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Temporal changes in benthic ostracode assemblages in the Northern Bering and Chukchi Seas from 1976 to 2010

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ABSTRACT

We analyzed living ostracode assemblages from the northern Bering Sea, collected between 1976 and 2010, and from the Chukchi Sea, collected in 2009 and 2010, to examine how climatic and oceanographic changes are affecting modern ostracode species distributions. Totals of 21 and 28 ostracode species were identified, respectively, from Bering and Chukchi Sea surface sediment samples. The Bering Sea assemblage is largely transitional in species composition between those inhabiting western Arctic continental shelves and the subarctic Gulf of Alaska. Temporal changes in the Bering Sea assemblage provide evidence that decadal temperature changes have affected species composition. For example, the proportion of *Normanicythere leioderma*, a predominantly Arctic species, decreased from 70% of the total assemblage population in 1999 to 15% by 2006. This decrease coincided with a shift in the Arctic Oscillation toward a positive mode and warmer Bering sea-surface temperatures (SST) beginning in the early 2000s. In contrast, the more temperate species, *Pectocythere janae* (also known as *Kotoracythere arctoborealis*) made up less than 4% of the Bering assemblage prior to 2000 but increased in abundance to as much as 30% as Bering Sea temperatures rose from 2001 to 2006. This pattern has reversed since 2006 when cooler temperatures led to a decline in *P. janae* and return in the prominence of *N. leioderma*. Our results support the idea that recent ocean temperature changes and a reduced sea-ice season in the Bering–Chukchi Sea region are changing species composition in benthic ecosystems.

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1. Introduction

As surface temperatures rise in the Arctic Ocean and sub-polar seas, satellite observations document a corresponding reduction in the extent, thickness, and duration of seasonal sea-ice cover (Stroeve et al., 2008) and a potential increase in primary production as a result of greater light penetration into sea ice-free waters (Pabi et al., 2008). In recent years, Arctic multi-year ice has declined by almost 50% in extent, and fall freeze-up occurs later in the year (Serreze et al., 2007; Stroeve et al., 2008). Model results indicate these trends will continue, and that the Arctic Ocean might become predominantly ice-free in summer in a few decades (Wang and Overland, 2009). Sea-ice retreat has been particularly dramatic in the Arctic Ocean just north of the Bering Strait; sea-ice retreats in 2007 and 2009 lengthened the open-water season by about four weeks compared with a decade ago (Grebmeier et al., 2010).

While these patterns of sea-ice decline are well documented, much less is known about the responses of biological communities to ice cover changes. According to Yasuhara et al. (2012a) sea-ice cover is an important factor controlling benthic faunal distributions and species diversity. Here we present new data on benthic ostracode distributions from the Chukchi Sea continental shelf, the Chirikov Basin of the northern Bering Sea, and the area south of St. Lawrence Island (Fig. 1). Ostracodes have environmentally sensitive distributions, and water temperature is one of the most influential factors controlling reproduction, survival, geographic distribution and diversity (Hutchins, 1947; Smith and Horne, 2002; Yasuhara et al., 2009). Ostracodes are meiobenthic, bivalved Crustacea, and have several distinct advantages for retrospective ecosystem studies. Their calcium carbonate shells are preserved in marine sediments enabling species identification from shell morphology, even after their soft parts decompose. Unlike macrofaunal species, which cannot be analyzed quantitatively in sediment cores because of their size and scarcity, adult ostracodes range in size from 0.5 mm to 2 mm and can be quantified in small samples available from individual grab and/or

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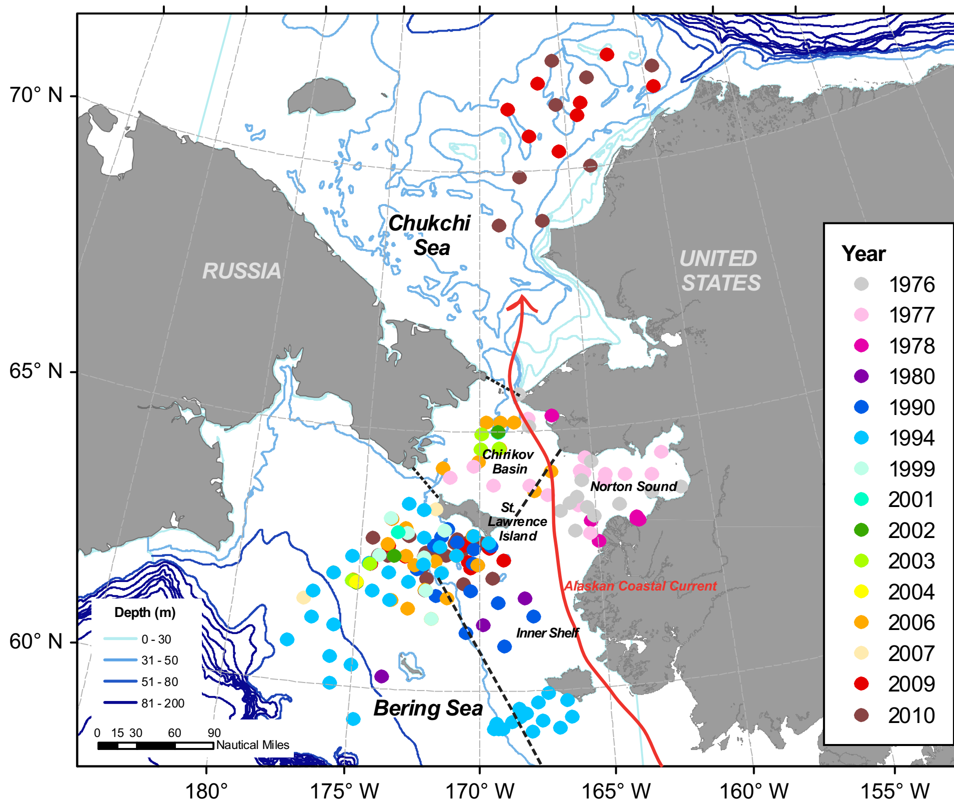

