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Epibenthic community variability in the northeastern Chukchi Sea

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ABSTRACT

Epibenthic organisms can occur in large numbers and high biomass on the continental shelf of the northeastern Chukchi Sea. From an ecosystem perspective, epibenthic organisms are important in recycling and redistributing organic matter deposited from the pelagic zone, and they also are key members of the local food web. Data for biological (epibenthic species composition, abundance, and biomass) and environmental (bottom water temperature, salinity, dissolved oxygen and pH, sediment grain size, sediment organic matter and sediment chlorophyll content, latitude, longitude, and water depth) variables were collected at 53 stations in the northeastern Chukchi Sea during the summers of 2009–2010 to characterize the epibenthos and provide a benchmark for potential future changes due to possible anthropogenic disturbances. Community biomass, abundance, species composition and taxa richness varied in patches throughout the study area, but were generally dominated by crustaceans and echinoderms. These two groups had an inverse relationship in the distribution of their dominance. Communities dominated by crustaceans had significantly higher Simpson's dominance and Pielou's evenness values compared to echinoderm-dominated communities. Correlation coefficients for six environmental variables (longitude, bottom water temperature, water depth, bottom water dissolved oxygen, sediment grain size 2 phi and total organic carbon) with epifaunal abundance and biomass were moderate (0.42 for abundance and 0.51 for biomass at a significance level of 0.1%). However, assemblages within the study area followed a distinct spatial distribution pattern that matched the path of important water masses in the region.

1. Introduction

Epibenthic organisms on the continental shelf of the Chukchi Sea can be found in high abundance and biomass. Several members of the benthic community constitute key elements in the Arctic food web, as prey of marine mammals, birds and fish (Bluhm and Gradinger, 2008). Arctic epibenthic community structure is highly variable. Often there are peaks in abundance of specific groups, such as echinoderms and crustaceans, which create a mosaic or patchiness in species distribution (Ambrose et al., 2001; Bluhm et al., 2009; Piepenburg, 2005). Distinct communities are influenced by an array of environmental variables, including water depth, water current, seafloor composition and food availability (Bluhm et al., 2009; Piepenburg, 2005). However, which factors define the epibenthic community variability and to what extent is still uncertain for some areas and may vary by region (Bluhm et al., 2009). Echinoderms (particularly ophiuroids) typically dominate in abundance and/or biomass of Arctic epibenthic communities (Frost and Lowry, 1983). Arctic ophiuroid assemblages are known to be less diverse than similar assemblages in Antarctica (Piepenburg, 2005). However, when comparing the diversity of all macrozoobenthos, the Arctic species richness is only marginally lower than comparable Antarctic communities (Piepenburg, 2005). The increasing resource exploitation in the Chukchi Sea has raised concern with regard to the negative effects that anthropogenic activities, such as offshore oil exploration, mineral extractions and fisheries (fish and shellfish) may have on the stability and growth of the epibenthic communities in this region (Bluhm et al., 2009; Grebmeier et al., 2006). In addition, global climate change and ocean acidification have the potential to create acute stressors for Arctic benthic organisms (Bluhm et al., 2009; Fabry et al., 2008; Grebmeier, 2012; Piepenburg, 2005). Thus to conserve and manage this significant ecosystem component, it is important to document the epibenthic community composition and its relationship with the environmental processes that define its natural variability.

The continental shelf of the Chukchi Sea is relatively shallow, with an average water depth of 50 m. The northeastern area is covered by ice seven to eight months of the year, causing light

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limitation and vertical stability of the water column (Woodgate et al., 2005). Compared to other Arctic regions, the Chukchi Sea is considered highly productive, with water column primary productivity values ranging from 80 to 90 g C m^{-2} y^{-1} in the northern shelf to 470 g C m^{-2} y^{-1} in the southern Chukchi Sea. Lower values of 20–70 g C m^{-2} y^{-1} have been recorded in coastal water (Sakshaug, 2004). Seasonal changes in salinity, solar irradiance and ice coverage in the Chukchi Sea directly affect primary production. In the spring, light increases and sea ice melt creates stratification in the water column, favoring phytoplankton blooms in the ice edge zone. These marginal ice zone blooms occur before phytoplankton growth in the open ocean, and add up to 50% of the total primary production in Arctic waters (Sakshaug, 2004). The distinct water masses found in the region are defined by variations in salinity. Low salinity levels (<31.8) characterize the low nutrient Alaska Coastal Water (ACW), which flow northward along the coast from Cape Lisburne up to Barrow Canyon (Fig. 1) (Walsh et al., 1989). Bering Sea Water (BSW) also flows northward through the Bering Strait and heads westward in the Chukchi Sea and is characterized by high salinity and nutrient levels. South of Bering Strait this water mass is composed of Bering Shelf water and Anadyr water (AW) (Coachman et al., 1975; Pickart et al., 2005; Woodgate et al., 2005). In general, input of high nutrient water originates in the Bering Sea and is then transported northward through the Bering Strait. This water mass movement supports high seasonal primary production, which in conjunction with low grazing pressure, translates into high deposition of organic matter to the benthos (Grebmeier et al., 1988, 2006). Once passed the Bering Strait, BSW flows northward in two branches. One branch moves eastward through Hope Valley and Herald Valley, and is characterized by high salinity and nutrient rich waters (Weingartner et al., 2005). The second branch travels east of Herald Shoal through the Central Channel (Fig. 1) (Weingartner et al., 2005). On an annual average, this branch could be responsible for approximately 25% of the mean Bering Strait transport (Weingartner et al., 2005). The water moving through the Central Channel follows the bathymetry north and to the east of Herald Shoal, continuing in a slow flow up to Hanna Shoal, moving eastward and merging with the ACW close to Barrow Canyon (Coachman et al., 1975; Winsor and Chapman, 2004; Weingartner et al., 2005). This northeastward drift of nutrient and carbon rich waters could support high benthic standing stocks despite a relatively low annual primary production (Feder et al., 1994) (Fig. 1).

