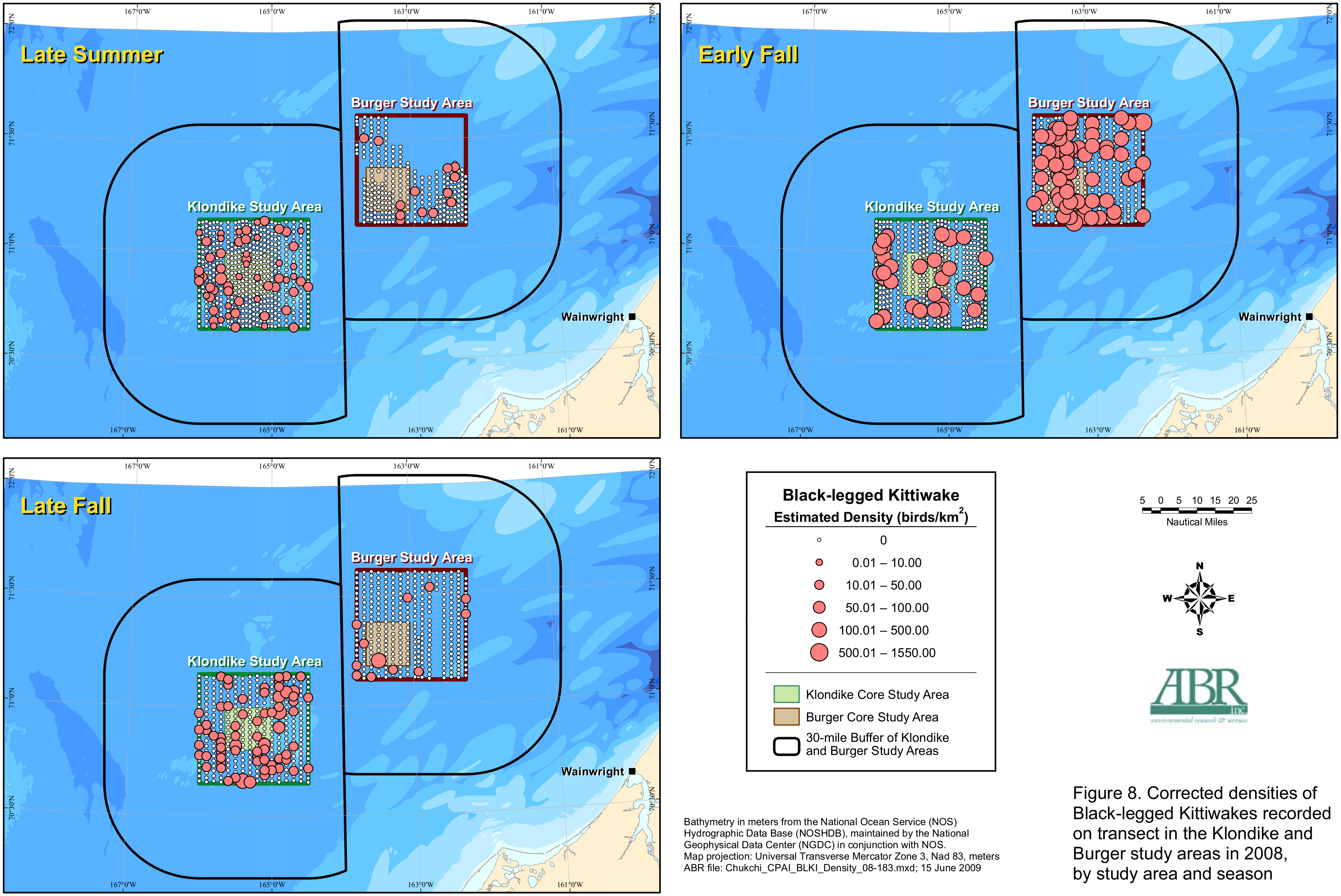
Of the other seven species of larids, Sabine's Gulls, Arctic Terns, Pomarine Jaegers, and Parasitic Jaegers were most common in early fall, whereas Ross's Gulls and Ivory Gulls were recorded only in Burger and only in late fall and Herring Gulls occurred in low numbers in both late summer and late fall. Sabine's Gulls and Arctic Terns occurred primarily in Klondike, whereas jaegers were more common in Burger.

ALCIDS

Alcids were the third-most-abundant species group recorded during the surveys. Densities of alcids were significantly higher in Klondike than in Burger during all three cruises (Figure 10, Table 2). Of the 11 species of alcids recorded on transect within the study areas, Crested Auklets, Least Auklets, and Thick-billed Murres were abundant enough to generate estimates of density after accounting for detection probability.

Crested Auklets occurred in Klondike in all three seasons and in Burger in early and late fall (Table 2). In both study areas, densities of Crested Auklets were lowest in early fall, intermediate in late summer, and highest in late fall (Figure 10, Table 2). They were more abundant in Klondike than in Burger in late fall (difference = 19.8 birds/km^2; 95% CI 16.0–23.7 birds/km^2; $P < 0.001$); densities were slightly higher in Klondike than in Burger in late summer and early fall, but the differences were not significant ($P > 0.400$ for both comparisons). Although densities were similar between study areas in late summer and early fall, counts of Crested Auklets were higher in Klondike than in Burger in all three seasons (Figure 11). Crested Auklets were most common in the western half of Klondike in late fall (Figure 11). There was no apparent spatial pattern of distribution in Klondike in the other seasons or in Burger during any season.

Least Auklets also occurred in Klondike in all three seasons and in Burger in early and late fall and were generally more common in Klondike than in Burger (Table 2). The significant interaction term ($P < 0.001$) indicated different patterns in seasonal variation between study areas. In Klondike, densities of Least Auklets were lowest in late summer, intermediate in late fall, and highest in early fall (Figure 10, Table 2). In Burger, densities were low in both late summer and early



Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CPAI_BLKI_Density_08-183.mxd; 15 June 2009

Figure 8. Corrected densities of Black-legged Kittiwakes recorded on transect in the Klondike and Burger study areas in 2008, by study area and season

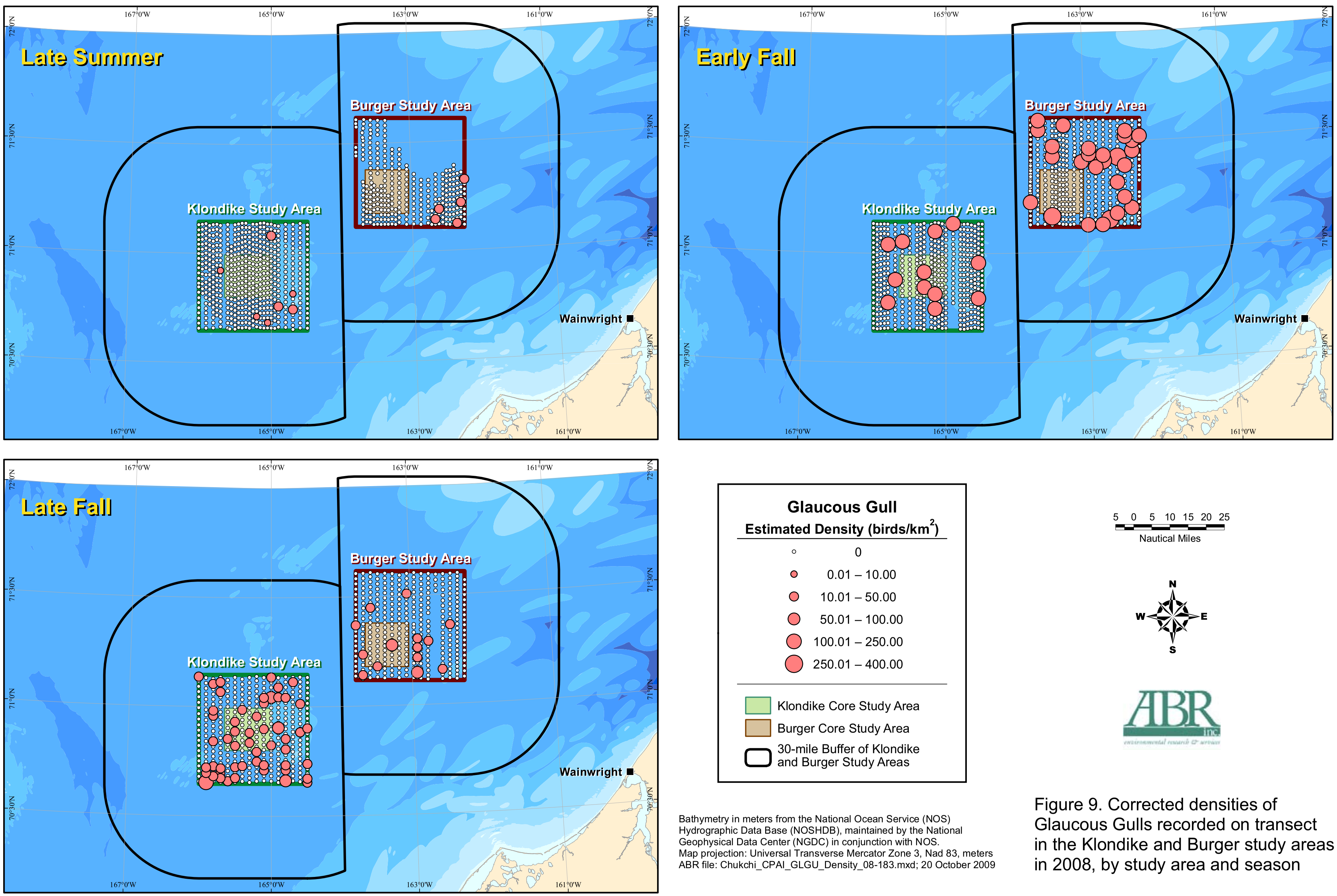


Figure 9. Corrected densities of Glaucous Gulls recorded on transect in the Klondike and Burger study areas in 2008, by study area and season

