# DISTRIBUTION AND ABUNDANCE OF SEABIRDS IN THE NORTHEASTERN CHUKCHI SEA, 2008–2009

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ANCHORAGE, ALASKA

AND

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

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

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FINAL REPORT

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## EXECUTIVE SUMMARY

- In 2008 and 2009, we collected data on the distribution and abundance of seabirds in the northeastern 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 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) compare our results with historical data available in the North Pacific Pelagic Seabird Database (NPPSD).
- We conducted seabird surveys during three seasons that covered the entire open-water period of the northeastern Chukchi Sea: late summer (late July–mid August), early fall (late August–mid September), and late fall (late September–mid October).
- The surveys were conducted as line transects from the bridges of the M/V *Bluefin* in 2008 and the M/V *Westward Wind* in 2009.
- 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 ~56 km (30 NM) of each study-area box were used when making comparisons with historical data.
- In 2008, sampling effort was greater in Klondike than in Burger, especially during the late-summer cruise, because it generally had less ice cover than did Burger. In 2009, we did not encounter any ice in the study areas during the sampling period, and sampling effort was similar in both study areas.
- Seabirds were more abundant in the study areas in 2009 than they were in 2008, although we recorded fewer species in 2009. In 2008, we recorded 4,646 individuals of 31 species on transect within the 2 study areas combined; in 2009, we recorded 31,617 individuals of 24 species on transect within the 2 study areas combined.
- We had sufficient detections to generate reliable estimates of density for 8 focal species. Densities of each of the 8 focal species differed significantly among seasons, and these seasonal patterns differed between years. In 2008, seabirds were more abundant in the second half of the open-water period: 7 of the 8 focal species were more common in early or late fall than in late summer. In 2009, however, seabirds were more abundant in the first half of the open-water period: 6 of the 8 focal species were more common in late summer or early fall than in late fall.
- Alcids were the most abundant species group recorded in 2008 and the second-most abundant species group recorded in 2009. In 2008, densities of alcids were significantly higher in Klondike than in Burger during all three seasons, whereas, in 2009, densities were higher in Burger than in Klondike during late summer and early fall and higher on Klondike than on Burger in late fall.
- Tubenoses were the second-most-abundant species-group recorded during 2008 and the most abundant species-group recorded in 2009, primarily because of large flocks of Short-tailed Shearwaters moving through Klondike in early fall. The estimated density of Short-tailed Shearwaters in 2009 was nearly 40 times the density estimated in 2008.
- The total density of marine birds was considerably higher in 2009 than it was in 2008 and generally was higher in Klondike than in Burger in both years. We estimated total densities of 4 birds/km² in Klondike and 3 birds/km² in Burger in early fall 2008. In contrast, total densities in early fall 2009 were 81 birds/km² in Klondike and 46 birds/km² in Burger.
- In Klondike, alcids were the most abundant species-group in late summer and late fall of both years, whereas tubenoses were most abundant in early fall of both years. In Burger, larids were the most abundant species-group in late summer and late fall and second-most common in early fall 2008, whereas they were most abundant in Burger only in late fall of 2009. Alcids were the most common species

group in Burger in late summer and early fall 2009.

- 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.
- Spatial overlap between the NPPSD historical data set and the 2008–2009 data set was greatest in late summer and, to some extent, early fall, but no historical transects were conducted within ~9 km of either study area in late fall. Consequently, comparisons between the 2 data sets have been made with several caveats.
- Densities from the historical data collected within the study areas suggest that total densities of seabirds in Klondike and Burger were similar between the historical data and densities in 2008, whereas densities in 2009 were more than 6 times any historical values.
- Seasonal and spatial patterns in species-composition suggest that alcids and tubenoses are more abundant in the central Chukchi Sea now than they were historically.
- 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 with a higher biomass of copepods than seen in Burger. The Burger study area appears to be more of a benthically-dominated system with higher abundance, biomass, and number of benthic taxa than Klondike. Diving alcids and Short-tailed Shearwaters that forage on large oceanic copepods and euphausiids are more abundant in Klondike, whereas surface-feeding or near-surface-feeding larids that feed on zooplankton and fishes are more abundant in Burger.
- The distribution of seabirds, particularly the planktivorous species, may be influenced by the advective processes that transport oceanic species of zooplankton from the Bering Sea to the Chukchi Sea. This transport apparently differed between years and resulted in a broader northeastward intrusion of Bering Sea Water, higher abundance of large oceanic copepods and euphausiids, and wider distribution of planktivorous seabirds in both study areas, in 2009 than in 2008.

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## 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. Of the colonial seabirds, Thick-billed Murres (*Uria lomvia*), Common Murres (*U. aalge*), and Black-legged Kittiwakes (*Rissa tridactyla*) in particular nest in large numbers 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 the tundra, such as phalaropes and jaegers, move out to sea in early fall and join millions of migratory Short-tailed Shearwaters (*Puffinus tenuirostris*) 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*) migrate from high-arctic breeding areas in Russia and Canada into the Chukchi Sea as the ice advances southward in the late fall. As many as 5 million seabirds of at least 22 species may use the American waters of the Chukchi Sea during the 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 of five wells in 1989 and 1990. Two of these wells, known as Klondike and Burger, are located ~110–180 km (~60–100 NM) 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 Oceanographic and Atmospheric Administration's Outer Continental Shelf Environmental Assessment Program (OCSEAP), but there are few recent data on the distribution and abundance of seabirds in the areas proposed for development. This study was conducted to inform managers and industry about the distribution, abundance, and timing of seabirds using the northeastern Chukchi Sea. It forms one component of a multidisciplinary study of the marine ecology on this area.

## 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 [USFWS]), who built on earlier work begun on nesting seabirds by Swartz (1966) during the Cape Thompson environmental studies of the U.S. Atomic Energy Commission.

Another area of research has focused on use of the coastal-lagoon systems of the northeastern Chukchi Sea by birds. The earlier work by Johnson (1993) and Johnson et al. (1993) described baseline use of the Chukchi lagoon systems, 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 (ESA) of 1973, as amended (PL 93-205; 16 USC §1531), in the Chukchi Sea have indicated that shallow, nearshore waters of Ledyard Bay and Peard Bay form important stopover areas for migrating Spectacled and King (*Somateria spectabilis*) eiders in both the summer and fall (Balogh 1997, Oppel et al. 2009). In fact, the USFWS designated the nearshore waters of Ledyard Bay as critical habitat for Spectacled Eiders in 2001 (Federal Register 2001).

In comparison 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. 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) Watson and Divoky (1972), who studied seabirds in the eastern Chukchi Sea from a U.S. Coast Guard 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 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.

Studies conducted during the past five years are filling in some gaps in knowledge about the ecology of the northeastern Chukchi Sea. Recently, there has been ship-of-opportunity sampling of seabirds in the Chukchi Sea conducted primarily by the USFWS. These data have not been published yet, but they have been contributed to the North Pacific Pelagic Seabird Database (NPPSD), a publicly available information resource maintained by the U.S. Geological Survey, that is updated periodically. The current version of that database includes data from USFWS surveys as recent as October 2009. Other ongoing studies that are providing detail on the use of nearshore and offshore waters by birds include satellite telemetry studies of Spectacled Eiders (Sexson 2010); Long-tailed Ducks (*Clangula hyemalis*) and King Eiders (Dickson and Bowman 2008); and Red-throated (*Gavia stellata*) and Yellow-billed loons (*G. adamsii*; Rizzolo and Schmutz 2009). The present study conducted in 2008, 2009, and continuing in 2010 will provide information on the distribution and abundance of marine birds in the northeastern Chukchi Sea.

## STUDY OBJECTIVES

In this study, we explored the distribution and abundance of seabirds in the northeastern Chukchi Sea in 2 areas where ConocoPhillips Company, Shell Exploration & Production Company, and Statoil USA E & P have several lease-blocks for offshore oil 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) compare our results with historical data that are publicly available in the NPPSD. This study 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 in the vicinity of those lease areas. This information will be used for an analysis of potential impacts resulting from 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 ~110–180 km (~60–100 NM ) west of the village of Wainwright, which is located on the northwestern coast of Alaska. The overall survey area is bounded by 2 outflows from the Chukchi Sea to the Arctic Ocean: the Central Channel, to the west, and

Barrow Canyon, to the east (Weingartner et al. 2005, 2008). The survey area included 2 study areas called "Klondike" and "Burger" (Figure 1). The Klondike study area was located on the eastern side of the Central Channel and near the inflow of Bering Shelf water, whereas the Burger study area was located to the northeast of Klondike and on the southern slope of Hanna Shoal. The Alaska Coastal Current flows east of both study areas.

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 (Figure 1). The larger study-area box included a buffer zone around the proposed exploration area for marine mammals and provided spatial context for all of the scientific disciplines. These ~3,087-km$^2$ (900-NM$^2$) study-area boxes were the primary focus of all sampling. We surveyed along a series of parallel survey lines that ran north–south through these study-area 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, 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) and was sampled as time allowed, when the primary lines were obstructed by ice, or if nearby primary lines had been sampled under poor observation conditions. 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 and south of the basin of the Arctic Ocean. The primary inflow of nutrient-rich water comes from the south through Bering Strait and has 3 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 and 2009 may be seen in a series of vertical sections of CTD data collected during each of the 3 research cruises (Figures 2 and 3). These vertical sections show temperature (°C) and salinity (psu [practical salinity units]) 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. The physical oceanography of the 2 study areas is described in greater detail by Weingartner and Danielson (2010).

In 2008, the water structure of the 2 study areas was influenced by the presence of ice that lasted into August. On the late-summer cruise (24 July–18 August 2008), there was an apparent southwest-northeast division in the water masses. Water near the surface 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, which was cold and lower salinity meltwater from melting sea ice (Figure 2, top panel); however, the entire study area was underlain by extremely cold, high-salinity water that was a remnant of the winter ocean (winter water). The presence of warm, salty water indicates the edge of the Central Channel Current, which carries Bering Shelf Water (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 a more-complex temperature and salinity structure than in the late summer (Figure 2, middle panel). Warm water still was 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 meltwater, with the 2 areas separated by warmer and saltier filaments. At this time, the winter water under Klondike had been replaced nearly completely by Bering Shelf Water. On the late-fall cruise (20 September–12 October 2008), the hydrography was similar to the earlier cruises, with the front between the 2 water masses being very distinct and centered near the zone between the 2 study-area boxes (Figure 2, bottom panel). Warm, higher-salinity waters of the Central Channel Current remained over most of the Klondike study

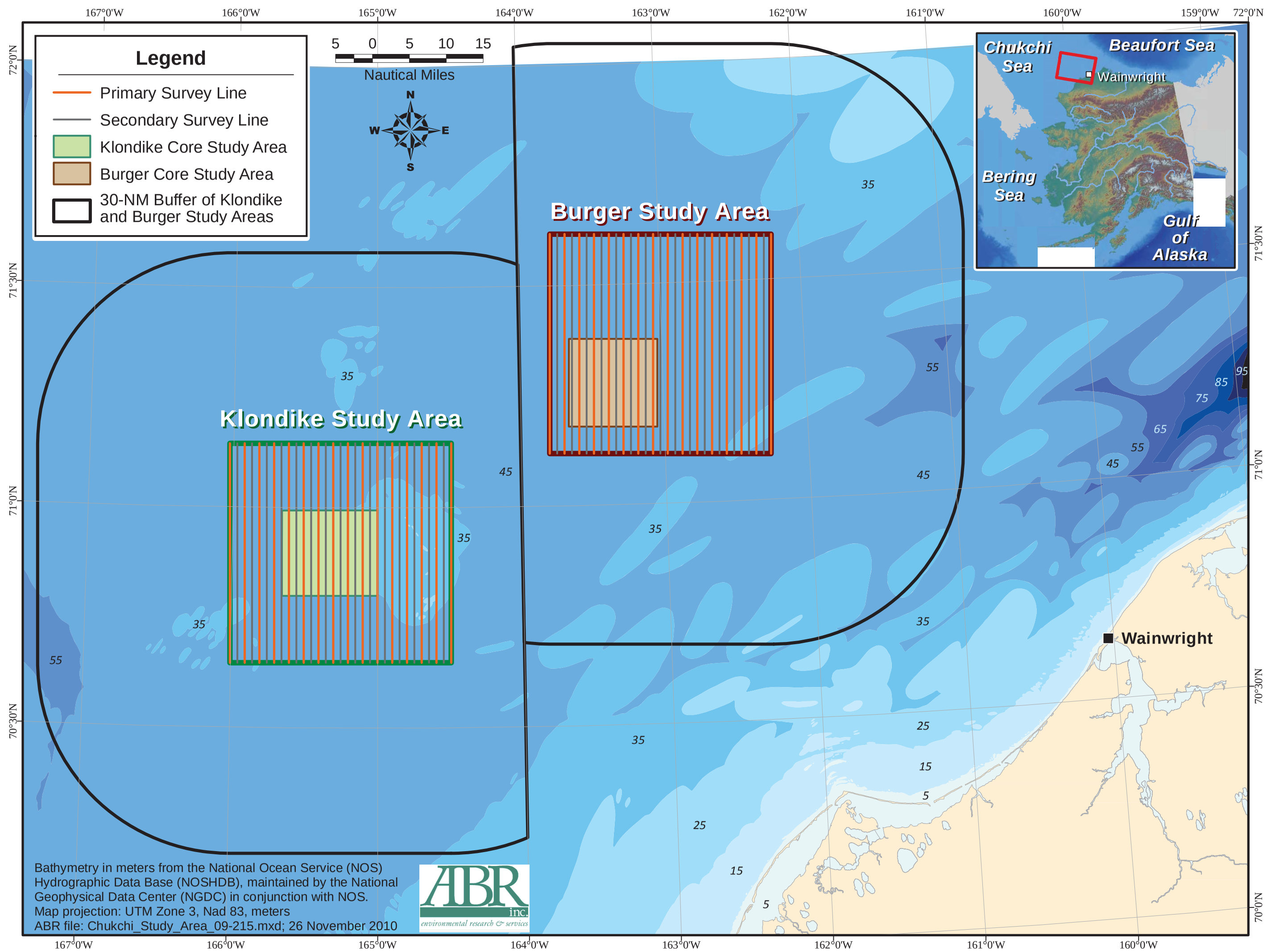



Figure 1. Locations of the Klondike and Burger study areas in the northeastern Chukchi Sea. Also shown are the locations of the survey lines and the 30-NM buffer zones used for examining the historical data.

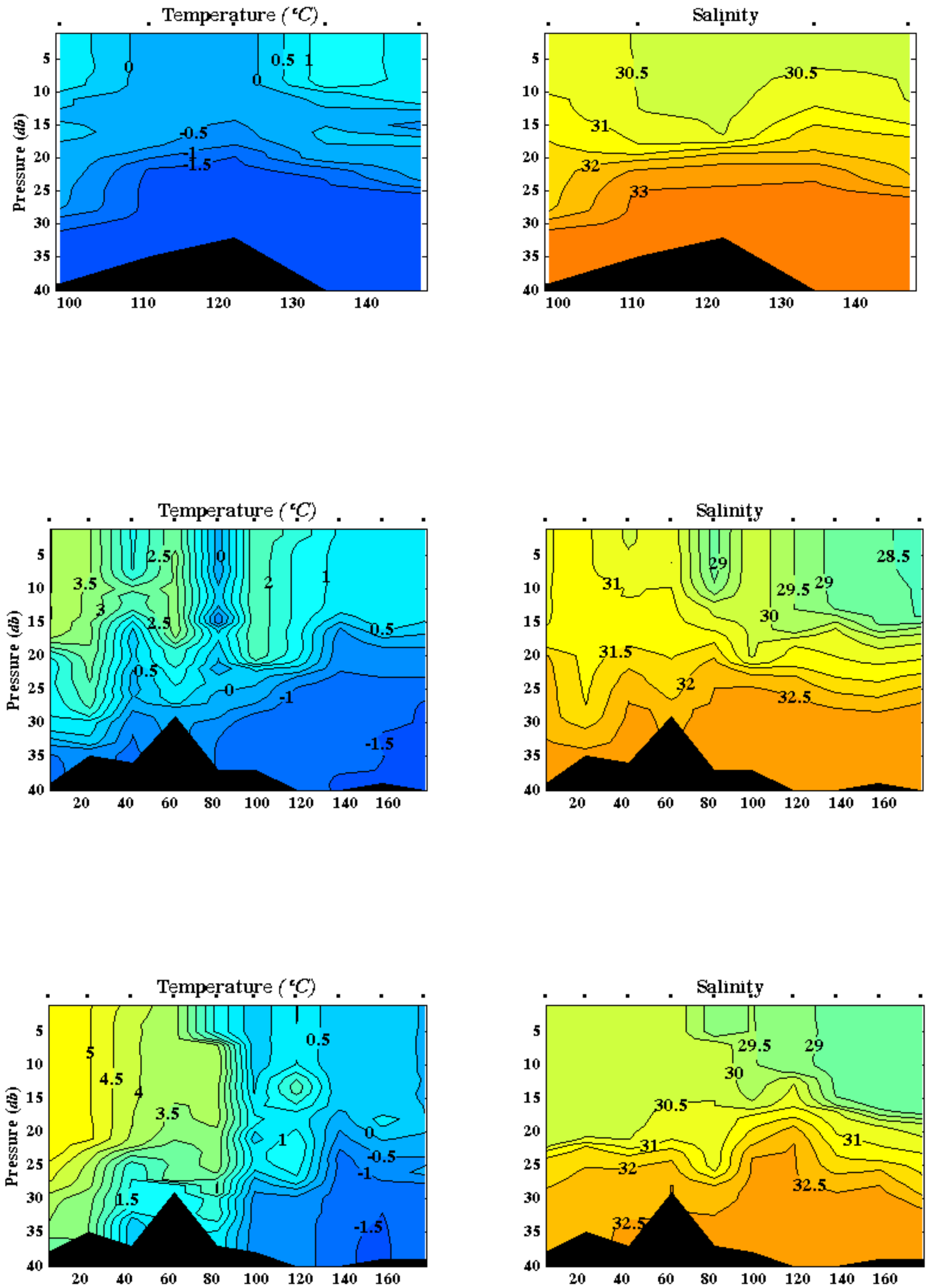



Figure 2. Vertical sections of temperature (°C), and salinity (psu) in the Klondike and Burger study areas, 2008 (Weingartner and Danielson 2010).

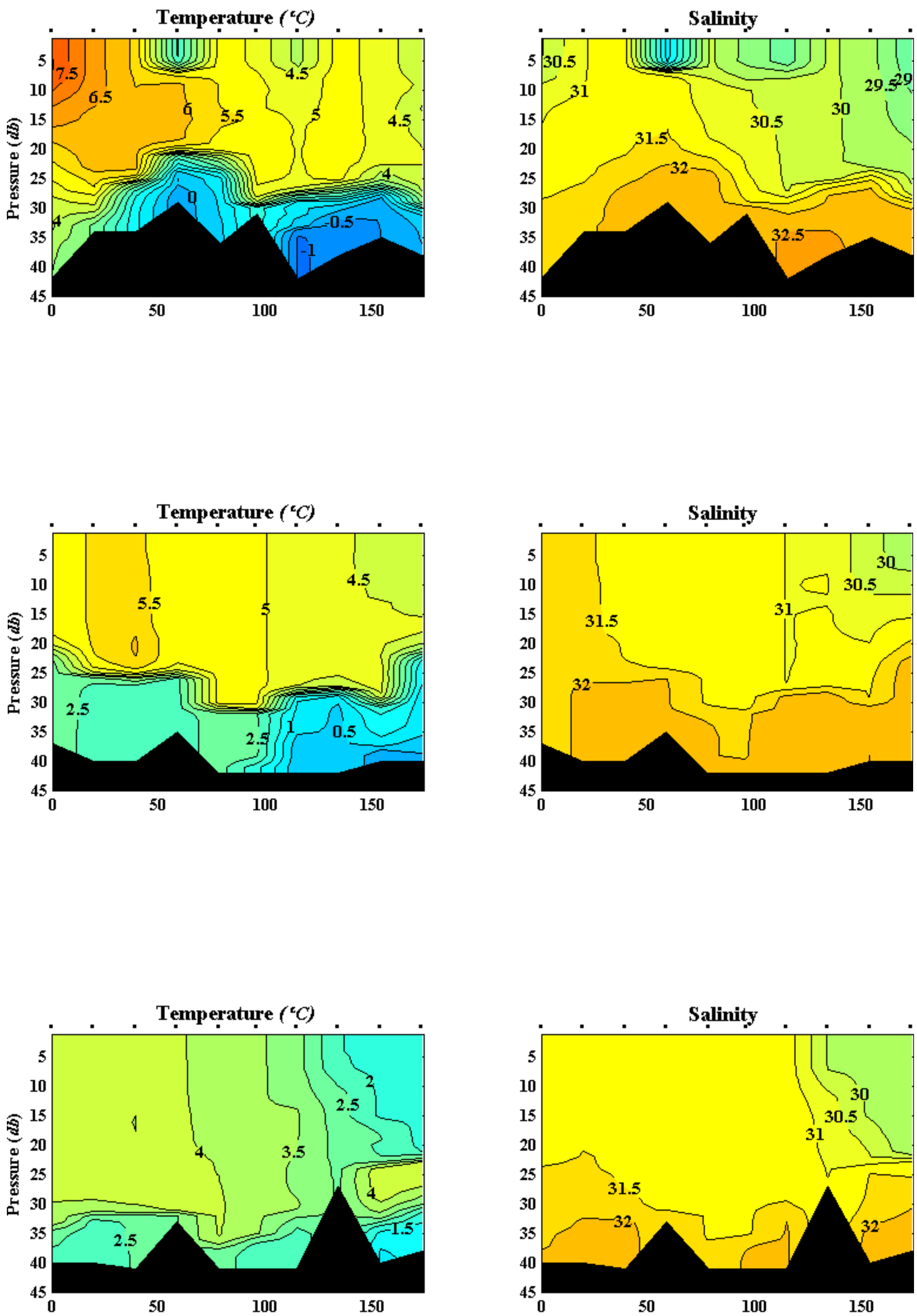



Figure 3. Vertical sections of temperature (°C) and salinity (psu) in the Klondike and Burger study areas, 2009 (Weingartner and Danielson 2010).

area (0 to ~60 km along the X-axis), whereas meltwater 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) and winter water occupied the lower layer.

In 2009, the study area was ice-free at the beginning of sampling in August, and the water structure was nearly homogenous throughout both study areas during the entire study period. On the late-summer cruise (14–29 August 2009), water in the western edge of the Klondike study area (0 to ~25 km along the X-axis) was warmer and more saline than water in the eastern half of Klondike and in Burger (Figure 3, top panel), although both study areas showed similar stratification. A cold, salty pool of winter water lay across the bottom of much of Klondike and all of Burger. On the early-fall cruise (5–19 September 2009), stratification was consistent across both study areas, with both the thermocline and halocline located 20–30 m below the surface (Figure 3, middle panel). By this time, the pool of cold, salty winter water at the bottom was present only in Burger. On the late-fall cruise (26 September–10 October 2009), the hydrography was homogenous throughout both study areas and showed little stratification: the water mass that covered all of Klondike and most of Burger was essentially uniform in temperature and salinity (Figure 3, bottom panel). A filament of cold, low-salinity meltwater remained at the surface in the northeastern corner of Burger (~150 km to 200 km along the X-axis), probably indicating the edge of a larger pool of meltwater over Hanna Shoal.

## 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 2008 and 12–29 August 2009), early fall (19 August–21 September 2008 and 4–19 September 2009), and late fall (22 September–12 October 2008 and 20 September–16 October 2009). These surveys were designed to quantify the distribution, abundance, and species composition of the seabird community within the 2 study areas.

The surveys were conducted 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, 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 conditions still were good (e.g., if seas were a Beaufort 6 [2–3 m or 6–10 ft] 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 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, 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. 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) in 2008 and TigerObserver software (TigerSoft, Las Vegas, NV) in 2009; these programs time-stamped and geo-referenced every observation entered in real time. In 2008, the primary GPS connected to the data-collection computer lost communication with satellites on three occasions (a total of 74 min during 2 days), 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 the ship's position with the time stamp of the observations. In 2009, we patched the few gaps in the location record (a total of 42 min during 2 days) by interpolating the ship's location in GIS from the start and end waypoints of the gap in the ship's track.

## DATA ANALYSIS

The analyses of densities, species-richness, and species-composition used data collected only within the boundaries of the 2 study-area boxes (Figure 1). Because the historical data set covered a much larger area, we included data collected opportunistically within ~55 km (30 NM) of each study area to increase our sampling area (Figure 1) when making comparisons with the 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 line-transect sampling analyses available in the program DISTANCE 6.0 Release 2 (Thomas et al. 2010a, 2010b) 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, for each year, 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.

Of the 31 species recorded during surveys in 2008 and 24 species recorded during surveys in 2009, only 8 were common enough (i.e., there were ≥ 80 observations) in both years to fit detection functions for each one with confidence. We assigned each of the remaining species to a detection group that included one of the 8 focal species based on its similarity in size, color, and/or behavior. We analyzed data for each year separately because the observation platforms (i.e., ship) and the visibility from each of the observation platforms differed between years. For each detection group, we fitted 2 models that used one 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. We selected the model with the lowest Akaike Information Criterion (AIC) to be the one that best fit the data. The exceptions were Short-tailed Shearwaters and Glaucous Gulls in 2008, when the detections for both of these species were strongly 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.). The fit of each model was assessed with diagnostic plots and a Kolmogorov–Smirnov goodness-of-fit test (following Buckland et al. 2004). 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).

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 focused on statistical analyses of trends in seasonal and spatial abundance of the 8 focal species, which had the most reliable estimates of density.

We used ANOVAs in SPSS (2009) to examine differences between study areas, among seasons, and between years for each species. The models included the additive effects of study area and season and interactions between these main effects. Based on results from the first year of the study (Gall and Day 2009) and an initial exploration of the 2009 data, we analyzed each year separately to simplify the interpretation of interactions among the main effects. 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 all birds combined and for individual species of interest.

### COMMUNITY ANALYSES

We summarized species-richness and species-composition of all birds by study area, season, and year 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 aggregated individual species into 6 taxonomic species-groups. These 6 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 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 and are stored in the NPPSD (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 methods (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 2 study areas and extracted all transects that occurred either in each study-area box or a ~55-km (30-NM) buffer around it (Figure 1) to increase the sample sizes 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 and 2009 data as uncorrected densities (total birds/km$^2$). We also compared historical species-richness and species-composition in each study area with the 2008–2009 data.

## RESULTS

Within the 2 study areas, we sampled a total of 6,037 km (3,260 NM) of transects during 449 h of observation in 2008 and 5,133 km (2,772 NM) during 424 h of observation in 2009. In 2008, sampling effort was greater in Klondike (846–1,329 km/cruise [457–717 NM/cruise]) than in Burger (716–1,071 km/cruise [387–578 NM/cruise]), especially during the late-summer cruise, because it generally had less ice cover than Burger did. In 2009, we did not encounter any ice in the study areas during the sampling period, and sampling effort was similar in both study areas, with 833–855 km (450–460 NM) surveyed within each study area/cruise.

### PATTERNS OF ABUNDANCE AND DISTRIBUTION

Seabirds were more abundant in the study areas in 2009 than they were in 2008, although we recorded fewer species in 2009. In 2008, we recorded a total of 4,646 individuals of 31 species during surveys within the 2 study areas combined; we also recorded 2 other species only off-transect (Table 1). In 2009, we recorded a total of 31,617 individuals of 24 species on transect within the 2 study areas combined; no other species were seen only off-transect. Species that we saw only in 2008 included King Eider, Common Eider, Red-throated Loon, Parasitic Jaeger, Ivory Gull, Pigeon Guillemot, Black Guillemot, and Dovekie. The species that we saw only in 2009 was Long-tailed Jaeger, although we did record that species off-transect in 2008.

Of the 23 species seen in both 2008 and 2009, we had sufficient detections to generate reliable estimates of density for 8 of them (Tables 2 and 3). Densities of each of the 8 focal species differed significantly among seasons ($P < 0.001$ for all models), but these seasonal patterns differed between years. In 2008, seabird densities were higher in the second half of the open-water period: 7 of the 8 focal species were more common in early or late fall than in late summer (Table 2). Only densities of Thick-billed Murres were higher in late summer than in early or late fall. In 2009, however, seabirds generally were more abundant in the earlier part of the open-water period: 4 of the 8 focal species were more common in late summer than in early or late fall. Densities of Northern Fulmars were highest in late summer; densities of Crested Auklets were higher in late summer and early fall than in late fall; and densities of Pacific Loons, Short-tailed Shearwaters, Black-legged Kittiwakes, and Thick-billed Murres were highest in early fall (Table 3). In contrast, Least Auklets showed no significant seasonal variation in abundance in 2009 (Table 3). Only densities of Glaucous Gulls were higher in early and late fall than they were in late summer (Table 3), similar to the pattern seen in 2008 (Table 2).

Densities of the 8 focal species differed significantly between study areas, and the pattern of differences varied among seasons. In 2008, densities of Northern Fulmars, Short-tailed Shearwaters, Glaucous Gulls, Thick-billed Murres, Crested Auklets, and Least Auklets were higher in Klondike in all seasons, whereas densities of Black-legged Kittiwakes and Pacific Loons were higher in Burger in early fall and in Klondike in late fall (Figures 4 and 5). In 2009, densities of Crested Auklets and Least Auklets were higher in Burger in late summer and early fall and higher in Klondike in late fall, densities of Pacific Loons and Glaucous Gulls were higher in Burger than Klondike in early fall, and densities of Short-tailed Shearwaters were higher in Klondike than in Burger in early fall (Figures 4 and 5). Densities of Black-legged Kittiwakes were not significantly different between study areas in early fall but were higher in Klondike than in Burger during late fall (Figure 5). Only densities of Northern Fulmars were similar between study areas in all three seasons of 2009.

## ALCIDS

Alcids were the most abundant species-group in 2008 and 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 late fall but higher in Burger than in Klondike during the late summer and early fall (Figure 4, Tables 2 and 3). Of the 11 species of alcids recorded on transect within the study areas, Crested Auklets, Least Auklets, and Thick-billed Murres were abundant enough for us to generate estimates of density after accounting for detection probability.

Crested Auklets were the most abundant species recorded in 2008 and were the second-most-abundant species recorded in 2009 (Figure 4, Tables 2 and 3). The maximal density in 2009 was nearly 7 times the maximal density estimated in 2008. Densities differed significantly among seasons and between study areas in both years ($P < 0.001$ for STUDY AREA*SEASON), in that these birds were more abundant in Klondike than in Burger in 2008 but more abundant in Burger than in Klondike in 2009. In 2008, densities were low in both study areas in late summer and early fall and highest in late fall, especially in Klondike. In 2009, the seasonal pattern of abundance differed significantly between the 2 study areas. Densities in Klondike were low in late summer, highest in early fall, and intermediate in late fall, whereas densities in Burger were highest in late summer and early fall and declined in late fall. The only spatial pattern of distribution consistent in both years was the abundance of Crested Auklets in Klondike and their near-absence from Burger in the late fall (Figures 6 and

Table 1. Species of seabirds identified during boat-based surveys in the northeastern Chukchi Sea, by study area and season. Species identified on-transect within the study area are designated as “X8” and/or “X9,” for 2008 and 2009, respectively. Species identified only off-transect in a given year are designated as “OT8” and “OT9”, for 2008 and 2009, respectively. Species seen only on-transect and only within the 30-NM buffer zone (used in the historical comparisons) are designated as “B8” and “B9”, for 2008 and 2009, 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 | Late summer | Early fall | Late fall | Late summer | Early fall | Late fall |
| WATERFOWL | | | | | | |
| Spectacled Eider | | X9 | | | OT9 | |
| King Eider | X8 | – | X8 | – | X8 | X8 |
| Common Eider | – | – | – | – | X8 | – |
| White-winged Scoter | – | – | OT8 | – | – | X8 |
| Long-tailed Duck | X8 | X9, H | X8, X9, H | B9 | X8, X9, H | X8, B9, H |
| LOONS | | | | | | |
| Red-throated Loon | – | – | – | – | X8 | – |
| Pacific Loon | – | X8, X9 | X8, X9 | – | X8, X9 | X8, X9 |
| Arctic Loon | – | – | – | – | H | – |
| Common Loon | – | H | – | – | H | – |
| Yellow-billed Loon | – | X8, X9 | X8, X9 | – | X8, X9 | OT9 |
| TUBENOSES | | | | | | |
| Northern Fulmar | X8, X9 | X8, X9, H | X8, X9 | X8, X9 | X8, X9 | X8, X9 |
| Short-tailed Shearwater | X8, X9 | X8, X9, H | X8, X9 | X9 | X8, X9 | X8, X9 |
| PHALAROPES | | | | | | |
| Red-necked Phalarope | X9 | X8, X9 | X8, X9 | X9 | X8, X9 | X9 |
| Red Phalarope | X8, X9 | X8, H | X8, X9 | X9 | X8, X9, H | X9 |
| LARIDS | | | | | | |
| Black-legged Kittiwake | X8, X9, H | X8, X9, H | X8, X9, H | X8, X9, H | X8, X9, H | X8, X9, H |
| Ivory Gull | – | – | – | H | H | X8, H |
| Sabine's Gull | X8, OT9, H | X8, X9, H | X8, X9 | X8, OT9, H | OT8 | X9 |

Table 1. Continued.

| | Study area/season | | | | | |
|---|---|---|---|---|---|---|
| | Klondike | | | Burger | | |
| Species-group/species | Late summer | Early fall | Late fall | Late summer | Early fall | Late fall |
| LARIDS (cont'd.) | | | | | | |
| Ross's Gull | – | – | – | H | OT9, H | X8, X9, H |
| Herring Gull | X8 | X9, H | X8 | X9 | X9 | X8 |
| Glaucous-winged Gull | OT8 | – | – | – | – | – |
| Glaucous Gull | X8, H | X8, X9, H | X8, X9 | X8, X9, H | X8, X9, H | X8, X9, H |
| Arctic Tern | H | X8 | – | X9, B8 | OT8, X9 | – |
| Pomarine Jaeger | X8, X9, H | X8, X9, H | X8, X9 | X8, X9, H | X8, X9 | – |
| Long-tailed Jaeger | X9, H | OT8, H | – | X9, H | OT8, H | – |
| Parasitic Jaeger | X8, H | X8, H | – | X8, H | B8, H | H |
| ALCIDS | | | | | | |
| Dovekie | X8 | – | X8 | – | H | X8 |
| Common Murre | X8, H | X9 | X8, X9 | H | X9 | X9 |
| Thick-billed Murre | X8, X9, H | X8, X9, H | X8, X9, H | X8, X9, H | X9, B8 | X8, X9 |
| Black Guillemot | X8, H | H | – | X8, H | B8, H | X8 |
| Pigeon Guillemot | X8 | – | – | X8 | – | – |
| Kittlitz's Murrelet | H | X9 | X8 | – | B9 | X9 |
| Parakeet Auklet | – | X8, X9, H | – | – | H | X8 |
| Least Auklet | X8, X9 | X8, X9, H | X8, X9, H | X9 | X8, X9 | X8, X9 |
| Crested Auklet | X8, X9 | X8, X9, H | X8, X9, H | X9 | X8, X9, H | X8, X9 |
| Horned Puffin | X8, X9, H | X9 | – | X8, OT9 | – | – |
| Tufted Puffin | X8, X9, H | – | X8 | – | – | – |

Table 2. Estimated corrected densities (birds/km$^2$) of the 8 focal 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 (<0.1–<0.1) | 0.1 (0.1–0.2) | 0.0 (0) | 0.1 (0.1–0.3) | <0.1 (<0.1–<0.1) |
| TUBENOSES | | | | | | |
| Northern Fulmar | 0.3 (0.2–0.4) | 0.6 (0.5–0.8) | 0.3 (0.2–0.4) | <0.1 (<0.1–0.1) | 0.1 (<0.1–0.1) | 0.1 (<0.1–0.1) |
| Short–tailed Shearwater | 0.0 (0) | 1.0 (0.6–1.7) | 1.5 (0.7–3.2) | 0.0 (0) | 0.8 (0.5–1.5) | 0.3 (0.2–0.6) |
| LARIDS | | | | | | |
| Black–legged Kittiwake | 0.5 (0.3–0.7) | 0.2 (0.2–0.4) | 0.9 (0.6–1.2) | 0.1 (0.1–0.2) | 0.8 (0.6–1.0) | 0.1 (0.1–0.3) |
| Glaucous Gull | <0.1 (<0.1–0.1) | 0.1 (<0.1–0.1) | 0.5 (0.3–0.6) | <0.1 (<0.1–0.1) | 0.2 (0.1–0.3) | 0.1 (0.1–0.2) |
| ALCIDS | | | | | | |
| Thick–billed Murre | 0.8 (0.6–1.0) | 0.1 (<0.1 –0.1) | <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 (<0.1–0.1) | 0.9 (0.6–1.3) | 0.5 (0.3–1.0) | 0.0 (0) | <0.1 (<0.1–<0.1) | <0.1 (<0.1–0.1) |
| Crested Auklet | 0.6 (0.3–1.6) | 0.5 (0.3–0.8) | 5.5 (4.1–7.3) | 0.0 (0) | <0.1 (<0.1–<0.1) | 0.2 (0.1–0.4) |

