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Late summer zoogeography of the northern Bering and Chukchi seas

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A B S T R A C T

Ocean currents, water masses, and seasonal sea ice formation contribute to determining relationships among the biota of the Bering and Chukchi seas. The Bering Sea communicates with the Chukchi Sea via northward advection of water, nutrients, organic matter, and plankton through Bering Strait. We used data from concurrent surveys of zooplankton, pelagic fishes and jellyfish, epibenthic fishes and invertebrates, and seabirds to identify faunal distribution patterns and environmental factors that are related to these faunal distributions within the US portions of the Chukchi Sea shelf and Bering Sea shelf north of Nunivak Island. Regional differences in late summer (August–September) distributions of biota largely reflected the underlying hydrography. Depth, temperature, salinity, stratification, and chlorophyll *a*, but less so sediment-related or nutrient-related factors, were related to the distributions of the assemblages (zooplankton: depth, salinity, stratification; pelagic fishes and jellyfish: depth, stratification, chlorophyll *a*; epibenthic fishes and invertebrates: depth, temperature, salinity; seabirds: temperature, salinity, stratification). These six environmental factors that most influenced distributions of zooplankton, pelagic fishes/jellyfish, epibenthic fishes and invertebrate, and seabird assemblages likely can be simplified to three factors reflecting bottom depth, water mass, and their stratification and productivity (which are tightly linked in the study region). The assemblages were principally structured from nearshore to offshore and from south to north. The nearshore to offshore contrast usually was stronger in the south, where the enormous discharge of the Yukon River is more apparent and extends farther offshore, influencing zooplankton, pelagic fish/jellyfish, and seabird assemblages. Some assemblages overlapped spatially (e.g., seabird and zooplankton), indicating shared influential environmental factors or trophic linkages among assemblages. The gradients in assemblage composition were gradual for epibenthic taxa, abrupt for zooplankton taxa, and intermediate for pelagic fish/jellyfish and seabird taxa, implying that zooplankton assemblage structure is most strongly tied to water mass, epibenthic least, with the other two taxa intermediates. Three communities (i.e., cross-assemblage groupings) emerged based on maps of ordination axes and core use areas by taxa; one associated with Alaska Coastal Water (warmer, fresher, nutrient depauperate), second associated with Chirikov Basin and the southern Chukchi Sea (colder, saltier, nutrient rich), and third associated with the northern Chukchi shelf (colder and saltier but not as

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nutrient rich). Gradients in species composition occurred both within and between these communities. The Chirikov Basin/southern Chukchi Sea community was characterized by distinct zooplankton and seabird taxa, but was not strongly associated with distinct pelagic or epibenthic fish and invertebrate taxa. Although comprehensive data were only available for a single year and annual variation may affect the generality of our results, our comprehensive ecosystem survey approach yielded new insights into the ecological relationships (specifically, gradients in assemblage composition and identification of communities) of this Arctic region.

1. Introduction

This paper describes the integrated zoogeography of zooplankton, fishes, epifaunal invertebrates, and seabirds in the northern Bering and Chukchi seas during late summer and identifies the environmental factors structuring these assemblages. The zoogeography of the northern Bering and Chukchi seas has previously been characterized for zooplankton (Hopcroft et al., 2010; Eisner et al., 2013; Ershova et al., 2015), pelagic fishes (Eisner et al., 2013), epibenthic fishes and invertebrates (Bluhm et al., 2009; Norcross et al., 2010, 2013; Ravelo et al., 2014; Logerwell et al., 2015) and seabirds (Piatt and Springer, 2003; Kuletz et al., 2015), as well as for macrofaunal benthos, which we did not include here (Feder et al., 2007; Blanchard et al. 2013a, 2013b; Petryashov et al., 2013; Grebmeier et al., 2015a). Our study is novel in that we characterize all four assemblages simultaneously. Another study (Sigler et al., 2011) also characterized these four assemblages simultaneously but used data collected from different, widely scattered years, whereas our study uses data collected in a single year (2012), except for epibenthic fishes and invertebrate data for the northern Bering Sea, which were collected in 2010. This approach allows us to infer whether these four assemblages are linked to the same environmental factors or whether and how the influential factors differ among assemblages.