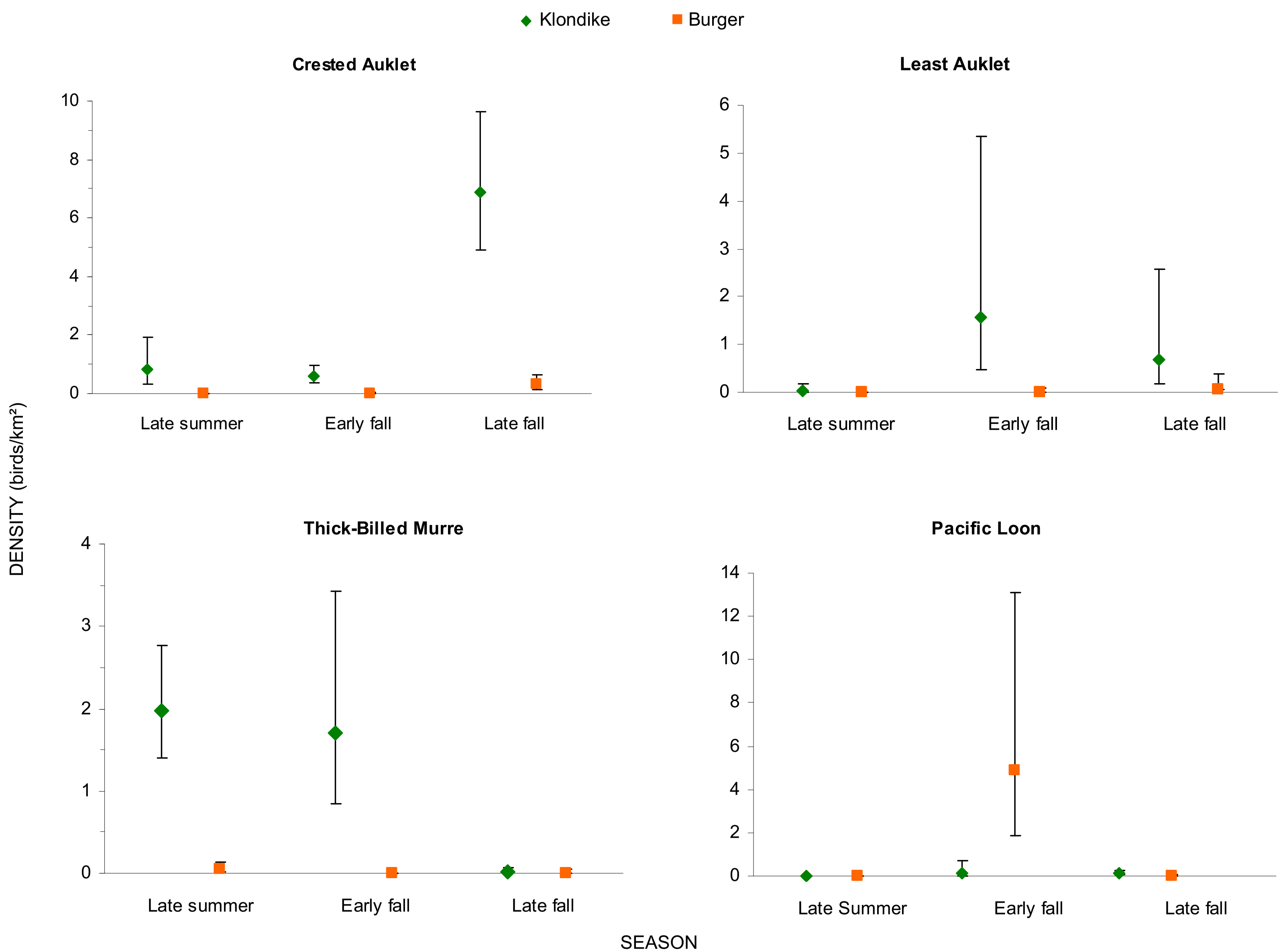


Figure 10. Mean corrected density (birds/km^2) of Crested Auklets, Least Auklets, Thick-billed Murres, and Pacific Loons on transect in the Klondike and Burger study areas in 2008, by study area and season. Error bars represent 95% confidence intervals.

fall and high in late fall. Densities of Least Auklets were 6.4 birds/km^2 higher (95%CI 4.3–8.4 birds/km^2; $P < 0.001$) in early fall and 3.7 birds/km^2 higher (95% CI 1.3–6.1 birds/km^2; $P = 0.003$) in late fall in Klondike than in Burger. There was no significant difference between study areas in late summer ($P = 0.909$). Least Auklets were most common in the northeastern half of Klondike in early fall and in the southwestern half in late fall (Figure 12). There was no apparent spatial pattern of distribution in the other seasons or in Burger.

Thick-billed Murres occurred in Klondike in all three seasons and in Burger in both late summer and late fall (Table 2). The significant interaction term ($P < 0.001$) indicated different patterns between study areas by season. In Klondike, densities of Thick-billed Murres were lowest in late fall, intermediate in late summer, and highest in early fall (Figure 10, Table 2). In Burger, Thick-billed Murres were rare in all three seasons. Consequently, when Thick-billed Murres were present, they were more abundant in Klondike than in Burger. Densities of Thick-billed Murres were 3.6 birds/km^2 higher (95%CI 1.8–5.4 birds/km^2; $P < 0.001$) in late summer and 3.5 birds/km^2 higher (95%CI 1.9–5.1 birds/km^2; $P < 0.001$) in early fall in Klondike than in Burger. Thick-billed Murres were seen primarily in Klondike (Figure 13).

Of the other eight species of alcids recorded, Common Murres were the most abundant, occurring primarily in Klondike during late summer and late fall. Black Guillemots, Tufted Puffins, Horned Puffins, and Pigeon Guillemots also were seen in Klondike in low numbers, primarily in late summer. Dovekies and Kittlitz's Murrelets were rare, but both species were recorded in Klondike in late fall; Dovekies also were seen in Klondike in late summer, and one individual was seen in Burger in late fall.

LOONS

Loons were most abundant in late fall (primarily in late September and early October). Of the three species of loons recorded in 2008, only Pacific Loons were abundant enough to generate estimates of density after accounting for detection probability. Pacific Loons occurred in both study areas in both early fall and late fall, but none were seen in late summer (Figure 10, Table 2). In Klondike, Pacific Loons were rare in early and late fall. In Burger, however, densities were low in late fall and high in early fall. In early fall, Pacific Loons were significantly more abundant in Burger than in Klondike (difference = 13.4 birds/km^2; 95% CI 6.7–20.0 birds/km^2; $P < 0.001$). In late fall, they were present in low numbers in both study areas. Although there was no significant difference in estimated densities in late fall, more Pacific Loons were recorded in Klondike than in Burger (Figure 14).

Both Red-throated and Yellow-billed loons were rare during these surveys. We saw one Red-throated Loon in Burger on 18 September. In Klondike, we saw a group of three Yellow-billed Loons on 31 August and one bird on 25 September; we also saw a group of two in Burger on 18 September.

WATERFOWL

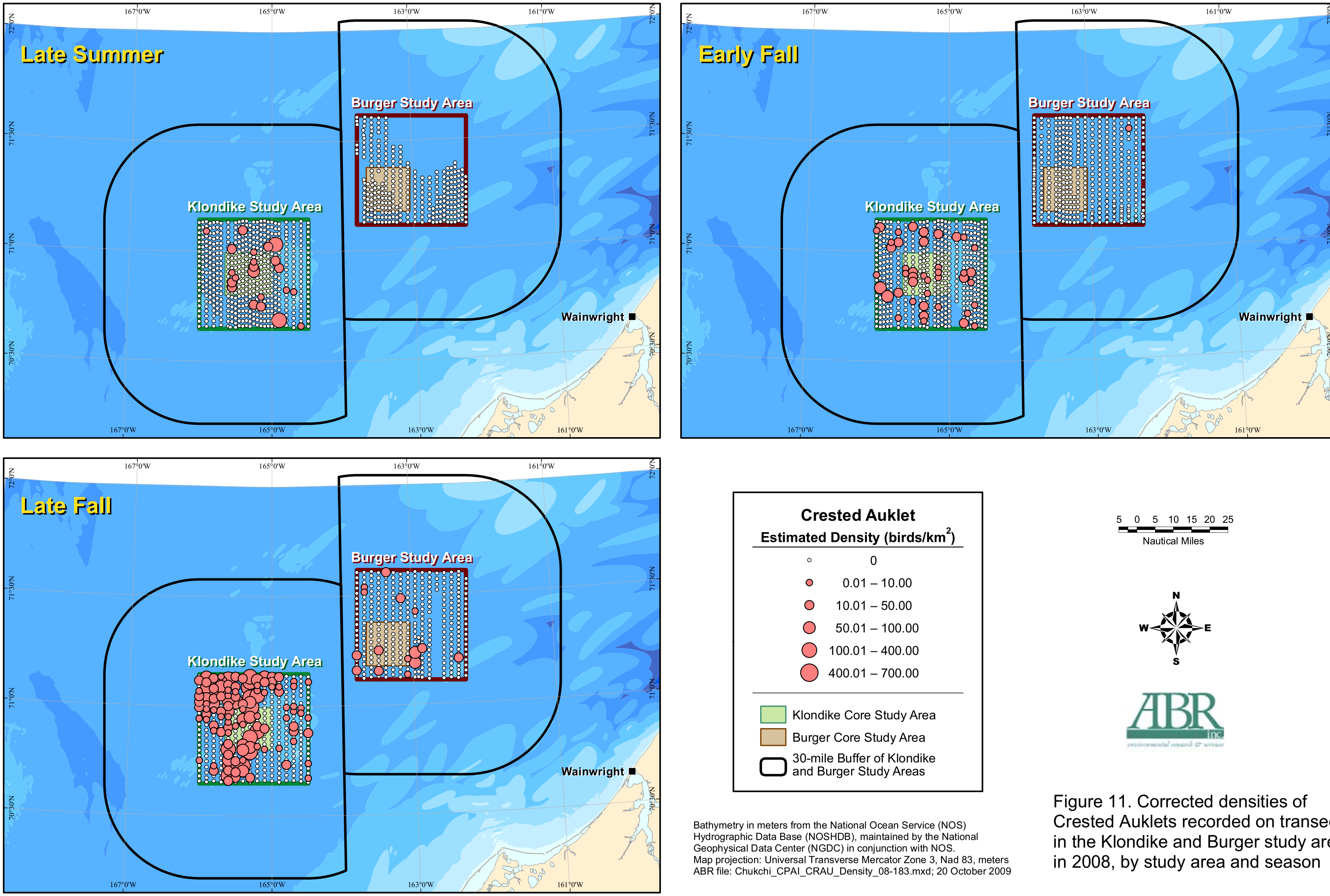
Waterfowl were seen in low densities throughout the study in both study areas. Of the four species of waterfowl identified, none was abundant enough to provide reliable estimates of density after accounting for detection probability. Long-tailed Ducks were the most abundant waterfowl, and they were seen in both study areas and in all seasons. King Eiders were seen flying singly or in pairs on all three cruises. One flock of Common Eiders and one flock of White-winged Scoters were recorded in Burger in late fall.

PHALAROPES

Phalaropes were seen in low densities, primarily during early fall. Both Red and Red-necked phalaropes were seen feeding in mixed-species flocks, primarily near floating ice. Phalaropes were not abundant enough to provide a reliable estimate of density after accounting for detection probability. They were most common in Klondike during late fall and in Burger during early fall; because the study areas were surveyed consecutively, these high counts both correspond to survey transects conducted in September. We saw few phalaropes in August and none in October.