Table 3. Estimated corrected densities (birds/km$^2$) of the 8 focal species of seabirds counted during boat-based marine surveys in the central Chukchi Sea, by study area and season, 2009. 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 (0.1–0.2) | 0.1 (0.1–0.3) | 0.0 (0) | 1.1 (0.8–1.5) | <0.1 (<0.1–<0.1) |
| TUBENOSES | | | | | | |
| Northern Fulmar | 0.9 (0.6–1.3) | 0.4 (0.3–0.6) | 0.1 (<0.1–0.1) | 1.2 (0.8–1.8) | 0.2 (0.2–0.4) | 0.2 (0.1–0.3) |
| Short–tailed Shearwater | 0.1 (0.1–0.2) | 54.5 (36.6–81.0) | 1.6 (0.9–2.9) | 1.3 (0.4–3.8) | 1.7 (1.3–2.2) | 0.3 (0.2–0.5) |
| LARIDS | | | | | | |
| Black–legged Kittiwake | 0.1 (<0.1–0.1) | 2.0 (1.5–2.9) | 0.8 (0.5–1.1) | 0.1 (0.1–0.3) | 2.0 (1.5–2.6) | 0.2 (0.1–0.3) |
| Glaucous Gull | 0.0 (0) | 0.1 (0.1–0.3) | 0.3 (0.2–0.4) | <0.1 (<0.1–0.1) | 0.4 (0.3–0.5) | 0.3 (0.2–0.5) |
| ALCIDS | | | | | | |
| Thick–billed Murre | 0.3 (0.2–0.5) | 1.6 (1.3–2.1) | 0.1 (<0.1–0.2) | 0.1 (0.1–0.1) | 0.1 (<0.1–0.4) | 0.1 (<0.1–0.2) |
| Least Auklet | 0.6 (0.4–0.9) | 0.8 (0.6–1.2) | 2.3 (1.7–3.0) | 1.7 (1.1–2.7) | 1.1 (0.9–1.5) | 0.4 (0.2–0.6) |
| Crested Auklet | 3.0 (2.2–4.2) | 21.0 (18.0–24.4) | 10.8 (8.6–13.6) | 34.5 (29.2–40.8) | 37.7 (29.1–48.7) | 0.1 (0.1–0.2) |

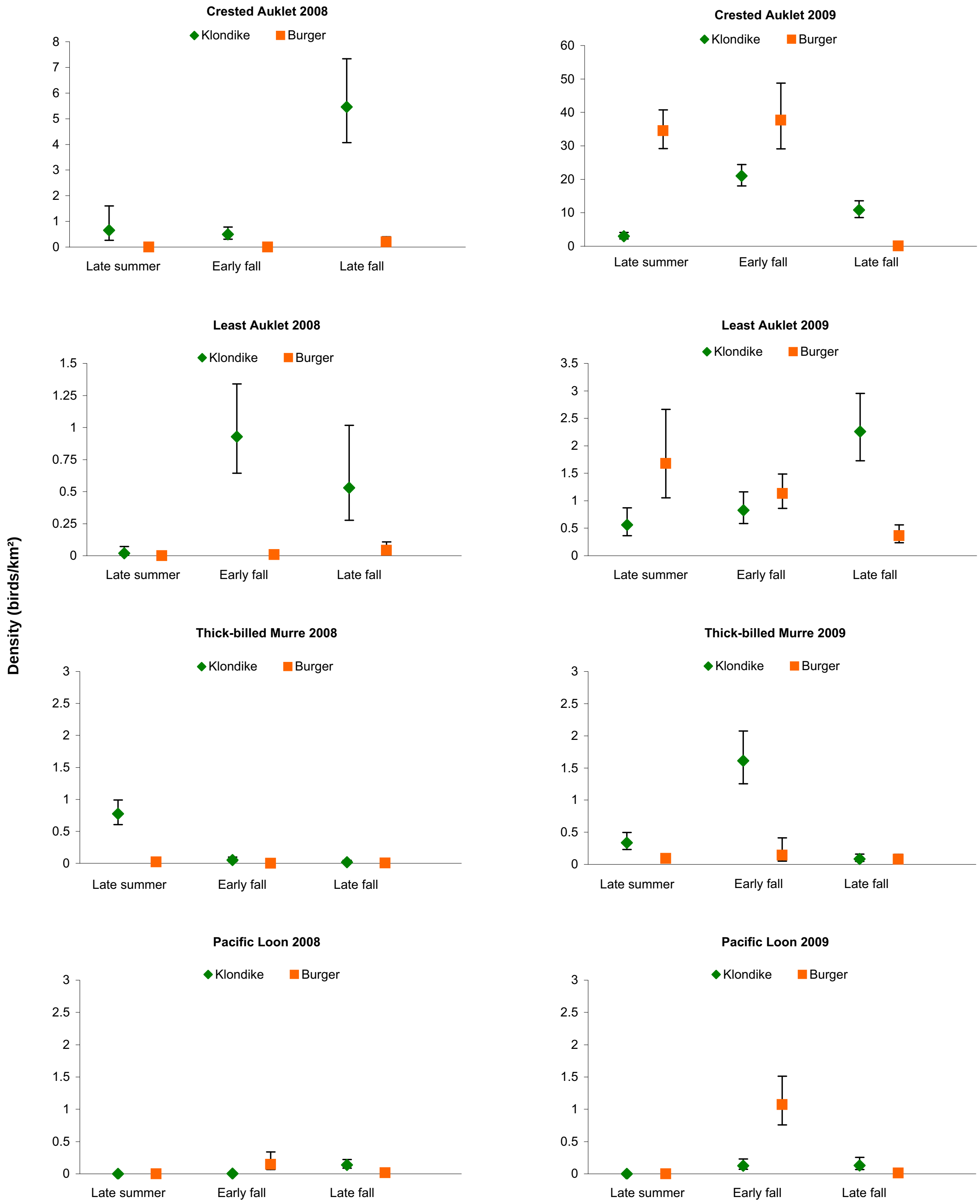



Figure 4. Mean corrected density (birds/km$^2$) of Crested Auklets, Least Auklets, Thick-billed Murres, and Pacific Loons on transect in the Klondike and Burger study areas in 2008–2009, by study area and season. Error bars represent 95% confidence intervals.

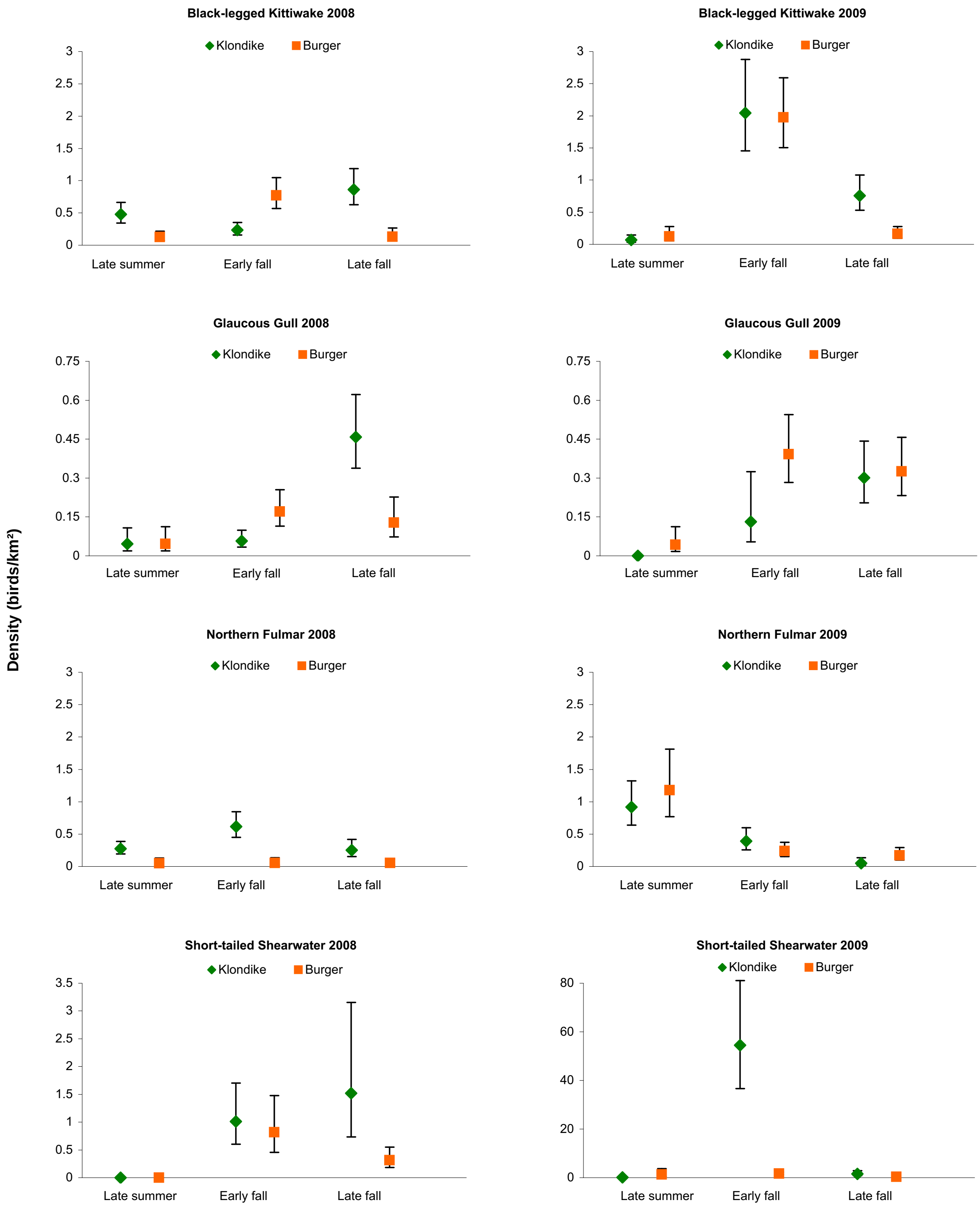
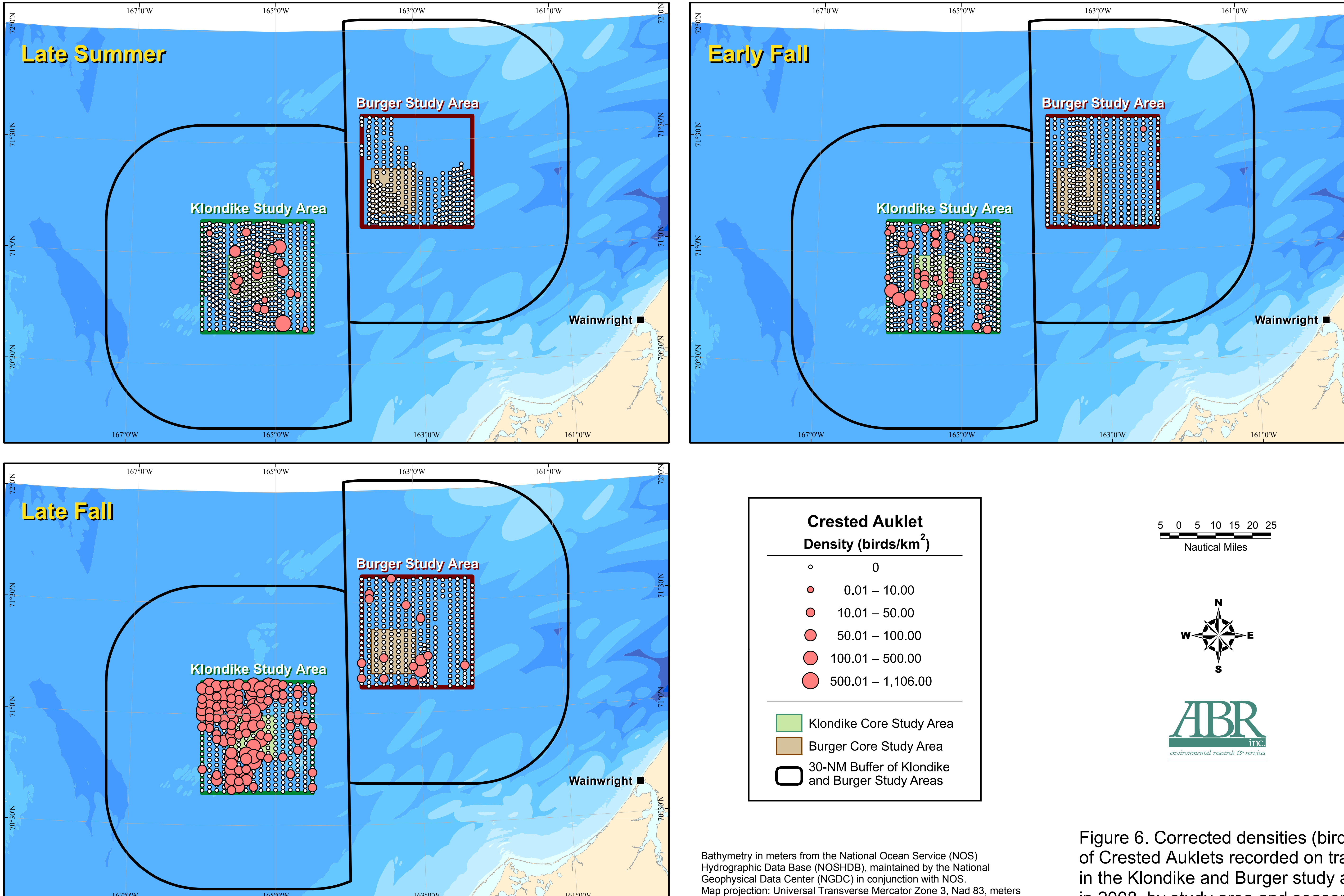
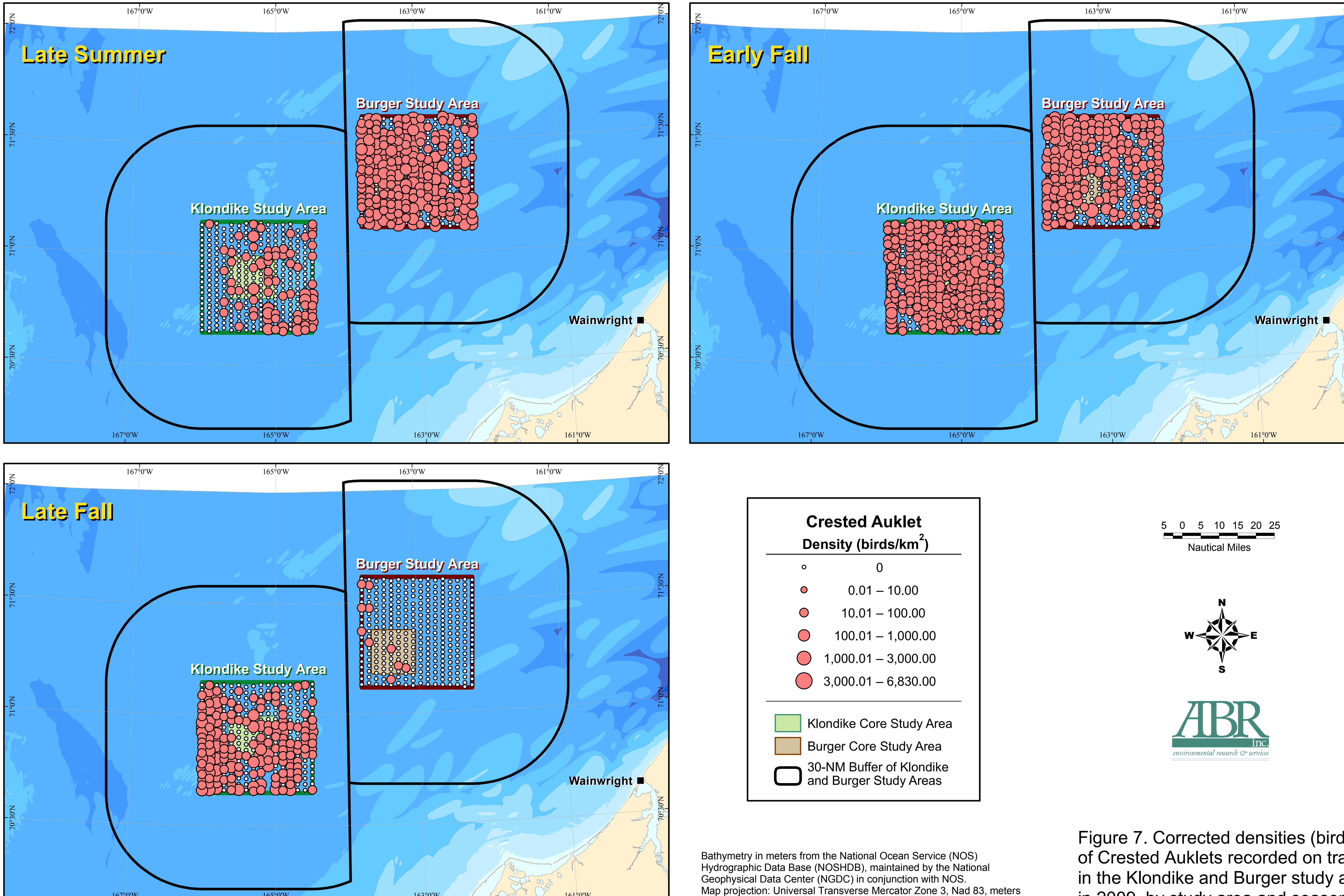



Figure 5. Mean corrected density (birds/km$^2$) of Short-tailed Shearwaters, Northern Fulmars, Black-legged Kittiwakes, and Glaucous Gulls on transect in the Klondike and Burger study areas in 2008–2009, by study area and season. Error bars represent 95% confidence intervals.



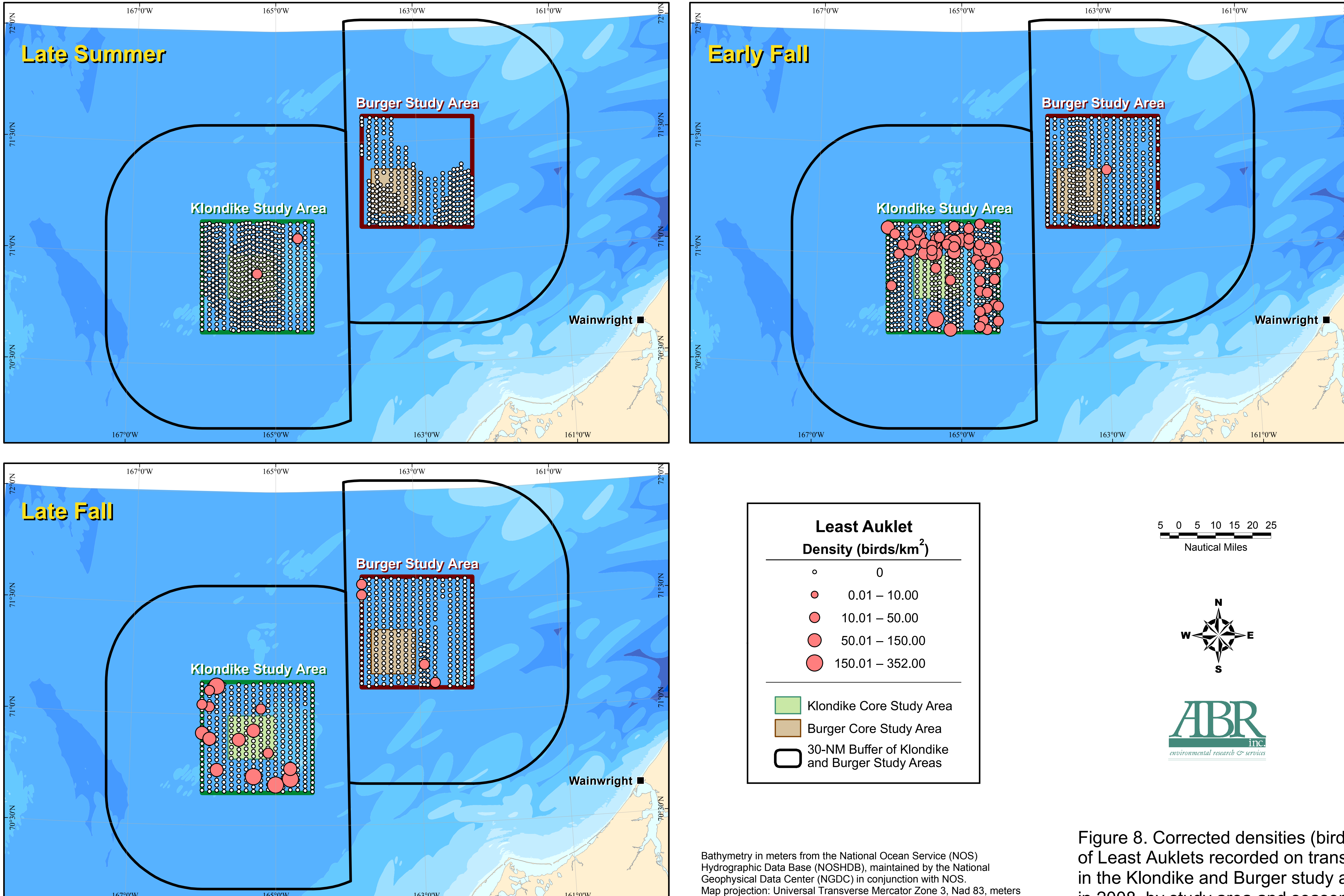

Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CRAU_2008_09-215.mxd; 8 November 2010

Figure 6. Corrected densities (birds/km$^2$) of Crested Auklets recorded on transect in the Klondike and Burger study areas in 2008, by study area and season.



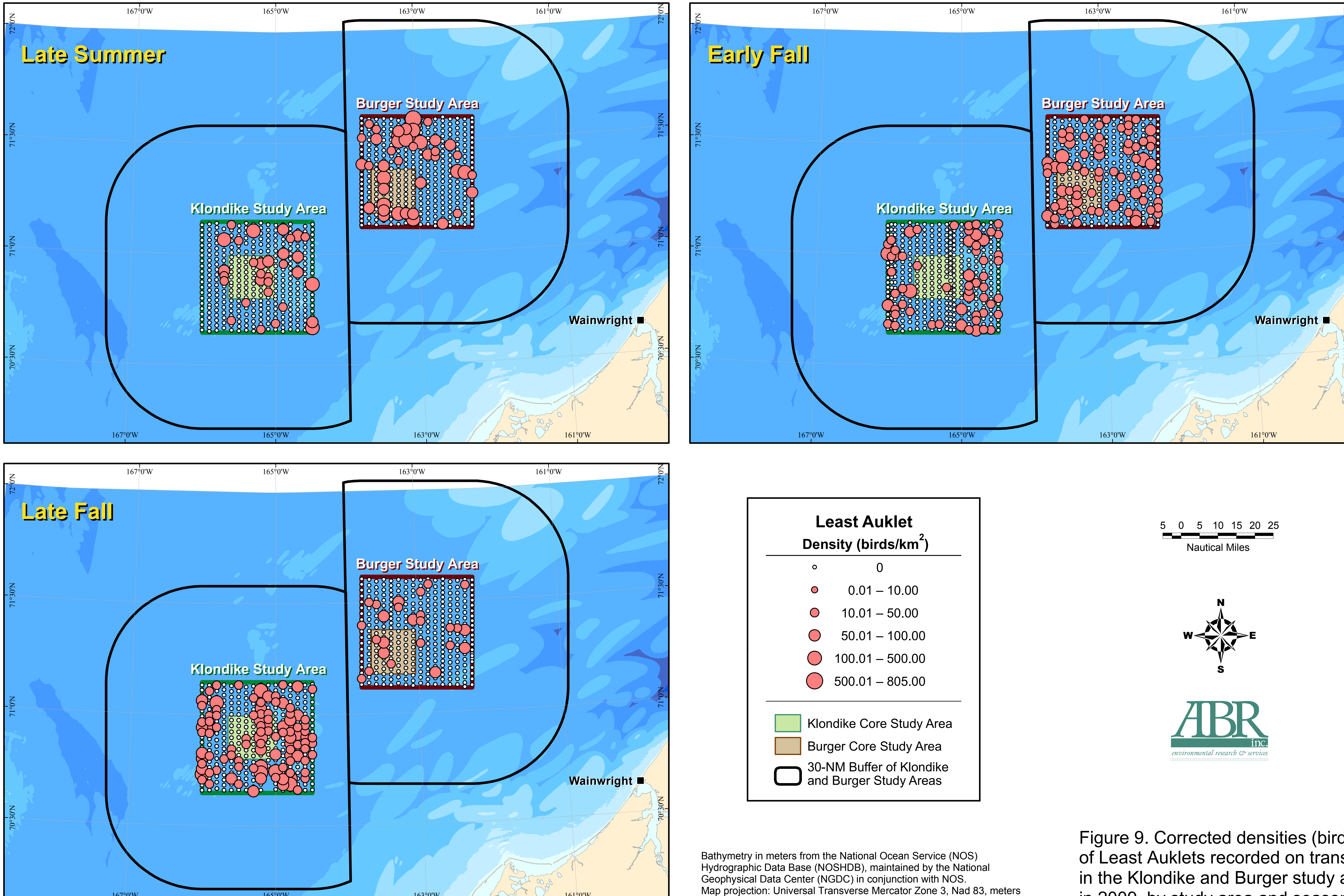

Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_CRAU_2009_09-215.mxd; 8 November 2010

Figure 7. Corrected densities (birds/km$^2$) of Crested Auklets recorded on transect in the Klondike and Burger study areas in 2009, by study area and season.



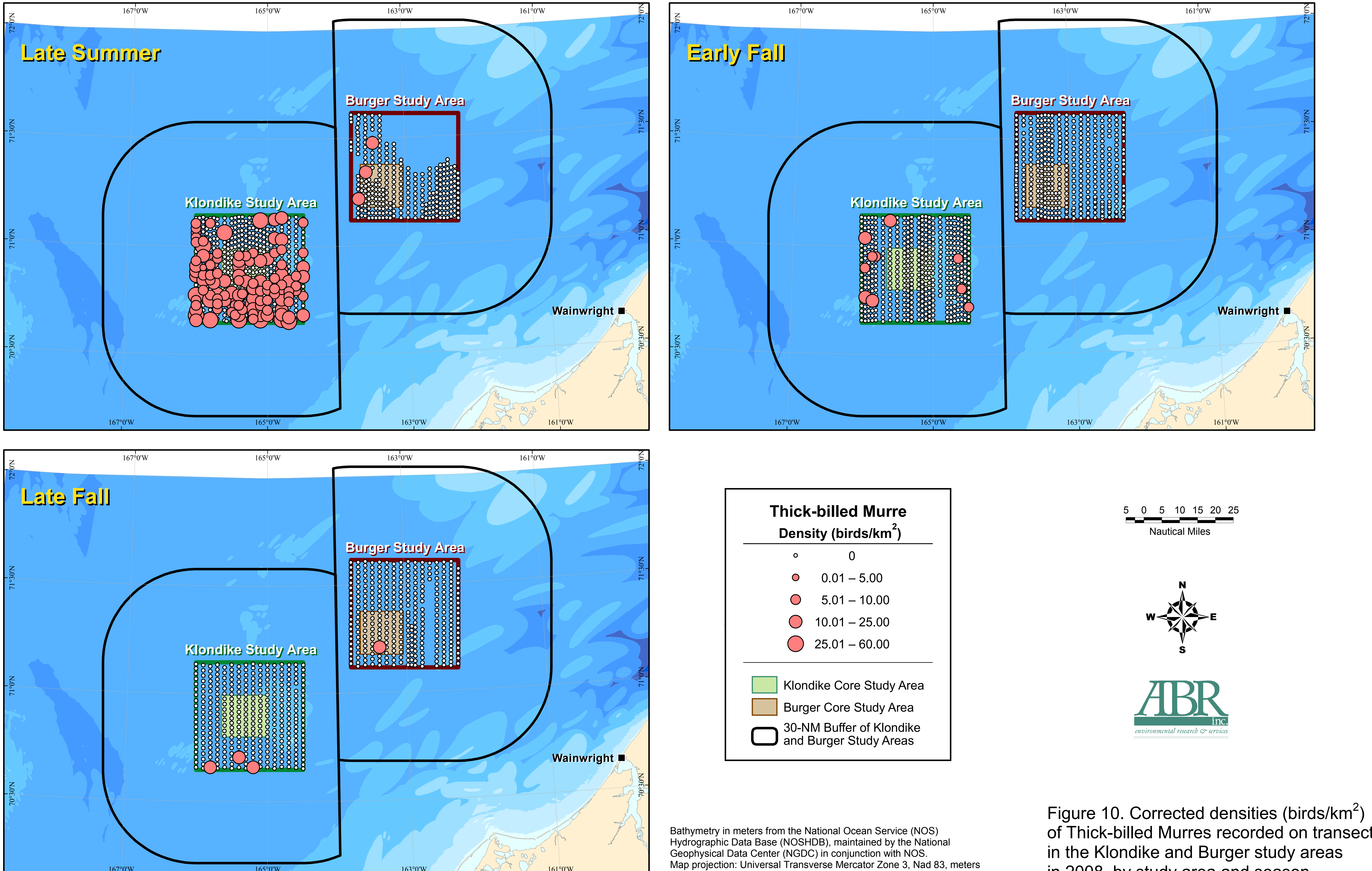

Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_LEAU_2008_09-215.mxd; 8 November 2010

Figure 8. Corrected densities (birds/km$^2$) of Least Auklets recorded on transect in the Klondike and Burger study areas in 2008, by study area and season.



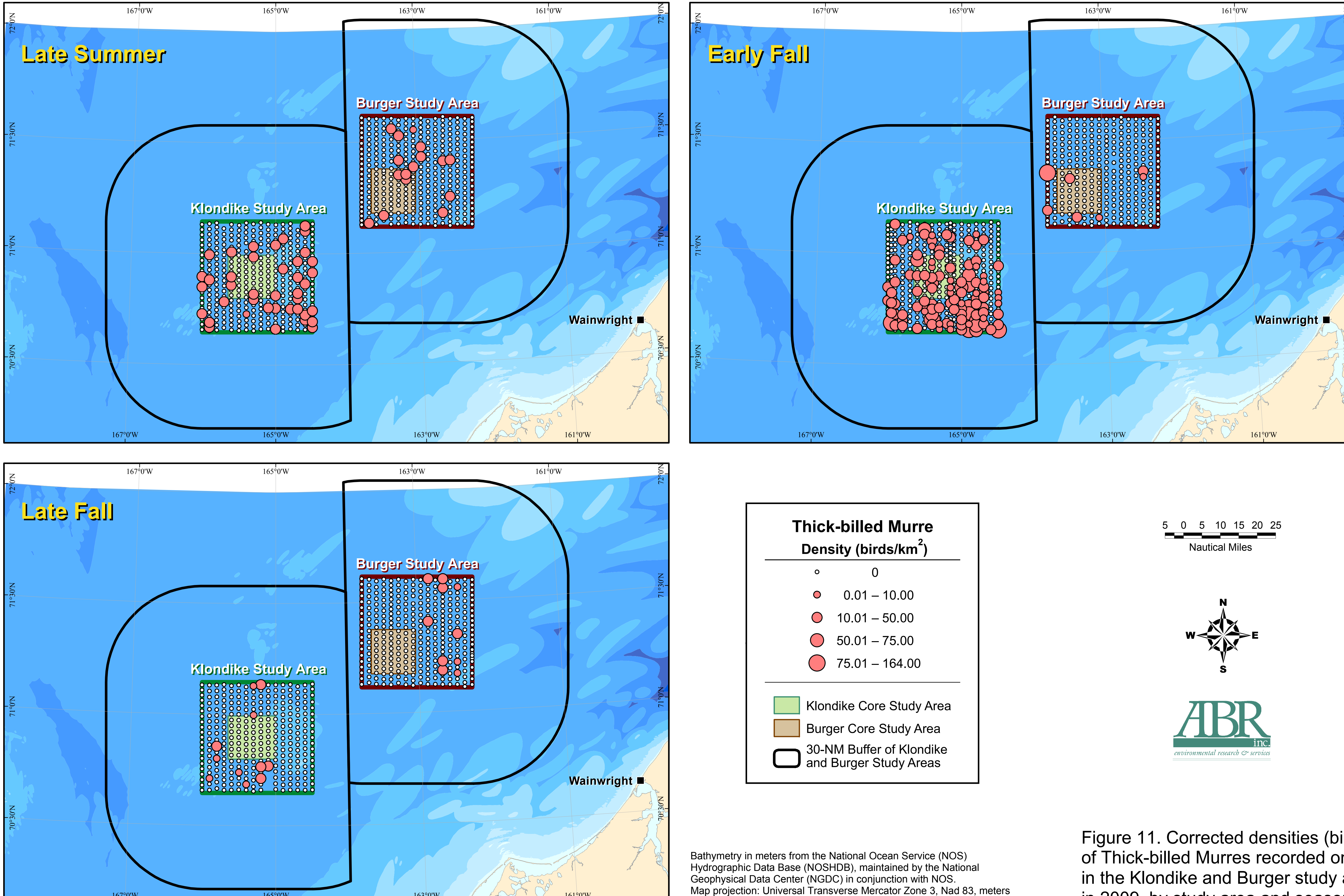

Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_LEAU_2009_09-215.mxd; 8 November 2010

Figure 9. Corrected densities (birds/km$^2$) of Least Auklets recorded on transect in the Klondike and Burger study areas in 2009, 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_TBMU_2008_09-215.mxd; 8 November 2010

Figure 10. Corrected densities (birds/km$^2$) 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_TBMU_2009_09-215.mxd; 9 November 2010

Figure 11. Corrected densities (birds/km$^2$) of Thick-billed Murres recorded on transect in the Klondike and Burger study areas in 2009, by study area and season.

7). There was no apparent spatial pattern of distribution within Klondike or Burger in 2008. Patterns in 2009 indicated that Crested Auklets were concentrated primarily in eastern Klondike in late summer and throughout Klondike in early and late fall, whereas they were distributed throughout Burger in both late summer and early fall.

Least Auklet densities differed significantly among seasons and between study areas in both years ($P < 0.001$ for STUDY AREA*SEASON). Densities of Least Auklets were higher in Klondike than in Burger in all 3 seasons of 2008 and in late fall 2009, higher in Burger than in Klondike in late summer 2009, and similar between study areas in early fall 2009 (Figure 4, Tables 2 and 3). In both years, the seasonal pattern of abundance differed substantially between the 2 study areas. In 2008, densities of Least Auklets in Klondike were lowest in late summer, highest in early fall, and intermediate in late fall, whereas densities in Burger were zero in late summer and low in both early and late fall. In 2009, densities of Least Auklets in Klondike increased from late summer to late fall, whereas densities in Burger decreased from late summer to late fall. Spatial patterns of distribution were most apparent in 2008, with birds concentrating in the northeastern half of Klondike in early fall and in the southwestern half in late fall (Figure 8). In 2009, there was a shift in overall distribution from Burger in late summer to Klondike in late fall, whereas there was no apparent spatial pattern of distribution within either study area (Figure 9).

Thick-billed Murre densities differed significantly among seasons and between study areas in both years ($P < 0.001$ for STUDY AREA*SEASON). In both years, densities of Thick-billed Murres were higher in Klondike than in Burger in late summer and early fall and were extremely low, but similar, in both study areas in late fall (Figure 4, Tables 2 and 3). In 2008, densities of Thick-billed Murres in Klondike were low in early and late fall and highest in late summer, whereas densities in Burger were extremely low in all three seasons. In 2009, densities of Thick-billed Murres in Klondike were low in late fall, high in early fall, and intermediate in late summer, whereas densities in Burger again were extremely low in all three seasons. There was a weak spatial pattern of distribution suggesting lower densities in the northernmost part of Klondike in 2008, whereas the few observations in Burger occurred in the western half of the study area (Figure 10). There was no apparent spatial pattern of distribution within either study area in 2009 (Figure 11).

Of the other 8 species of alcids recorded, Common Murres were the most abundant, occurring primarily in Klondike during late summer and late fall in 2008 and in both Klondike and Burger during early and late fall in 2009 (Appendices B and C). Parakeet Auklets were seen in Klondike in early fall of both years and in Burger in late fall 2008. In both years, Tufted Puffins and Horned Puffins were seen primarily in Klondike in late summer. Kittlitz's Murrelets were rare in both years and were recorded in Klondike in late fall 2008 (we believe that the 5 unidentified murrelets were of this species) and early fall 2009 and in Burger in late fall 2009 (Appendices B and C). Black Guillemots, Pigeon Guillemots, and Dovekies also were seen in both Klondike and Burger, but only in low numbers and only in 2008 (Appendix A).

### TUBENOSES

Tubenoses were the second-most-abundant species-group in 2008 and the most abundant group in 2009, primarily because of large flocks of Short-tailed Shearwaters moving through Klondike in early fall (Figure 5). This species-group represents 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 Chukchi Sea and visit the study area during the open-water season.

Short-tailed Shearwaters were the second-most-abundant species in 2008 and were the most abundant species in 2009. The maximal density in 2009 was nearly 40 times the maximal density in 2008 (Figure 5, Tables 2 and 3; note that the scale on the Y-axis in 2009 is much larger than the scale on the Y-axis in 2008). Short-tailed Shearwaters occurred in both study areas in early and late fall in 2008 and in both study areas and in all 3 seasons in 2009; however, they were more abundant in Klondike than in Burger in both years. Densities differed significantly among seasons and between study areas in 2008 (*P* < 0.001 for SEASON and *P* = 0.019 for STUDY AREA) and in 2009 (*P* < 0.001 for SEASON*STUDY AREA). In 2008, densities were lowest in late summer and high in early and late fall, when they are preparing to move from summer feeding areas back to breeding areas in the Southern Hemisphere. In 2009, densities were low at all times except for a large pulse of birds in Klondike in early fall. The distribution of Short-tailed Shearwaters tended to be clumped in both years. In 2008, they were abundant in both study areas at times but tended to occur in the northeastern half of Klondike and the southwestern half of Burger when they were present (Figure 12). In 2009, Short-tailed Shearwaters clumped on the western halves of both Klondike and Burger in late summer and late fall and were abundant throughout both study areas in early fall (Figure 13).

