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Structure and variability of the marine-bird community in the northeastern Chukchi Sea ☆

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ABSTRACT

We examined the seasonal and interannual variation in the marine-bird community and its relationship to physical oceanography in the northeastern Chukchi Sea in 2008–2010 as part of a multi-year, interdisciplinary study. We sampled 3 study areas, each $\sim$3000 km^2, located in the offshore northeastern Chukchi Sea: Klondike, Burger, and Statoil. We quantified the marine habitat by measuring strength of stratification, depth of the mixed layer, and temperature and salinity in the upper mixed layer. The total density of seabirds was the highest in 2009, when warm (5–6 °C), moderately saline (31–31.5) Bering Sea Water (BSW) extended across Burger and Klondike at all depths. Bird density was generally higher in Klondike than in Burger in 2008 and 2009; densities did not differ significantly among study areas in 2010, when BSW covered all 3 study areas. The relative abundance of alcids in all study areas combined increased from 2008 to 2010. Klondike was numerically dominated by alcids and tubenoses in all years, whereas Burger was numerically dominated by larids and tubenoses in 2008 and by alcids in 2009 and 2010; Statoil also was numerically dominated by alcids in 2010. Least auklets, crested auklets, and northern fulmars were positively associated with strong stratification and high salinity (>31) in the upper mixed layer, characteristics that indicated the presence of BSW. Phalaropes were positively associated with salinity but negatively associated with stratification, suggesting that well-mixed water provides better foraging opportunities for these surface-feeding planktivores. The distribution and abundance of marine birds, particularly the planktivorous species, is influenced by advective processes that transport oceanic species of zooplankton from the Bering Sea to the Chukchi Sea. This transport apparently differed among years and resulted in a broader northeastward intrusion of Bering Sea Water and greater total abundance of planktivorous seabirds in the region in 2009 than in 2008 or 2010.

1. Introduction

The seasonally ice-covered Chukchi Sea shelf is among the largest continental shelves in the world. It also is highly productive, although much of the primary production and zooplankton biomass can be attributed to the northward flow of nutrient-rich oceanic water that originates far to the south, in the basin of the Bering Sea (Springer and McRoy, 1993; Grebmeier et al., 2006). This influx of nutrients and oceanic plankton sustains a marine-bird community that would otherwise have little prey available (Springer et al., 1989). Despite an understanding of the importance of advection to the food web of the Chukchi Sea, questions remain about the spatial and temporal scales of processes that link the Bering and Chukchi ecosystems (Springer et al., 1996). Seasonal and interannual changes in advection may have profound effects on the distribution and abundance of non-breeding, staging, and migratory birds that rely on marine resources during the open-water season (June to mid-October). These relationships between community structure and oceanography must be explored if marine birds are to serve as informative indicators of ecosystem change (Piatt et al., 2007).

Descriptions of the avifaunal communities of the northeastern Chukchi Sea are rare and tend to focus on a few species of interest (e.g., Divoky, 1976), rather than considering all of the bird species that feed in the marine environment during the open-water season (e.g., waterfowl, loons, phalaropes, larids [gulls and terns], procellariids, and alcids). Attention to the marine-bird community elsewhere in the Chukchi Sea has been focused primarily on the breeding colonies at Cape Lisburne and Cape Thompson (Springer et al., 1984,1989) and on summarizing data collected

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at sea south of 69° 30′ N (Divoky and Springer, 1988; Piatt and Springer, 2003). Recent efforts to describe the circumpolar species diversity and distribution of marine birds do not include regionally important taxa such as auklets and phalaropes (Bluhm et al., 2011; Huettmann et al., 2011) that are critical to understanding energy flow in this ecosystem (Piatt and Springer, 2003).

Marine-birds can display habitat preferences for water masses and water-column structure that enhance the abundance and the accessibility of prey (Haney, 1991; Elphick and Hunt, 1993; Piatt and Springer, 2003). For example, in the northern Bering Sea and Bering Strait, bird species that rely primarily on zooplankton such as euphausiids and copepods (hereafter referred to as planktivorous species) include least (*Aethia pusilla*), and crested auklets (*A. cristatella*) and typically are associated with oceanic Anadyr Water (Springer et al., 1987; Elphick and Hunt, 1993; Piatt and Springer, 2003). In contrast, species that primarily rely on fish such as black-legged kittiwakes (*Rissa tridactyla*) and thick-billed murres (*Uria lomvia*) typically are associated with Bering Shelf Water and Alaskan Coastal Water (Springer et al., 1987; Elphick and Hunt, 1993; Piatt and Springer, 2003). Bird species that are more flexible in their foraging requirements, however, may also be more flexible in their habitat relationships. Short-tailed shearwaters (*Puffinus tenuirostris*) can consume euphausiids, shrimp, and fish (Hunt et al., 2002) and are found in all water masses of the northern Bering and southern Chukchi seas (Piatt and Springer, 2003). Within water masses, species often are segregated spatially to exploit those hydrographic features that best meet their specific foraging ecology (Haney, 1991; Russell et al., 1999; Piatt and Springer, 2003). Hence, understanding the mechanisms that link the seabird community to the marine habitat in the northeastern Chukchi Sea requires quantifying both water-mass characteristics (e.g., temperature, salinity) and water-column structure.