TOTAL DENSITY ESTIMATES

We used the estimated corrected densities of the 31 species that we recorded in the study areas to calculate total density of marine birds within the study areas in each season (Table 3). Total density



Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CPAI_CRAU_Density_08-183.mxd; 20 October 2009

Figure 11. Corrected densities of Crested Auklets recorded on transect in the Klondike and Burger study areas in 2008, by study area and season

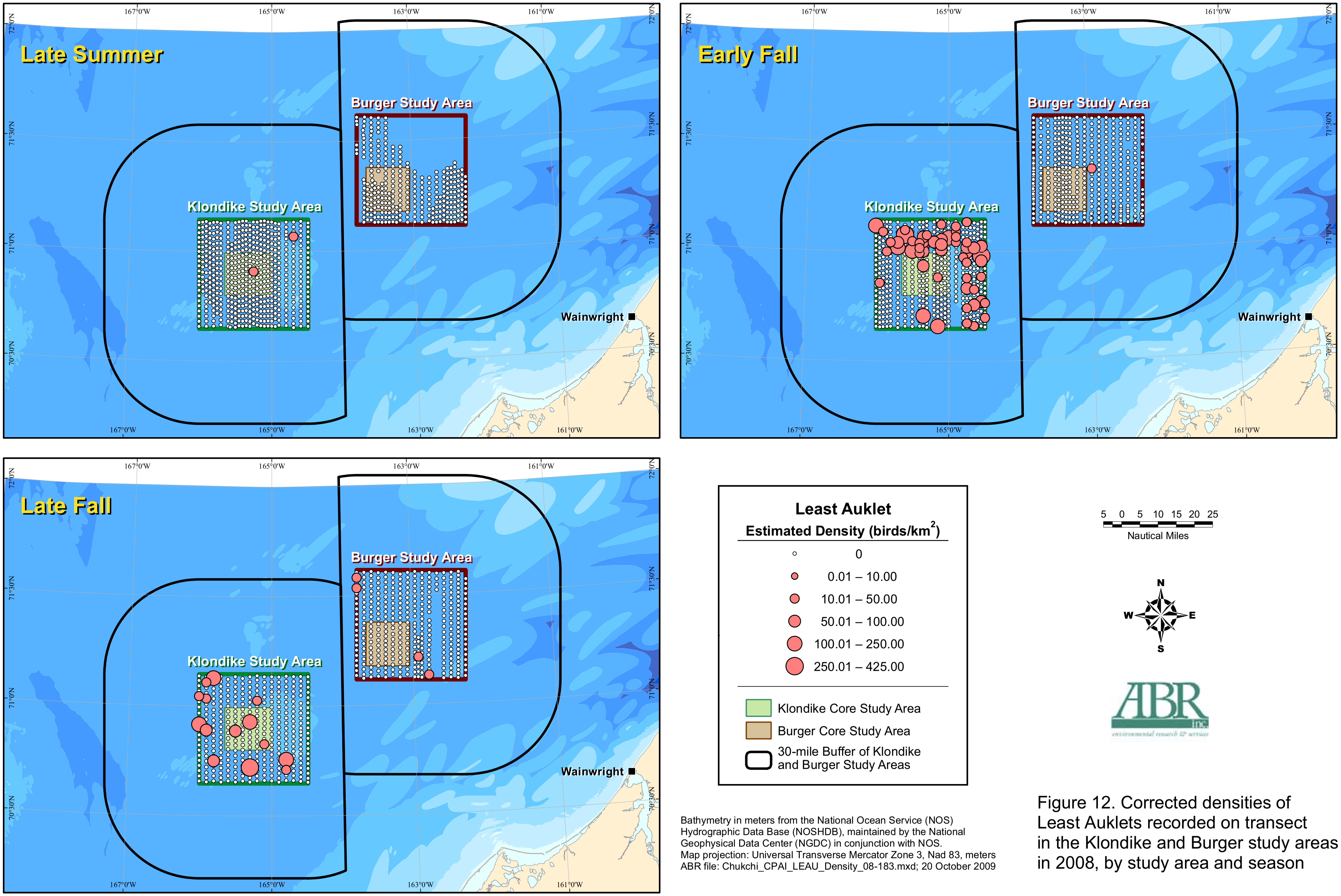
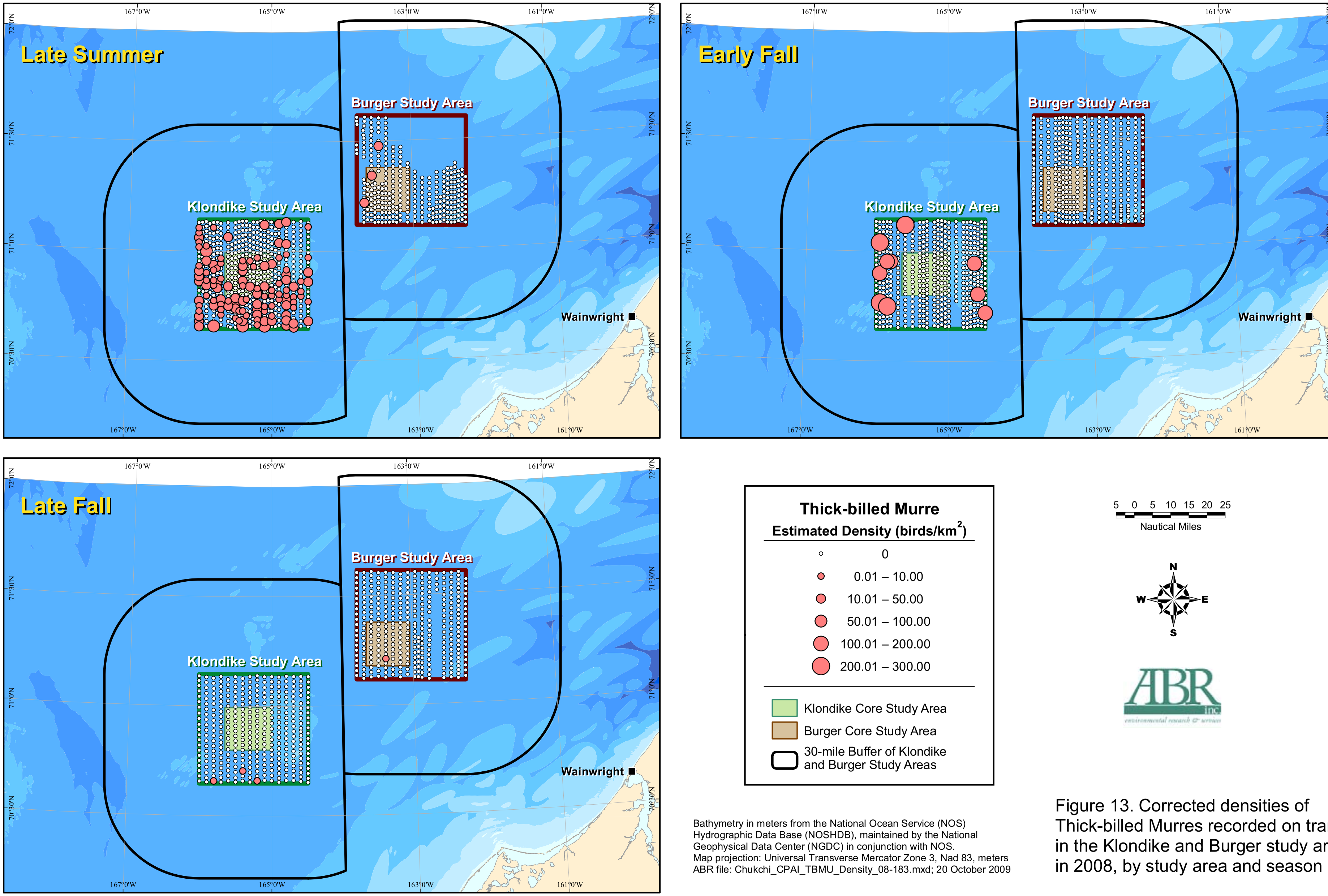
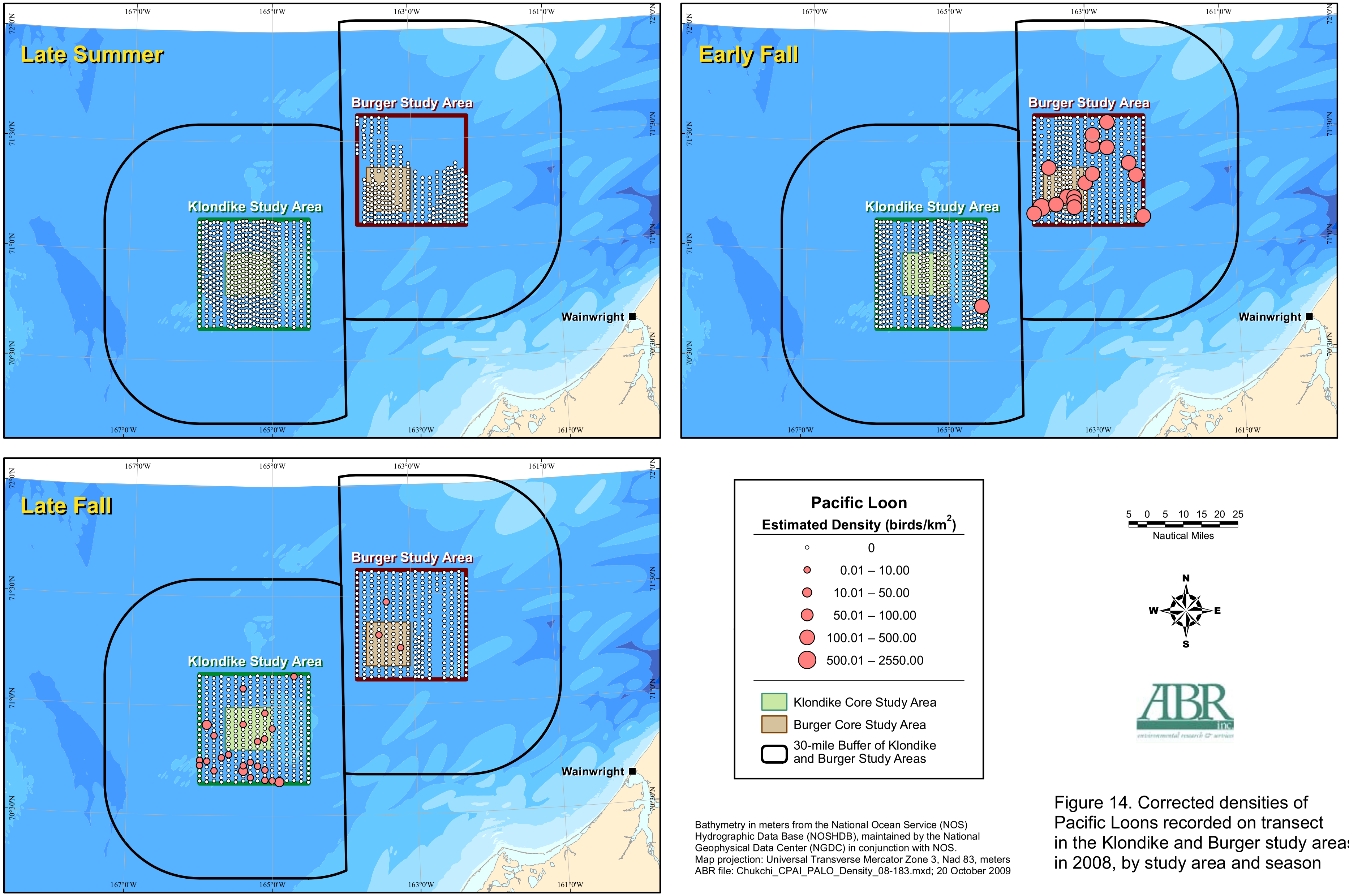