Northern Fulmars were widespread, occurring in both study areas and in all three seasons during both years; their seasonal patterns of density did not differ significantly between the 2 study areas (*P* = 0.071 for STUDY AREA*SEASON in 2008 and *P* = 0.666 for STUDY AREA*SEASON in 2009). Northern Fulmars were significantly more abundant in Klondike than in Burger in 2008 (*P* = 0.002 for STUDY AREA), whereas there was no difference in abundance between the 2 study areas in 2009 (*P* = 0.597 for STUDY AREA; Figure 5, Tables 2 and 3). The seasonal abundance of Northern Fulmars differed between years, in that they were most abundant in early fall in 2008 and in late summer in 2009. Northern Fulmars were distributed across the entire Klondike study area in both years (Figures 14 and 15) and across the entire Burger study area in 2009, whereas they tended to occur primarily in the western half of Burger in 2008.

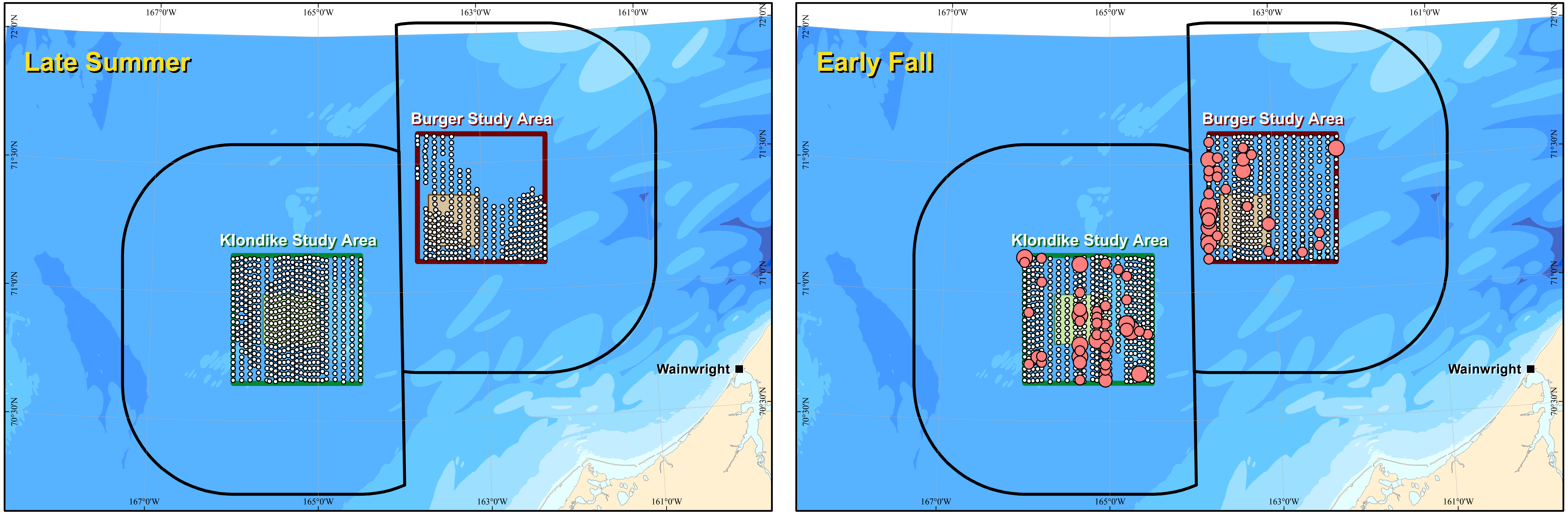
## LARIDS

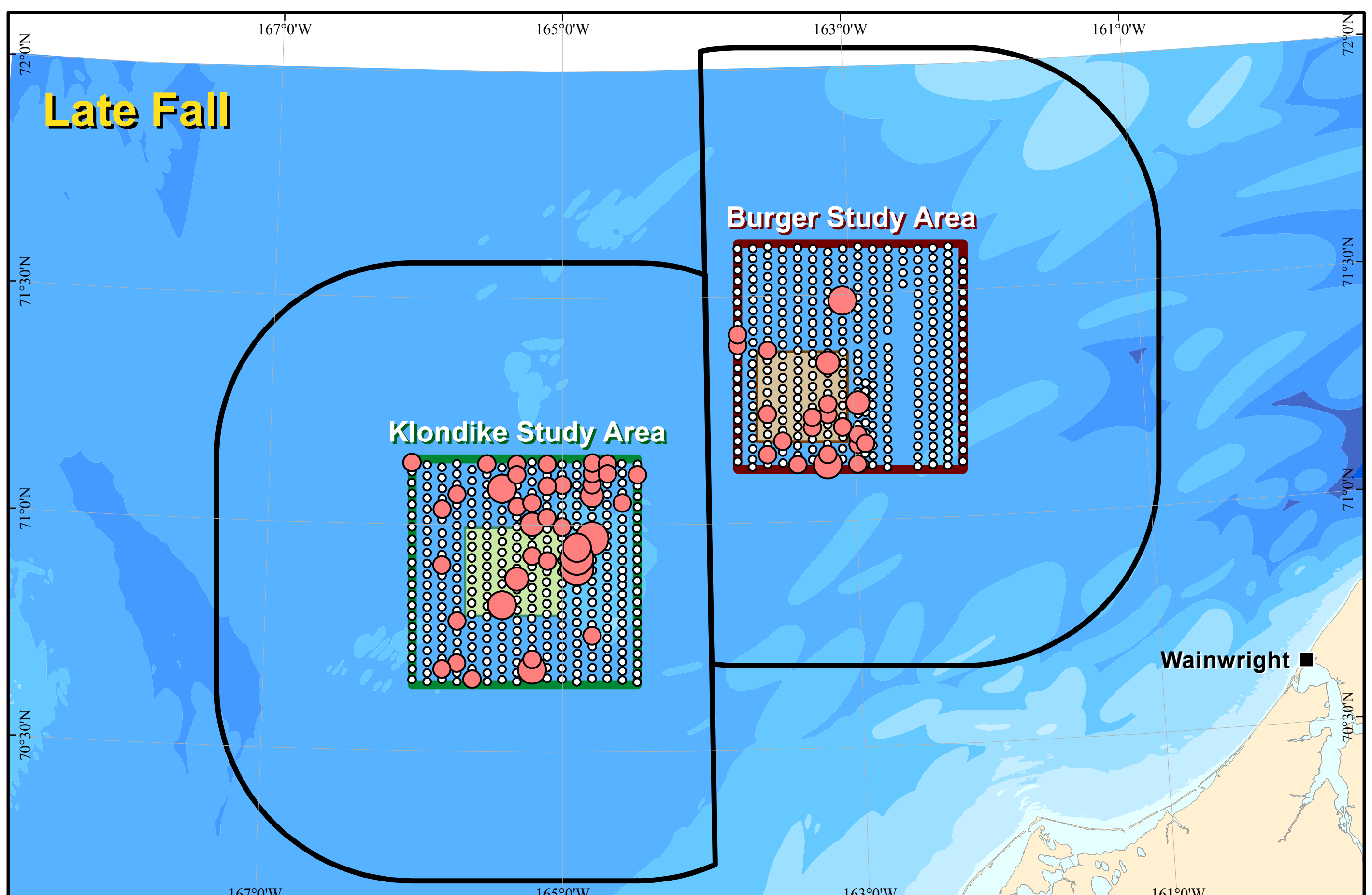
Larids, or gulls and gull-like birds, were the third-most-abundant species group recorded during surveys. This group included gulls, terns, and jaegers. Of the 11 species of larids recorded on transect, only Black-legged Kittiwakes and Glaucous Gulls were had enough detections for us to generate estimates of density after accounting for detection probability.

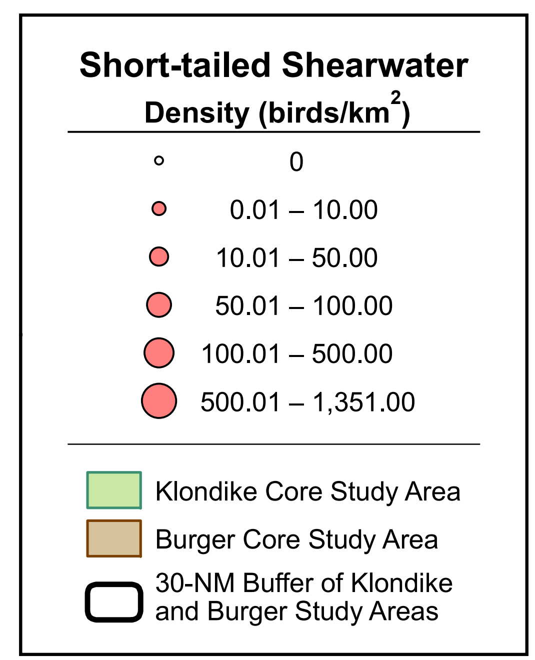
Black-legged Kittiwakes were widespread, occurring in both study areas and in all three seasons during both years (Figure 5, Tables 2 and 3). Densities of Black-legged Kittiwakes differed significantly among seasons and between study areas in both years (*P* < 0.001 for STUDY AREA*SEASON). Seasonal patterns differed more strongly between study areas in 2008, when densities were higher in Klondike in late summer and late fall but higher in Burger in early fall. In contrast, densities in 2009 were low and similar in late summer, highest and similar in early fall, and lower overall but higher on Klondike in late fall. There was little evidence of a spatial pattern in the distribution of Black-legged Kittiwakes within the study areas in any season or either year (Figures 16 and 17).

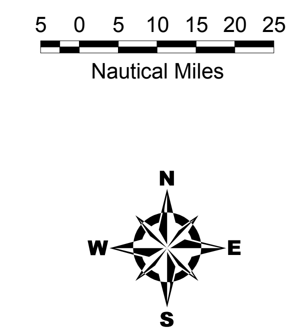
Glaucous Gulls also were widespread, occurring in both study areas and in all three seasons except for Klondike in late summer 2009 (Figure 5, Tables 2 and 3). Densities of Glaucous Gulls also differed significantly among seasons and between study areas in both years (*P* ≤ 0.01 for STUDY AREA*SEASON). In both years, densities of Glaucous Gulls in Klondike increased consistently from late summer to late fall, whereas they increased in Burger from late summer to early fall and declined in late fall. There were few strong spatial patterns in the distribution of Glaucous Gulls within the study areas in any season or either year; however, they appeared to be more common in the northeastern half of Burger in early fall 2008 and in the southwestern half of Burger in late fall 2008 and late summer 2009 (Figures 18 and 19).

Of the other 9 species of larids, Sabine's Gulls, Arctic Terns, Pomarine Jaegers, and Parasitic Jaegers were most common in early fall, Ross's Gulls were recorded only in Burger and only in late fall, and Herring Gulls occurred primarily in early and late fall (Appendices B and C). Sabine's Gulls occurred primarily in Klondike, whereas jaegers were more common in Burger; in contrast, Arctic Terns occurred in Klondike in 2008 but in Burger in 2009. Long-tailed Jaegers were seen off-transect on both study areas in early fall 2008 and on transect in both study areas in late summer 2009. Ivory Gulls occurred only in Burger and only in late fall 2008. A single Glaucous-winged Gull was seen only off-transect in Klondike and only in late summer 2008 after a storm with strong southerly winds.



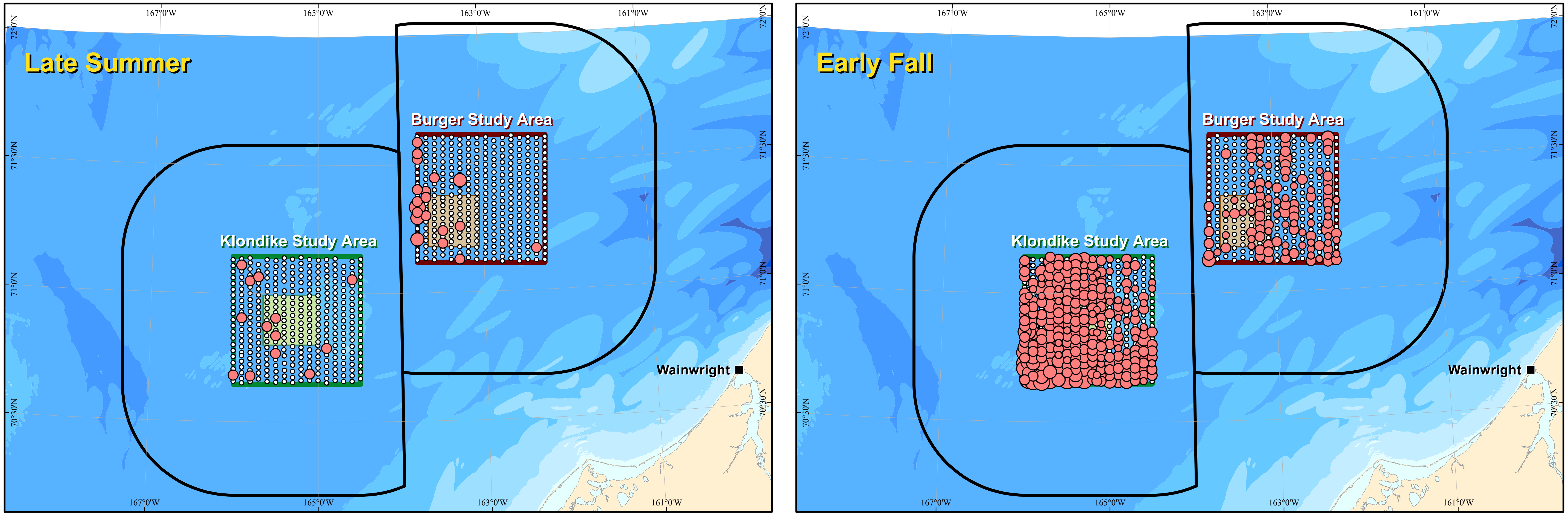



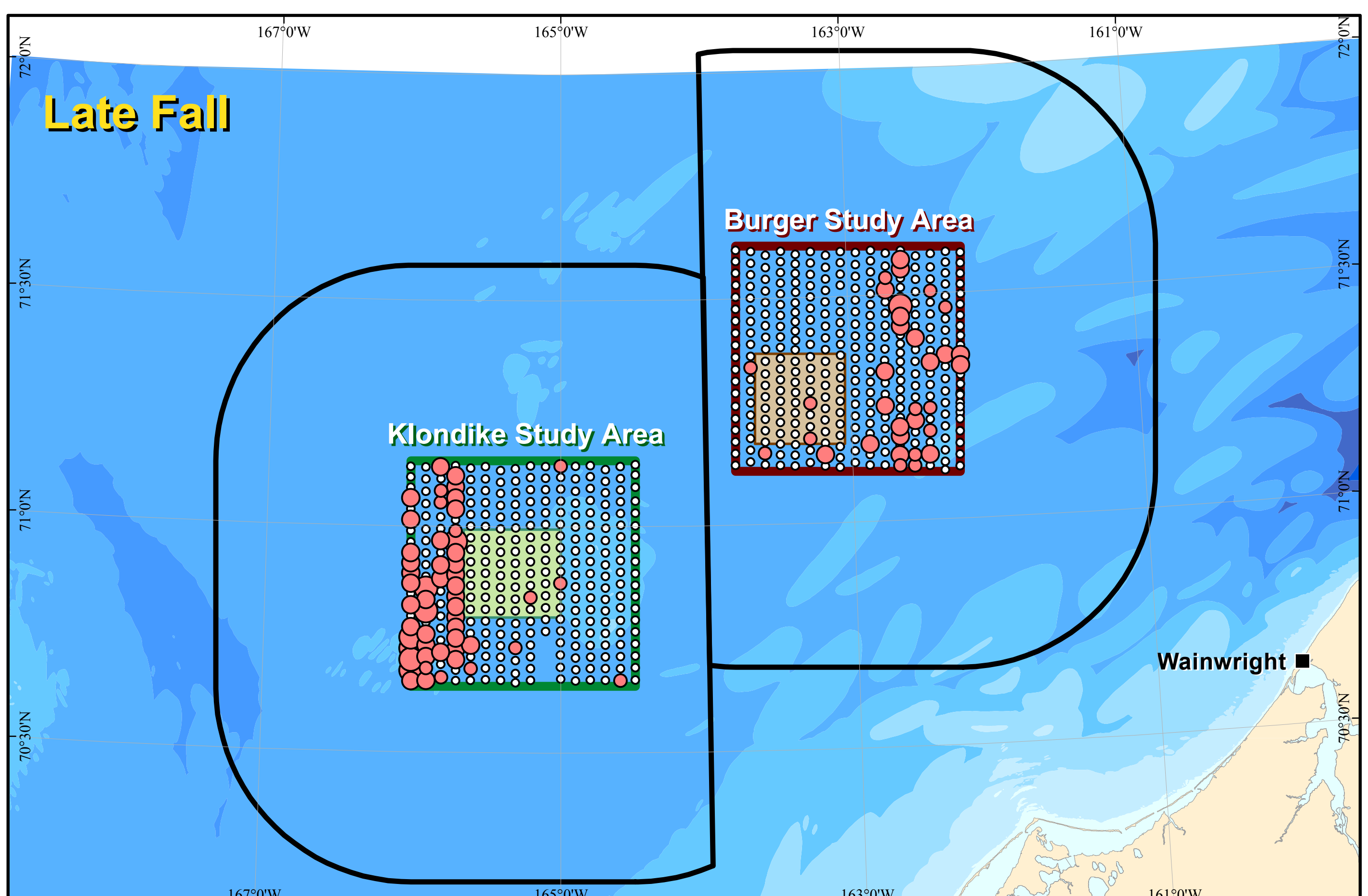



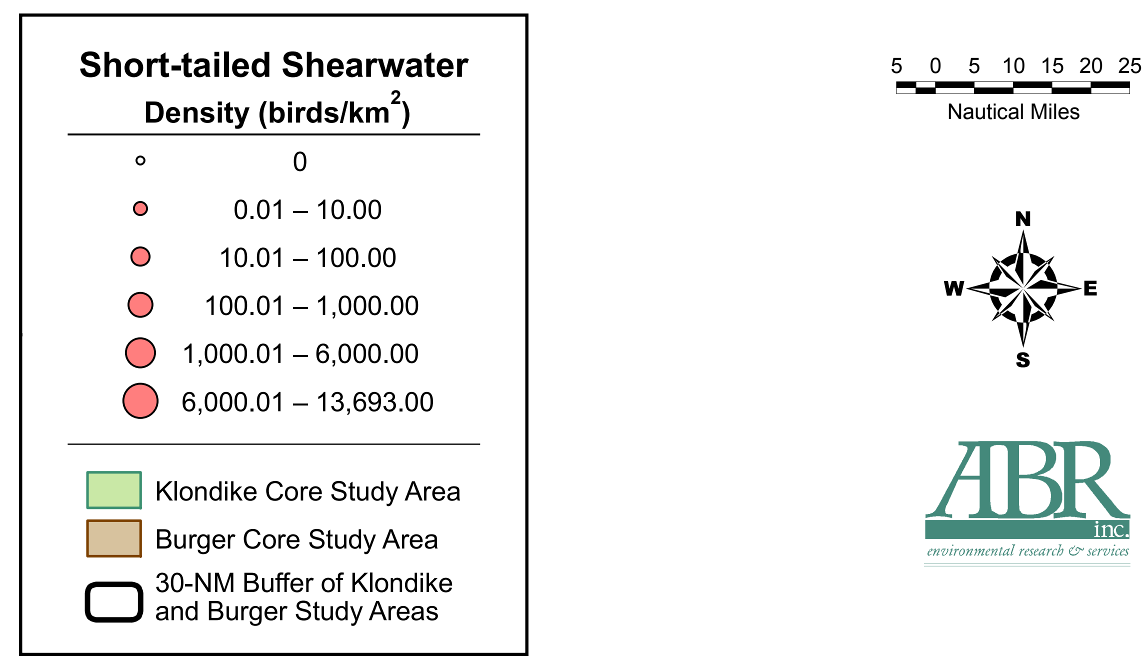




Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_SRTS_2008_09-215.mxd; 8 November 2010

Figure 12. Corrected densities (birds/km$^2$) of Short-tailed Shearwaters recorded on transect in the Klondike and Burger study areas in 2008, by study area and season.

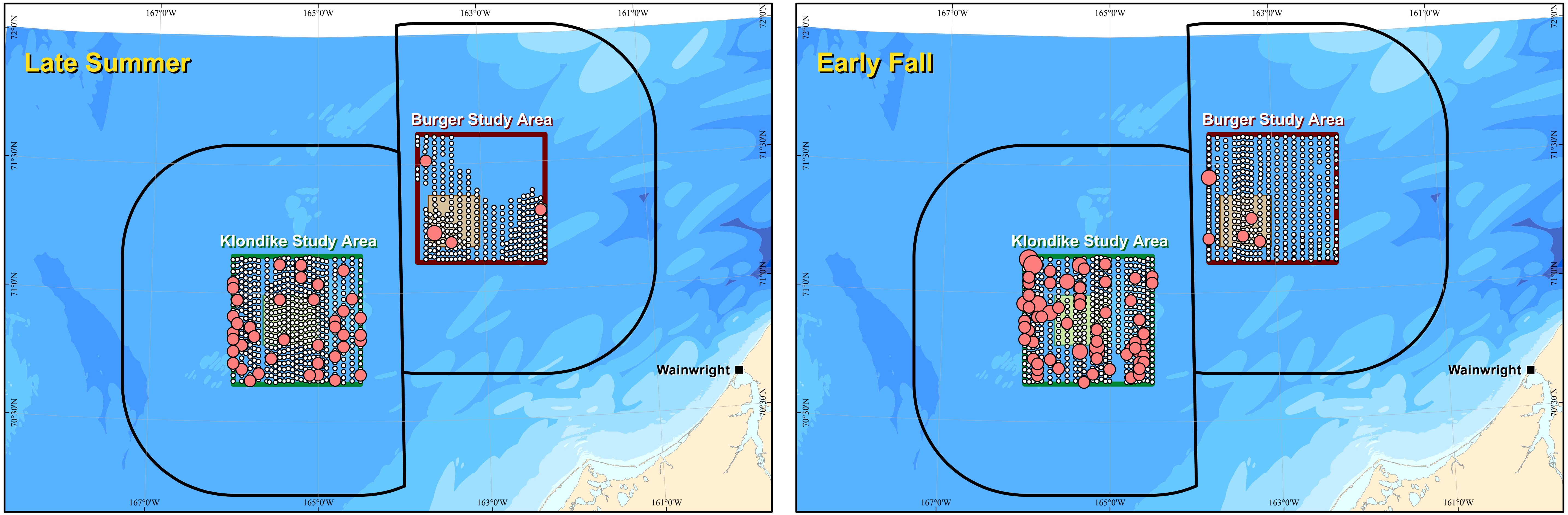


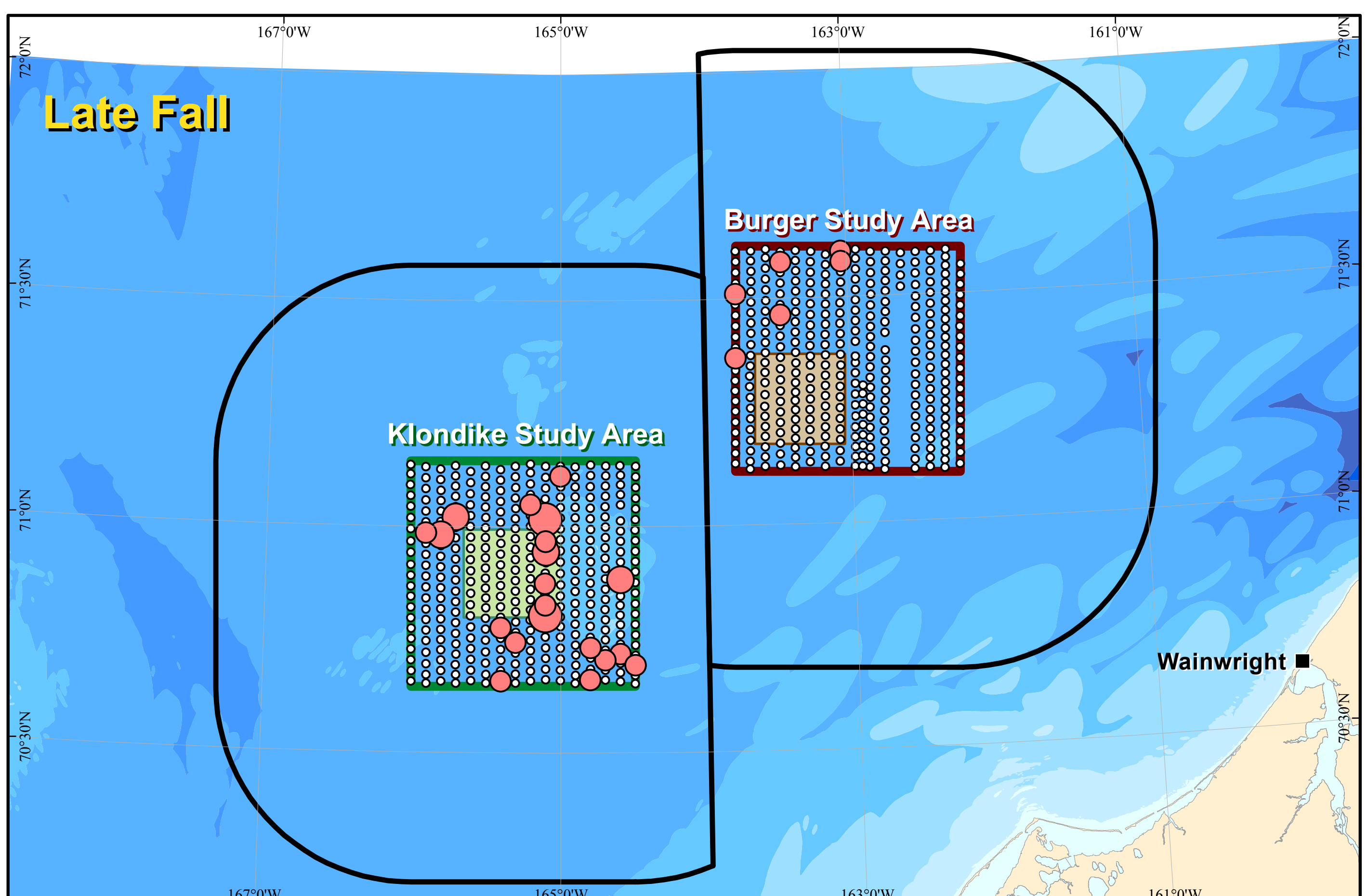



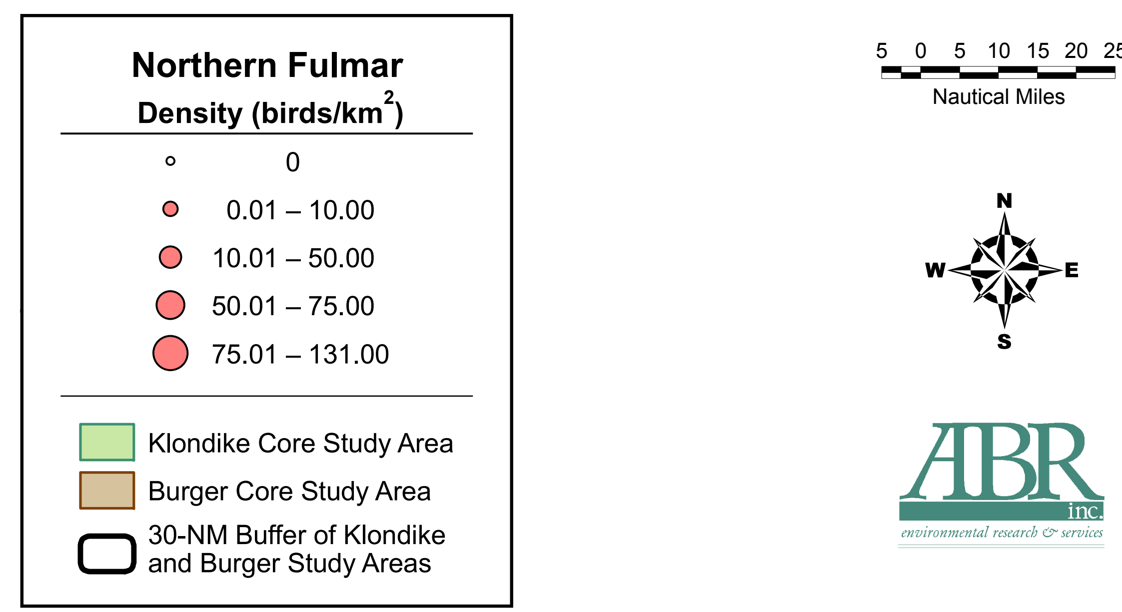




Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_SRTS_2009_09-215.mxd; 9 November 2010

Figure 13. Corrected densities (birds/km$^2$) of Short-tailed Shearwaters recorded on transect in the Klondike and Burger study areas in 2009, by study area and season.

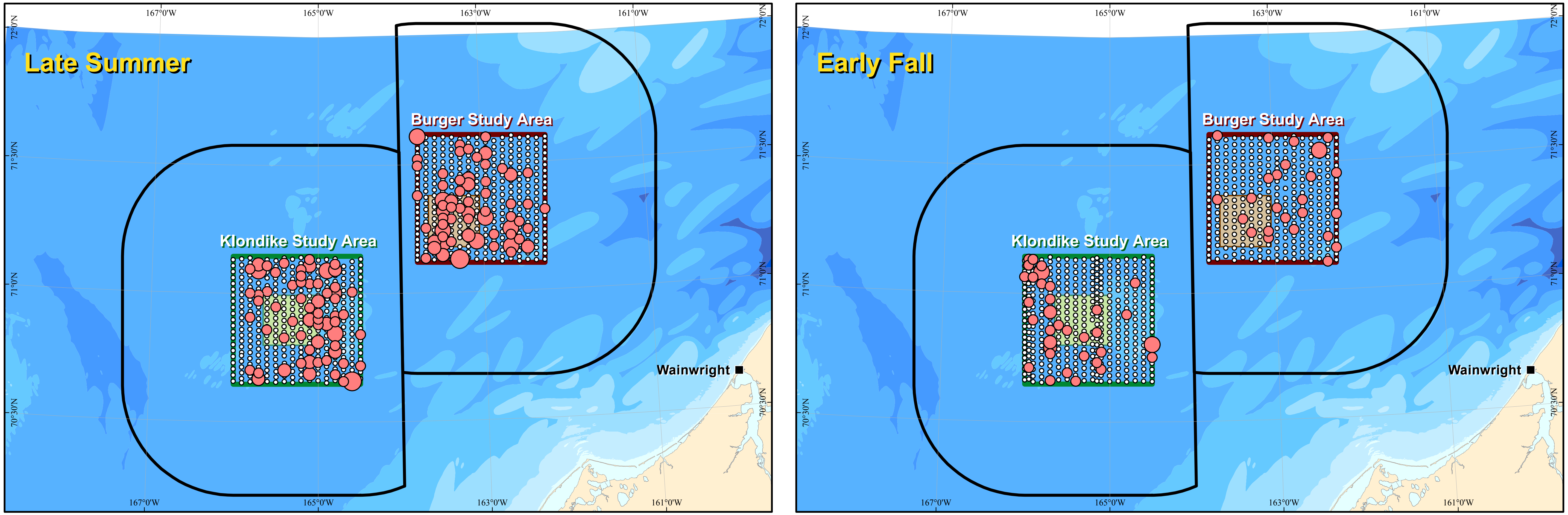


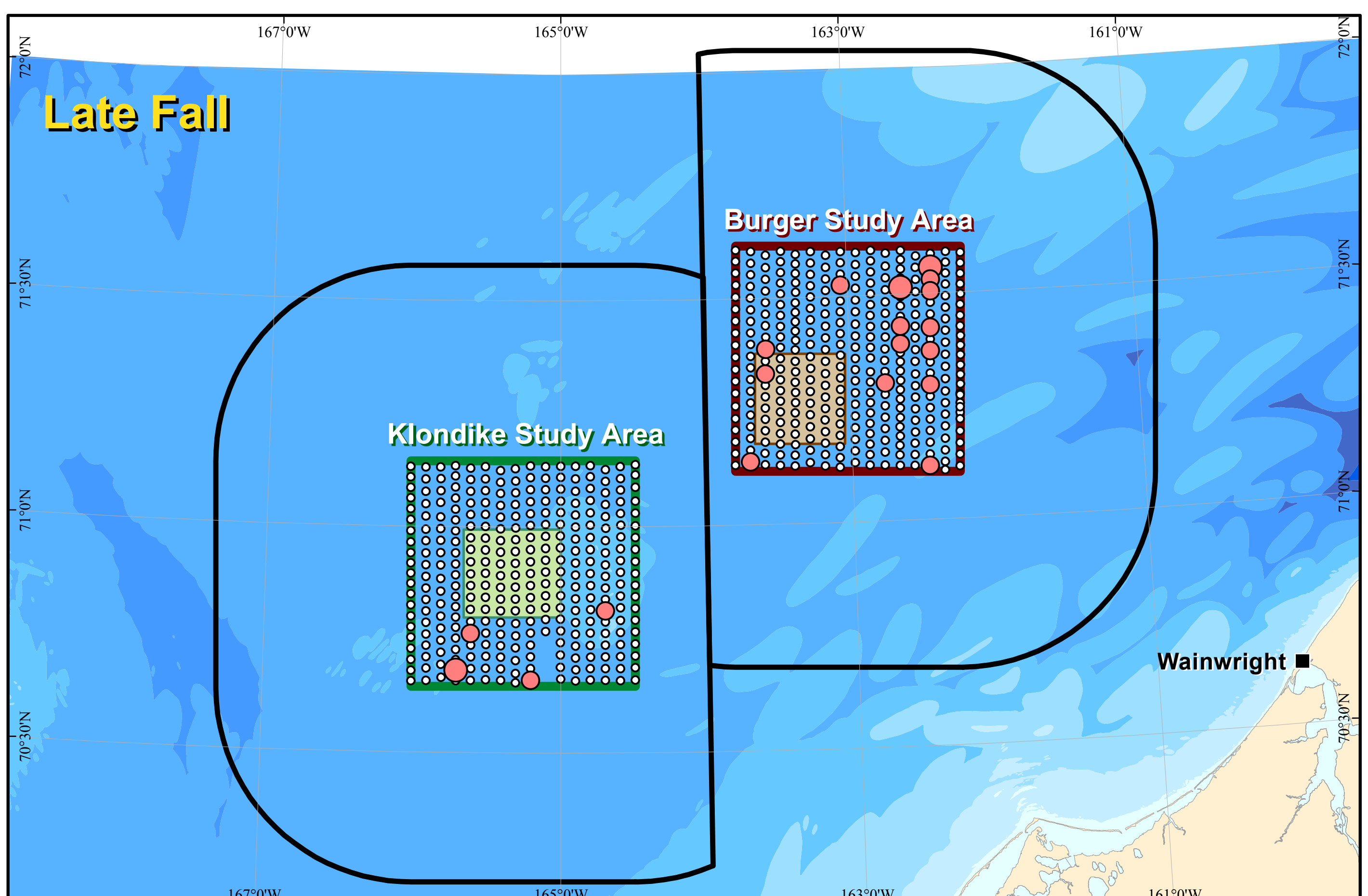



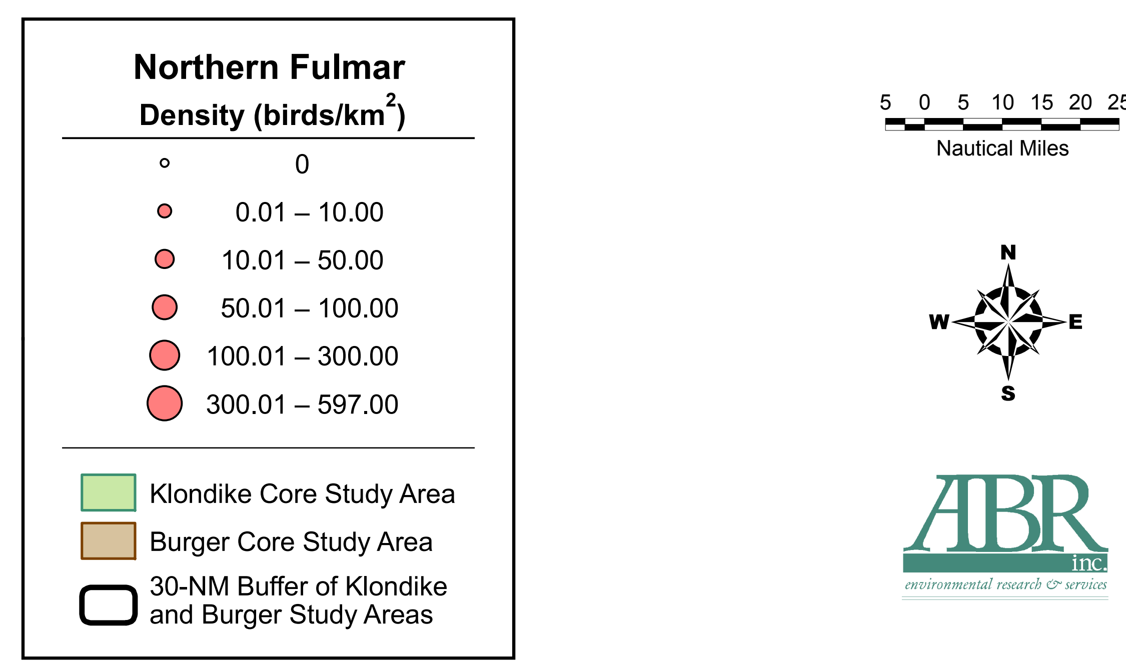




Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_NOFU_2008_09-215.mxd; 8 November 2010

Figure 14. Corrected densities (birds/km$^2$) of Northern Fulmars recorded on transect in the Klondike and Burger study areas in 2008, by study area and season.