Many characteristics of the epibenthic communities in the Arctic make them especially important to benthic systems. In the Chukchi Sea, echinoderms occur in dense assemblages (several hundred individuals per meter square) with biomass up to 30% higher than the highest values reported for echinoderms in the Barents Sea (Ambrose et al., 2001). These assemblages also showed higher respiration values compared to the Barents Sea (up to 25% of the total benthic respiration). Many members of the epifaunal community have great mobility that allows them to access and redistribute organic carbon deposited from the pelagic zone. Epibenthic organisms are also significant bioturbators and contributors to the total benthic energy turnover (Grebmeier and McRoy, 1989; Piepenburg et al., 1995). The Chukchi Sea is populated by many species with slow growth rates and long life spans, such as echinoderms and molluscs (Gage, 1990; Piepenburg et al., 1995). These characteristics have added importance due to the high levels of trace metals these organism can bioaccumulate throughout their life and subsequently transfer to higher trophic levels (Clarke, 1983; Dehn et al., 2006; Mariani et al., 1980). Several epibenthic organisms constitute an important opportunistic dietary supplement for many Arctic marine mammals, such as bearded seals and walruses. With this in consideration, the potential for biomagnification of some potential pollutants to higher trophic levels becomes an issue of great concern, especially for species that are important to the subsistence harvests of local human communities (Bluhm and Gradinger, 2008; Dehn et al., 2006).

Epibenthic organisms that inhabit the Chukchi Sea, such as ophiuroids, endure a severe seasonal food limitation seven to eight months out of the year, which is reflected in the slow growth rates and long life spans of many of these Arctic benthic organisms (Clarke, 1983). As typical of any shelf benthos, the benthic community structure and biomass in the Chukchi Sea is strongly influenced by the carbon input from the water column and the quality of the organic carbon (Grebmeier and McRoy, 1989; Grebmeier et al., 1988, 2006). Many studies have highlighted the importance of the pelagic-benthic coupling as a major factor altering the benthic communities in Arctic ecosystems (Grebmeier and McRoy, 1989; Grebmeier et al., 2006; Piepenburg, 2005). In addition, environmental variables such as sediment grain size, water depth, temperature, as well as sediment

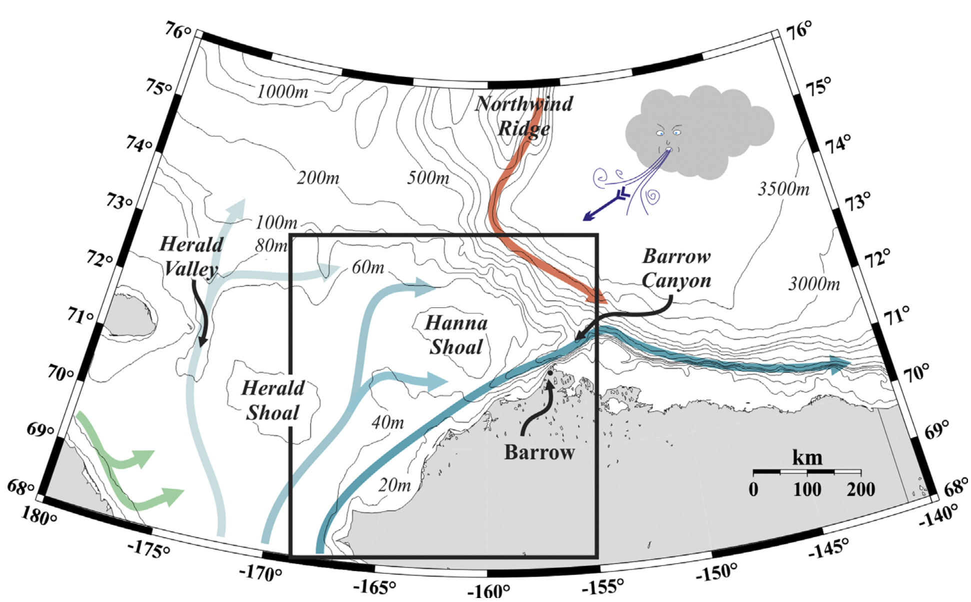

Fig. 1. A schematic of the circulation over the Chukchi Sea and Beaufort/Chukchi slope, showing the three branches along which Pacific waters cross the Chukchi shelf. These are color-coded with navy blue being the most nutrient-rich waters (Bering Sea water) and light blue being the least nutrient-rich (ACC water). Courtesy of Tom Weingartner, modified from http://www.ims.uaf.edu/chukchi/#chan. The dark red rectangle is enclosing the area of interest for this study.