Understanding the environmental factors that influence the structure of these assemblages on a large, regional scale will provide insight into current assemblage structure and information for others to forecast community responses to climate change. Changes in climatic conditions as well as biological production and faunal distribution patterns in the region have already been recorded for recent decades (Grebmeier et al., 2006; Mueter and Litzow 2008; Arrigo and van Dijken 2015), and are expected to continue (e.g., Hollowed et al., 2013). The simultaneous surveys of the four assemblages provide a benchmark for assessing climate effects as more surveys are conducted in the future. In the meantime, the simultaneous surveys also provide a space-for-time substitution as a temporary alternative to long-term studies (Pickett, 1989). Space-for-time substitution is one of the most common techniques in ecology and in general, is the extrapolation of a temporal trend from a series of different-aged samples (Pickett, 1989). In our application, latitude substitutes for time, with the current state of southerly locations serving as a proxy for the future state of northerly locations (i.e., as influenced by climate change (Blois et al., 2013)).

The faunal assemblages considered here are directly or indirectly influenced by several features. First, ice seasonally covers the northern Bering and Chukchi seas (Fig. 1), with the extent of the seasonal sea ice advance and retreat being the largest of any of the Arctic or subarctic regions, averaging ~1700 km, while interannual variability has been as great as ~400 km, or ~25% of the seasonal range (Niebauer et al., 1999; Frey et al., 2014). Sea ice covers the northern Bering and Chukchi seas each winter, and by late summer, open water recurs over most or even all of these shelf regions. Second, the northern Bering (Grebmeier et al., 2006; Sigler et al., 2011, Stabeno et al., 2012) and Chukchi shelves are strongly connected by Pacific origin waters flowing northward through Bering Strait, including nutrient-rich Anadyr Water near the Siberian coast, Bering Shelf Water, and nutrient-poor Alaska

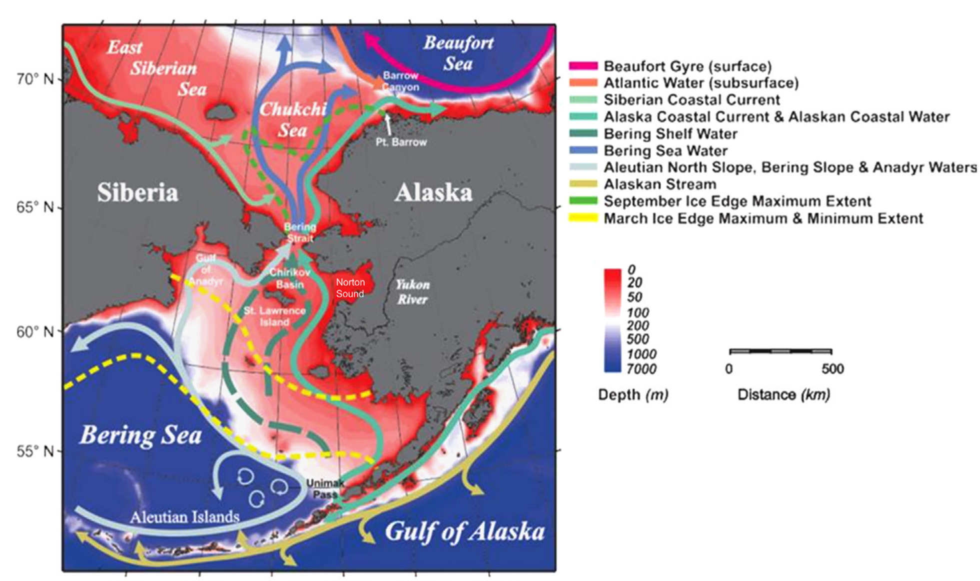

Fig. 1. The Bering, Chukchi, and Beaufort Seas form a continuum between the North Pacific Ocean and the Arctic Ocean. This idealized schematic denotes some of the important water masses and currents that impact regional differences in physical habitat characteristics. Figure courtesy of S. Danielson and T. Weingartner, University of Alaska Fairbanks.

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