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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_NOFU_2009_09-215.mxd; 8 November 2010

Figure 15. Corrected densities (birds/km$^2$) of Northern Fulmars recorded on transect in the Klondike and Burger study areas in 2009, by study area and season.

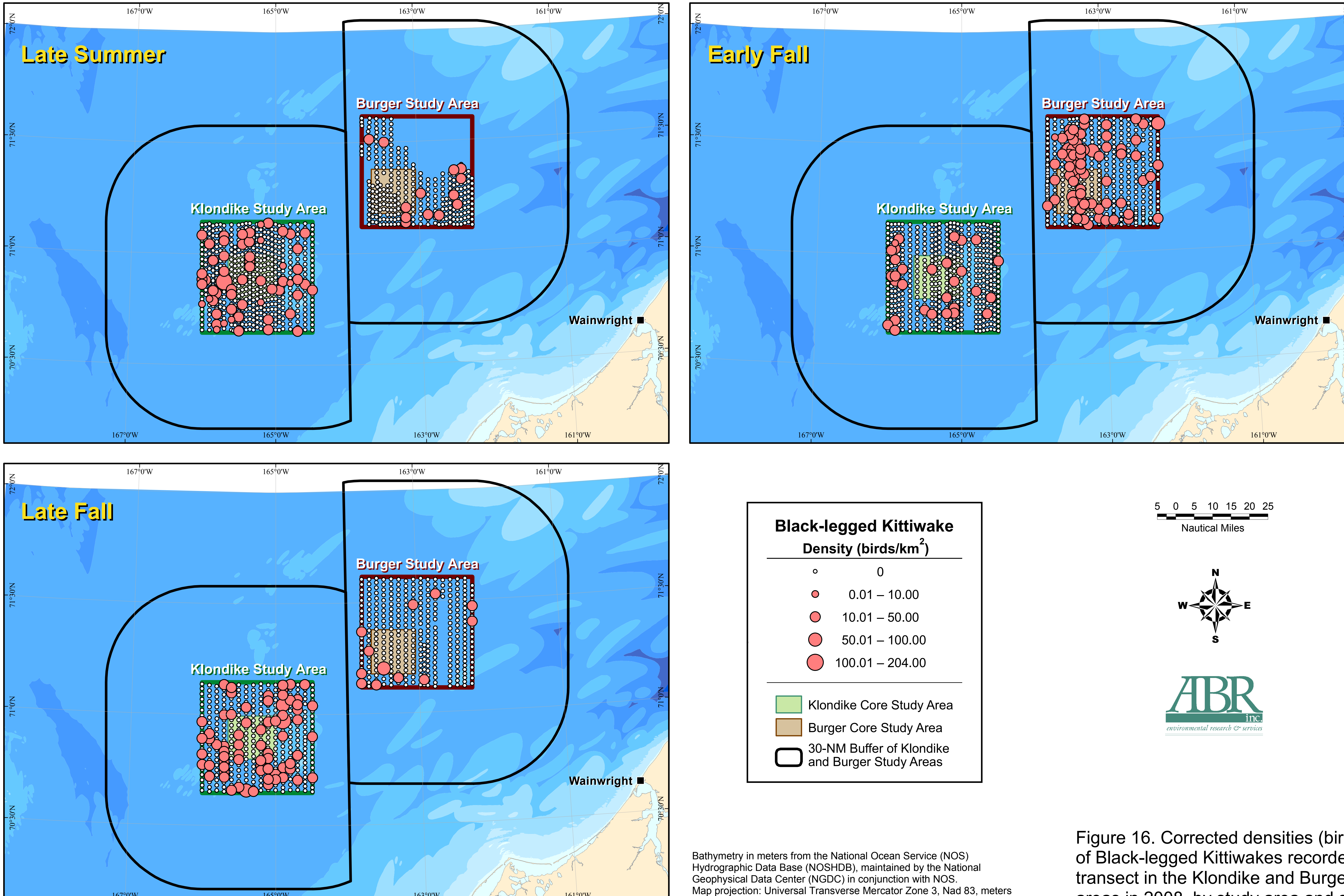
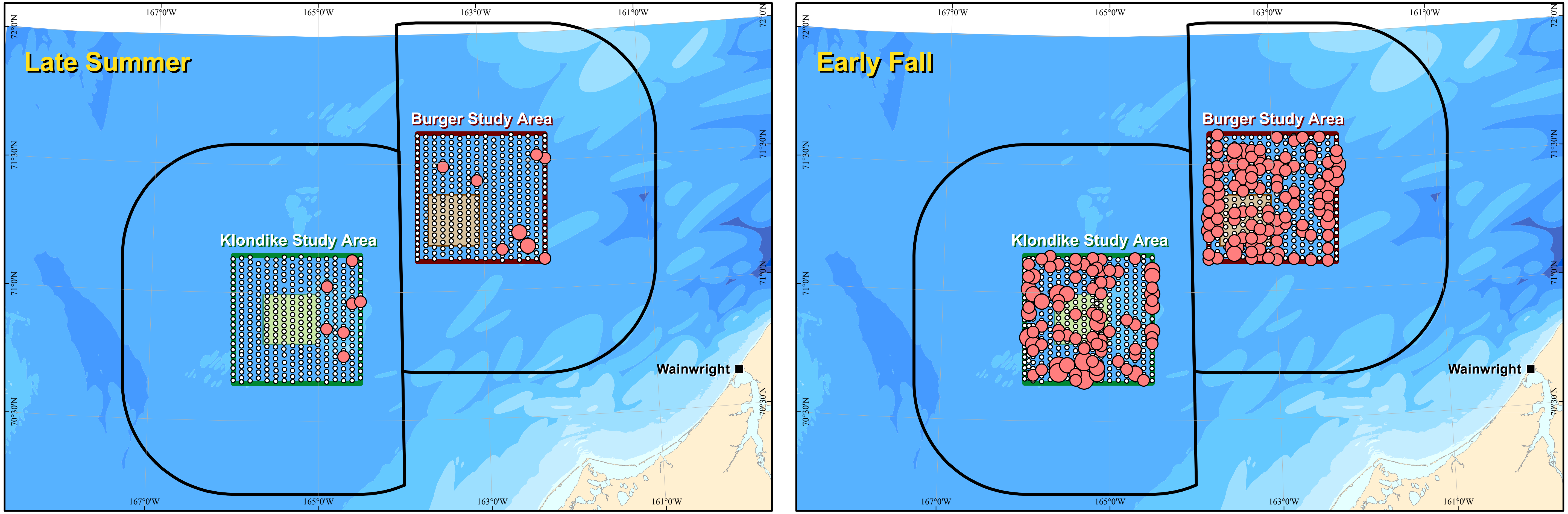
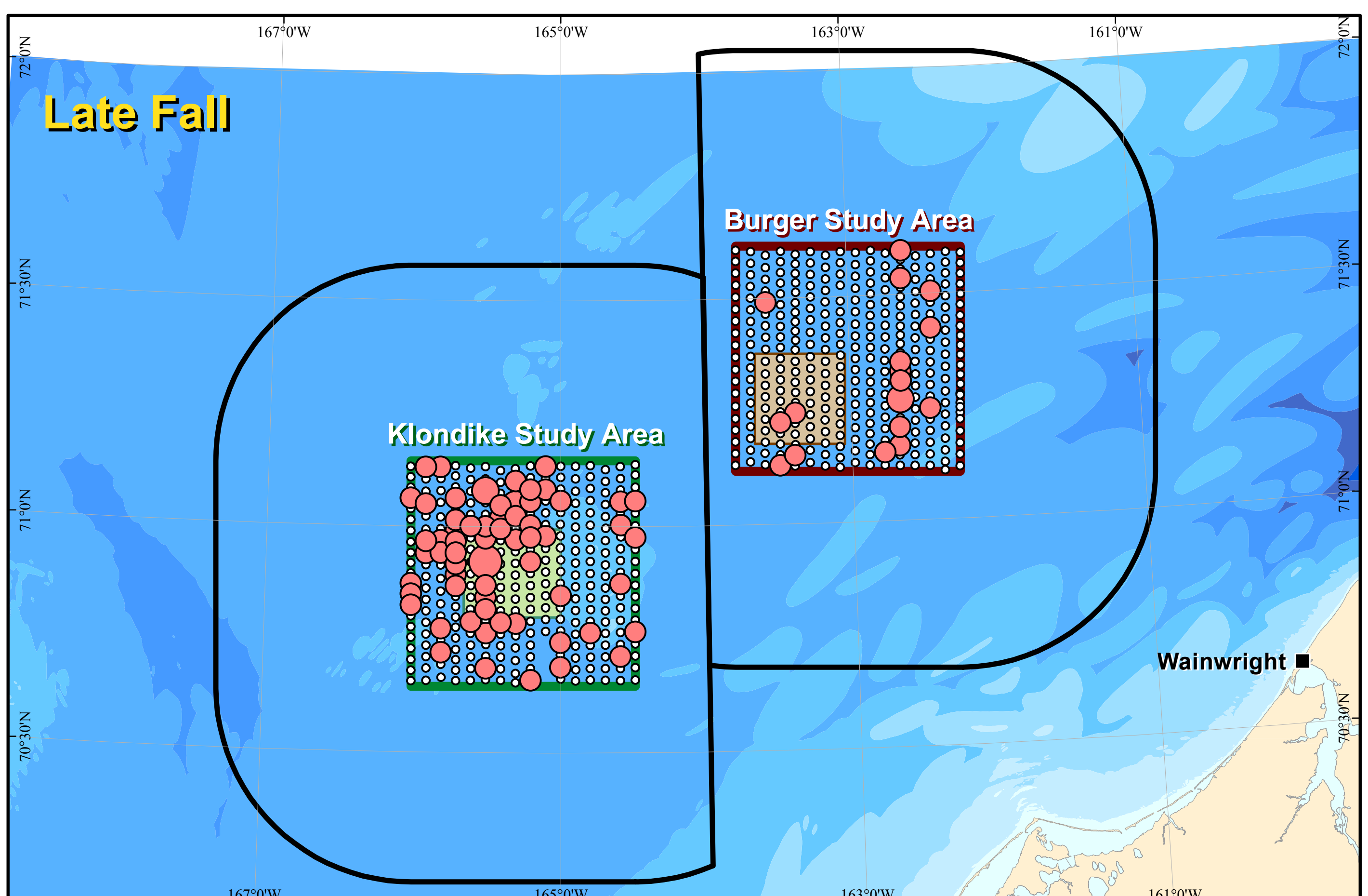
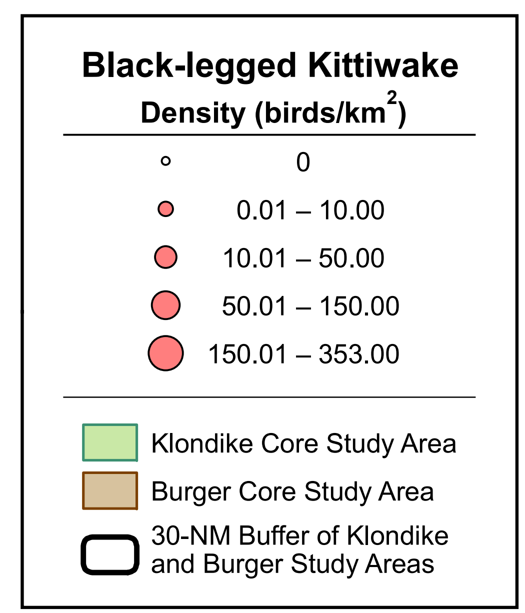
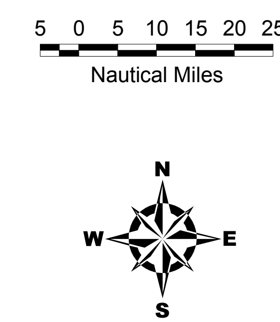



Figure 16. Corrected densities (birds/km$^2$) of Black-legged Kittiwakes recorded on transect in the Klondike and Burger study areas in 2008, by study area and season.



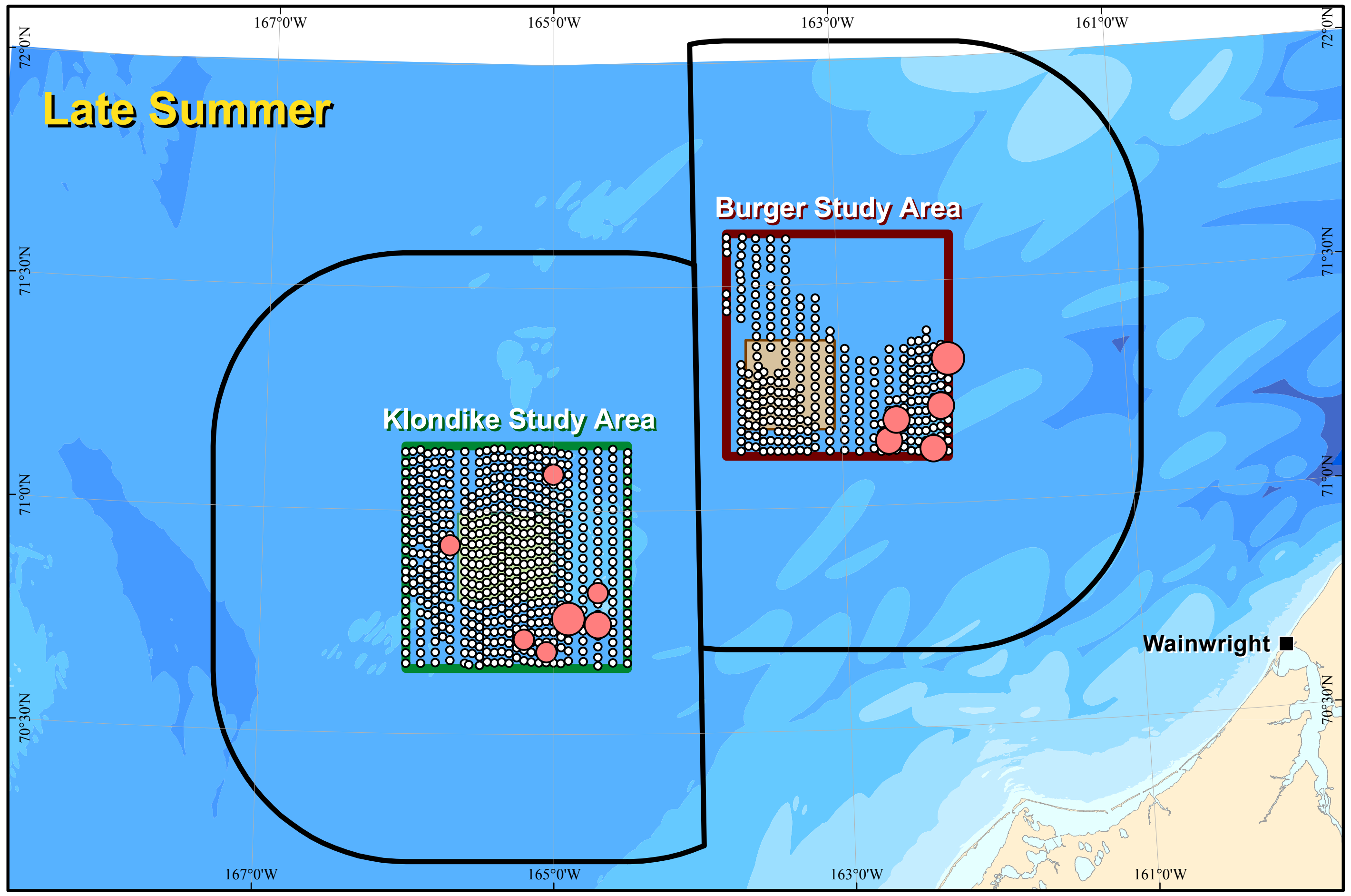



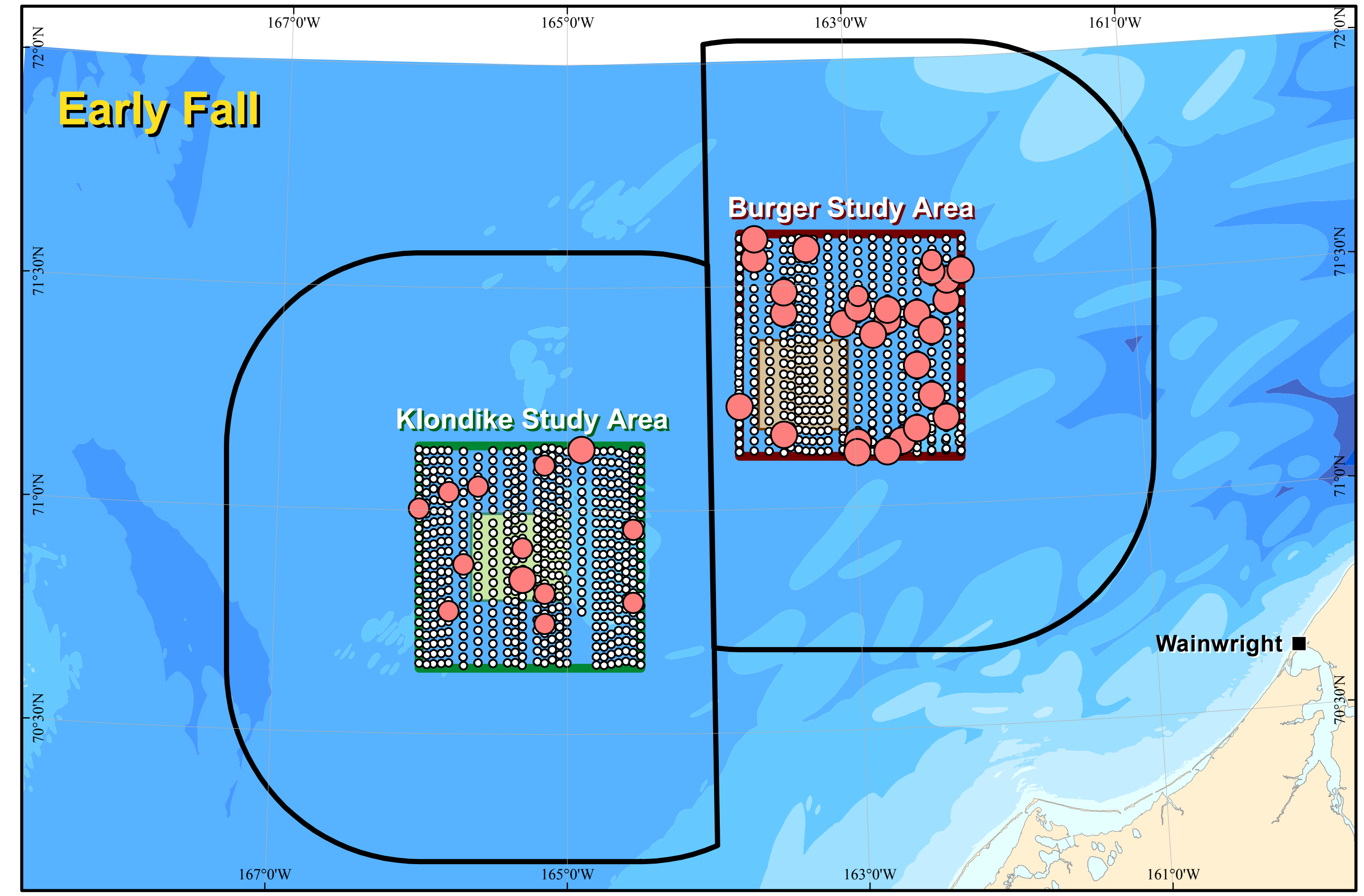



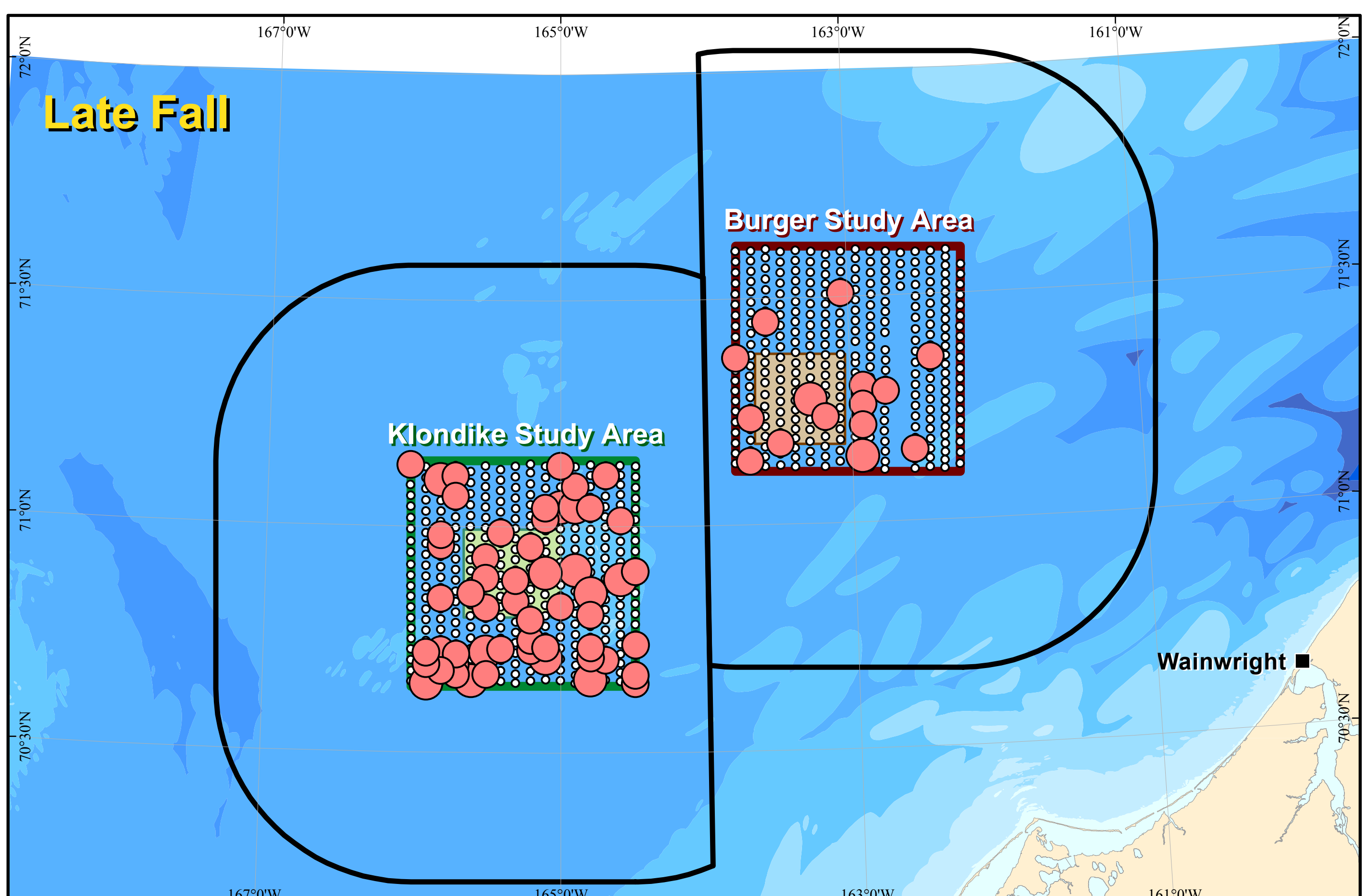



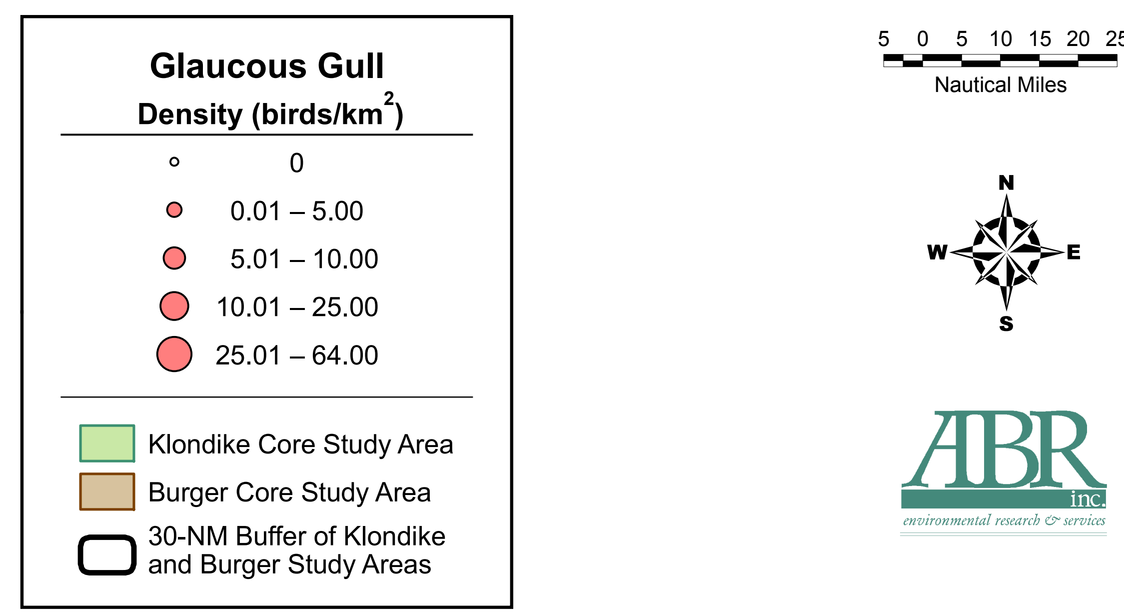

Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDBB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_BLKI_2009_09-215.mxd; 8 November 2010

Figure 17. Corrected densities (birds/km$^2$) of Black-legged Kittiwakes recorded on transect in the Klondike and Burger study areas in 2009, by study area and season.

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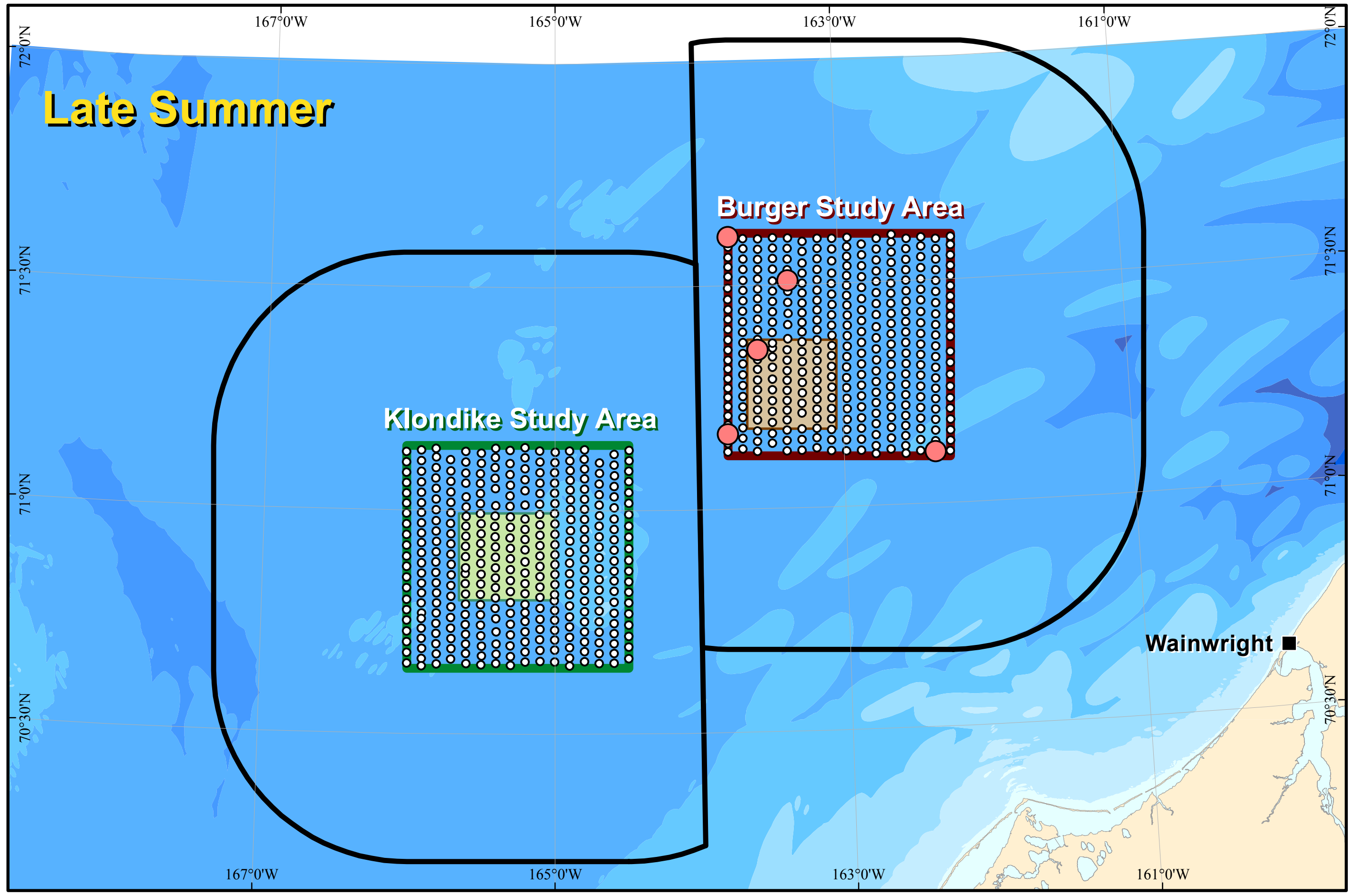
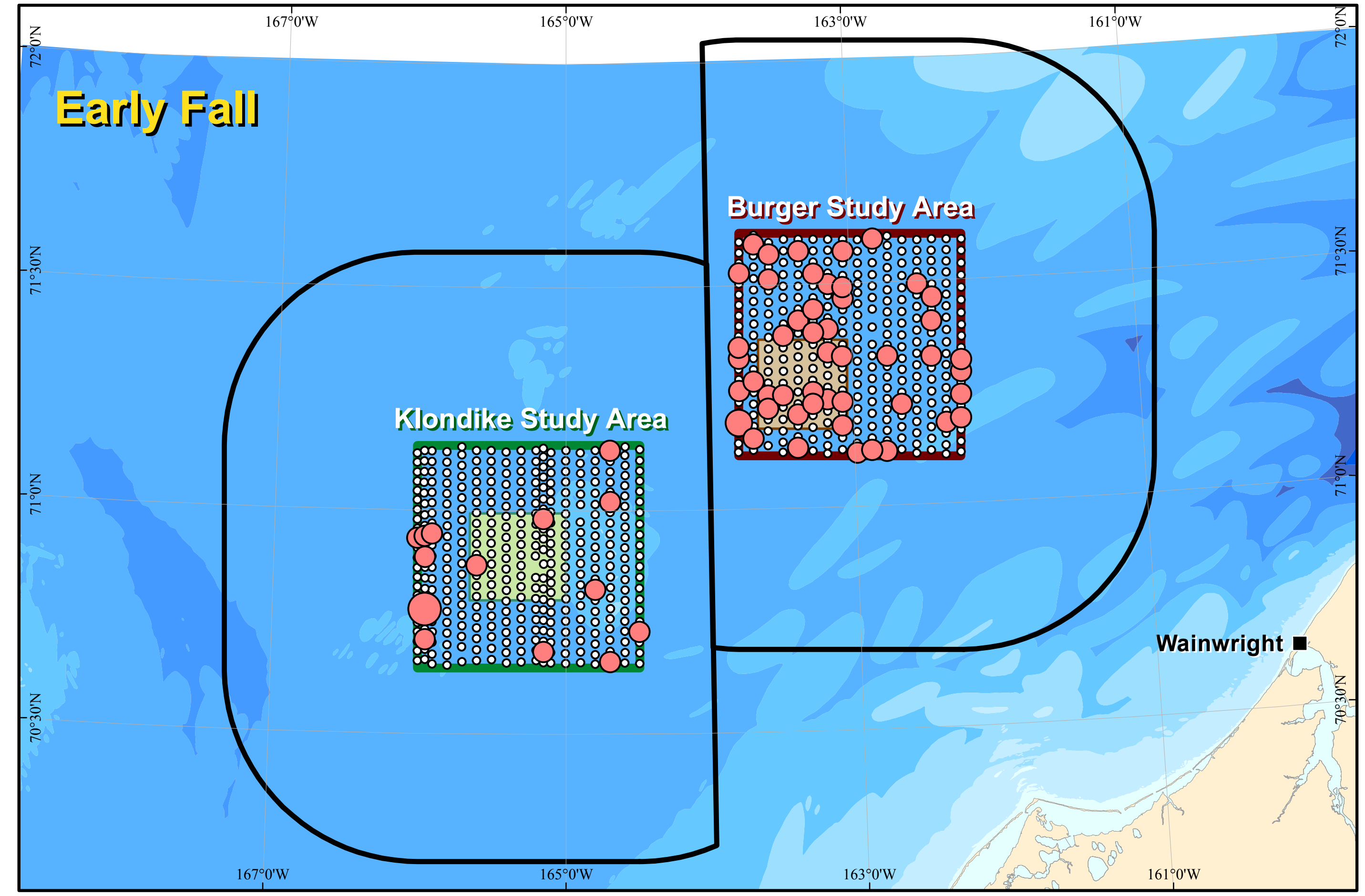
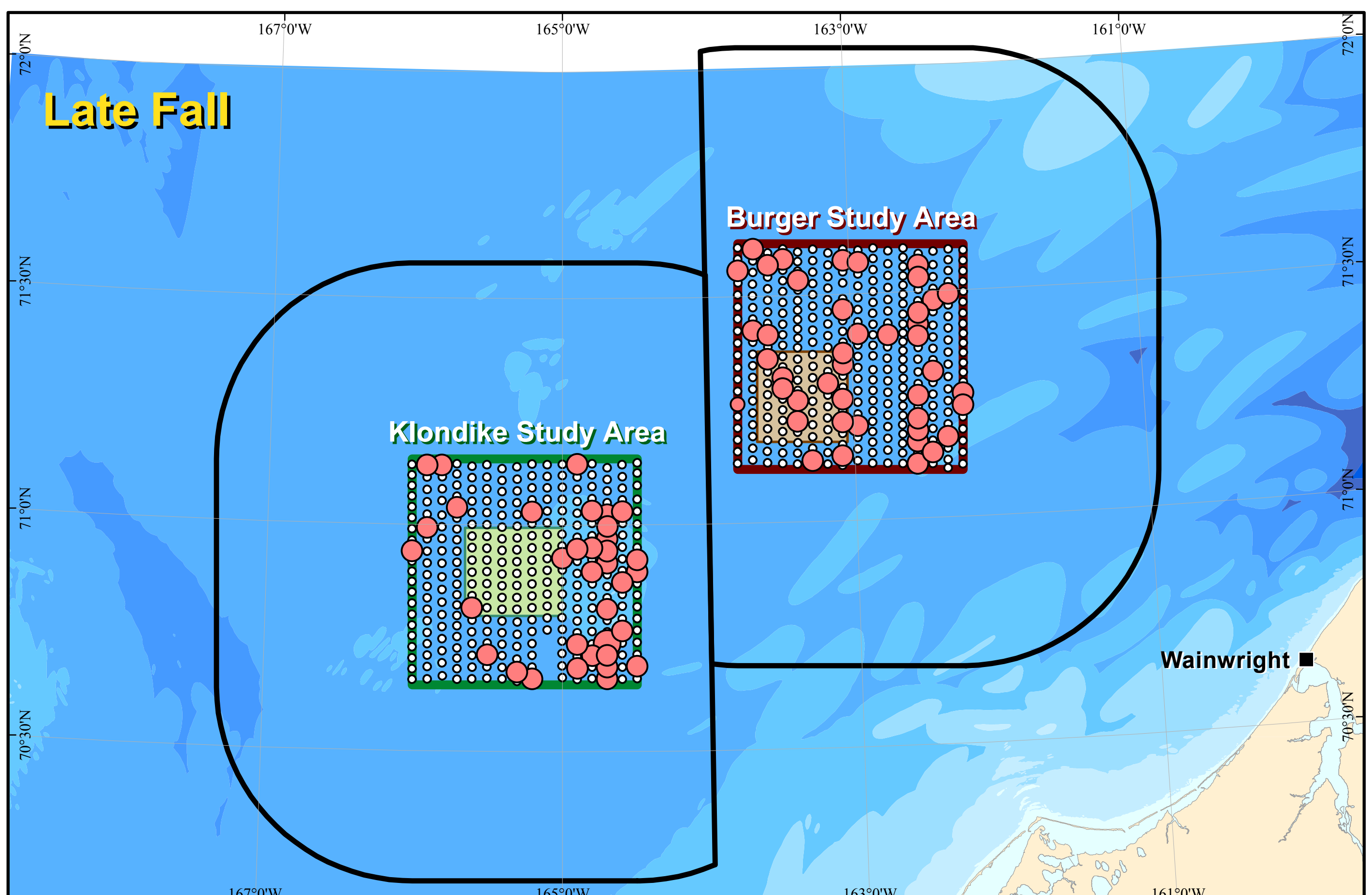
Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_GLGU_2008_09-215.mxd; 8 November 2010

Figure 18. Corrected densities (birds/km$^2$) of Glaucous Gulls recorded on transect in the Klondike and Burger study areas in 2008, by study area and season.