Historical studies conducted in the late 1970s and the early 1980s provided a snapshot of the community composition and density of seabirds in the northeastern Chukchi Sea (Divoky, 1987) but did not address the variability of this community or link species to their habitat. In this study, we employed a systematic survey design to quantify the temporal variability in the marine-bird community and relate it to the physical oceanography of the northeastern Chukchi Sea. The objectives of this study were to (1) describe seasonal, spatial, and interannual variation in the distribution, abundance, and community composition of marine birds; (2) describe seasonal, spatial, and interannual variation in physical oceanography; and (3) explore relationships between the abundance of 8 marine-bird species and the hydrographic structure of their habitat.

2. Study area

In the Chukchi Sea, the net flow of water is northward through Bering Strait and toward the Arctic Ocean (Coachman et al., 1975). The broad northward flow through Bering Strait is steered by bathymetry into three main branches—one east of Hanna Shoal that feeds into Barrow Canyon, one west of Herald Shoal that feeds into Herald Valley, and one between the two shoals, referred to as the Central Channel flow (Fig. 1; Weingartner et al., 1998,2005). This separation also is evident in water-mass properties (Woodgate et al., 2005). Within the Chukchi Sea, the Alaska Coastal Current (ACC) lies east near the Alaska coastline and flows northward, carrying Alaskan Coastal Water (ACW), a warm (>2 °C), low-salinity (<32.2) water mass that originates south of Bering Strait. The currents farther offshore move Bering Sea Water (BSW; Coachman et al., 1975), a warm (>2 °C), high-salinity (>32.4) water mass, northward through the Central Channel and Herald Valley (Weingartner et al., 2005). This BSW is a mixture of Anadyr Water and Bering Shelf Water from south of Bering Strait, so it has a higher nutrient content and transports greater numbers of oceanic zooplankton than does ACW (Walsh et al., 1989; Springer and McRoy, 1993).

In addition to these water masses that are advected northward, water in the Chukchi Sea is modified during the fall and winter by ice formation and during the spring by ice melt. As is the case with ACW, cold (-1 to $+2$ °C), low-salinity (<30) Meltwater (MW) is depleted of nutrients and large oceanic zooplankton. In the summer, the bottom half of the water column usually still contains cold (-2 to $+1$ °C), salty (>32) Winter Water (WW) left over from the previous winter, whereas the surface layer consists of either MW or BSW. This stratification increases from spring to summer and typically erodes in the fall as strong winds, cooling, and freezing enhance vertical mixing (Weingartner et al., 2005).

This study was conducted in the northeastern Chukchi Sea, in a region extending ~110–180 km west of the village of Wainwright, off of the northwestern coast of Alaska and included 3 study areas that are of interest for oil and gas exploration: Klondike, Burger, and Statoil (Fig. 1). The Klondike study area was located on the eastern side of the Central Channel and nearest the inflow of BSW, whereas the Burger study area was located to the northeast of Klondike and on the southern slope of Hanna Shoal. The Statoil study area was located to the north of both Klondike and Burger; its western edge was near to the Central Channel and its eastern half lay on the southern slope of Hanna Shoal. The ACC flows east of all 3 study areas, exiting the area via Barrow Canyon, whereas the Central Channel flow passes over or just west of Klondike and Statoil.

3. Methods

3.1. Data collection

We conducted research cruises during 3 seasons in 2008–2010 that covered the entire open-water period of the northeastern Chukchi Sea (Fig. 2): late summer (hereafter "Jul/Aug"), early fall (hereafter "Aug/Sep"), and late fall (hereafter "Sep/Oct"). The Klondike and Burger study areas consisted of boxes that were ~56 km on a side (Fig. 1). The Statoil box was configured to encompass several Statoil oil-lease blocks and had the same total area as Klondike and Burger. These ~3000-km^2 study-area boxes were the primary focus of all sampling. We conducted line-transect surveys for birds along a series of parallel survey lines that ran north–south through the study areas. The sampling grid included lines on the eastern and western boundaries of each study area and lines spaced ~1.8 km apart within each study area, creating a set of 31 parallel survey lines in Klondike and Burger that were ~56 km long each. Because the Statoil box was not square, its survey lines were of variable length, ranging from 42 to 56 km. We surveyed continuously when the ship was moving along a straight-line course at a minimal velocity of 9.3 km h^{-1} (5 kt; Tasker et al., 1984; Gould and Forsell, 1989) and recorded environmental conditions every 10 min. We collected data 9–12 h day^{-1} during daylight hours, weather and ice conditions permitting. We generally stopped surveys when sea height was Beaufort 6 (seas ~2–3 m) or higher, although we occasionally continued to sample if observation conditions were still acceptable (e.g., if seas were at the lower end of Beaufort 6 and we were traveling with the wind and seas). 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