Figure 12. Corrected densities of Least Auklets recorded on transect in the Klondike and Burger study areas in 2008, by study area and season



Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CPAI_TBMU_Density_08-183.mxd; 20 October 2009

Figure 13. Corrected densities of Thick-billed Murres recorded on transect in the Klondike and Burger study areas in 2008, by study area and season



Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CPAI_PALO_Density_08-183.mxd; 20 October 2009

Figure 14. Corrected densities of Pacific Loons recorded on transect in the Klondike and Burger study areas in 2008, by study area and season

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

	Study area	
Season	Klondike	Burger
Late summer	4.8 (3.8–6.1)	0.5 (0.3–0.8)
Early fall	71.3 (53.2–95.5)	73.0 (51.1–104.4)
Late fall	13.9 (11.2–17.3)	3.1 (2.3–4.0)

of marine birds was highest in early fall, lowest in late summer, and intermediate in late fall (Table 3). We estimate that the eight most abundant species (Short-tailed Shearwaters, Black-legged kittiwakes, Northern Fulmars, Crested Auklets, Least Auklets, Glaucous Gulls, Pacific Loons, and Thick-billed Murres) collectively accounted for 68 birds/km^2 in the Klondike study area and 60 birds/km^2 in the Burger study area during early fall. In contrast, the 23 rarer species occurred in lower numbers and collectively accounted for 3 birds/km^2 in the Klondike study area and 13 birds/km^2 in the Burger study area at that time. Total densities were higher in Klondike than in Burger in late summer and late fall ($P < 0.001$ for both seasons); however, there was no significant difference in densities between the two study areas in early fall ($P = 0.03$).

COMMUNITY COMPARISON

The total species list of birds seen on transect within the two study areas was similar between Klondike and Burger during the 2008 surveys (Table 1). Of the 31 species recorded on transect in the two study areas combined, we recorded 26 in the Klondike study area and 27 in the Burger study area. Many of the species recorded on transect during surveys were seen on both study areas: 22 species were seen on both study areas, 4 were seen only in Klondike, and 5 were seen only in Burger. Species-richness of birds seen on transect within the two study areas was similar between the two study areas in all seasons, although richness always was higher in Klondike than in Burger (Figure 15). In Klondike, species-richness showed no seasonal pattern, with the number of species ranging between 16 and 20 species. In Burger, however, richness increased from 10 species in late summer to 15 in early fall and 17 in late fall.

Species-composition varied substantially among seasons and between study areas (Figure 16). During late summer, alcids (primarily Thick-billed Murres) and larids (primarily Black-legged Kittiwakes) were the dominant species-groups in Klondike, composing 62% and 22% respectively of all birds; waterfowl and phalaropes collectively composed 16% of all birds, whereas loons were not recorded. Conversely, larids (primarily Black-legged Kittiwakes) were the numerically-dominant species-group in Burger at that time, composing 65% of all birds, followed in decreasing order by alcids (20%) and tubenoses (15%); the other three species-groups were not recorded.

During early fall, tubenoses (especially Short-tailed Shearwaters) were the numerically-dominant species-group on both study areas, composing 46% of all birds recorded in Klondike and 38% of all birds recorded in Burger. Larids also remained important in both study areas, but alcids again were more common in Klondike than in Burger. In Burger, alcids were rare, whereas phalaropes, waterfowl (primarily Long-tailed Ducks), and loons collectively composed nearly one-third of all birds recorded there.

During late fall, the pattern of species-composition was similar to that seen in late summer. Alcids were the numerically-dominant species-group in Klondike and larids were the numerically-dominant species-group in Burger, but the species representing each species-group differed from that seen in late summer. At this time of the year, the dominant alcid species in Klondike

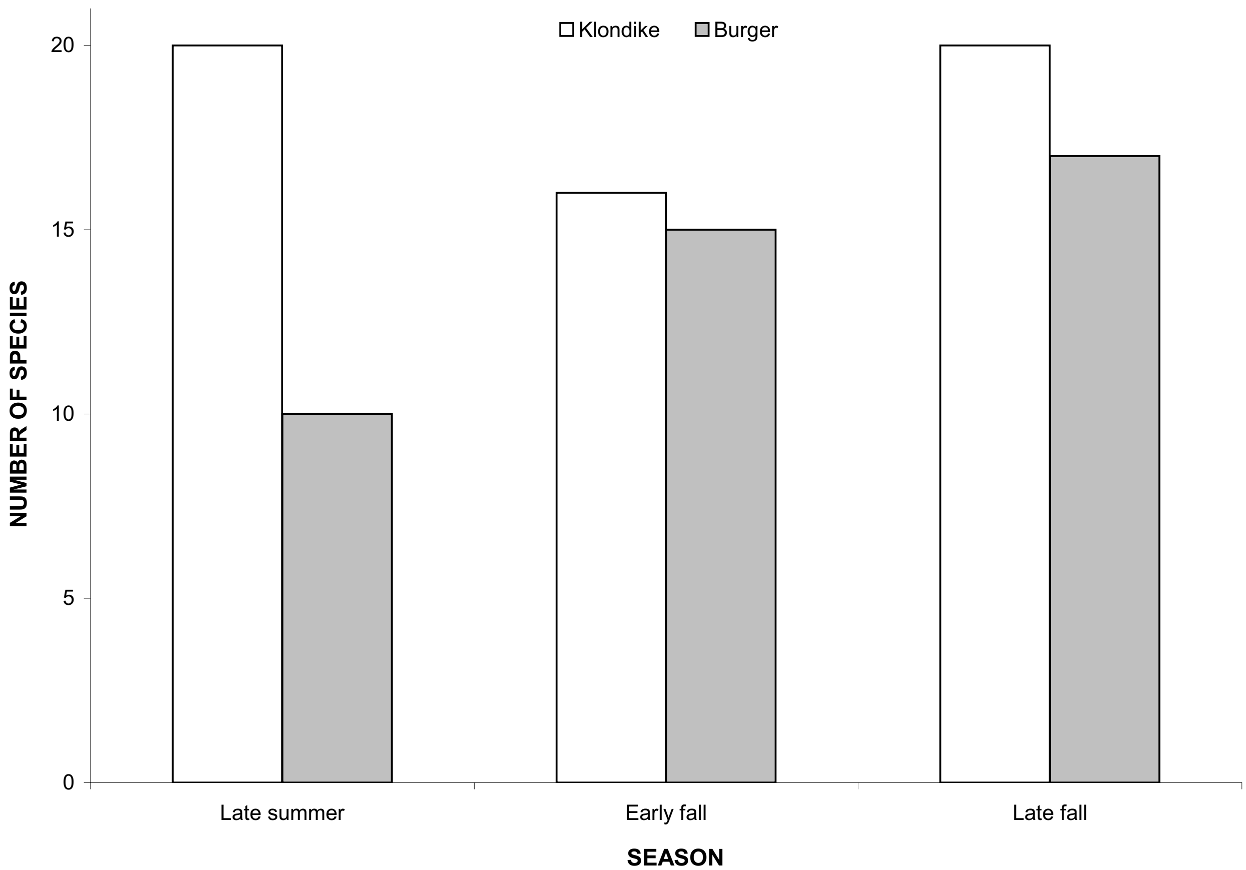


Figure 15. Species-richness of the seabird community recorded on transect in the Klondike and Burger study areas in 2008, by study area and season.

was Crested Auklet, and the dominant larid species in Burger was Ross's Gull. Loons, shorebirds, and waterfowl were rare during late fall.

CONSERVATION STATUS

In 2008, we recorded ten species on transect in the study areas that are classified as being of conservation concern (Table 4). All of these species occurred on at least two of the five lists. Of these ten species, two (Kittlitz's Murrelet and Yellow-billed Loon) are classified as candidate species under the ESA, and two (Red-throated Loon and Arctic Tern) are classified as species of conservation concern by the USFWS. The BLM considers all four species listed by the USFWS and two others to be sensitive species. Surprisingly, ADF&G does not list any of the USFWS-listed species as species of special concern; instead, that state agency classifies eight species as featured for management in the State of Alaska's Comprehensive Wildlife Conservation Strategy. The non-governmental organization Audubon Alaska classifies six of the ten species as being of conservation concern. Finally, the non-governmental organization Alaska Natural Heritage Program classifies five of the ten species as being of conservation concern.

Of the ten species of conservation concern, only three (King Eider, Yellow-billed loon, and Kittlitz's Murrelet) occurred on all five lists, and Red-throated Loon occurred on four of the five lists, indicating that there is a high level of concern about the long-term fate of these four species in a wide variety of organizations. Only Arctic Tern occurred on three of the five lists, including both the USFWS and the State of Alaska, so there is a