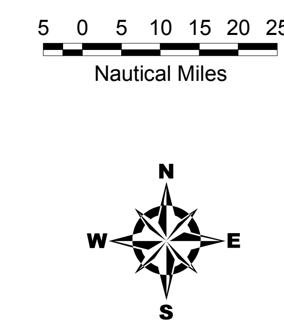




**Glaucous Gull**

**Density (birds/km$^2$)**

- 0
- 0.01 – 10.00
- 10.01 – 50.00
- 50.01 – 75.00
- 75.01 – 129.00

- Klondike Core Study Area
- Burger Core Study Area
- 30-NM Buffer of Klondike and Burger Study Areas

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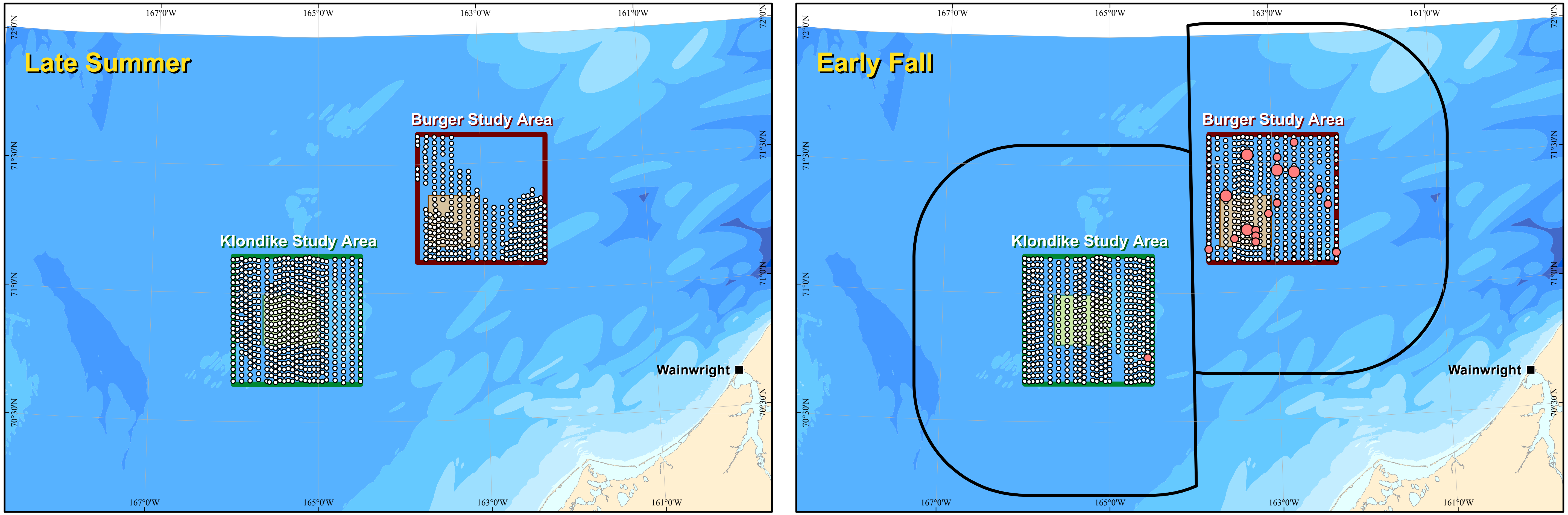
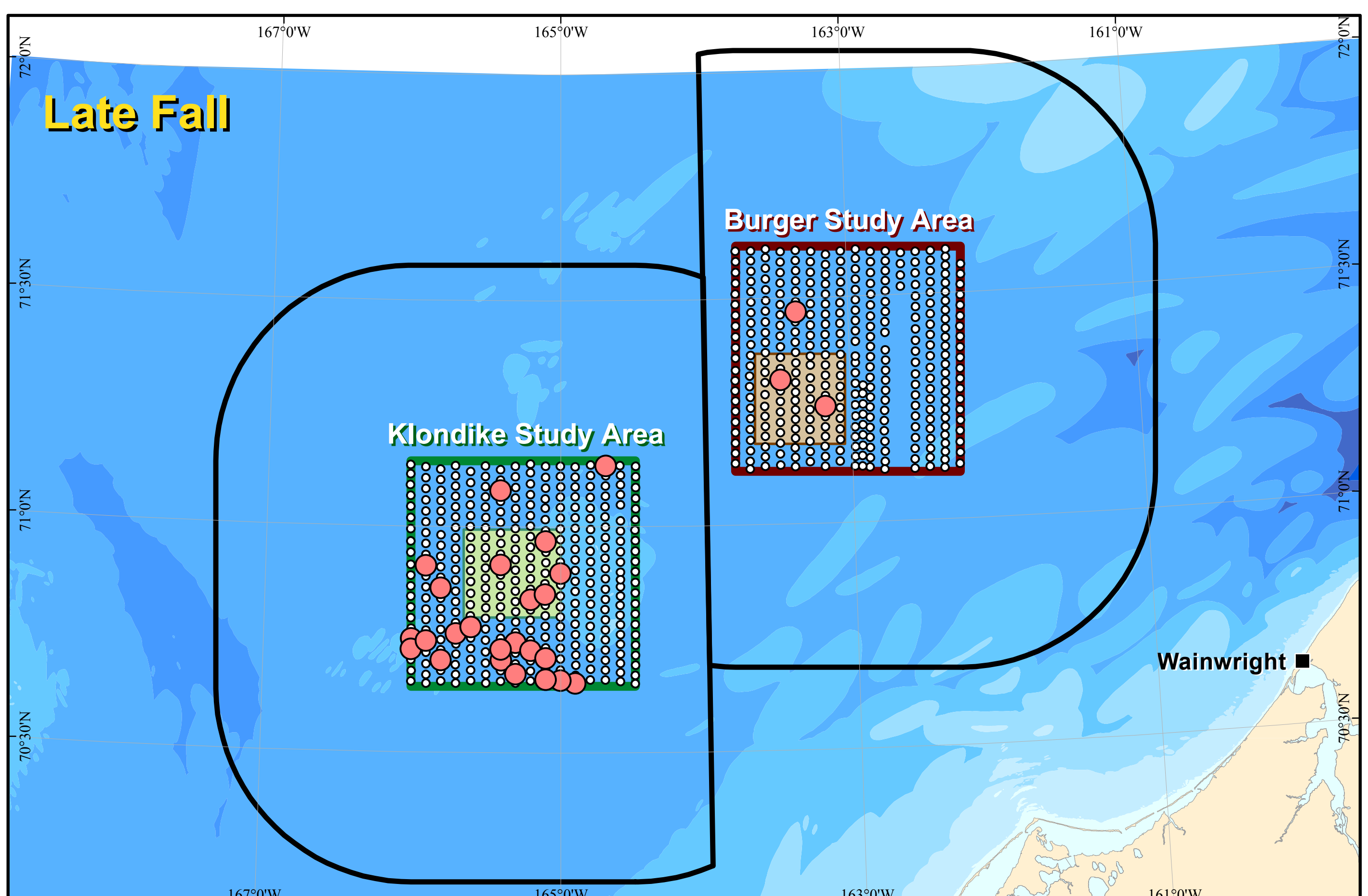
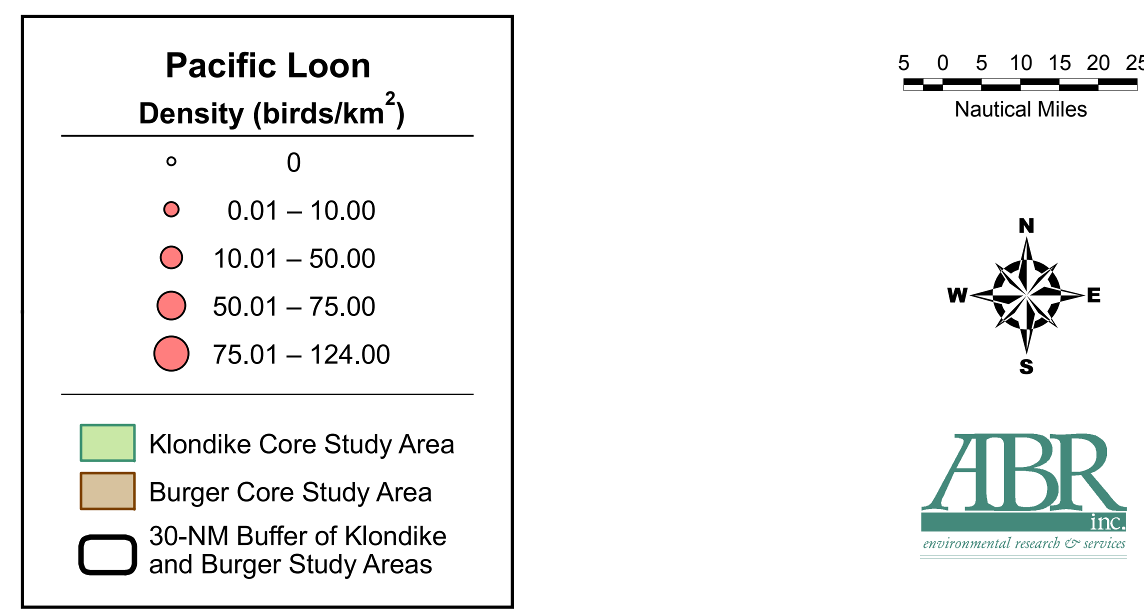
Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_GLGU_2009_09-215.mxd; 8 November 2010

Figure 19. Corrected densities (birds/km$^2$) of Glaucous Gulls recorded on transect in the Klondike and Burger study areas in 2009, by study area and season.

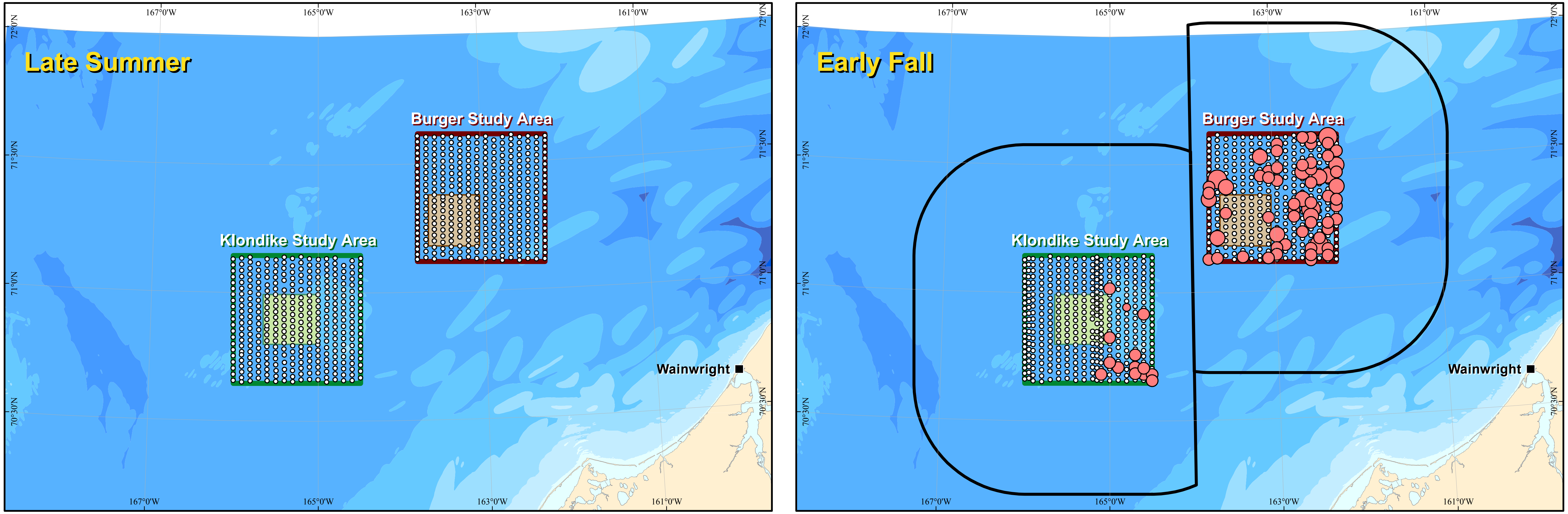


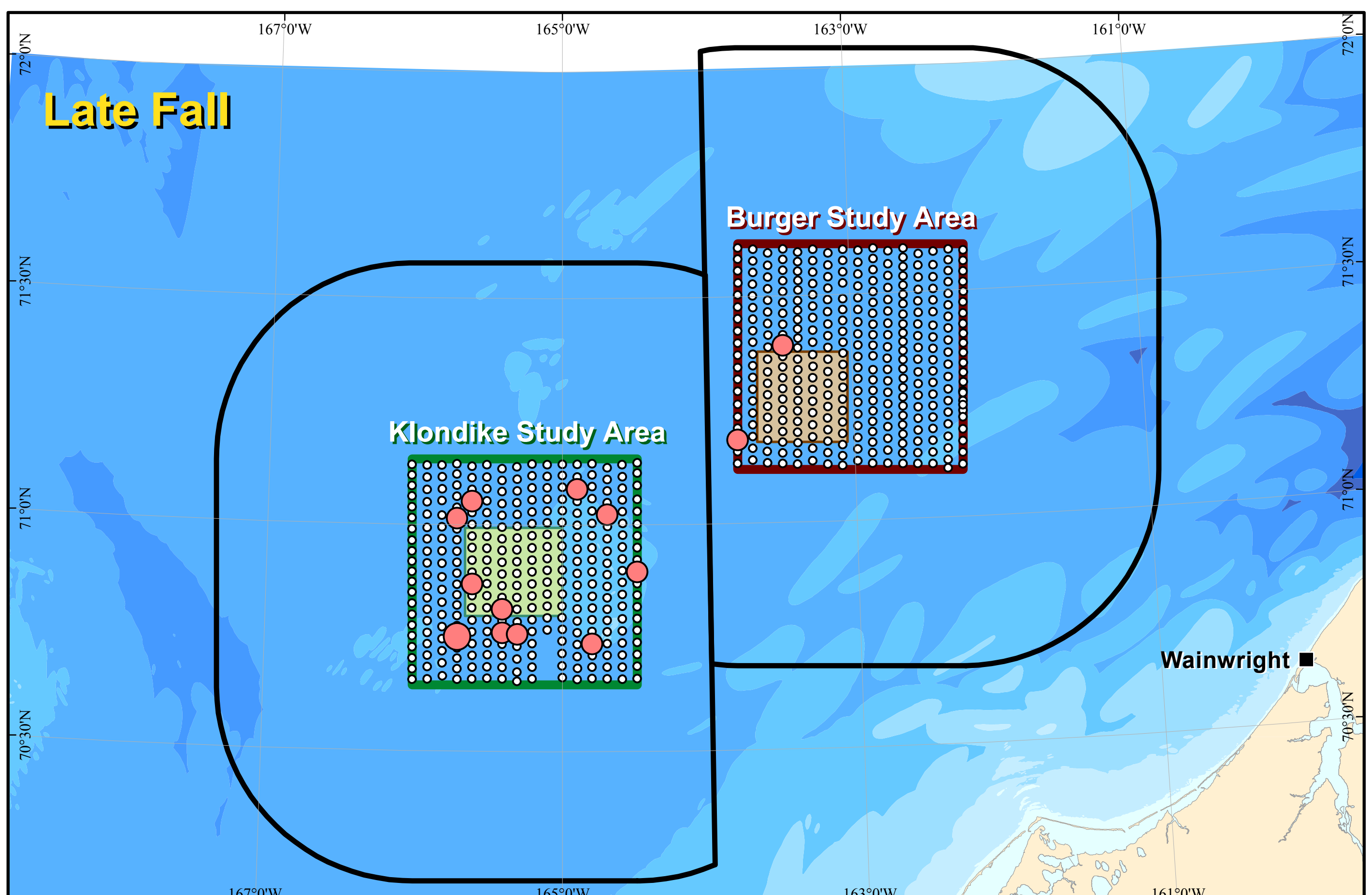



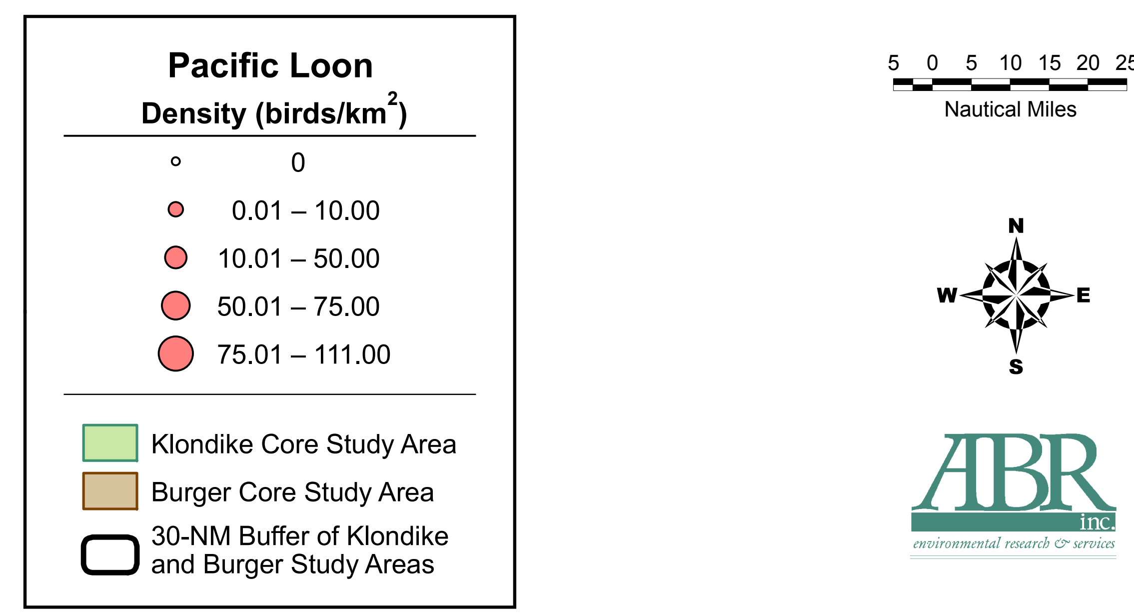




Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_PALO_2008_09-215.mxd; 8 November 2010

Figure 20. Corrected densities (birds/km$^2$) of Pacific Loons recorded on transect in the Klondike and Burger study areas in 2008, by study area and season.

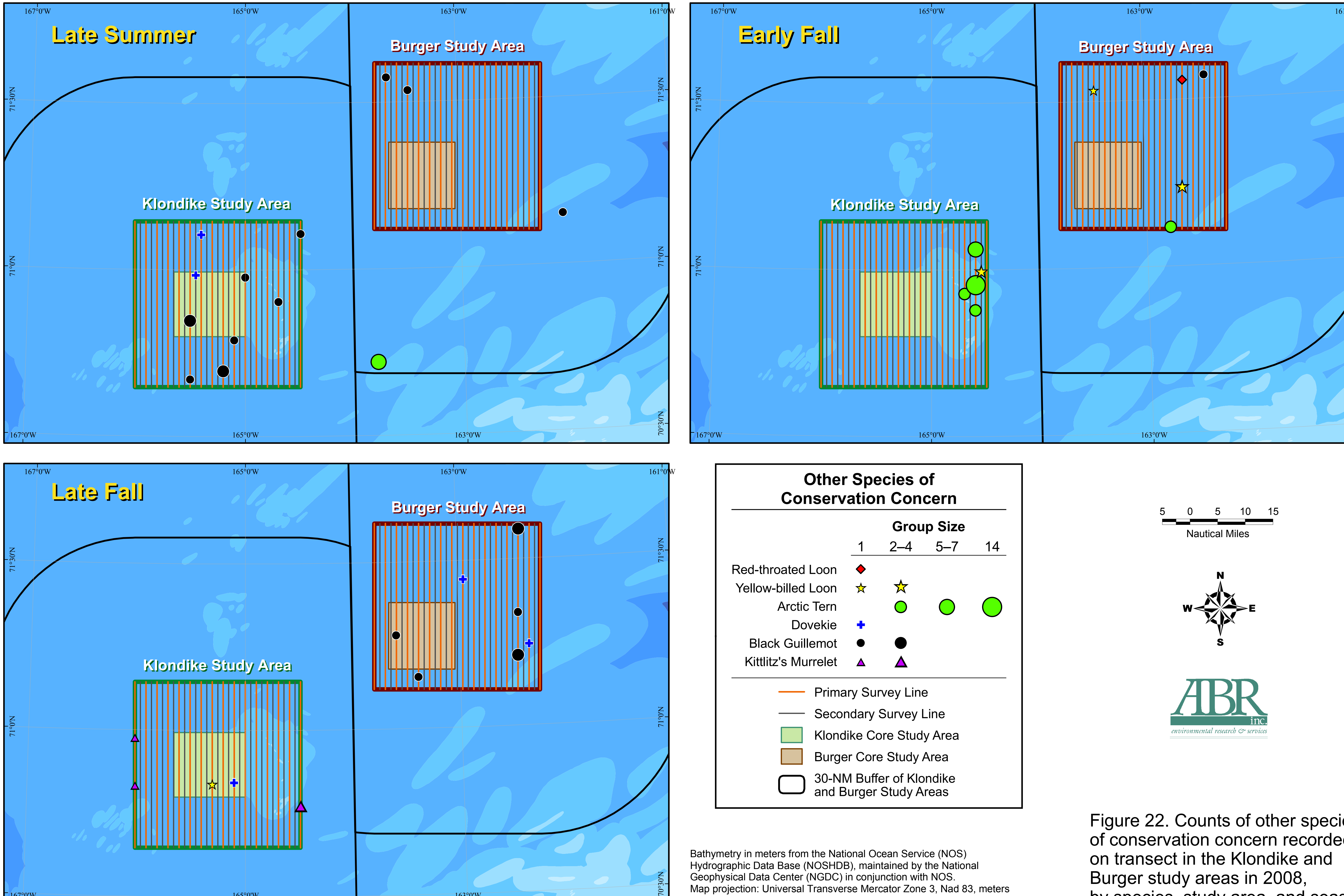


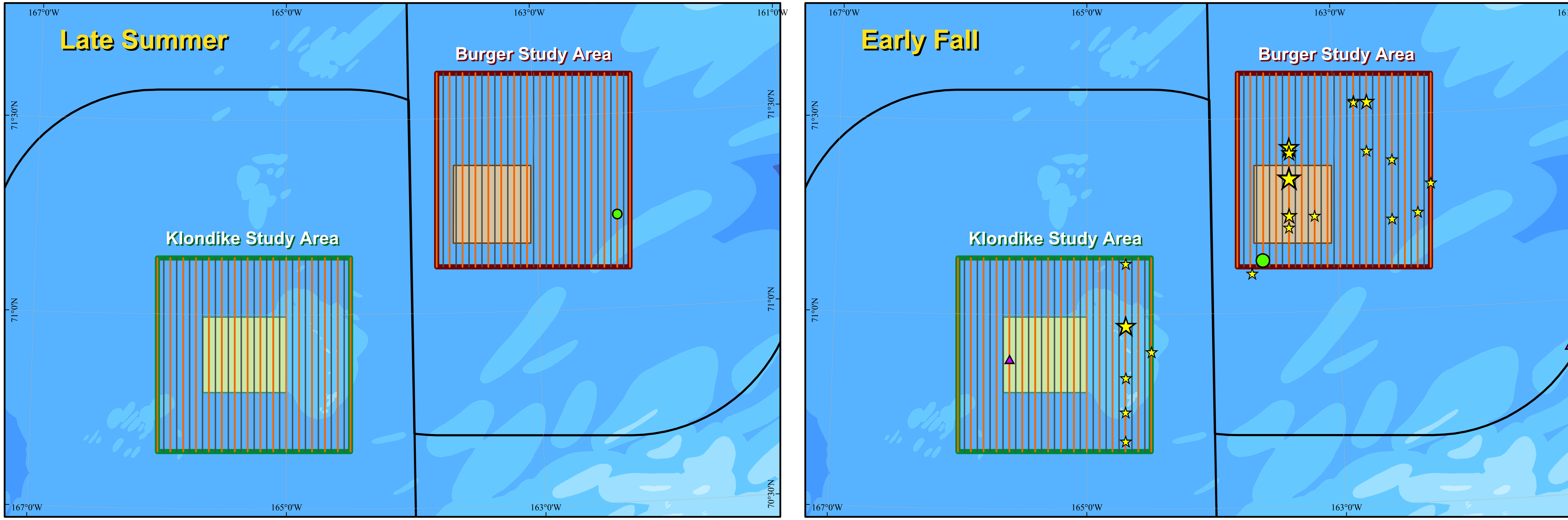

Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_PALO_2009_09-215.mxd; 9 November 2010

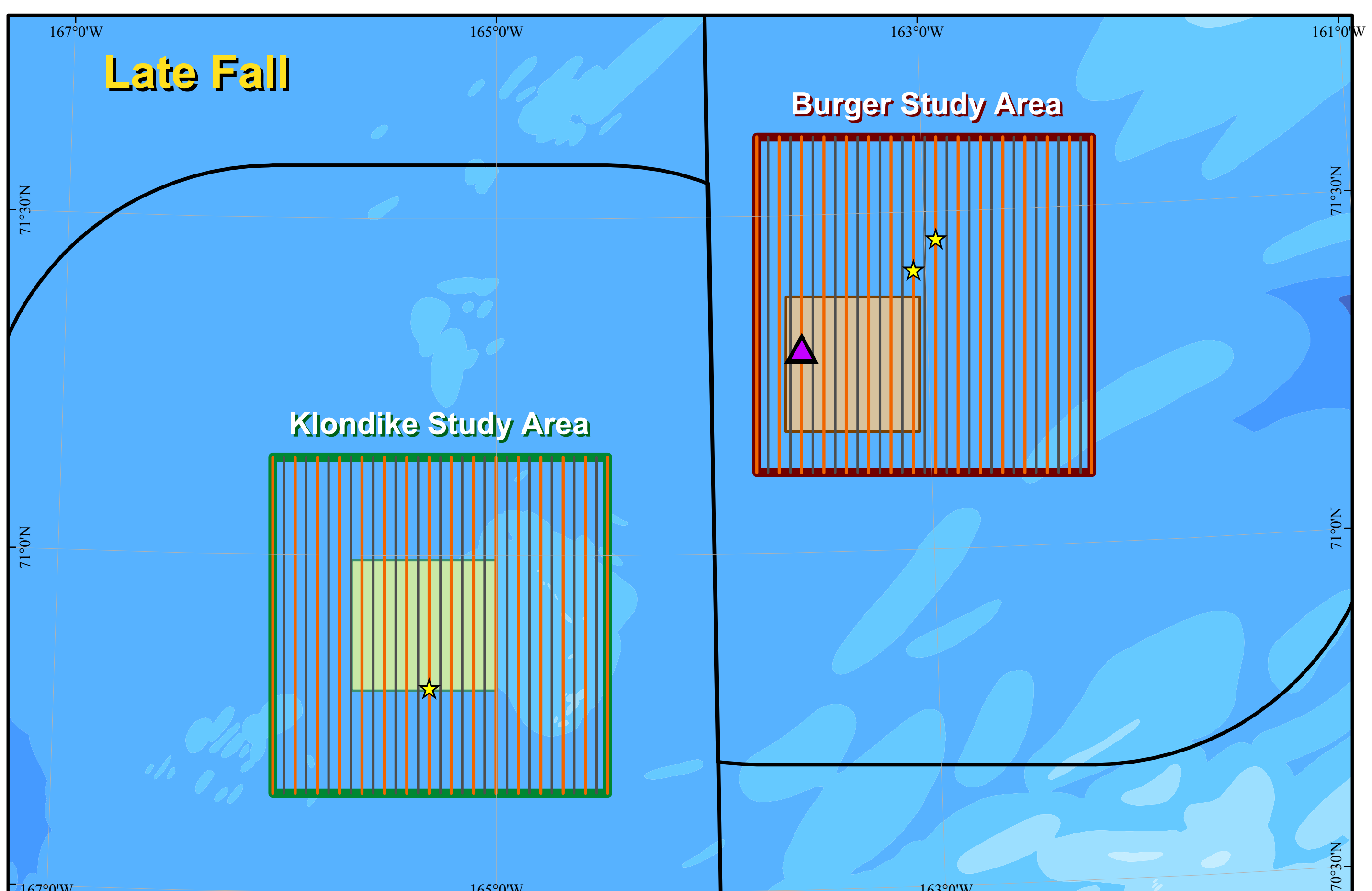
Figure 21. Corrected densities (birds/km$^2$) of Pacific Loons recorded on transect in the Klondike and Burger study areas in 2009, by study area and season.

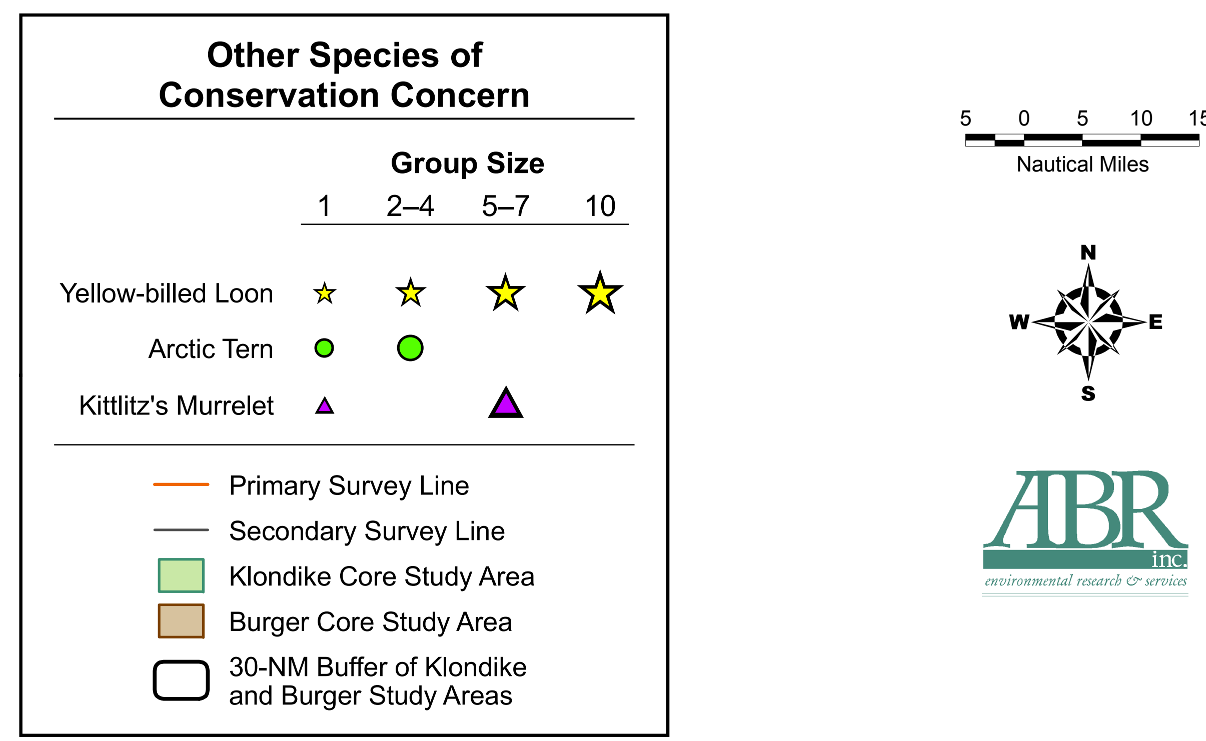



Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_Other_SppConcern_2008_09-215.mxd; 8 November 2010

Figure 22. Counts of other 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_Other_SppConcern_2009_09-215.mxd; 9 November 2010

Figure 23. Counts of other species of conservation concern recorded on transect in the Klondike and Burger study areas in 2009, by species, study area, and season.

LOONS

In both years, loons were recorded in both early and late fall (primarily in September) and were completely absent from both study areas in late summer (Appendices B and C). Of the 3 species of loons recorded on transect, only Pacific Loons had enough detections for us to generate estimates of density after accounting for detection probability.

Pacific Loons occurred in both study areas but only in early and late fall. Pacific Loon densities differed significantly among seasons and between study areas in both years ($P < 0.001$ for STUDY AREA*SEASON), although the seasonal pattern of changes in density was similar between years (Figure 4, Tables 2 and 3). In both years, densities of Pacific Loons were higher in Burger than Klondike in early fall but were higher in Klondike than Burger in late fall. The density of Pacific Loons was 10 times higher in Burger than in Klondike in early fall 2009. In both years, the spatial distribution of Pacific Loons shifted from the eastern half of Klondike and all of Burger in early fall to all of Klondike and the southwestern half of Burger in late fall (Figures 20 and 21).

Of the 2 other species of loons, only Yellow-billed Loons occurred in both years. Yellow-billed Loons were rare in 2008 but were more common in 2009 (Figures 22 and 23, Appendices B and C). In 2008, we saw a group of 3 Yellow-billed Loons in Klondike and 2 groups totaling 3 birds in Burger in early fall; we also saw a single bird in Klondike in late fall. In 2009, we saw 23 groups totaling 48 Yellow-billed Loons, and they were seen primarily in early fall and primarily in Burger and the eastern half of Klondike. Red-throated Loons were rare during these surveys. We saw one Red-throated Loon in Burger in early fall 2008 and saw none in 2009 (Appendices B and C).

WATERFOWL

Waterfowl were seen in low densities in all seasons and in both study areas and were generally more common in 2008 than in 2009 (Table 1, Appendices B and C). Of the 4 species of waterfowl identified, none was abundant enough to provide reliable estimates of density after accounting for detection probability. In both years, Long-tailed Ducks were the most abundant waterfowl species, and they were seen in both study areas and in all seasons in 2008 and primarily in early fall in 2009. Waterfowl species seen only in 2008 included King Eiders, which were seen flying singly or in pairs on all three cruises, and single flocks of Common Eiders and White-winged Scoters recorded in Burger in late fall. In 2009, we recorded a single Spectacled Eider in Klondike on 8 September and a single Spectacled Eider off transect in Burger on 16 September.

PHALAROPES

Phalaropes were seen in low densities, primarily in early and late fall in 2008 and in late summer and early fall in 2009 (Table 1, Appendices B and C). Both Red and Red-necked phalaropes were seen feeding in mixed-species flocks. Phalaropes were not abundant enough to provide reliable species-specific estimates of density after accounting for detection probability. In 2008, they were most common in Klondike in late fall and in Burger in early fall. Because the study areas were surveyed consecutively, these high counts corresponded to transects conducted in September; we saw few phalaropes in August and none in October. In 2009, phalaropes were most common in Burger and in both late summer and early fall.

**TOTAL DENSITY ESTIMATES**

We used the estimated corrected densities of the 31 species recorded in the study areas in 2008 and the 24 species recorded in 2009 to calculate total density of marine birds within the study areas in each season and year (Table 4). The total density of marine birds was significantly higher in 2009 than it was in 2008. In spite of the much higher overall densities in 2009, however, relative densities between the 2 study areas were similar between years in both early fall (~60–77% higher in Klondike than in Burger) and late fall (~350–630% higher in Klondike than in Burger); in contrast, the pattern differed between years in late summer (~830% higher in Klondike than in Burger in 2008 but only ~13% of those in Burger in 2009). Total densities were significantly higher in Klondike than in Burger in all seasons of 2008 and in both early and late fall 2009 ($P < 0.001$ for all comparisons) and were higher in Burger than Klondike only in late summer 2009 ($P < 0.001$).

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

| | Study area | |
|---|---|---|
| Year/season | Klondike | Burger |
| 2008 | | |
| Late summer | 2.8 (2.1–3.7) | 0.3 (0.2–0.5) |
| Early fall | 4.3 (3.5–5.2) | 2.7 (2.1–3.5) |
| Late fall | 10.5 (8.6–12.9) | 2.3 (1.7–3.0) |
| 2009 | | |
| Late summer | 5.5 (4.5–6.7) | 40.8 (35.1–47.4) |
| Early fall | 81.3 (62.0–106.6) | 45.9 (37.1–56.8) |
| Late fall | 16.1 (13.6–19.1) | 2.2 (1.8–2.6) |

## COMMUNITY COMPARISON

The total species list of birds seen on transect within the 2 study areas was similar between Klondike and Burger during both years (Table 1), although overall species richness was higher in 2008 than in 2009. Of the 31 species recorded on transect in 2008, we recorded 26 in the Klondike study area and 27 in the Burger study area. Of the 24 species recorded on transect in 2009, we recorded 23 in the Klondike study area and 20 in the Burger study area. Species seen only in 2008 included ice-associated ones such as Ivory Gulls and Black Guillemots, as well as Red-throated Loons, Common Eiders, King Eiders, Parasitic Jaegers, Pigeon Guillemots, and Dovekies. Species recorded on transect only in 2009 included Long-tailed Jaegers (but seen off-transect in 2008) and Spectacled Eiders. Species-richness of birds seen on transect was higher in Klondike than in Burger in all seasons and years except for late summer 2009 (Figure 24).