Fig. 1. Bathymetry of the Bering and Chukchi seas and locations of 225 Bering Sea and 18 Chukchi Sea surface sediments analyzed in this study, color-coded by year of collection.

core samples. Moreover, marine ostracode species have biogeographical and ecological limits controlled by temperature, salinity, or nutrient/food availability (Cronin et al., 2010a; Stepanova et al., 2007; Yasuhara et al., 2012a). Consequently, these crustaceans are used extensively in paleoecology and paleoclimatology to document climatically driven changes in ocean temperature, circulation, salinity, and ocean productivity (e.g.; Cronin et al., 1994, 1996, 2005, 2010b; Didié and Bauch, 2000; Yasuhara et al., 2012a, 2012b). In this study, we sought to determine whether recent changes in temperature and ice cover in the Bering Sea have affected species distributions. To the best of our knowledge, this is the first published report on modern ostracode fauna from the northern Bering shelf. Adjacent areas where ostracode data are available include the Arctic Ocean (Cronin et al., 2010b) including the Chukchi/Beaufort Seas to the north of Bering Strait (Joy and Clark, 1977) and the Gulf of Alaska to the south of the Bering Sea (Brouwers, 1990; 1993; 1994).

1.1. Environmental setting

The Bering and Chukchi Seas are among the world's most productive ecosystems supporting high, seasonal primary productivity that exceeds 1 gC m^{-2} d^{-1} during the spring bloom (Brown et al., 2011; Springer et al., 1996) as well as diverse invertebrate, fish, seabird, and marine mammal populations (National Research Council, 1996). About 50% of the Bering Sea is a wide continental shelf to the north and east, which is less than 200 m in depth (Brown et al., 2011). This shelf extends through the Bering Strait into the Chukchi continental shelf in the western Arctic Ocean.

The Bering Sea is located in a transition region between a generally cold, dry Arctic air mass to the north and moist, relatively warm air to the south (Mantua and Hare, 2002). Hunt and Stabeno (2002) concluded that the southeastern Bering Sea climate is jointly influenced by both the Pacific Decadal Oscillation (PDO) and the Arctic Oscillation (AO). The PDO is a multi-decadal pattern of Pacific climate variability involving air–ocean interactions that create current and sea surface temperature changes in the North Pacific (Mantua and Hare, 2002). In contrast, the northern Bering Sea, which we define as the shelf north of St. Matthew Island (approximately 61–65°N), and the Chukchi Sea are more directly influenced by the AO (Grebmeier et al., 2006a, 2006b). The state of the AO is determined by the atmospheric pressure gradient in the high Arctic, and it alternates between negative (high pressure over the North Pole) and positive (low pressure) modes. This coupled air–sea interaction is closely linked to the strength and position of the Beaufort Gyre in the Arctic Ocean. From 1989 to 2006, the AO was predominantly in a positive mode, causing lower Arctic air pressure and higher sea surface temperatures in the Arctic Ocean (Overland et al., 2008). NOAA's Climate Prediction Center (http://www.cpc.ncep.noaa.gov/) indicates that the AO has been in a negative mode for the period 2009–2010 but has exhibited an overall positive trend since 1989.

These air–sea interactions, and also anthropogenic factors, have contributed to interannual and decadal changes in temperature and sea ice in the North American Arctic over the last several decades (Overland et al., 2008; Serreze et al., 2007). These changes have happened in the context of general circulation in the Bering and Chukchi Seas, which is influenced by three northward flowing water masses arrayed east to west: less saline and nutrient-poor Alaska coastal water (Fig. 1); a mixed, more saline Bering Shelf water mass to the west; and a seasonally cold and even more saline Anadyr water mass further to the west (Stabeno et al., 2007; Belkin et al., 2009). As these water masses extend into the Chukchi Sea, the differences between the mixed shelf water and Anadyr water become less distinct; and there are also