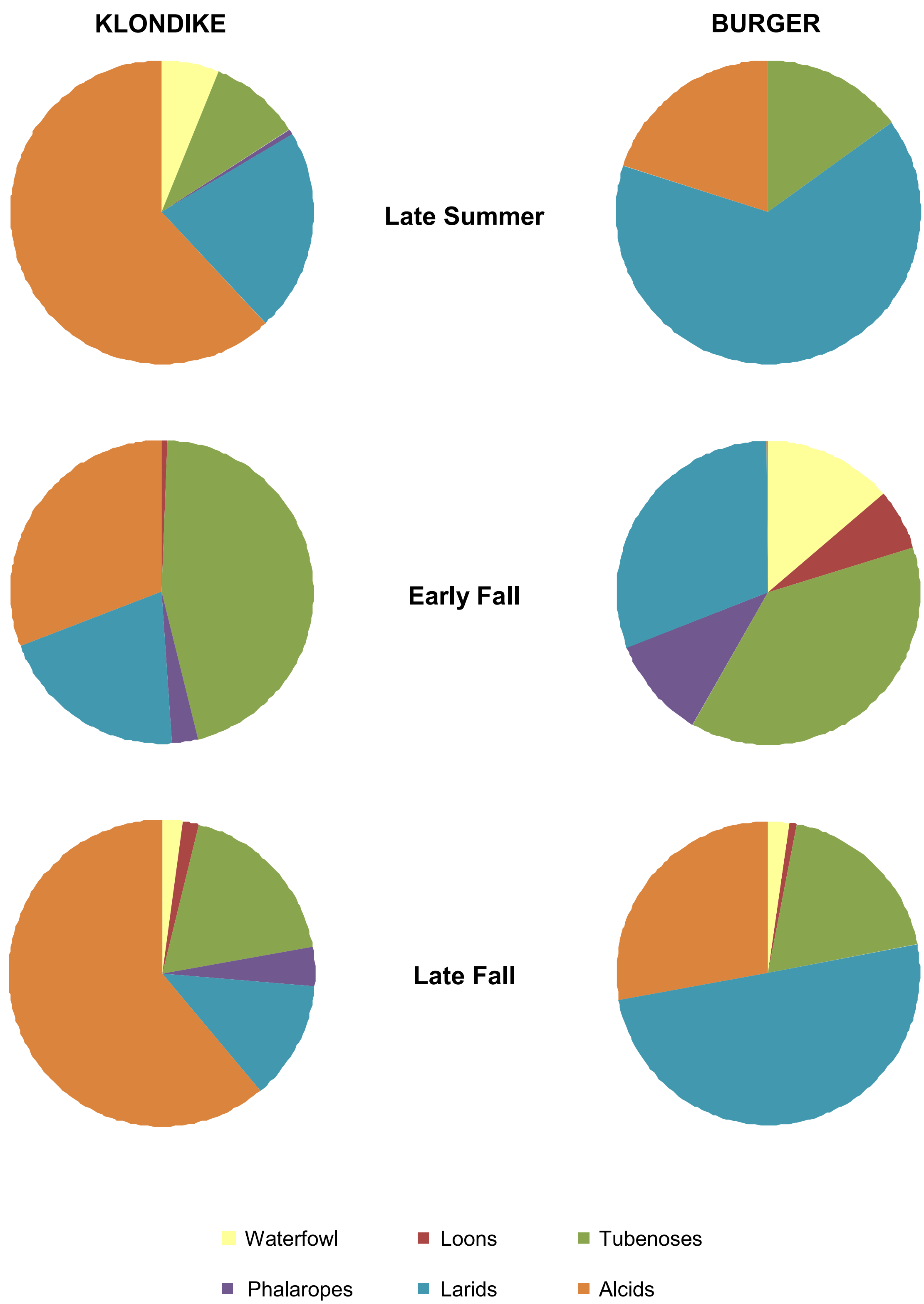
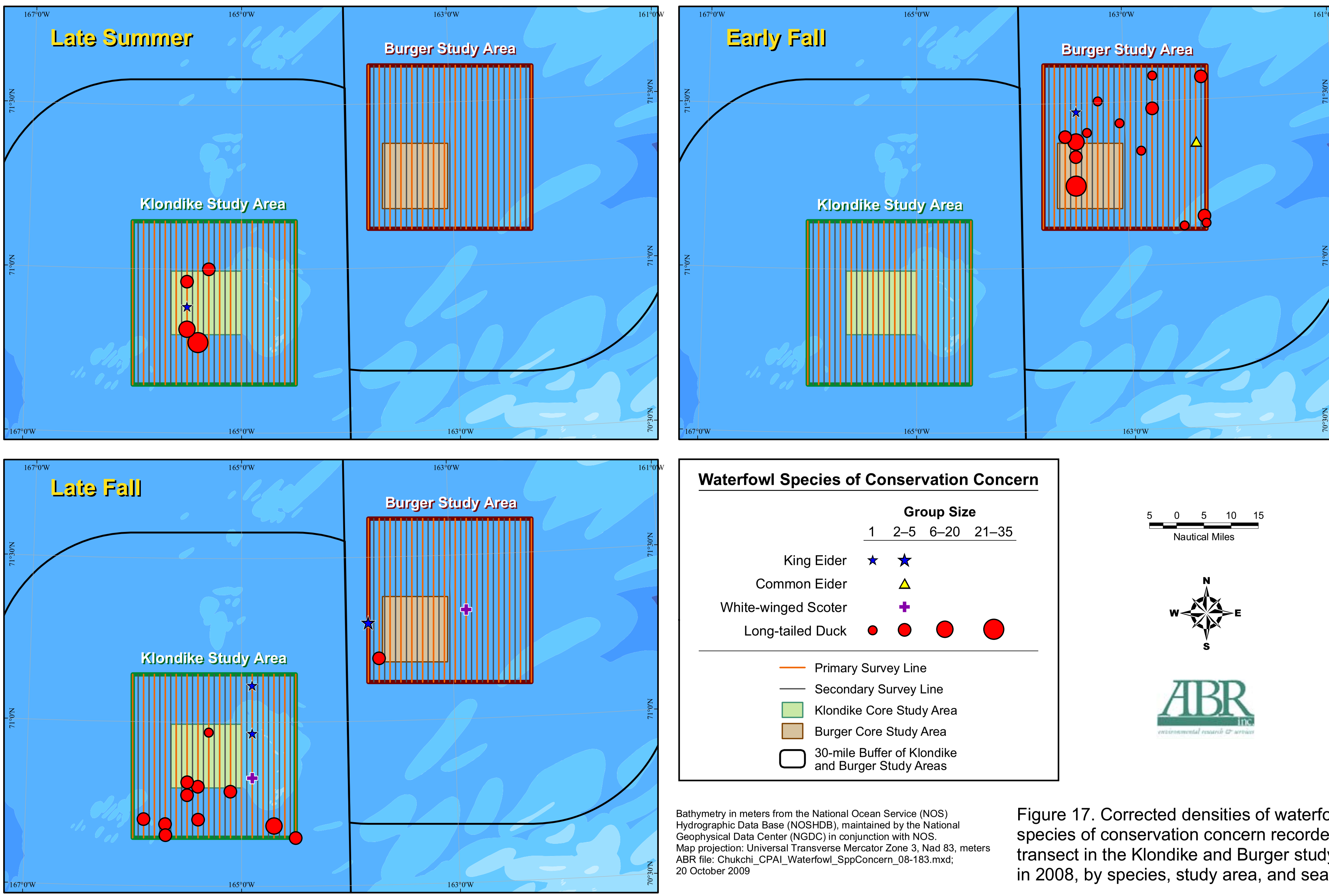


Figure 16. Species-composition of the seabird community on transect in the Klondike and Burger study areas in 2008, by study area and season.

Table 4. Bird species in the central Chukchi Sea that are of conservation concern.

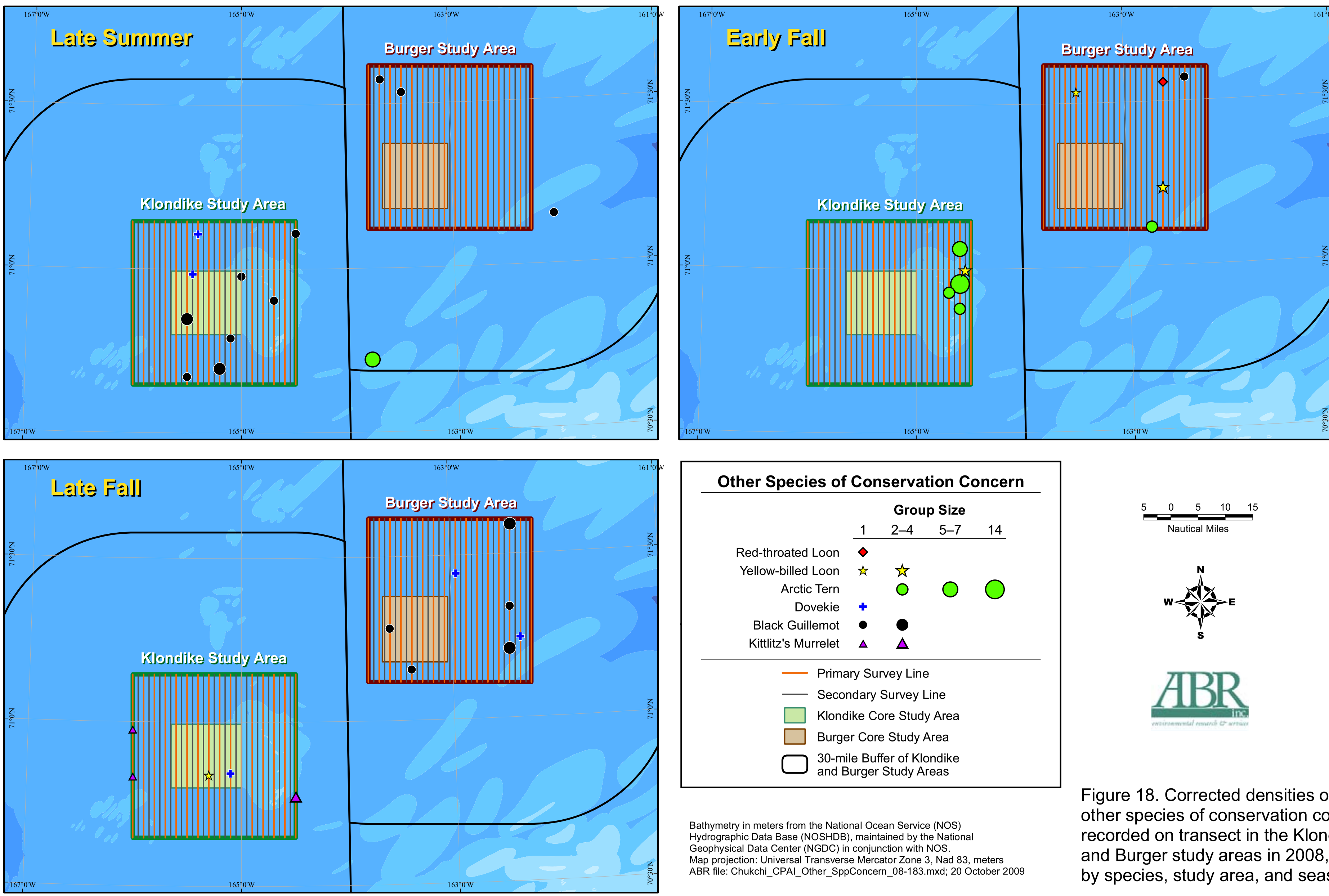
Species[a]	Listing organization				
	USFWS[b]	BLM[c]	ADFG[d]	Audubon Alaska[e]	Alaska Natural Heritage Program[f]
King Eider	–	sensitive species	featured species	species of conservation concern	species of conservation concern
Common Eider	–	–	featured species	species of conservation concern	–
White-winged Scoter	–	–	featured species	species of conservation concern	–
Long-tailed Duck	–	sensitive species	featured species	–	–
Red-throated Loon	species of conservation concern	sensitive species	featured species	species of conservation concern	–
Yellow-billed Loon	candidate species under the ESA	sensitive species	featured species	species of conservation concern	species of conservation concern
Arctic Tern	species of conservation concern	sensitive species	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	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).
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. Audubon Alaska, Alaska Watchlist 2005 (Audubon Alaska 2005).
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/pdfs/tracking_lists/2008_VertebrateSpeciesTrackingList.pdf)