Species-composition varied substantially among seasons and between study areas, and these patterns differed between years (Figure 25). Klondike was numerically dominated by alcids and tubenoses in both years. In 2008, alcids were the most abundant species-group in Klondike and composed 53% of all birds, followed in decreasing order by tubenoses (24%) and larids (17%); in 2009, however, tubenoses were the most abundant species-group, composing 65% of all birds. Alcids remained important but larids were present in trace numbers. Burger was numerically dominated by larids and tubenoses in 2008, but alcids were most abundant in 2009, composing 82% of all birds recorded there.

In late summer, alcids were the most abundant species-group in Klondike in both years (Figures 26 and 27). In 2008, alcids (primarily Thick-billed Murres) and larids (primarily Black-legged Kittiwakes) were the most abundant species-groups, composing 62% and 22% of all birds, respectively; waterfowl and tubenoses collectively composed 16% of all birds, whereas loons were not recorded (Figure 25). During late summer 2009, alcids (primarily Crested Auklets) again were the most abundant species-group in Klondike, composing 68% of all birds; phalaropes and tubenoses collectively composed 30% of all birds, whereas larids composed only 2%. In contrast to the pattern seen in Klondike, the species-composition in Burger in late summer changed substantially between years. In 2008, larids (primarily Black-legged Kittiwakes) were the most abundant species-group in late summer 2008, composing 65% of all birds, followed in decreasing order by alcids (20%) and tubenoses (15%); the other three species-groups were not recorded. In 2009, however, alcids (primarily Crested Auklets) were the most abundant species-group in Burger, composing 87% of all birds and followed in decreasing order by

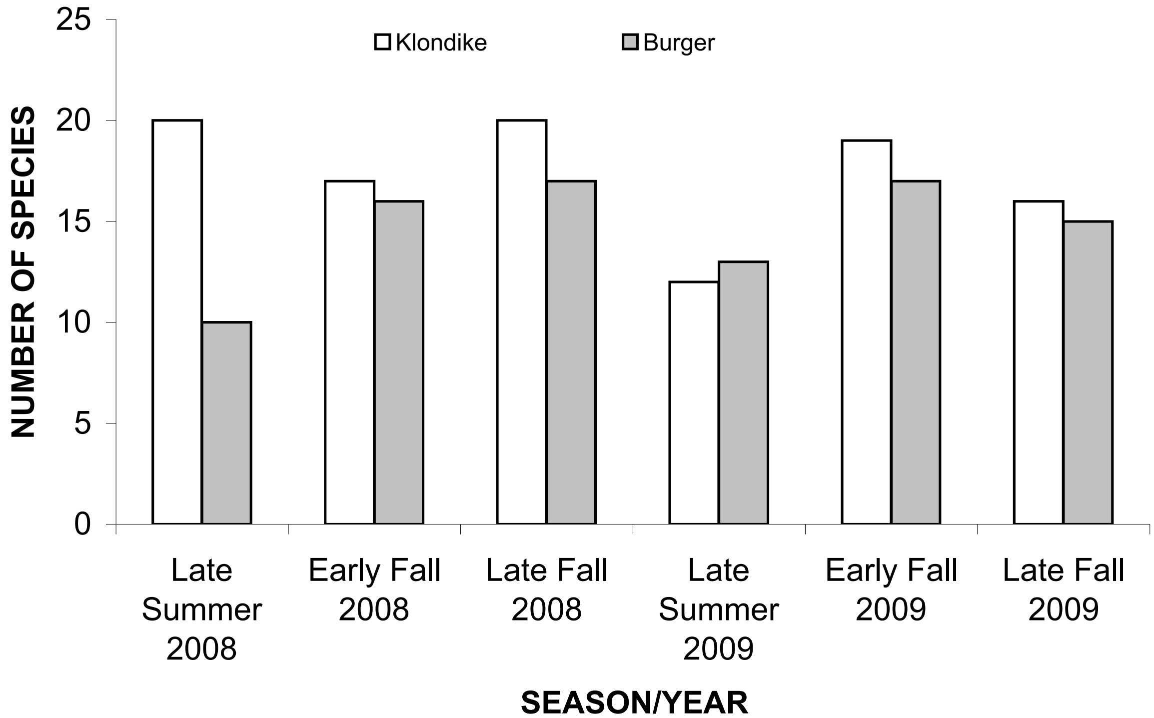



Figure 24. Species-richness of the seabird community recorded on transect in the Klondike and Burger study areas in 2008 and 2009 by study area and season.

tubenoses (7%) and phalaropes (5%); larids accounted for <1% of all birds in Burger at that time.

In early fall, tubenoses were the most abundant species-group in Klondike in both years (Figures 26 and 27). In 2008, tubenoses (especially Short-tailed Shearwaters) composed 46% of all birds recorded in Klondike, followed in decreasing order by alcids (30%) and larids (20%); loons and phalaropes occurred in minor percentages. In 2009, tubenoses again were the most abundant species-group in Klondike (74% of all birds), followed by alcids (23%), and trace percentages of other taxa. The species-composition in Burger in early fall also changed substantially between years. In 2008, tubenoses (38% of all birds) and larids (30%) were the most abundant groups, followed in decreasing order by small percentages of waterfowl (primarily Long-tailed Ducks), phalaropes, and loons (primarily Pacific Loons). In 2009, however, alcids composed 82% of all birds, with tubenoses, larids, and loons in low and similar percentages; waterfowl and phalaropes were rare.

In late fall, the pattern of species-composition in both study areas was similar between years (Figures 26 and 27). Alcids (primarily Crested Auklets) were the most abundant species-group in Klondike and larids were the most abundant species-group in Burger, with tubenoses (primarily Short-tailed Shearwaters) second in abundance in Klondike and third in abundance in Burger. The most abundant larid species in Burger in 2008 was Ross's Gull, whereas the most abundant species in 2009 were Glaucous Gulls and Ross's Gulls. Loons, phalaropes, and waterfowl were rare in both study areas and in both years during late fall.

## CONSERVATION STATUS

During the surveys of 2008 and 2009, we recorded 11 species on transect in the study areas that are classified as being of conservation concern (Table 5). All of these species occurred on at least

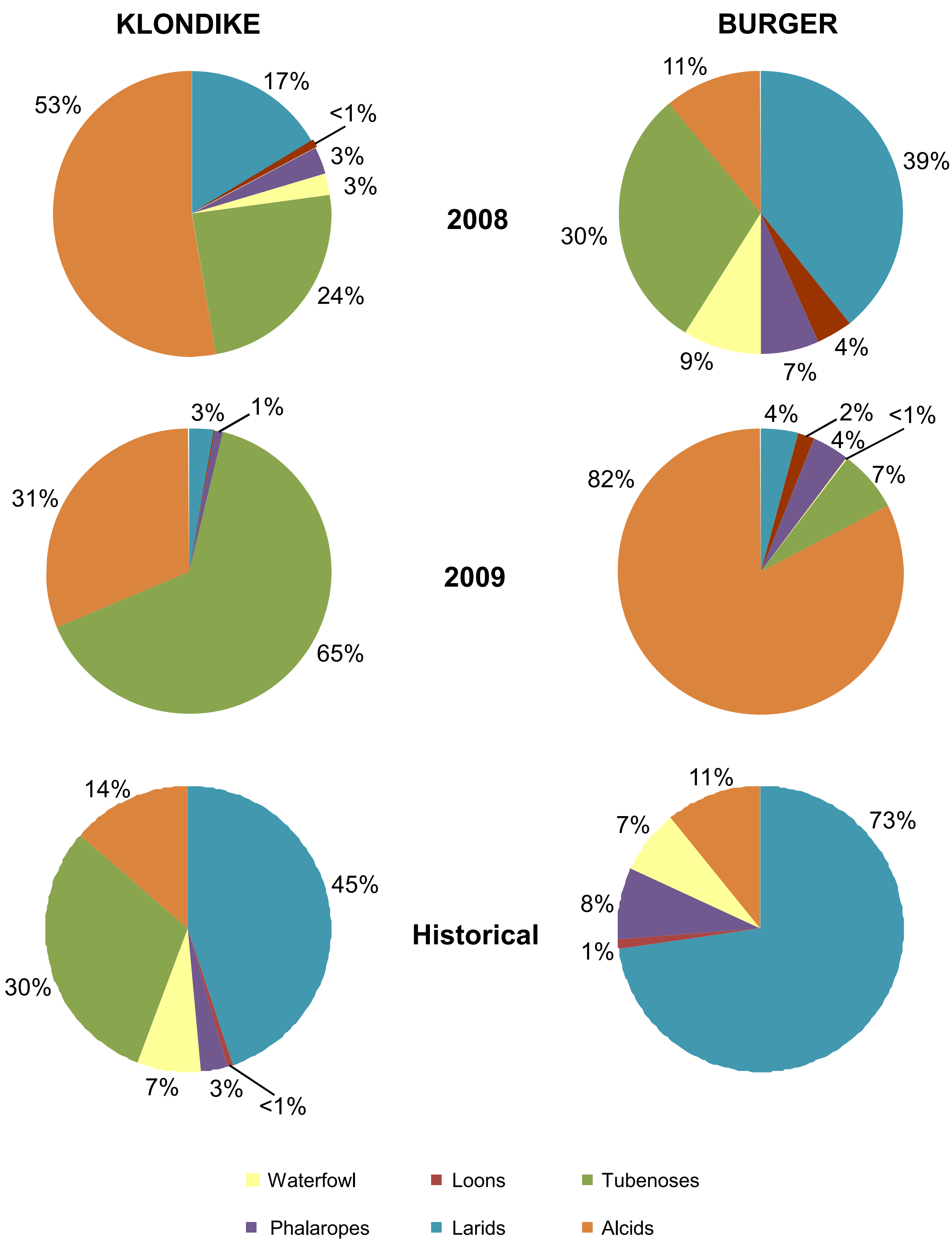



Figure 25. Species-composition of the seabird community on transect in the Klondike and Burger study areas, by year.

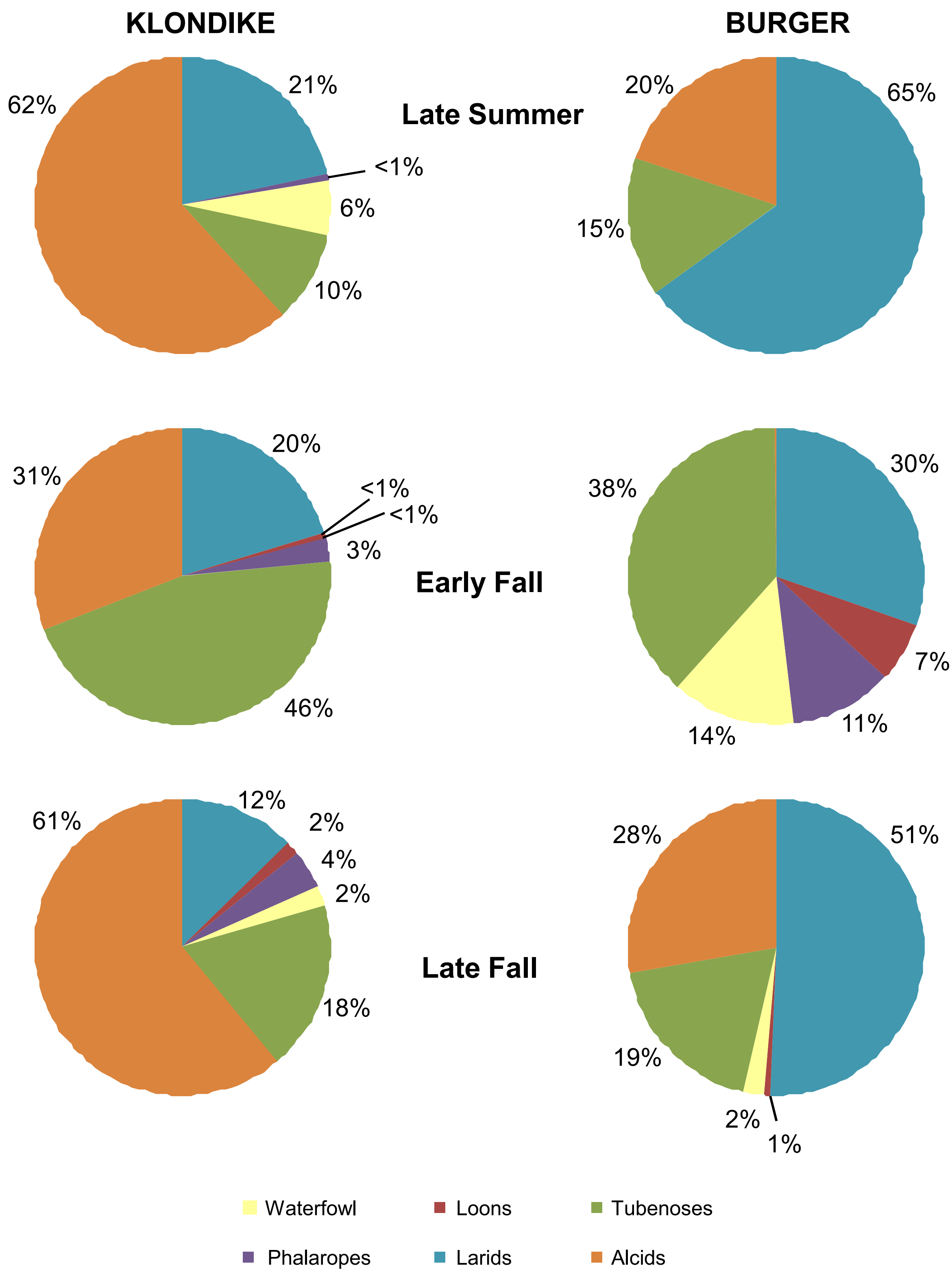



Figure 26. Species-composition of the seabird community on transect in the Klondike and Burger study areas in 2008, by study area and season.

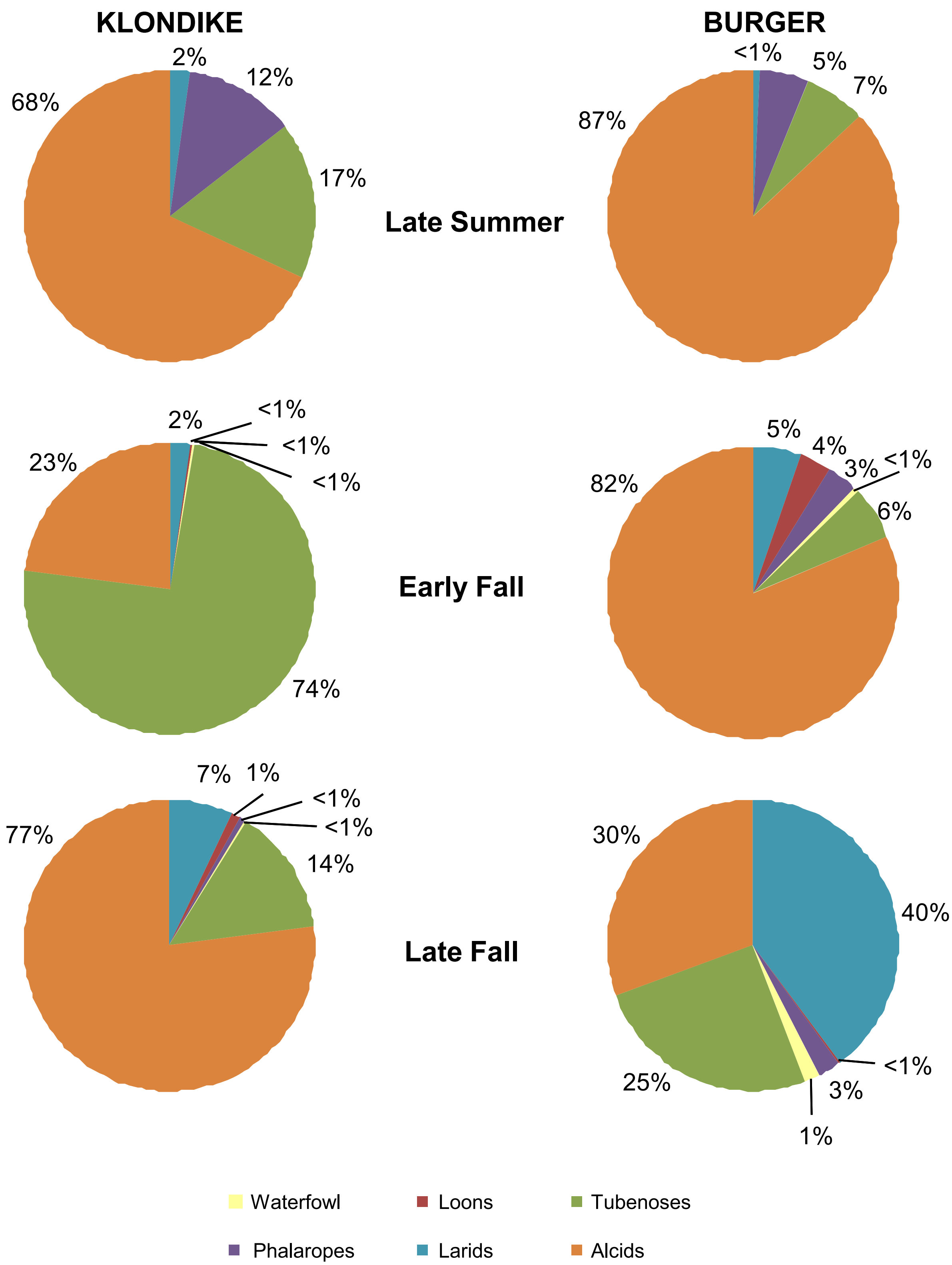



Figure 27. Species-composition of the seabird community on transect in the Klondike and Burger study areas in 2009, by study area and season.

Table 5. 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).

2 of the 5 lists. Of these 11 species, one (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. Surprisingly, 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 eight species as featured for management in the State of Alaska’s Comprehensive Wildlife Conservation Strategy. The nongovernmental 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 a wide variety of 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.

Yellow-billed Loons were rare in 2008, with a total of 4 seen in Klondike and 3 seen in Burger; in 2009, however, they were widely distributed throughout Burger and occurred in the eastern half of Klondike in early fall, and occurred in both study areas in low numbers in late fall (Figure 22). Of the 5 species of waterfowl that are of conservation concern, only the Long-tailed Duck was recorded and widely distributed in both years (Figures 28 and 29). Surprisingly, in 2008, that species occurred only in Klondike in late summer, only in Burger in early fall, and essentially only in Klondike in late fall. In 2009, however, Long-tailed Ducks occurred in both study areas, primarily in late fall. Waterfowl species recorded only in 2008 included King Eiders in both study areas, whereas Common Eiders were recorded only in Burger (early fall) and White-winged Scoters were recorded only in Klondike (late fall). Spectacled Eiders were seen only in late fall 2009, when we recorded one individual in Klondike and one in Burger.

The other 5 species of conservation concern were rare, with ≤14 observations/species in all seasons and both years combined (Figures 22 and 23). The single Red-throated Loon was seen in Burger in early fall 2008. 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 5 Dovekies (all single birds) occurred in Klondike in late summer and late fall 2008, whereas the 2 seen in Burger occurred there in late fall 2008. 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. Finally, the few Kittlitz's Murrelets seen in 2008 were recorded only in Klondike and only in late fall. In 2009, we recorded a single Kittlitz’s Murrelet in Klondike in early fall and a group of 6 in Burger 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 and 2009 surveys (Figures 30–32); however, the differences in sampling intensity between the 2 data sets precludes direct statistical comparisons. Spatial overlap between the 2 data sets was greatest in late summer and, to some extent, early fall, but no historical transects were conducted within ~9 km of either study area in late fall. Consequently, we are unable to derive any strong inferences from a qualitative comparison between the 2 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 30). The highest densities in the vicinity of Klondike occurred west of the study area in early fall, whereas the highest densities in the vicinity of Burger occurred north of

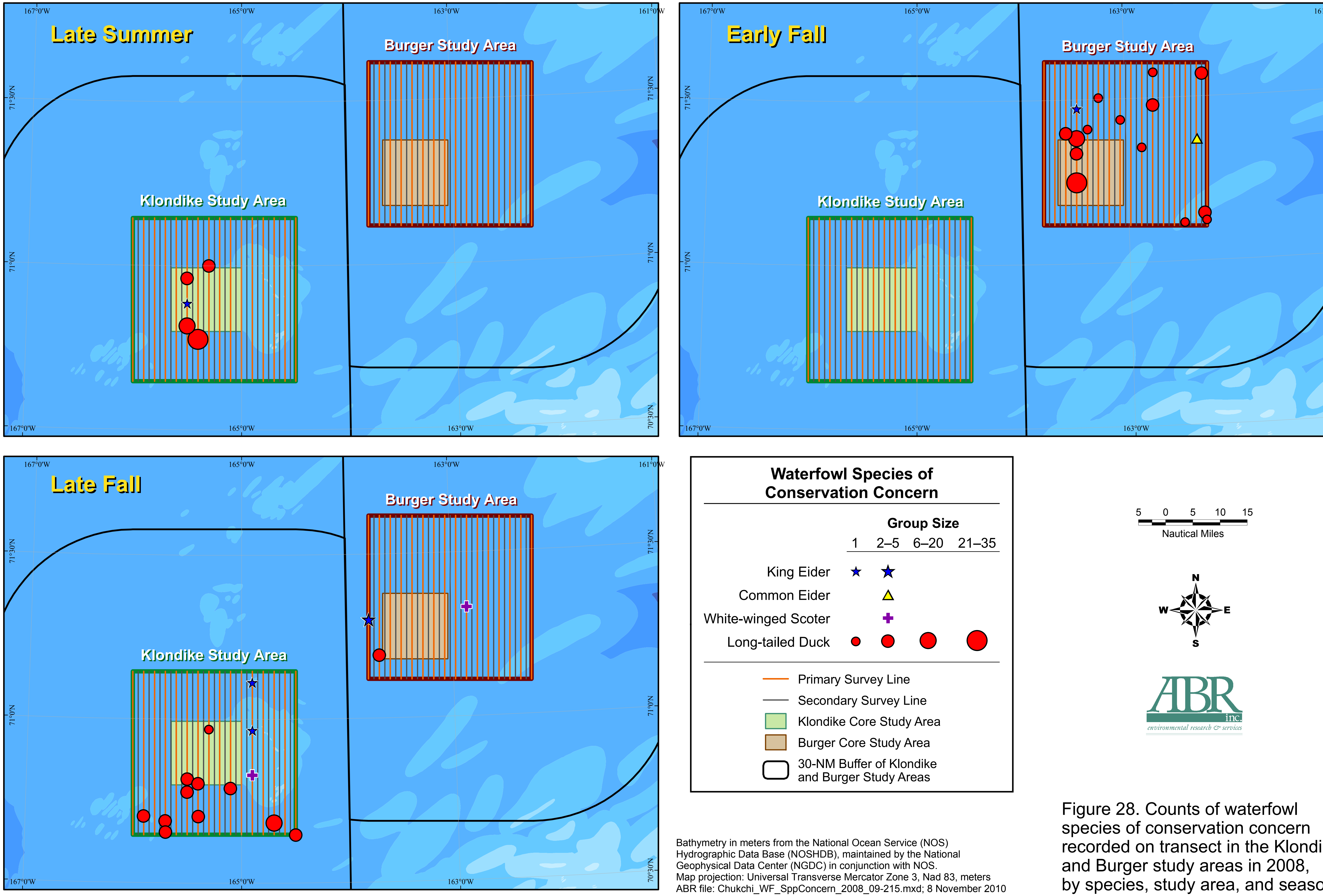
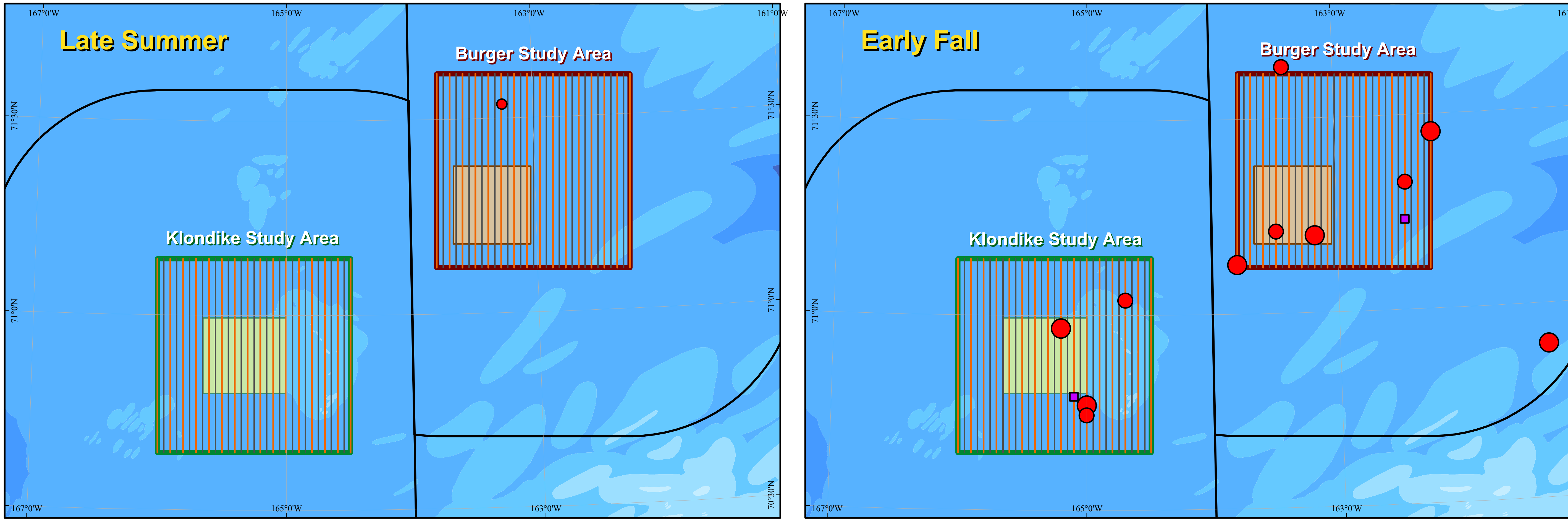
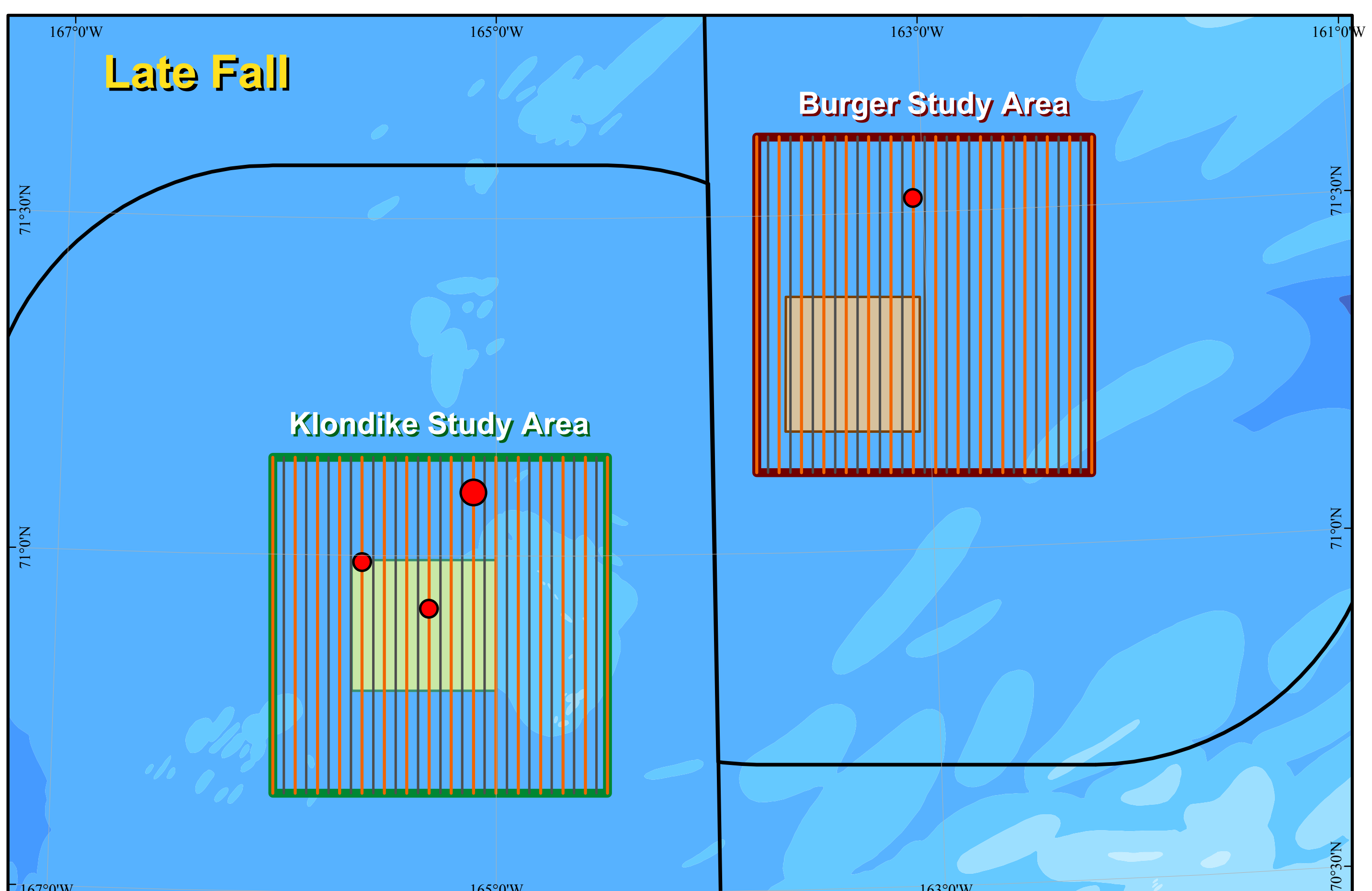
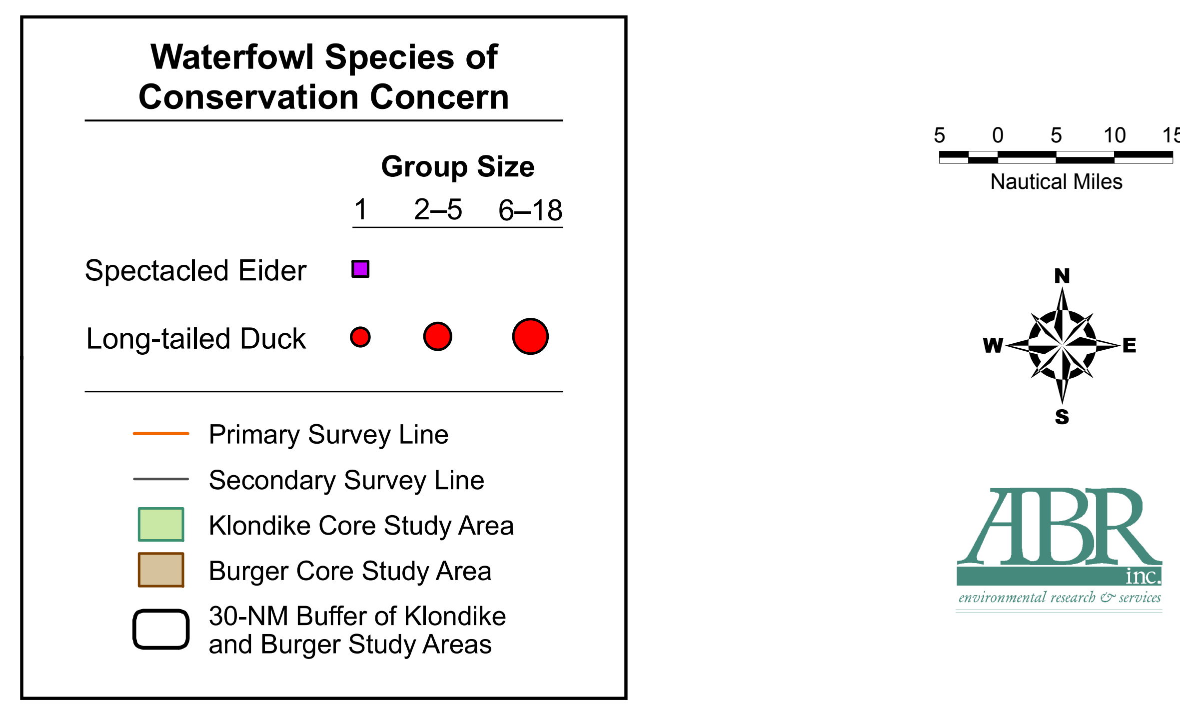



Figure 28. Counts of waterfowl species of conservation concern recorded on transect in the Klondike and Burger study areas in 2008, by species, study area, and season.

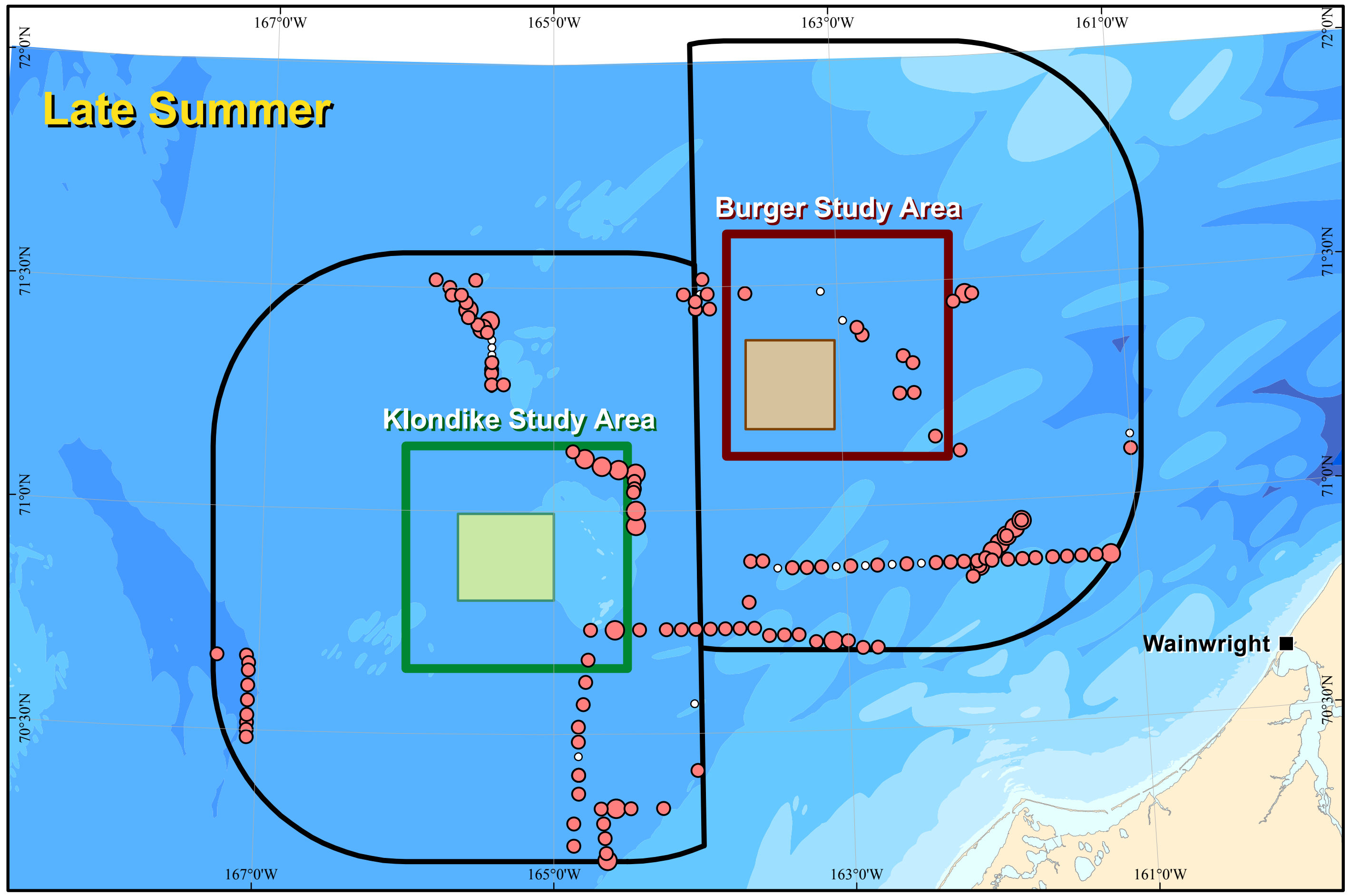


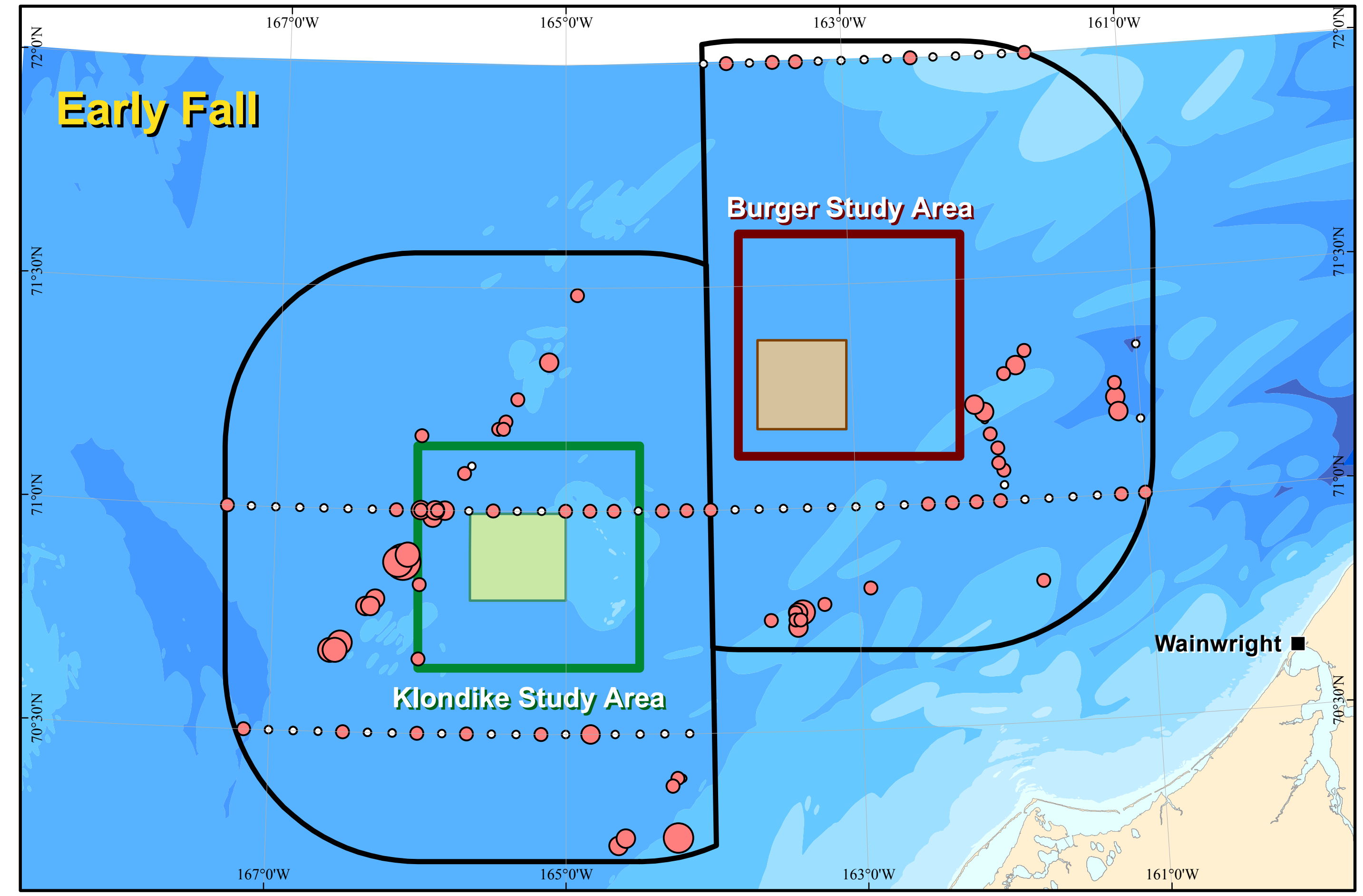



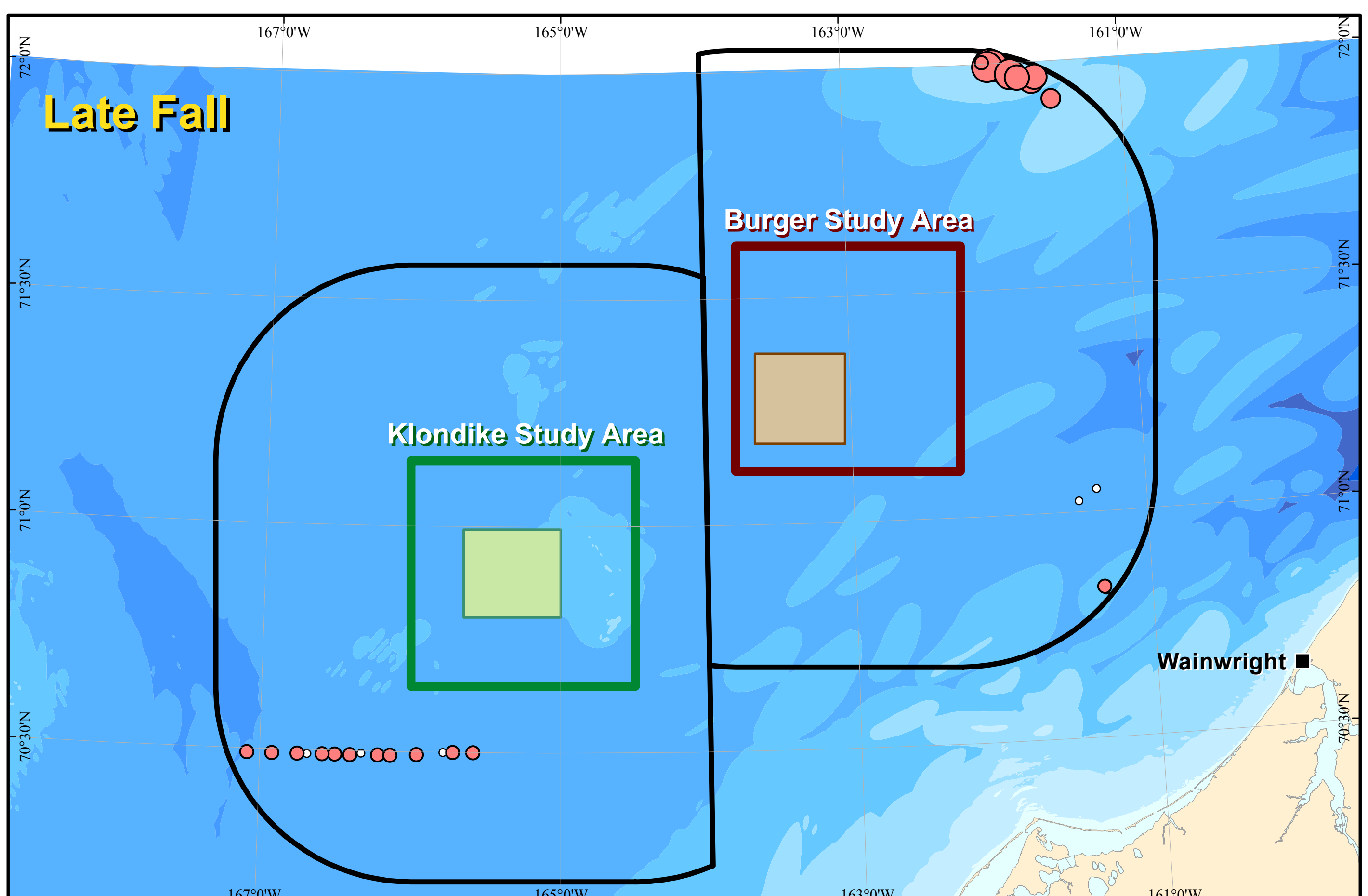



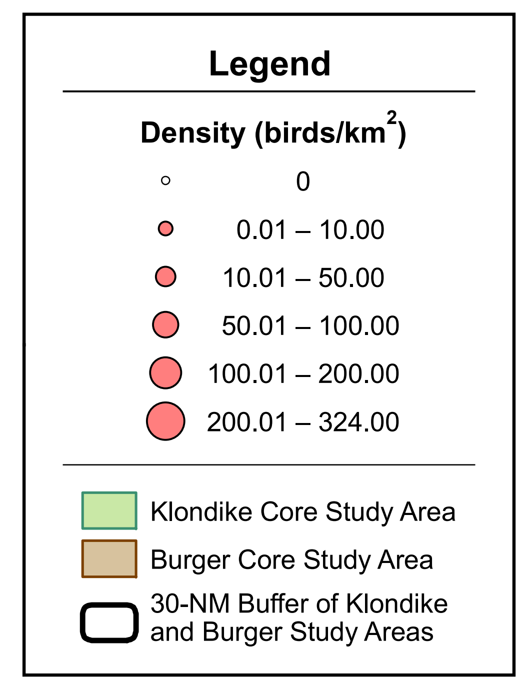

Bathymetry in meters from the National Ocean Service (NOS) Hydrographic Data Base (NOSHDB), maintained by the National Geophysical Data Center (NGDC) in conjunction with NOS.
Map projection: Universal Transverse Mercator Zone 3, Nad 83, meters
ABR file: Chukchi_WF_SppConcern_2009_09-215.mxd; 9 November 2010

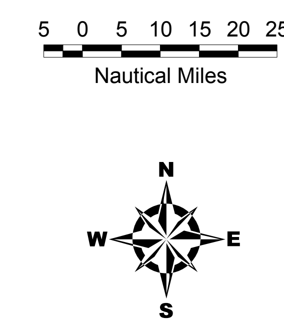
Figure 29. Counts of waterfowl species of conservation concern recorded on transect in the Klondike and Burger study areas in 2009, by species, study area, and season.

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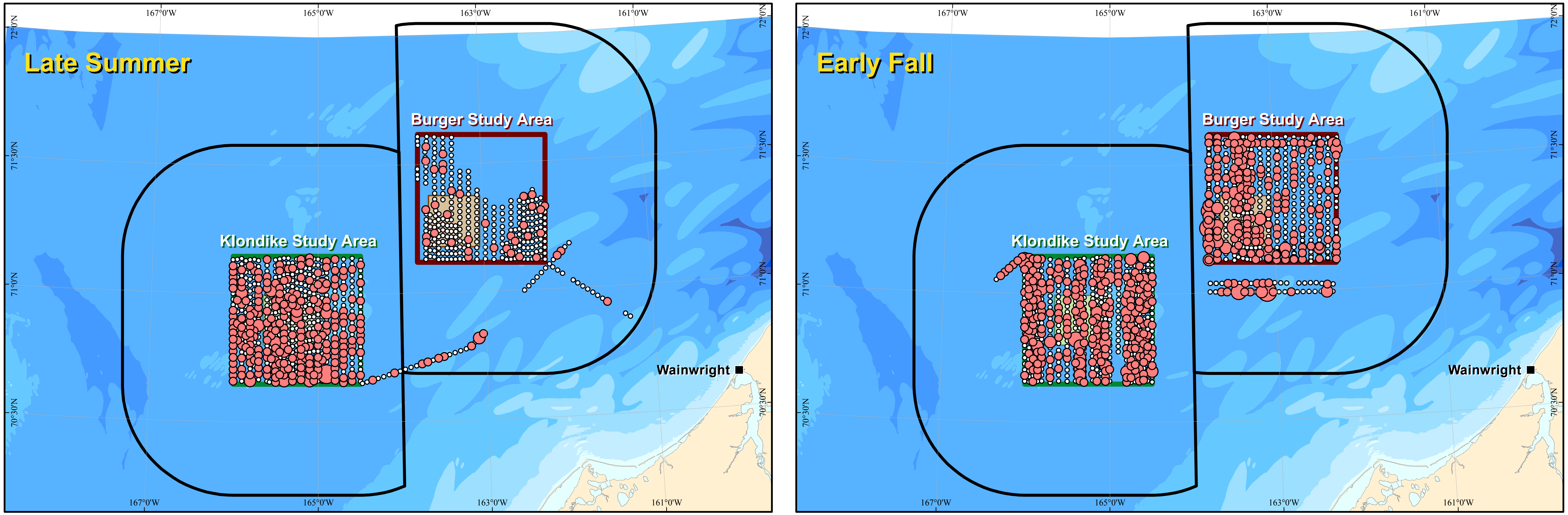
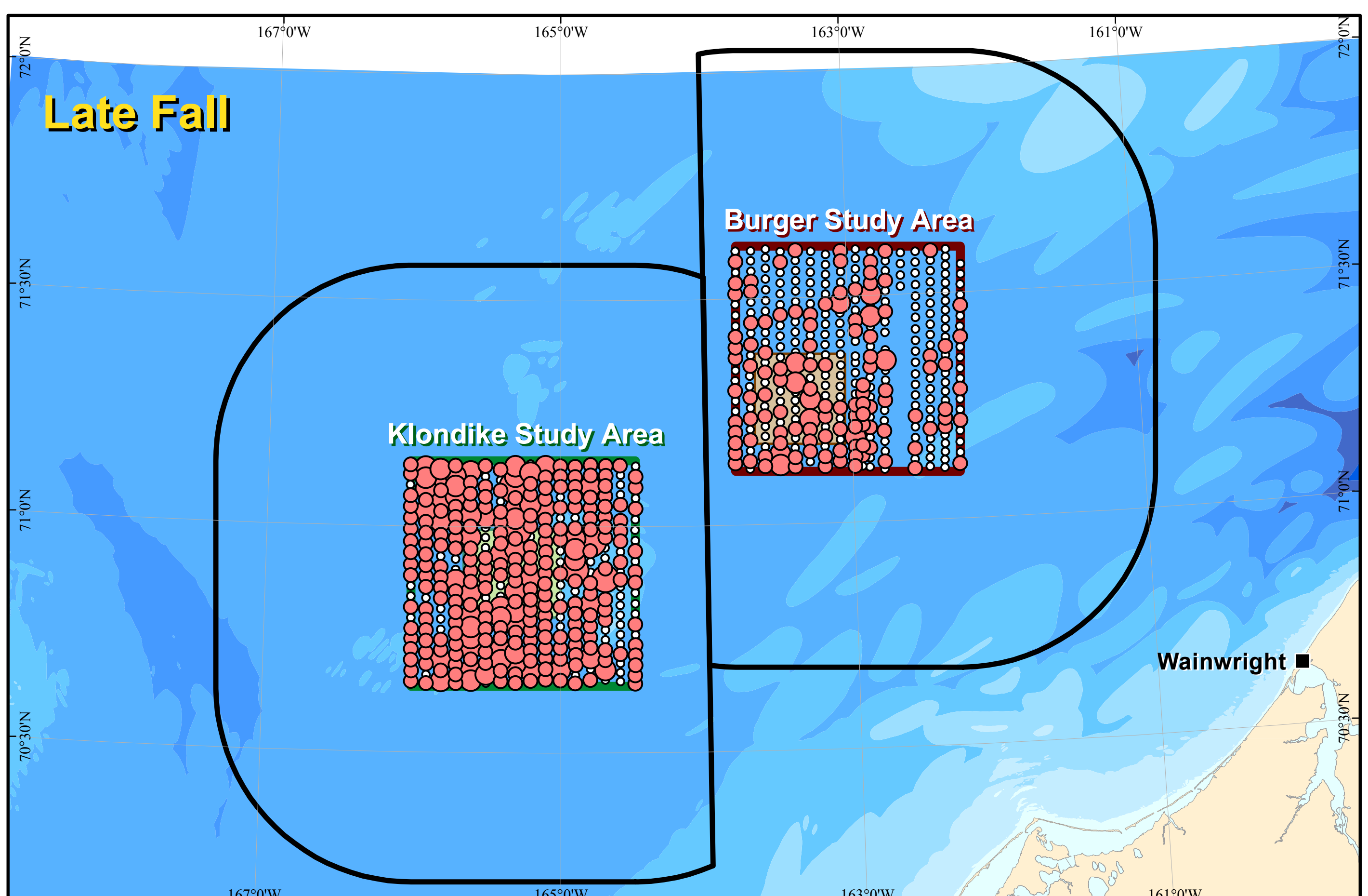
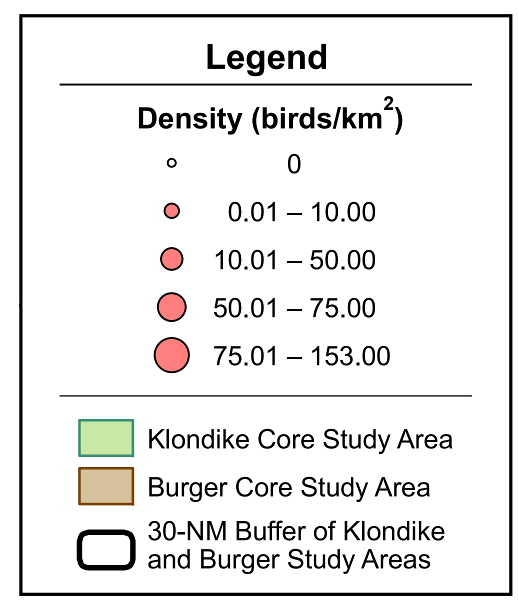
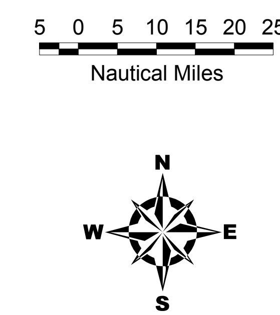
USGS (U.S. Geological Survey). 2005. North Pacific Pelagic Seabird Database (NPPSD v1.0). U.S. Geological Survey, Alaska Science Center, Anchorage, AK. Date of use: 26 January 2009. <http://www.absc.usgs.gov/research/NPPSD/index.htm>
Bathymetry in meters from the National Ocean Service (NOS) Hydrographic 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_HistDens_2008_09-215.mxd; 8 November 2010

Figure 30. Uncorrected total densities (birds/km$^2$) 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. These data are from the North Pacific Pelagic Seabird Database (NPPSD; USGS 2005).




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_Density_AllSpp_2008_09-215.mxd; 8 November 2010

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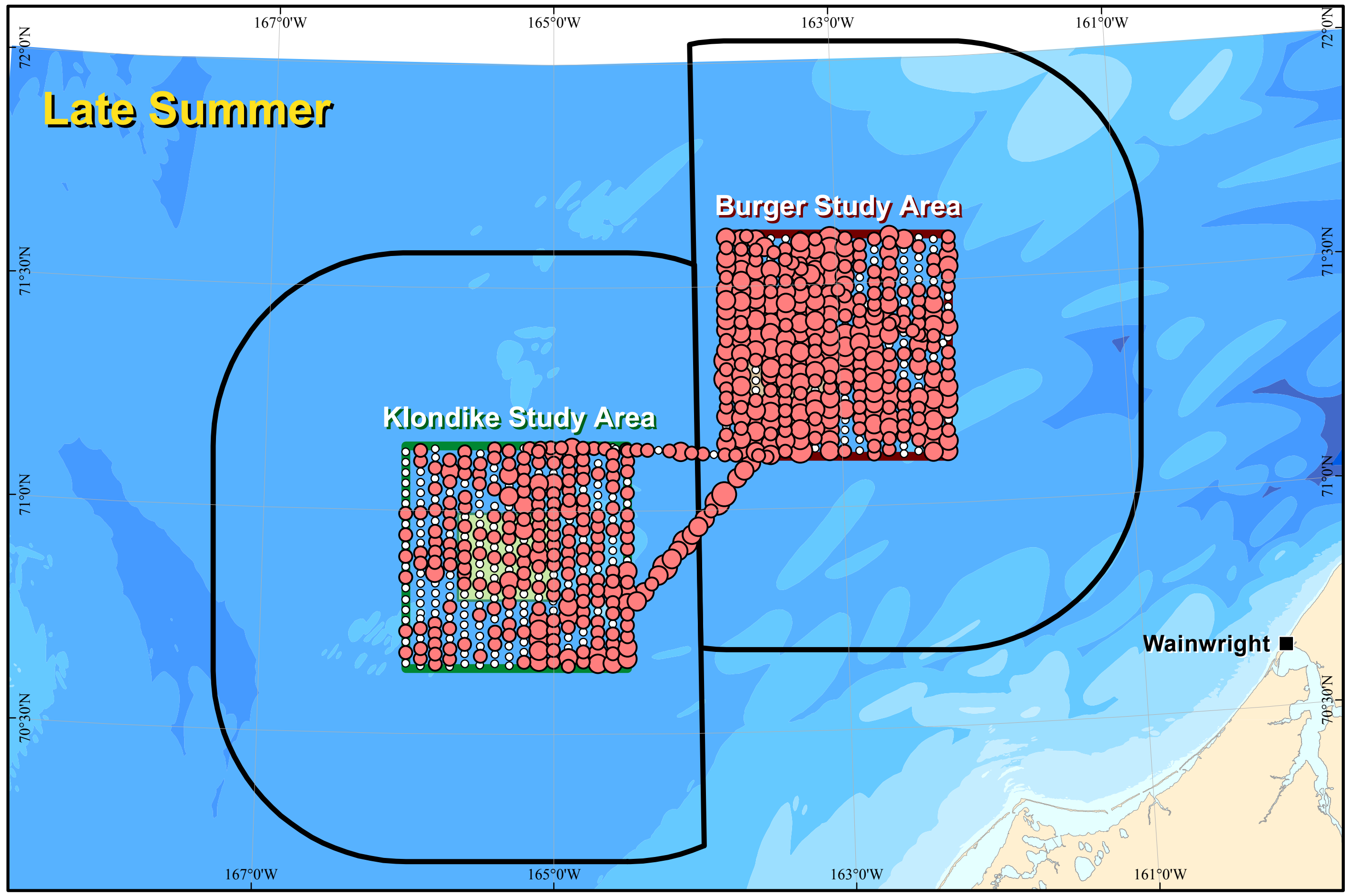
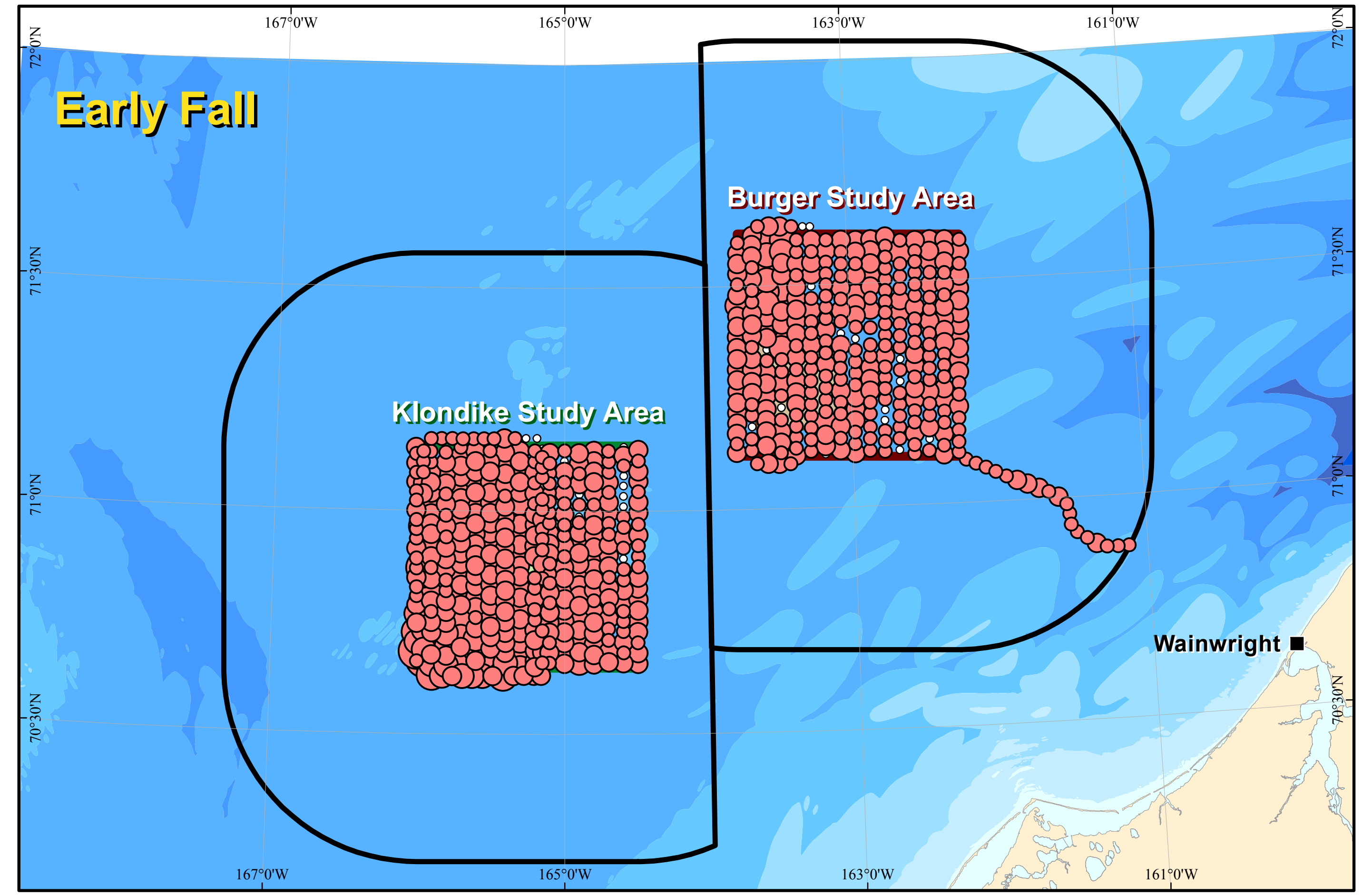
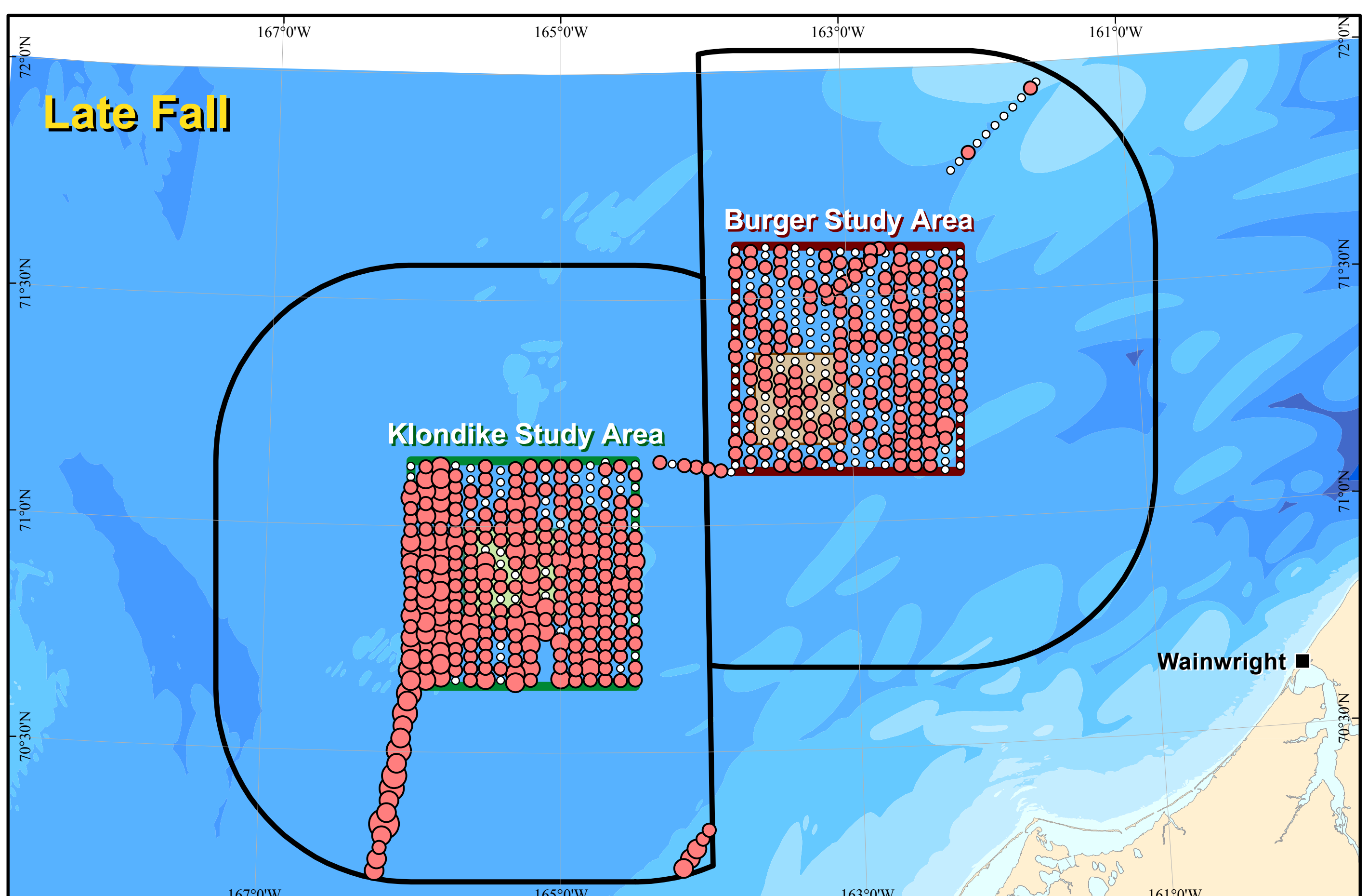
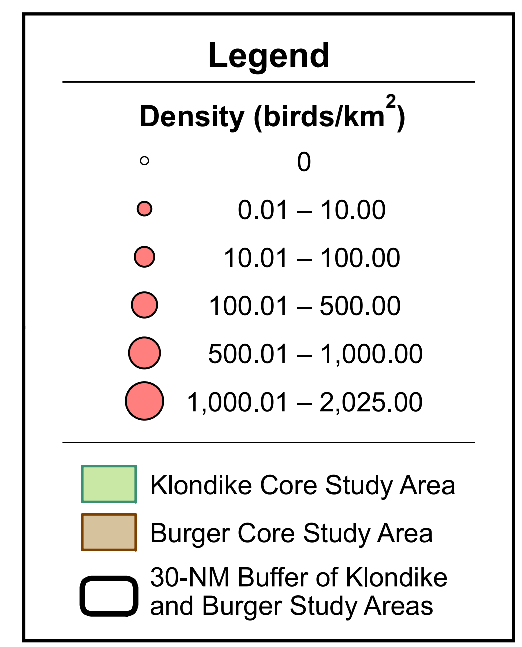
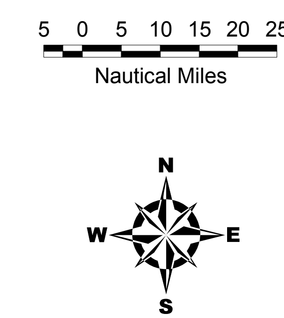
Figure 31. Uncorrected total densities (birds/km$^2$) of all birds recorded on transect in the Klondike and Burger study areas and surrounding buffer zone in 2008, by study area and season. These recent data were re-analyzed as uncorrected densities to make them comparable to the historical data.

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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_Density_AllSpp_2009_09-215.mxd; 8 November 2010

Figure 32. Uncorrected total densities (birds/km$^2$) of all birds recorded on transect in the Klondike and Burger study areas and surrounding buffer zone in 2009, by study area and season. These recent data were re-analyzed as uncorrected densities to make them comparable to the historical data.

the study area, over the shallow waters of Hanna Shoal, in late fall. Mean uncorrected densities recorded on transects within the study-area boxes were 5.1 ± 2.2 birds/$km^2$ in late summer and 7.6 ± 6.0 birds/$km^2$ early fall. Mean uncorrected densities for data collected in 2008 were 1.3 ± 0.3 birds/$km^2$ in late summer and 2.7 ± 0.4 birds/$km^2$ early fall (Figure 31). The highest mean uncorrected densities were recorded in 2009 during late summer (14.3 ± 2.2 birds/$km^2$) and early fall (51.2 ± 11.8 birds/$km^2$, Figure 32). Although historical data were sparse in our study areas, these results indicate that the densities recorded in 2009 were 2 times higher in late summer and 6 times higher in early fall than were densities in the historical dataset.

The species-richness of birds in and near the 2 study areas was lower in the historical surveys (Figure 33) than it was in the 2008 and 2009 surveys, especially in late fall (Figure 24). Although 8 of the 10 most abundant species were shared between the 2 data sets, another 7 species (King Eider, Common Eider, White-winged Scoter, Red-throated Loon, Yellow-billed Loon, Red-necked Phalarope, and Pigeon Guillemot) recorded on the 2008 surveys were not recorded on the historical surveys. All species recorded on the 2009 surveys were 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 and 2009 surveys, and it is possible that that record may have been an uncorrected data point (Pacific Loon was separated taxonomically from Arctic Loon in the 1980s). To a great extent, however, the higher richness in 2008 and 2009, 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 suggest that alcids and tubenoses are more abundant in the central Chukchi Sea now than they were historically (Figures 25–27 and 34). In Klondike, the historical data indicate that larids were more abundant in late summer, tubenoses were in early fall, and alcids were in late fall. In Burger, however, the historical data indicate that larids were more abundant in all 3 seasons, whereas waterfowl, phalaropes, and alcids also were important in early fall.

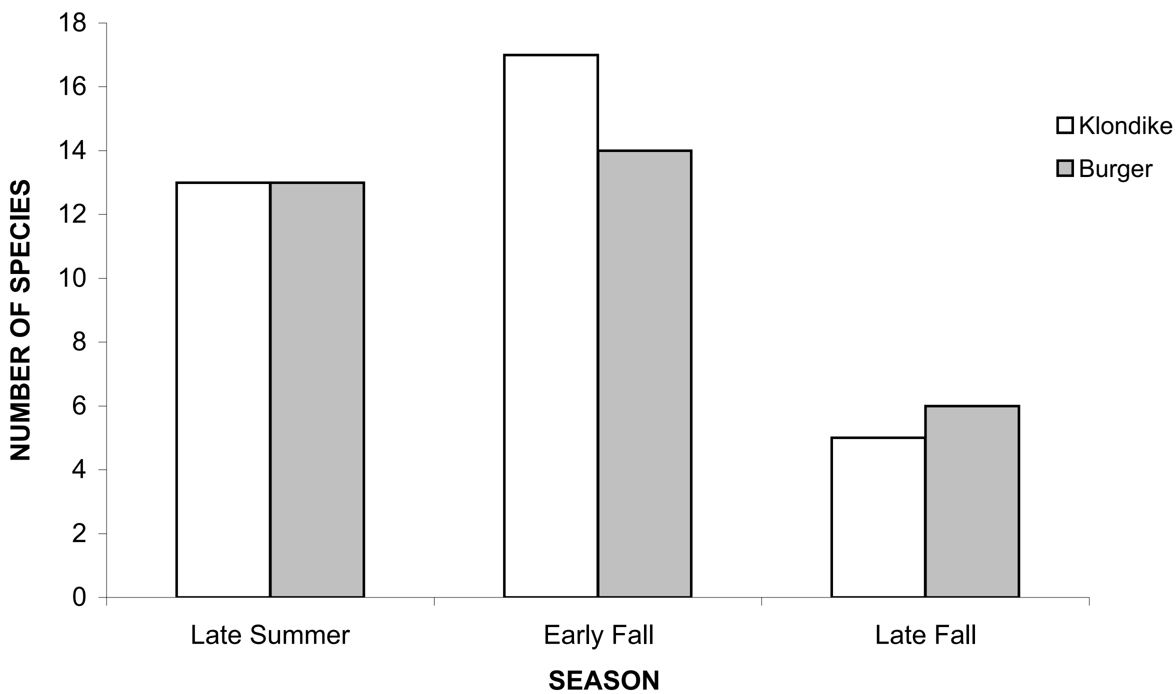


Figure 33. Species-richness of the seabird community on transect in the Klondike and Burger study areas and surrounding buffer zone in historical times, by study area and season. These data are from the North Pacific Pelagic Seabird Database (NPPSD; USGS 2005).

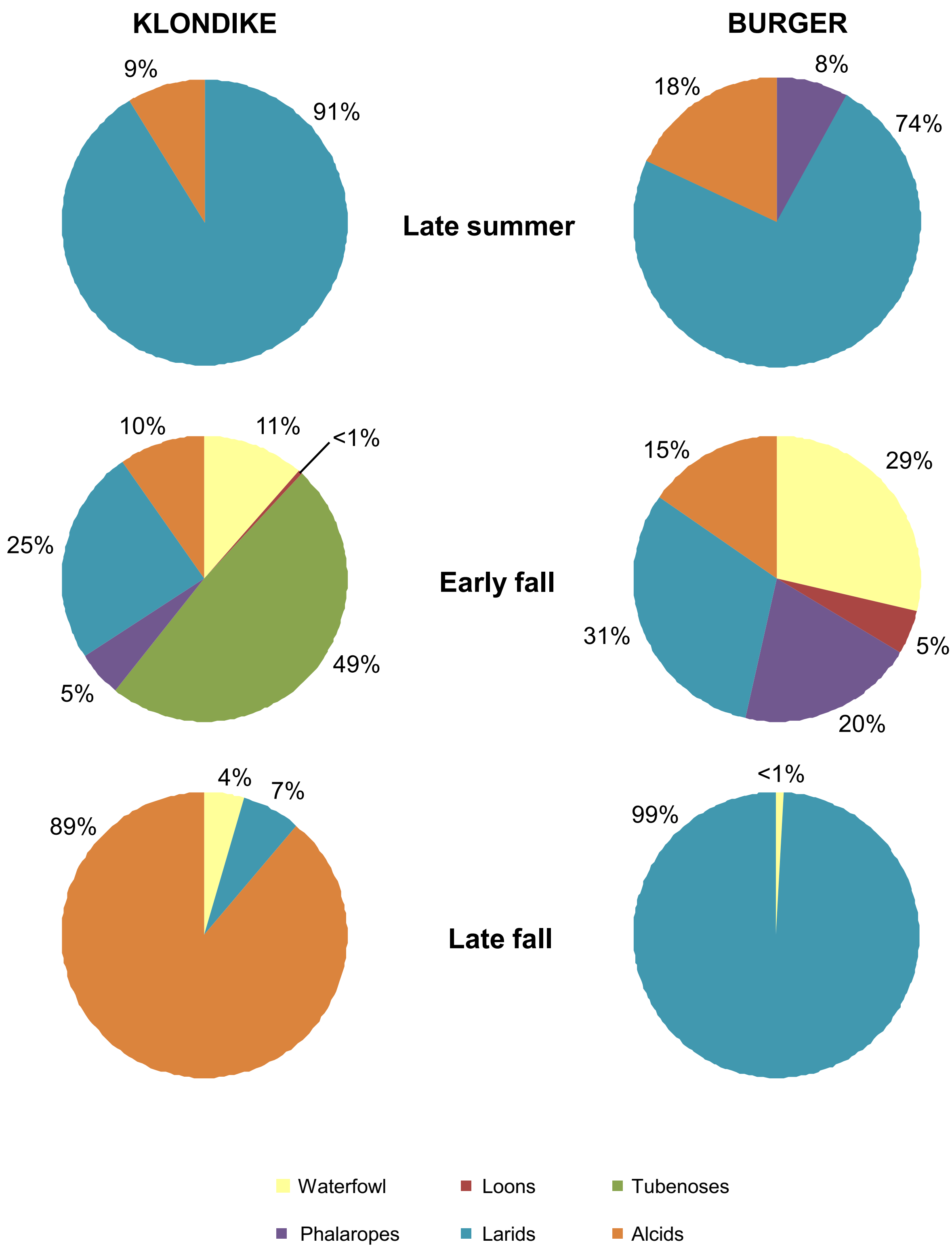


Figure 34. Species-composition of the seabird community on transect in the Klondike and Burger study areas and surrounding buffer zone in historical times, by study area and season. These data are from the North Pacific Pelagic Seabird Database (NPPSD; USGS 2005).