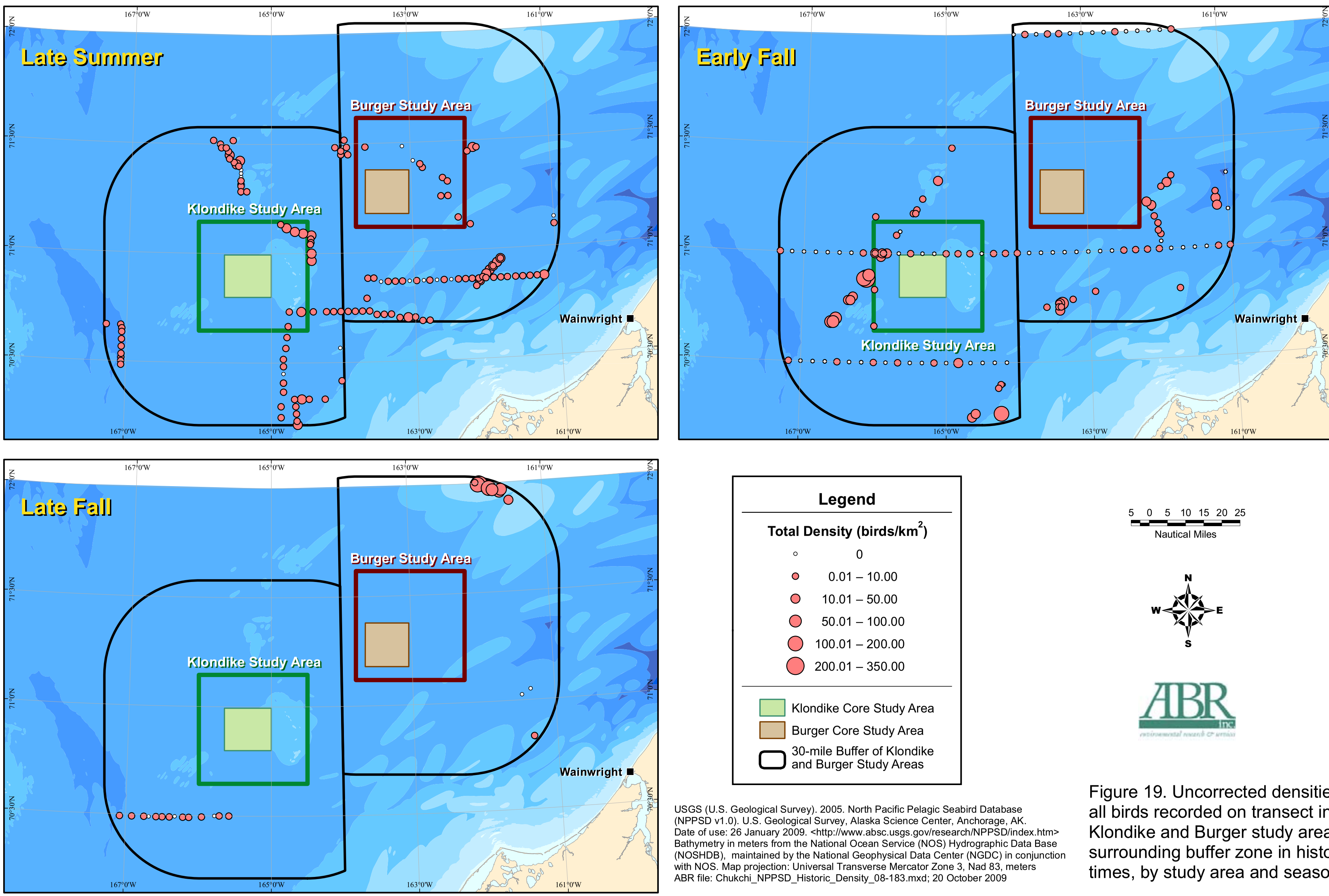
Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CPAI_Waterfowl_SppConcern_08-183.mxd;
20 October 2009

Figure 17. Corrected densities of waterfowl species of conservation concern recorded on transect in the Klondike and Burger study areas in 2008, by species, study area, and season



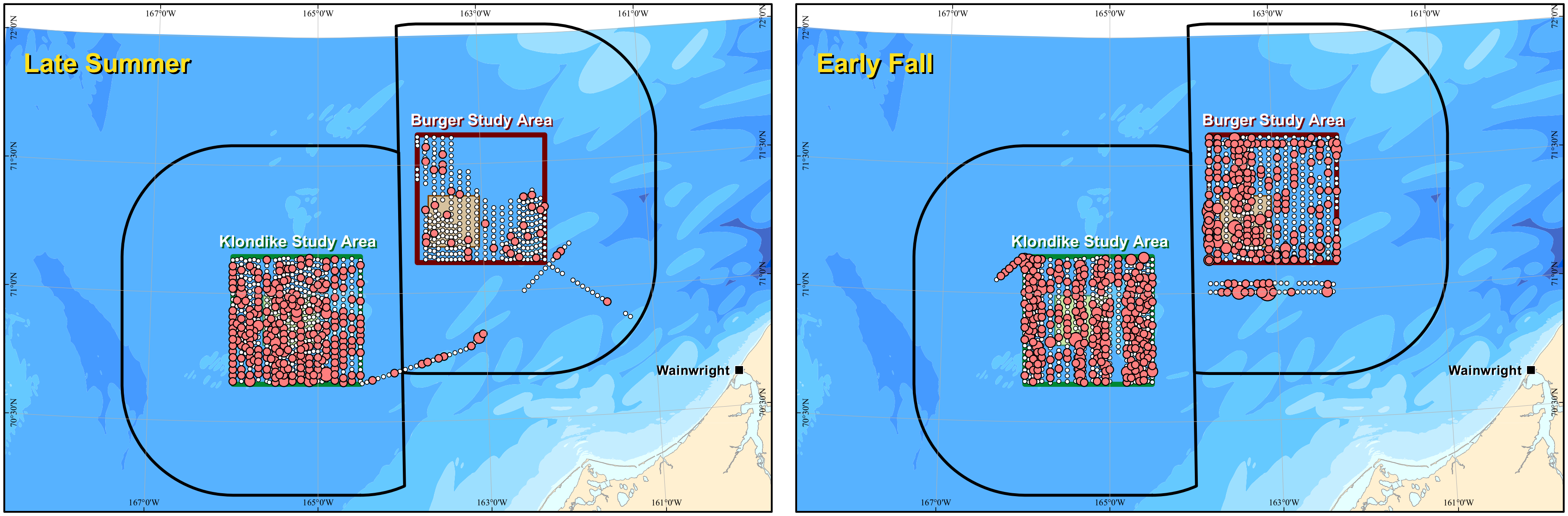
Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CPAI_Other_SppConcern_08-183.mxd; 20 October 2009

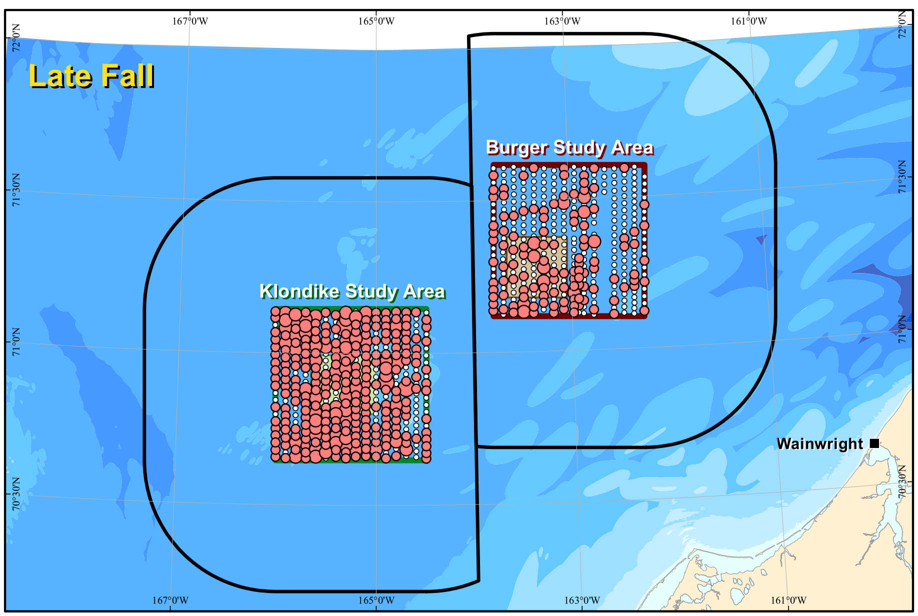
Figure 18. Corrected densities of other species of conservation concern recorded on transect in the Klondike and Burger study areas in 2008, by species, study area, and season

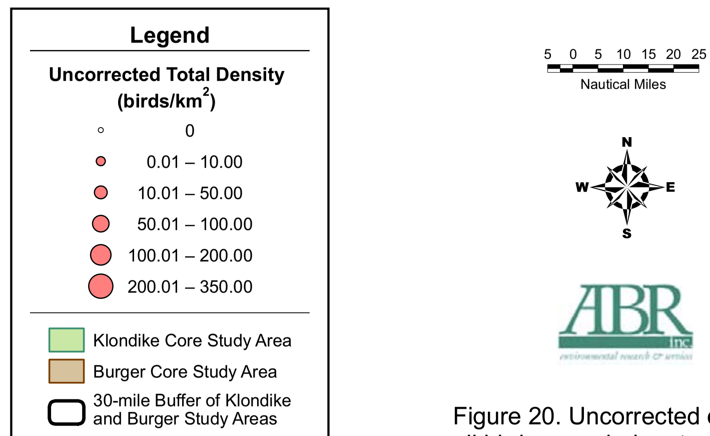


USGS (U.S. Geological Survey). 2005. North Pacific Pelagic Seabird Database (NPPSD v1.0). U.S. Geological Survey, Alaska Science Center, Anchorage, AK. Date of use: 26 January 2009. <http://www.absc.usgs.gov/research/NPPSD/index.htm>
Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS. Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_NPPSD_Historic_Density_08-183.mxd; 20 October 2009

Figure 19. Uncorrected densities of all birds recorded on transect in the Klondike and Burger study areas and surrounding buffer zone in historical times, by study area and season







Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CPAI_Density_AllSpp_08-183.mxd; 20 October 2009

Figure 20. Uncorrected densities of all birds recorded on transect in the Klondike and Burger study areas and surrounding buffer zone in 2008, by study area and season

substantial concern about them. The other five species occurred on two of the five lists, indicating concern but not widespread alarm about population trends of those species.

Of the four species of waterfowl that are of conservation concern, only the Long-tailed Duck was widely distributed in 2008 (Figure 17). Surprisingly, however, that species occurred only in Klondike in late summer, only in Burger in early fall, and essentially only in Klondike in late fall. King Eiders were recorded in both study areas, whereas Common Eiders were recorded only in Burger and White-winged Scoters were recorded only in Klondike.