Surprisingly, there were no historical records of tubenoses in or near Burger in any season. In contrast, data from 2008 and 2009 indicated that alcids were most abundant in Klondike in late summer and late fall in both years, alcids were present in Burger in all three seasons and were most abundant in late summer and early fall 2009, and tubenoses were recorded in Burger in all 3 season of both years and were the most abundant species in early fall 2008.

## DISCUSSION

### SPECIES DISTRIBUTION AND ABUNDANCE

Data collected in the first 2 years of this study suggest that there is high seasonal, interannual, and spatial variation in densities and species-composition of the seabird community in the northeastern Chukchi Sea. In 2008, total corrected densities increased seasonally and peaked in late fall at 10.5 birds/km$^2$ in Klondike and 2.3 birds/km$^2$ in Burger. In contrast, total densities started high in Burger in 2009 (40.8 birds/km$^2$) and peaked in both study areas in early fall, with peak densities that were 7 times higher in Klondike (81.3 birds/km$^2$) and nearly 17 times higher in Burger (45.9 birds/km$^2$) than peak densities recorded in the previous year. Densities in both study areas declined in late fall 2009 but were similar to densities seen in late fall 2008.

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 32 species of seabirds within the 2 study-area boxes during our sampling and saw 2 other species off-transect, but only 8 focal species were common enough in both years for us to estimate densities with confidence: 1 loon (Pacific Loon), 2 tubenoses (Northern Fulmar and Short-tailed Shearwater), 2 larids (Black-legged Kittiwake and Glaucous Gull), and 3 alcids (Thick-billed Murre, Crested Auklet, and Least Auklet). The other 24 species were uncommon to 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 in the second year of this program improved the reliability of the density estimates; a third year of data will inform this analysis further.

The numerical dominance of the seabird community by just a few species resulted in simplified patterns of species-composition that, like total densities, differed between years. Most notably, larids were most abundant in Burger and either second or third in importance in Klondike in 2008 but were far less common in both study areas in late summer and early fall 2009, when alcids and tubenoses were the most abundant components of the seabird community. This shift in species composition between years reflects an increase in use of the study areas by plankton-feeding seabirds (especially Crested Auklets and Short-tailed Shearwaters) in 2009.

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 both years, however, none of the species occurred within the 2 study areas 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. There is substantial concern about 3 other species (King Eider, Red-throated Loon, Arctic Tern), whereas the level of concern is lower for the other 5 species.

### OCEANOGRAPHIC RELATIONSHIPS

We propose here that the structure of the seabird community in the northeastern Chukchi Sea differs spatially and temporally and that these differences reflect oceanographic differences between the 2 study areas and between years. 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, Hopcroft et al. 2008). In the Chukchi Sea, the net flow of water is northward through Bering Strait and toward the Arctic Ocean. The flow is contained within 2 main water-masses, with (1) the 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 (a combination of both shelf water from the Bering Sea and oceanic Anadyr Water that has flowed northward across the Bering Sea shelf) 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).

Although the exact placement of these 2 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 transition zone between the 2 systems appearing to fall somewhere between the 2 study areas. As seen on the vertical sections of temperature and salinity, the edge of the current flowing north in the Central Channel (the Central Channel 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 had no strong currents and was dominated by water indicative of remnants of the pack ice that were melting in place (i.e., it functioned more as shelf or coastal water than as oceanic water). These oceanographic distinctions between the 2 study areas were less apparent in 2009, a warmer year when the pack ice retreated before the start of our sampling and the water-column structure was essentially oceanic water across most of both study areas.

The distribution of seabirds, particularly the planktivorous species, may be influenced by the advective processes that transport oceanic species of zooplankton from the Bering Sea to the Chukchi Sea, and this transport apparently differed between years. In 2008, Klondike was characterized by warm, salty Bering Shelf Water, and the copepods found there were primarily large oceanic copepods, especially in late fall (Hopcroft et al. 2010). In contrast, Burger was characterized by cold, fresh meltwater in all three seasons, and the copepods found there were small and typical of coastal water (Hopcroft et al. 2010). In 2008, diving planktivorous birds consistently were more abundant in Klondike but surface-feeding larids were consistently more abundant in Burger. In 2009, however, the water generally was warm, salty oceanic water spread across both Klondike and Burger in all seasons, indicating that Bering Shelf Water intruded farther east from the Central Channel than it did in 2008. As a result, planktivorous auklets and Short-tailed Shearwaters were abundant in both study areas in late summer and early fall 2009, suggesting that these birds rapidly respond to changes in oceanographic conditions and exploit food resources when and where they are available. Despite oceanographic differences between years, species-composition and densities in each study area were similar between years in late fall, with auklets more common in Klondike and larids more common in Burger. It is possible that toward the end of the open-water season, much of the prey available in Burger earlier in the season had been consumed, causing planktivores to concentrate closer to the Central Channel, where the Central Current continues to supply zooplankton advected from the Bering Sea. Migration phenology of the birds also may play a role in determining when they move south out of Burger and then Klondike.

We hypothesize that differences in oceanographic structure between the 2 study areas and between years explains many of the ecological differences in the seabird community and in other trophic levels as well. For example, as mentioned above, larger oceanic zooplankton were more common in the Klondike study area, whereas smaller shelf zooplankton were more common in the Burger study area (Hopcroft et al. 2010). Similarly, analysis of benthic samples suggests that the infaunal benthic community differed between the 2 study areas, with the Klondike study area having lower biomass and species-diversity than the Burger study area (Blanchard et al. 2010). The scientists conducting baseline chemical sampling in 2008 found large numbers of epibenthic amphipods, most of which are detritivores, in Burger but few in Klondike (Neff et al. 2010), suggesting that much of the primary productivity is falling to the bottom in Burger but not in Klondike. Finally, the benthic-feeding marine mammals such as Pacific Walruses (*Odobenus rosmarus*) and bearded seals (*Erignathus barbatus*) were more common in Burger than in Klondike, whereas pelagic-feeding seals were more common in Klondike (Brueggeman 2009). All of this information suggests that these 2 study areas may be different ecologically and that the differences in the seabird community reflect the influence of oceanography on trophic structure in the northeastern Chukchi Sea.

## COMPARISON WITH HISTORICAL DATA

We must begin our discussion about the comparisons of the 2008–2009 data and historical NPPSD data with several caveats. First, the historical data set was collected over several years in the 1970s and 1980s with incomplete spatial and/or seasonal coverage in any given year, whereas the data in this study were collected systematically during most of the open-water season in both years. Although our data provide strong evidence of seasonal and interannual differences in densities, there are not enough data for a quantitative comparison with historical data among seasons or years.  Second, the historical data do not have good spatial overlap with our study-area boxes. As a result, we had to increase our comparison area by adding ~56-km (30-NM) buffer zones around the study areas to provide enough data for a minimal comparison. Third, survey design differed between the 2 data sets: some of the historical data were collected opportunistically during other oceanographic sampling, so few transects were replicated, whereas data from the 2008–2009 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 across all years), whereas sample sizes in the 2008–2009 data sets were large ($n$ = 2,690 transects in 2008 and $n$ = 2,000 transects in 2009).

Given these caveats, it nevertheless appears that, although the patterns in the seasonal occurrence of many species and the general distribution of many species are similar to those seen in both the NPPSD data and data presented in Divoky (1987), planktivorous seabirds are more common now than they were historically. 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 then called the central Chukchi Sea), and those seasonal periods matched ours almost exactly. In Klondike, 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. In Burger, however, alcids were rare and tubenoses were absent in the historical data, whereas they now are abundant.

Historically, the areas of highest bird densities were located 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). For example, 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 Current. The highest densities in the vicinity of Burger were recorded north of the study area, along the edge of the advancing pack ice in late fall. Historical densities on transects conducted within the boundaries of the Klondike and Burger study areas were lower than those conducted outside of the boundaries. This spatial difference in historical densities is consistent with the hypothesis that oceanographic structure influences the distribution and abundance of seabirds in the northern Chukchi Sea.

After accounting for spatial and temporal overlap, it appears that densities recorded historically (Divoky 1987, USGS 2005) were similar to those recorded in 2008 and at least 5 times lower than those recorded in 2009. Uncorrected densities within Klondike and Burger during late summer and early fall were 2.8–8.3 birds/km$^2$ in the historical data, 2.0–5.3 birds/km$^2$ in 2008, and 14.3–51.2 birds/km$^2$ in 2009. We caution that comparisons between the historical data and the recent data are imperfect, but they suggest that densities were higher in 2009 than in previous years.

## CONCLUSIONS

The 2 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 80 birds/km$^2$ within a study area. Eleven species of seabirds of conservation concern occur in this area, including 1 (Spectacled Eider) listed as threatened and 2 listed as candidate species under the ESA. There is extensive seasonal and interannual variation in the abundance of the seabirds in this area, with the greatest number of birds generally 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 differed between the 2 study areas and between years. We hypothesize that these differences reflect oceanographic differences between the 2 study areas and propose 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 (Blanchard et al. 2010, Hopcroft et al. 2010), and we believe that a synthesis of the data collected by all disciplines will elucidate this difference more clearly.

## LITERATURE CITED

ADFG (Alaska Department of Fish and Game). 2009. Lists of Endangered Species and Species of Special Concern in Alaska. Alaska Department of Fish and Game, Division of Wildlife Conservation, Anchorage, AK. Date of use: 25 March 2010. <http://www.adfg.state.ak.us/special/esa/esa_home.php>

ADFG (Alaska Department of Fish and Game). 2006. Our wealth maintained: A strategy for conserving Alaska's diverse wildlife and fish resources. Alaska Department of Fish and Game, Juneau, Alaska. 824 p. Date of use: 25 March 2010. <http://www.sf.adfg.state.ak.us/statewide/ngplan/NG_outline.cfm>

Alaska Natural Heritage Program. 2008. AKNHP Vertebrate Species Tracking List, November 2008. Environmental and Natural Resources Institute, University of Alaska, Anchorage, AK. Date of use: 25 March 2010. <http://aknhp.uaa.alaska.edu/zoology/pdfs/tracking_lists/2008_VertebrateSpeciesTrackingList.pdf>

Balogh, G. R. 1997. Status report of the Spectacles Eider (*Somateria fischeri*), a threatened species. Unpublished report prepared by U.S. Fish and Wildlife Service, Anchorage, AK. 62 pp.

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. Unpublished report prepared for ConocoPhillips and Shell Exploration and Production Company, Anchorage, AK, by the Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, AK. 86 pp.

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.

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

Brueggeman, J. 2009. Marine mammal surveys at the Klondike and Burger survey areas in the Chukchi Sea during the 2008 open water season. Unpublished report prepared for ConocoPhillips and Shell Exploration and Production Company, Anchorage, AK, by Canyon Creek Consulting LLC, Seattle, WA. 46 pp.

Coachman, L. K., K. Aagard, and R. B. Tripp. 1975. Bering Strait: the regional physical oceanography. University of Washington Press, Seattle, WA. 172 pp.

Dau, C. P., and W. W. Larned. 2004. Aerial population survey of Common Eiders and other waterbirds in near shore waters and along barrier islands of the Arctic Coastal Plain of Alaska, 24–27 June 2004. Unpublished report prepared by U.S. Fish and Wildlife Service, Anchorage, AK. 19 pp.

Day, R. H., J. R. Rose, A. K. Prichard, R. J. Blaha, and B. A. Cooper. 2004. Environmental effects on the fall migration of eiders at Barrow, Alaska. Marine Ornithology 32: 13–24.

Dickson, L. and T. Bowman. 2009. Identification of Chukchi and Beaufort Sea migration corridor for sea ducks. Unpublished annual project summary submitted to the Sea Duck Joint Venture by U.S. Fish and Wildlife Service, Anchorage, AK. 6 pp. Date of use: 14 April 2010. http://www.seaduckjv.org/studies/pro3/pr02B.pdf

Divoky, G. J., 1979. Sea ice as a factor in seabird distribution and ecology in the Beaufort, Chukchi, and Bering Seas. Pages 9–17 *in* Conservation of marine birds of northern North America (J. C. Bartonek and D. N. Nettleship, eds.). U.S. Fish and Wildlife Service, Wildlife Research Report No. 11.

Divoky, G. J. 1987. The distribution and abundance of birds in the eastern Chukchi Sea in late summer and early fall. Final report prepared 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., and A. M. Springer. 1988. Pelagic and coastal birds. Pages 69–83 *in* The environment and resources of the southeastern Chukchi Sea (M. J. Hameedi and A. S. Naidu, eds.). National Oceanic and Atmospheric Administration, Anchorage, AK.

Divoky, G., G. A. Sanger, S. A. Hatch, and J. C. Haney. 1988. Fall migration of Ross' Gull (*Rhodostethia rosea*) in Alaska Chukchi and Beaufort seas. U.S. Fish and Wildlife Service, Anchorage, AK. OCS Study MMS 88–0023. 120 pp.

Feder, H. M., N. R. Foster, S. C. Jewett, T. J. Weingartner, and R. Baxter. 1994a. Mollusks in the northeastern Chukchi Sea. Arctic 47: 145–163.

Feder, H. M., A. S. Naidu, S. C. Jewett, J. M. Hameedi, W. R. Johnson, and T. E. Whitledge. 1994b. The northeastern Chukchi Sea: benthos–environmental interactions. Marine Ecology Progress Series 111: 171–190.

Federal Register. 2001. Final determination of critical habitat for the spectacled eider. Federal Regsiter 66 (25): 9146-9185.

Gall, A. E., and R. H. Day. 2009. Distribution and abundance of seabirds in the northeastern Chukchi Sea, 2008. Unpublished report prepared for ConocoPhillips Alaska, Inc. and Shell Exploration and Production Company, Anchorage, AK, by ABR, Inc.—Environmental Research & Services, Fairbanks, AK. 55 pp.

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.

Hansell, D. A., J. J. Goering, J. J. Walsh, C. P. McRoy, L. K. Coachman, and T. E. Whitledge. 1989. Summer phytoplankton production and transport along the shelf break in the Bering Sea. Continental Shelf Research 9: 1085–1104.

Hopcroft, R., B. Bluhm, and R. Gradinger (eds.). 2008. Arctic Ocean synthesis: analysis of climate change impacts in the Chukchi and Beaufort seas, with strategies for future research. Unpublished report to the North Pacific Research Board, Anchorage, AK, by the Institute of Marine Sciences, University of Alaska, Fairbanks, AK. 184 pp.

Hopcroft, R. R., J. Questel, and C. Clarke-Hopcroft. 2010. Oceanographic assessment of the planktonic communities in the Klondike and Burger survey areas of the Chukchi Sea: Report for Survey year 2009. Unpublished report prepared for ConocoPhillips and Shell Exploration and Production Company, Anchorage, AK, by the Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, AK. 54 pp.

Jaques, F. L. 1930. Water birds observed on the Arctic Ocean and the Bering Sea in 1928. Auk 47: 353–366.

Johnson, S. R. 1993. An important early-autumn staging area for Pacific Flyway Brant: Kasegaluk Lagoon, Chukchi Sea. Journal of Field Ornithology 64: 539–548.

Johnson, S. R., D. A. Wiggins, and P. F. Wainwright. 1993. Late-summer abundance and distribution of marine birds in Kasegaluk Lagoon, Chukchi Sea, Alaska. Arctic 46: 212–227.

Kirchhoff, M. and V. Padula. 2010. The Audubon Alaska WatchList 2010. Audubon Alaska, Anchorage AK. Date of use: 26 October 2010. <http://ak.audubon.org/birds-science-education/alaska-watchlist>

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, NJ. 179 pp.

Neff, J. M., G. S. Durell, J. H. Trefrey, and J. H Brown. 2010. Environmental studies in the Chukchi Sea 2008: Chemical characterizations. Unpublished report prepared for ConocoPhillips and Shell Exploration and Production Company, Anchorage, AK, by Battelle Memorial Institute, Duxbury, MA. 135 pp.

Oppel, S., D. L. Dickson, and A. N. Powell. 2009. International importance of the eastern Chukchi Sea as a staging area for migrating King Eiders. Polar Biology 32: 775–783.

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

Rizzolo, D. J., and J. A. Schmutz. 2009. Monitoring marine birds of concern in the eastern Chukchi nearshore area (loons). U.S. Geological Survey, Alaska Science Center, Anchorage, AK. OCS Study MMS 2008. 36 pp.

Sexson, M. 2010. Spectacled Eider satellite telemetry research at the Alaska Science Center. U.S. Geological Survey, Alaska Science Center, Anchorage, AK. Date of use: 2 November 2010. < http://alaska.usgs.gov/science/biology/seaducks/spei/index.php >

Sambrotto, R. N., J. J. Goering, and C. P. McRoy. 1984. Large yearly production of phytoplankton in the western Bering Strait. Science 225: 1147–1150.

SPSS. 2009. SPSS for Windows, version 18.0.0 SPSS, Inc., Chicago, IL.

Suydam, R. S., D. L. Dickson, J. B. Fadely, and L. T. Quakenbush. 2000a. Population declines of King and Common eiders of the Beaufort Sea. Condor 102: 219–222.

Suydam, R. S., L. T. Quakenbush, D. L. Dickson, and T. Obritschkewitsch. 2000b. Migration of King, *Somateria spectabilis*, and Common, *S. mollissima v-nigra*, eiders past Point Barrow, Alaska, during spring and summer/fall 1996. Canadian Field–Naturalist 114: 444–452.

Suydam, R., L. T. Quakenbush, M. Johnson, J. C. George, and J. Young. 1997. Migration of King and Common eiders past Point Barrow. Pages 21–28 *in* King and Common eiders of the western Canadian Arctic (D. L. Dickson, ed.). Canadian Wildlife Service, Occasional Papers No. 94.

Swartz, L. G. 1966. Sea-cliff birds. Pages 611–678 *in* Environment of the Cape Thompson region (N. J. Wilimovsky and J. N. Wolfe, eds.). U.S. Atomic Energy Commission, Oak Ridge, TN.

Swartz, L. G. 1967. Distribution and movement of birds in the Bering and Chukchi seas. Pacific Science 21: 332–347.

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. 2010a. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14.

Thomas, L., J. L. Laake, S. Strindberg, F. F. C. Marques, S. T. Buckland, D. L. Borchers, D. R. Anderson, K. P. Burnham, S. L. Hedley, J. H. Pollard, J. R. B. Bishop, and T. A. Marques. 2010b. Distance Version 6.0 (Release 2). Research Unit for Wildlife Population Assessment, University of St. Andrews, St. Andrews, United Kingdom. Date of use: 1 March 2010. http://www.ruwpa.st-and.ac.uk/distance/

Thompson, D. Q., and R. A. Person. 1963. The eider pass at Point Barrow, Alaska. Journal of Wildlife Management 27: 348–356.

USFWS (U.S. Fish and Wildlife Service). 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, VA. 85 pp. Date of use: 25 March 2010. <http://www.fws.gov/migratorybirds/NewReportsPublications/SpecialTopics/BCC2008/BCC2008.pdf>

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. Date of use: 25 March 2010. <http://alaska.fws.gov/fisheries/endangered/index. htm>

USGS (U.S. Geological Survey). 2009. North Pacific Pelagic Seabird Database (NPPSD v2.0). U.S. Geological Survey, Anchorage, AK. Date of use: 2 February 2010. <http://www.absc.usgs.gov/research/NPPSD/index.htm>

Watson, G. E., and G. L. Divoky. 1972. Pelagic bird and mammal observations in the eastern Chukchi Sea, early fall 1970. Pages 111–172 *in* WEBSEC–70: An ecological survey in the eastern Chukchi Sea, September–October 1970. U.S. Coast Guard Oceanographic Report No. 50 (CG 373–50).

Weingartner, T., and S. Danielson. 2010. Physical oceanographic measurements in the Klondike and Burger prospects of the Chukchi Sea: 2008 and 2009. Unpublished DRAFT report prepared for ConocoPhillips and Shell Exploration and Production Company by the Institute of Marine Sciences, University of Alaska, Fairbanks, AK. 41 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: 3150–3174.

Weingartner, T., K. Shimada, F. McLaughlin, and A. Proshutinsky. 2008. Physical oceanography. Pages 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.). Unpublished report to the North Pacific Research Board, Anchorage, AK, by the Institute of Marine Sciences, University of Alaska, Fairbanks, AK.

Woodby, D.A., and G. J. Divoky. 1982. Spring migration of eiders and other waterbirds at Point Barrow, Alaska. Arctic 35: 403–410.

Woodgate, R. A., K. Aagard, and T. J. Weingartner. 2005. A year in the physical oceanography of the Chukchi Sea: moored measurements from autumn 1990–1991. Deep-Sea Research (Part II) 52: 3116–3149.

Appendix A. List of all birds recorded during boat-based marine surveys in the northeastern Chukchi Sea, 2008 – 2009. 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 |
| Thick-billed Murre | *U. lomvia* | |
| Black Guillemot | *Cepphus grylle* | iŋaġiq |
| Pigeon Guillemot | *C. columba* | |
| Kittlitz's Murrelet | *Brachyramphus brevirostris* | |
| Parakeet Auklet | *Aethia psittacula* | |
| Least Auklet | *A. pusilla* | |
| Crested Auklet | *A. cristatella* | |
| Horned Puffin | *Fratercula corniculata* | |
| Tufted Puffin | *F. cirrhata* | qiḷaŋaq |

Appendix A. Continued.

| Species-group/species | Scientific name | Iñupiaq name |
|---|---|---|
| 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 transects during boat-based marine surveys in the central Chukchi Sea, by study area and season, 2008.

| | | Study area/season | | | | | |
|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | |
| Species-group/species | Scientific name | Late summer | Early fall | Late fall | Late summer | Early fall | Late fall |
| WATERFOWL | | | | | | | |
| Spectacled Eider | *Somateria fischeri* | 0 | 0 | 0 | 0 | 0 | 0 |
| King Eider | *S. spectabilis* | 1 | 0 | 2 | 0 | 1 | 2 |
| Common Eider | *S. mollissima* | 0 | 0 | 0 | 0 | 5 | 0 |
| Unidentified eider | *Polysticta or Somateria sp.* | 0 | 10 | 5 | 0 | 9 | 0 |
| White-winged Scoter | *Melanitta fusca* | 0 | 0 | 0 | 0 | 0 | 3 |
| Long-tailed Duck | *Clangula hyemalis* | 44 | 0 | 37 | 0 | 68 | 2 |
| Unidentified diver | | 0 | 0 | 1 | 0 | 0 | 0 |
| LOONS | | | | | | | |
| Red-throated Loon | *Gavia stellata* | 0 | 0 | 0 | 0 | 1 | 0 |
| Pacific Loon | *G. pacifica* | 0 | 1 | 27 | 0 | 33 | 3 |
| Yellow-billed Loon | *G. adamsii* | 0 | 3 | 1 | 0 | 2 | 0 |
| Unidentified loon | *Gavia. sp.* | 0 | 0 | 1 | 0 | 22 | 0 |
| TUBENOSES | | | | | | | |
| Northern Fulmar | *Fulmarus glacialis* | 65 | 141 | 38 | 6 | 8 | 8 |
| Short-tailed Shearwater | *Puffinus tenuirostris* | 4 | 286 | 271 | 0 | 199 | 54 |
| Unidentified procellarid | | 0 | 0 | 25 | 0 | 0 | 1 |
| SHOREBIRDS | | | | | | | |
| Unid. (*Pluvialis*) plover | *Pluvialis sp.* | 0 | 2 | 0 | 0 | 0 | 0 |
| Pectoral Sandpiper | *Calidris melanotos* | 0 | 0 | 0 | 0 | 0 | 0 |
| Long-billed Dowitcher | *Limnodromus scolopaceus* | 0 | 0 | 0 | 0 | 0 | 0 |
| Red-necked Phalarope | *Phalaropus lobatus* | 0 | 20 | 69 | 0 | 59 | 0 |
| Red Phalarope | *P. fulicarius* | 5 | 5 | 1 | 0 | 1 | 0 |
| Unidentified phalarope | *Phalaropus sp.* | 0 | 74 | 10 | 0 | 85 | 0 |
| Unid. shorebird - small | | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix B. Continued.

| Species-group/species | Scientific name | Study area/season | | | | | |
|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | |
| | | Late summer | Early fall | Late fall | Late summer | Early fall | Late fall |
| SHOREBIRDS (cont'd.) | | | | | | | |
| Unid. shorebird - medium | | 0 | 0 | 0 | 0 | 0 | 0 |
| LARIDS | | | | | | | |
| Black-legged Kittiwake | *Rissa tridactyla* | 99 | 47 | 117 | 14 | 129 | 17 |
| Ivory Gull | *Pagophila eburnea* | 0 | 0 | 0 | 0 | 0 | 2 |
| Sabine's Gull | *Xema sabini* | 9 | 92 | 5 | 2 | 0 | 0 |
| Ross's Gull | *Rhodostethia rosea* | 0 | 0 | 0 | 0 | 0 | 127 |
| Herring Gull | *Larus argentatus* | 1 | 0 | 18 | 0 | 0 | 1 |
| Glaucous Gull | *L. hyperboreus* | 11 | 13 | 70 | 6 | 33 | 19 |
| Unidentified gull - small | | 0 | 0 | 0 | 0 | 0 | 0 |
| Unidentified gull - large | | 0 | 0 | 0 | 0 | 1 | 0 |
| Unidentified gull | | 0 | 0 | 0 | 0 | 0 | 0 |
| Arctic Tern | *Sterna paradisaea* | 0 | 24 | 0 | 0 | 0 | 0 |
| Pomarine Jaeger | *Stercorarius pomarinus* | 32 | 12 | 1 | 3 | 3 | 0 |
| Parasitic Jaeger | *S. parasiticus* | 4 | 2 | 0 | 1 | 0 | 0 |
| Long-tailed Jaeger | *S. longicaudus* | 0 | 0 | 0 | 0 | 0 | 0 |
| Unidentified jaeger | *Stercorarius sp.* | 0 | 0 | 0 | 0 | 0 | 0 |
| ALCIDS | | | | | | | |
| Dovekie | *Alle alle* | 2 | 0 | 1 | 0 | 0 | 2 |
| Common Murre | *Uria aalge* | 13 | 0 | 11 | 0 | 0 | 0 |
| Thick-billed Murre | *U. lomvia* | 228 | 14 | 3 | 3 | 0 | 1 |
| Unidentified murre | *Uria sp.* | 1 | 9 | 4 | 0 | 2 | 14 |
| Black Guillemot | *Cepphus grylle* | 9 | 0 | 0 | 2 | 0 | 6 |
| Pigeon Guillemot | *C. columba* | 4 | 0 | 0 | 1 | 0 | 0 |
| Unidentified guillemot | *Cepphus sp.* | 0 | 0 | 0 | 0 | 0 | 1 |
| Kittlitz's Murrelet | *Brachyramphus brevirostris* | 0 | 0 | 0 | 0 | 0 | 0 |

Appendix B. Continued.

| | | Study area/season | | | | | |
|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | |
| Species-group/species | Scientific name | Late summer | Early fall | Late fall | Late summer | Early fall | Late fall |
| ALCIDS (cont'd.) | | | | | | | |
| Unidentified murrelet | *Brachyramphus sp.* | 0 | 0 | 5 | 0 | 0 | 0 |
| Parakeet Auklet | *Aethia psittacula* | 0 | 7 | 0 | 0 | 0 | 44 |
| Least Auklet | *A. pusilla* | 4 | 139 | 55 | 0 | 1 | 4 |
| Crested Auklet | *A. cristatella* | 179 | 128 | 959 | 0 | 1 | 34 |
| Unidentified auklet | *Aethia sp.* | 1 | 22 | 66 | 0 | 0 | 1 |
| Horned Puffin | *Fratercula corniculata* | 2 | 0 | 0 | 2 | 0 | 0 |
| Tufted Puffin | *F. cirrhata* | 8 | 0 | 1 | 0 | 0 | 0 |
| Unidentified alcid - small | | 0 | 0 | 1 | 0 | 0 | 6 |
| Unidentified alcid | | 0 | 2 | 8 | 0 | 6 | 1 |
| OWLS | | | | | | | |
| Short-eared Owl | *Asio flammeus* | 0 | 0 | 0 | 0 | 0 | 0 |
| PASSERINES | | | | | | | |
| American Pipit | *Anthus rubescens* | 0 | 0 | 0 | 0 | 1 | 0 |
| Snow Bunting | *Plectrophenax nivalis* | 0 | 0 | 0 | 0 | 1 | 0 |

Appendix C. Counts of all birds recorded on transects during boat-based marine surveys in the central Chukchi Sea, by study area and season, 2009.

| | | Study area/season | | | | | |
|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | |
| Species-group/species | Scientific name | Late summer | Early fall | Late fall | Late summer | Early fall | Late fall |
| WATERFOWL | | | | | | | |
| Spectacled Eider | *Somateria fischeri* | 0 | 1 | 0 | 0 | 0 | 0 |
| King Eider | *S. spectabilis* | 0 | 0 | 0 | 0 | 0 | 0 |
| Common Eider | *S. mollissima* | 0 | 0 | 0 | 0 | 0 | 0 |
| Unidentified eider | *Polysticta or Somateria sp.* | 0 | 15 | 1 | 0 | 2 | 5 |
| White-winged Scoter | *Melanitta fusca* | 0 | 0 | 0 | 0 | 0 | 0 |
| Long-tailed Duck | *Clangula hyemalis* | 0 | 19 | 3 | 0 | 41 | 0 |
| Unidentified diver | | 0 | 2 | 0 | 0 | 0 | 0 |
| LOONS | | | | | | | |
| Red-throated Loon | *Gavia stellata* | 0 | 0 | 0 | 0 | 0 | 0 |
| Pacific Loon | *G. pacifica* | 0 | 24 | 22 | 0 | 181 | 1 |
| Yellow-billed Loon | *G. adamsii* | 0 | 9 | 1 | 0 | 24 | 0 |
| Unidentified loon | *Gavia. sp.* | 0 | 6 | 5 | 0 | 30 | 0 |
| TUBENOSES | | | | | | | |
| Northern Fulmar | *Fulmarus glacialis* | 115 | 52 | 5 | 141 | 34 | 22 |
| Short-tailed Shearwater | *Puffinus tenuirostris* | 22 | 11,946 | 313 | 252 | 331 | 66 |
| Unidentified procellarid | | 0 | 0 | 0 | 0 | 0 | 0 |
| SHOREBIRDS | | | | | | | |
| Unid. (*Pluvialis*) plover | *Pluvialis sp.* | 0 | 0 | 0 | 0 | 0 | 0 |
| Pectoral Sandpiper | *Calidris melanotos* | 0 | 3 | 0 | 3 | 5 | 0 |
| Long-billed Dowitcher | *Limnodromus scolopaceus* | 0 | 0 | 0 | 1 | 0 | 0 |
| Red-necked Phalarope | *Phalaropus lobatus* | 37 | 10 | 2 | 201 | 106 | 4 |
| Red Phalarope | *P. fulicarius* | 3 | 0 | 2 | 15 | 32 | 1 |
| Unidentified phalarope | *Phalaropus sp.* | 55 | 0 | 9 | 72 | 51 | 4 |
| Unid. shorebird - small | | 1 | 2 | 0 | 0 | 17 | 0 |

Appendix C. Continued.

| Species-group/species | Scientific name | Study area/season | | | | | |
|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | |
| | | Late summer | Early fall | Late fall | Late summer | Early fall | Late fall |
| SHOREBIRDS (cont'd.) | | | | | | | |
| Unid. shorebird - medium | | 0 | 1 | 0 | 0 | 10 | 0 |
| LARIDS | | | | | | | |
| Black-legged Kittiwake | *Rissa tridactyla* | 9 | 296 | 101 | 16 | 266 | 22 |
| Ivory Gull | *Pagophila eburnea* | 0 | 0 | 0 | 0 | 0 | 0 |
| Sabine's Gull | *Xema sabini* | 0 | 1 | 2 | 0 | 0 | 2 |
| Ross's Gull | *Rhodostethia rosea* | 0 | 0 | 0 | 0 | 0 | 48 |
| Herring Gull | *Larus argentatus* | 0 | 10 | 0 | 4 | 2 | 0 |
| Glaucous Gull | *L. hyperboreus* | 0 | 23 | 49 | 7 | 65 | 54 |
| Unidentified gull - small | | 0 | 0 | 3 | 0 | 0 | 0 |
| Unidentified gull - large | | 0 | 0 | 0 | 0 | 0 | 0 |
| Unidentified gull | | 2 | 0 | 3 | | 1 | 11 |
| Arctic Tern | *Sterna paradisaea* | 0 | 0 | 0 | 1 | 2 | 0 |
| Pomarine Jaeger | *Stercorarius pomarinus* | 6 | 23 | 0 | 10 | 1 | 0 |
| Parasitic Jaeger | *S. parasiticus* | 0 | 0 | 0 | 0 | 0 | 0 |
| Long-tailed Jaeger | *S. longicaudus* | 1 | 0 | 0 | 2 | 0 | 0 |
| Unidentified jaeger | *Stercorarius sp.* | 0 | 1 | 0 | 0 | 1 | 0 |
| ALCIDS | | | | | | | |
| Dovekie | *Alle alle* | 0 | 0 | 0 | 0 | 0 | 0 |
| Common Murre | *Uria aalge* | 0 | 8 | 3 | 0 | 3 | 14 |
| Thick-billed Murre | *U. lomvia* | 64 | 338 | 16 | 17 | 27 | 15 |
| Unidentified murre | *Uria sp.* | 0 | 35 | 7 | 0 | 8 | 1 |
| Black Guillemot | *Cepphus grylle* | 0 | 0 | 0 | 0 | 0 | 0 |
| Pigeon Guillemot | *C. columba* | 0 | 0 | 0 | 0 | 0 | 0 |
| Unidentified guillemot | *Cepphus sp.* | 0 | 0 | 0 | 0 | 0 | 0 |
| Kittlitz's Murrelet | *Brachyramphus brevirostris* | 0 | 1 | 0 | 0 | 0 | 6 |

Appendix C. Continued.

| | | Study area/season | | | | | |
|---|---|---|---|---|---|---|---|
| | | Klondike | | | Burger | | |
| Species-group/species | Scientific name | Late summer | Early fall | Late fall | Late summer | Early fall | Late fall |
| ALCIDS (cont'd.) | | | | | | | |
| Unidentified murrelet | *Brachyramphus sp.* | 0 | 0 | 0 | 0 | 0 | 0 |
| Parakeet Auklet | *Aethia psittacula* | 0 | 21 | 0 | 0 | 0 | 0 |
| Least Auklet | *A. pusilla* | 63 | 115 | 257 | 201 | 143 | 39 |
| Crested Auklet | *A. cristatella* | 394 | 3,139 | 1,455 | 4,566 | 5,082 | 16 |
| Unidentified auklet | *Aethia sp.* | 8 | 52 | 11 | 11 | 26 | 0 |
| Horned Puffin | *Fratercula corniculata* | 4 | 2 | 0 | 0 | 0 | 0 |
| Tufted Puffin | *F. cirrhata* | 1 | 0 | 0 | 0 | 0 | 0 |
| Unidentified alcid - small | | 0 | 0 | 10 | 0 | 0 | 14 |
| Unidentified alcid | | 0 | 18 | 0 | 0 | 11 | 0 |
| OWLS | | | | | | | |
| Short-eared Owl | *Asio flammeus* | 0 | 0 | 0 | 1 | 0 | 0 |
| PASSERINES | | | | | | | |
| American Pipit | *Anthus rubescens* | 0 | 0 | 0 | 0 | 2 | 0 |
| Snow Bunting | *Plectrophenax nivalis* | 0 | 0 | 0 | 0 | 0 | 0 |