The other six species of conservation concern were rare, with ≤14 observations/species in all seasons combined (Figure 18). The single Red-throated Loon was seen only in Burger, whereas half of the Yellow-billed Loons occurred in each study area. Arctic Terns occurred primarily in Klondike in early fall (there also was a small group in southern Burger at that time), and we also saw a small group while sampling south of Klondike in late summer. Three of the five Dovekies seen occurred in Klondike, but only in late summer and late fall, whereas the two seen in Burger occurred there in late fall. Black Guillemots were recorded in both study areas throughout the summer, but they primarily were associated with sea ice. Finally, the few Kittlitz's Murrelets seen were recorded only in Klondike and only in late fall.

COMPARISON WITH HISTORICAL DATA

We compared seabird densities in this part of the Chukchi Sea between historical data contained in the NPPSD and those from our 2008 surveys (Figures 19 and 20); however, the differences in sampling intensity between the two data sets precludes direct statistical comparisons at this time. Spatial overlap between the two data sets was greatest in the late summer and, to some extent, in the early fall, but no historical transects were conducted within ~9 km of either study area in late fall (Figure 19). Consequently, we are unable to derive any strong inference from a quantitative comparison between the two data sets during that season.

In general, average uncorrected densities (birds/km^2) in the historical data set were higher on transects outside of the study-area boxes than on transects within the boxes (Figure 19). The highest densities in the vicinity of Klondike were recorded west of the study area in early fall, whereas the highest densities in the vicinity of Burger were recorded north of the study area, over the shallow waters of Hanna Shoal, in late fall. Uncorrected densities recorded on transects within the study-area boxes in late summer and early fall were similar between the multi-year historical data set and data collected in 2008 (Figure 20).

Species-richness of birds seen on transect was lower in the historical surveys (Figure 21) than it was in the 2008 surveys (Figure 15). Although eight of the ten most abundant species were shared between the two data sets, another seven species (King Eider, Common Eider, White-winged Scoter, Red-throated Loon, Yellow-billed Loon, Red-necked Phalarope, and Pigeon Guillemot) were recorded on the 2008 surveys that were not recorded on the historical surveys. Only one species (Arctic Loon; *Gavia arctica*) was recorded on the historical surveys that was not recorded on the 2008 surveys, and it is possible that that record may have been an uncorrected data point (Pacific Loon was separated from Arctic Loon in the 1980s). To a great extent, however, the higher richness in 2008, when sampling effort was much greater than that in the historical data set, was to be expected because species-richness is sensitive to sampling effort (Magurran 1988).

Seasonal and spatial patterns in species-composition were similar between the historical data (Figure 22) and the 2008 data (Figure 16). In Klondike, larids were numerically dominant in late summer, tubenoses were dominant in early fall, and alcids were dominant in late fall. In Burger, larids were numerically dominant in late summer and late fall, whereas larids and alcids were most common in early fall. For Klondike, both data sets recorded the dominance of tubenoses in early fall and of alcids in late fall. For Burger, both data sets recorded the dominance of larids in late summer and late fall and the highest proportion of loons and phalaropes in early fall. Alcids were more common in Klondike than in Burger in late fall, and larids were more common in Burger than in Klondike in both early and late fall.

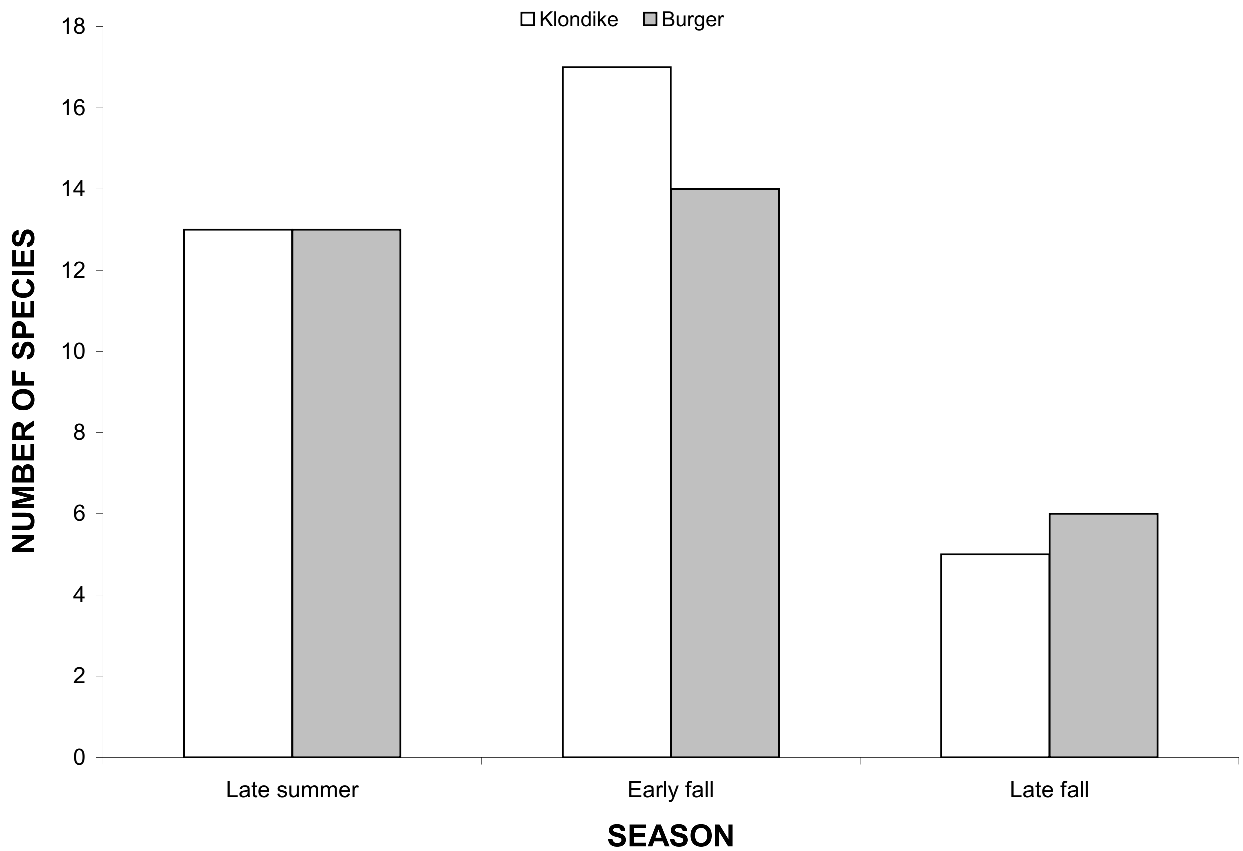


Figure 21. Species-richness of the seabird community on transect in the Klondike and Burger study areas and surrounding buffer zone in historical times, by study area and season. These data are from the North Pacific Pelagic Seabird Database (NPPSD; USGS 2005).

DISCUSSION

SPECIES DISTRIBUTION AND ABUNDANCE

Data collected in this first year of study suggest that the diversity of seabirds in the vicinity of the Klondike and Burger study areas is similar to that found in the central and southern Chukchi Sea (Divoky 1987, Piatt and Springer 2003). We recorded a total of 31 species of seabirds within the two study-area boxes during our sampling in 2008 and saw 2 other species off-transect. This seabird abundance is substantial at the peak of occupation in early fall (late August–late September) when total densities are estimated to be 71 birds/km^2 in Klondike and 73 birds/km^2 in Burger. These estimates are three times higher than historical estimates for the northern Chukchi Sea during a similar period (Divoky 1979). Densities in both study areas were considerably lower in late summer (2.6 birds/km^2) and late fall (8.5 birds/km^2) than in early fall.

We recorded 31 species of seabirds on transect within the two study-area boxes, but only 8 species dominated numerically and were common enough for us to estimate densities with some confidence: 2 tubenoses (Northern Fulmar, Short-tailed Shearwater), 1 loon (Pacific Loon), 2 larids (Black-legged Kittiwake, Glaucous Gull), and 3 alcids (Thick-billed Murre, Crested Auklet, Least Auklet). The other 23 species were rare and did not provide enough observations to fit species-specific detection functions to the data, resulting in less confidence in estimates of densities. The increased sample sizes of all species, particularly these rarer

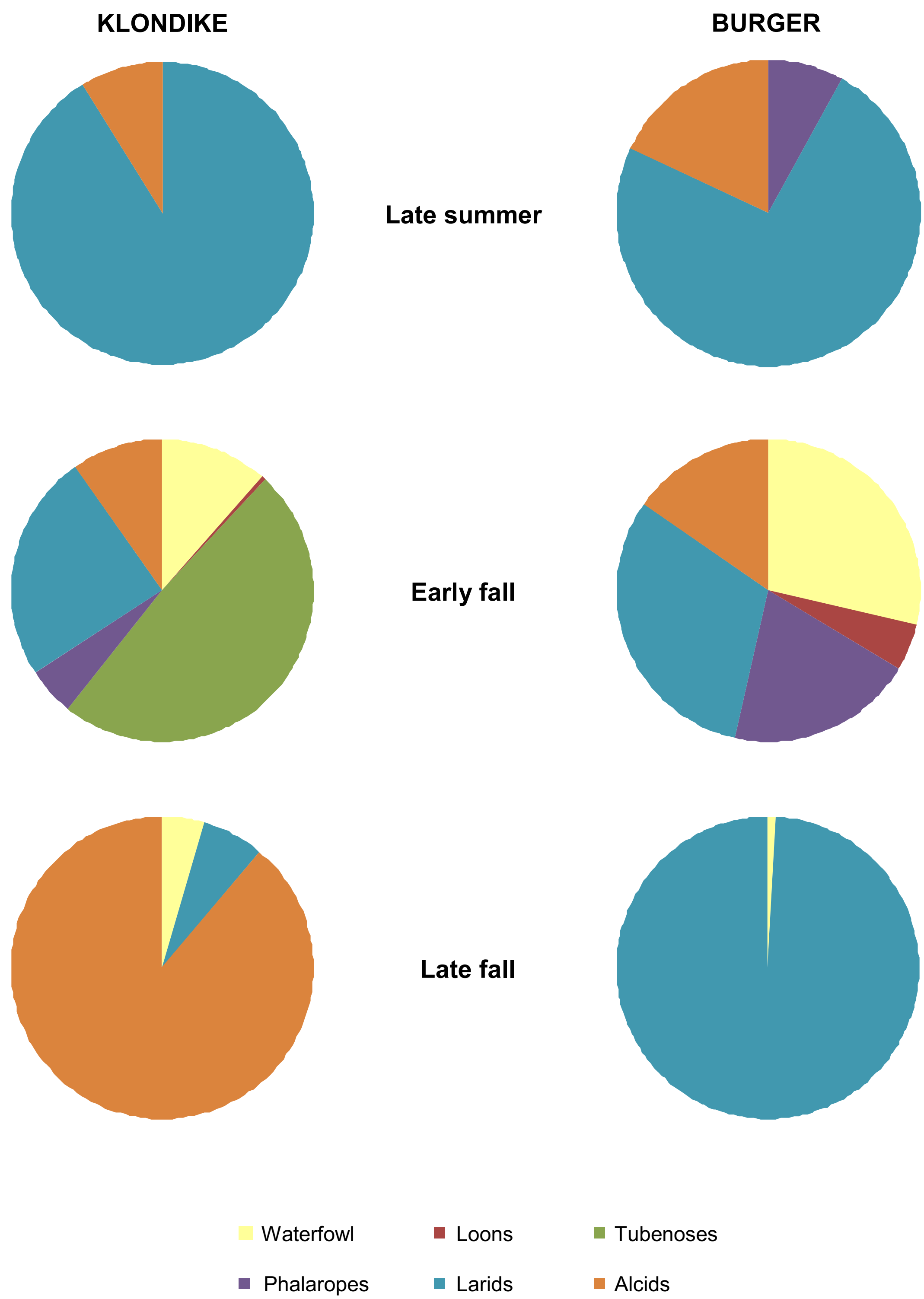


Figure 22. Species-composition of the seabird community on transect in the Klondike and Burger study areas and surrounding buffer zone in historical times, by study area and season. These data are from the North Pacific Pelagic Seabird Database (NPPSD; USGS 2005).

species, in future years of this program will improve the reliability of the density estimates.

This numerical dominance of the seabird community by just a few species resulted in simplified patterns of species-composition. In Klondike, alcids were either dominant or important components of the seabird community, with large numbers of tubenoses (especially Short-tailed Shearwaters) moving through the area in early fall and larids being either second or third in importance in all three seasons. In Burger, larids were dominant in most or all seasons, with tubenoses (again, Short-tailed Shearwaters) flooding the area in early fall and alcids generally being second or third in importance.

During these surveys, we recorded ten species of seabirds that are of conservation concern: four species of waterfowl (all seaducks), two species of loon, one species of tern, and three species of alcids. With the exception of Long-tailed Ducks, however, none of the species occurred in substantial numbers within the two study areas. Probably the highest-profile species are the Yellow-billed Loon and the Kittlitz's Murrelet, both of which are candidate species for listing under the Endangered Species Act. There is substantial concern about three other species (King Eider, Red-throated Loon, Pacific Loon), whereas the level of concern is lower for the other five species.

OCEANOGRAPHIC RELATIONSHIPS

We propose here that the structure of the seabird community differs between the two study areas and that these differences reflect what we believe are oceanographic differences between the two study areas. Diving alcids that forage on zooplankton (auklets, Dovekie) or pelagic fishes (murres, puffins) dominate in the Klondike area both historically (USGS 2005) and in the 2008 survey and generally are less common in the Burger area; other alcids that forage on both taxa, such as Kittlitz's Murrelet, also occur primarily or entirely in Klondike. In contrast, two main groups of birds are important in the Burger area: surface-feeding or near-surface-feeding larids (Black-legged Kittiwake, Glaucous Gull, Ross's Gull) and tubenoses (Northern Fulmar) and deep-diving epibenthic or demersal feeders such as seaducks and loons. The surface-feeding phalaropes search for microscale, often-ephemeral convergence zones and were found in both locations at various times, as were the near-surface-feeding Short-tailed Shearwaters, which forage on larger zooplankton such as euphausiids and are widespread across the entire northeastern Chukchi Sea in early fall.

These differences in the seabird community may be driven by differences in oceanography between the two study- areas. Although the exact placement of these two study areas was not intended to compare ecological systems, the Klondike study area appears to be more of a pelagically-dominated system and the Burger study area appears to be more of a benthically-dominated system, with the boundary between the two study areas appearing to fall somewhere between the two study areas or near the eastern edge of the Klondike study area. As seen on the vertical sections of temperature, salinity, and density, the edge of the current flowing north in the Central Channel (the Central Current) was visible along the western edge of the Klondike study area throughout the open-water season of 2008, and much of that study area was dominated by the edge of that current and its associated water mass (Bering Shelf Water). In contrast, the surface of Burger was a convergence zone with little movement and had water that was dominated by remnants of the pack ice that were melting in place.

The physical oceanography of this area is well documented in recent literature (Coachman et al. 1975, Weingartner et al. 2005, Woodgate et al. 2005, Grebmeier et al. 2006). In the Chukchi Sea, the net flow of water is northward through Bering Strait and toward the Arctic Ocean. The flow is contained within two main water-masses, with (1) an Alaska Coastal Current flowing northward in Alaska Coastal Water, a lower-salinity water-mass that lies near the Alaska coastline; and (2) a current farther offshore that moves Bering Shelf Water from the shelf-break and southern Bering Sea northward through Bering Strait. This movement of water influences the patterns of productivity throughout the Chukchi Sea, much of which has been summarized by Grebmeier et al. (2006). *In-situ* primary productivity in the northern Chukchi Sea generally is not very high (on the order of ~80 g C/m^2/yr), whereas productivity in the Bering Shelf Water that is transported from farther south may be on the order of ~470 g C/m^2/yr near Bering Strait (also see Sambrotto et al. 1984 and Hansell et al. 1989). This Bering Shelf Water also advects large oceanic zooplankton into the area from the oceanic Bering Sea (Grebmeier et al. 2006), and these large zooplankton can graze much of the phytoplankton when they are present. In contrast, shelf zooplankton associated with coastal waters are too small during most of the summer to graze much of the primary production, which falls to the bottom and nourishes a large and diverse benthic community (Feder et al. 1994a, 1994b; Grebmeier et al. 2006).

We suggest here that differences in oceanographic structure between the two study areas is a reasonable hypothesis to explain the spatial patterns that we saw in seabird distributions and abundance in 2008. Because seabirds depend exclusively on the marine environment for food, they are indicators of ecological differences at lower trophic levels as well. For example, larger oceanic zooplankton were common in the Klondike study area, whereas smaller shelf zooplankton were found in the Burger study area (R. Hopcroft, Institute of Marine Sciences, University of Alaska, Fairbanks, AK, pers. comm.). Similarly, a partial analysis of benthic samples suggests that the infaunal benthic community differed between the two study areas, with the Klondike study area having lower biomass and species-diversity than the Burger study area (A. Blanchard, Institute of Marine Sciences, University of Alaska, Fairbanks, AK, pers. comm.). The contaminants scientists working in this area in 2008 also found large numbers of epibenthic amphipods in Burger but few in Klondike, (J. Hardin, Battelle, Duxbury, MA, pers. comm.). Finally, the benthic-feeding marine mammals such as Pacific Walruses (*Odobenus rosmarus*) were more common in Burger than in Klondike, whereas pelagic-feeding seals were more common in Klondike (J. Brueggeman, Canyon Creek Consulting, Seattle, WA). All of this information suggests that these two study areas may be different ecologically and that the differences in the bird community reflect the influence of physical oceanography on trophic structure in the central Chukchi Sea.

COMPARISON WITH HISTORICAL DATA

We must begin our discussion about the comparisons of the 2008 data and historical (NPPSD) data with several caveats. First, the historical data set was collected over several years in the 1970s and 1980s, whereas the 2008 data were from only one recent year. As a result, we have no information on interannual variability in numbers and composition of the bird community in the recent data. Second, the historical data do not have good spatial overlap with our 2008 study-area boxes. As a result, we had to increase our comparison area by adding ~48-km (26-NM) buffer zones around the 2008 study areas to give us enough data for a minimal comparison. Third, survey design differed between the two data sets: some of the historical data were collected opportunistically during other oceanographic sampling, so few transects were replicated, whereas data from the 2008 surveys were collected during dedicated seabird surveys and along transects that were replicated among seasons. Finally, the sample size (number of transects) in the historical data set that met the spatial criteria for comparison was small (n = 320 transects), whereas the sample size in the 2008 data set was large (n = 2,690 transects).

Given these caveats, it nevertheless appears that patterns in the 2008 seasonal occurrence of many species and the general distribution of many species are similar to those seen in both the historical data and data presented in Divoky (1987). The latter report summarized several years of shipboard surveys in the Chukchi Sea by species or species-group and geographic area (our study areas were located in what he called the central Chukchi Sea), and his seasonal periods matched ours almost exactly. In 2008, most species showed distributional patterns similar to those seen in both historical data sets, and Divoky's (1987) data show that the same species showed peaks in abundance during the same seasons. The NPPSD data also show that species-composition and the timing of species occurrence in the area are similar to those seen in the 2008 data.

The areas of highest bird densities were located historically outside of the boundaries of the Klondike and Burger study areas (Divoky 1987, USGS 2005), near oceanographic features that may provide good foraging habitat (Piatt and Springer 2003). The highest densities in the vicinity of Klondike were recorded west of the study area and close to the main flow of the Central Channel than transects surveyed in 2008. The highest densities in the vicinity of Burger were recorded north of the study area along the edge of the advancing ice pack in late fall. Historical densities were lower on transects conducted within the boundaries of the Klondike and Burger study areas than those outside the boundaries. This spatial difference in historical densities is consistent with the hypothesis that currents and sea ice influence the distribution and abundance of seabirds in the northern Chukchi Sea.

After accounting for spatial and temporal overlap, it appears that the 2008 bird community had similar densities to those recoded historically (Divoky 1987, USGS 2005). Uncorrected densities within Klondike and Burger during late summer and early fall were 2.8–8.3 birds/km^2 in the historic data and 2.0–5.3 birds/km^2 in 2008. We caution that comparisons between the historic data and the 2008 data are imperfect, but suggest that if densities are similar in 2009, we will have more confidence that densities in the study areas have remained stable over time.

There are two ways in which we may be able to improve the strength of our comparisons to historical data. First, the NPPSD has additional data collected in the Chukchi Sea since the database was released to the public in 2005; we understand that a revision to the database will be released sometime in the next year (G. Drew, USGS, Anchorage, AK, pers. comm.). Another potential source of additional data is George Divoky, who has 3 or 4 years of at-sea data from this area that have not been contributed to the NPPSD yet, although he has agreed to provide his data to a future release of the database. It is not clear, however, whether any of the recent NPPSD data or the additional historical data of Divoky cover the exact areas examined in this study.

CONCLUSIONS

The two study areas in the northeastern Chukchi Sea collectively have a diverse seabird community of more than 30 species and, at times, overall densities of over 70 birds/km^2. Ten species of seabirds of conservation concern occur in this area, although only one (Long-tailed Duck) is common. There is extensive seasonal variation in the abundance of the seabirds in this area, with the greatest number of birds occurring in early fall (approximately 20 August to approximately 20 September), presumably reflecting a variety of factors that may include the melt of sea ice, seasonal changes in the oceanography of the area, bird migration, and nesting phenology and success of birds in the Arctic. There also is extensive spatial variation in the distribution and abundance of the seabirds in this area, with numbers of most (but not all) species generally higher in Klondike than in Burger. The structure of the seabird community differs between the two study areas. We hypothesize that these differences reflect oceanographic differences between the two study areas and speculate that the Klondike study area is characterized as more of a pelagically-dominated ecosystem and the Burger study area is characterized as more of a benthically-dominated ecosystem. Several other components of this integrated study also suggest a similar structuring of the ecosystem, and we believe that further years of study will elucidate this difference more clearly.

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