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Phytoplankton of the western Arctic in the spring and summer of 2002: Structure and seasonal changes

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ABSTRACT

We analyzed the taxonomic structure and spatial variability of phytoplankton abundance and biomass in the Chukchi and Beaufort Seas during spring and summer seasons of the SBI program. Phytoplankton samples were collected during two surveys from May 10 to June 13 and from July 19 to August 21 of 2002. In May and June, ice cover exceeded 80% over most of the study area and there was no vertical stratification, indicating that the successional state of the phytoplankton corresponded to the end of the winter biological season. The phytoplankton abundance ranged from a few tens to a few thousands of cells per liter, while biomass varied from 0.1 to 3.0 $mg\,C\,m^{-3}$. Small areas of high phytoplankton abundance ($0.13–1.3\times10^6$ $cells\,L^{-1}$) and biomass (22–536 $mg\,C\,m^{-3}$), dominated by early spring diatoms *Pauliella taeniata* and *Fragilariopsis oceanica* in the surface waters, which indicated the beginning of the spring bloom, were observed only in the southeastern part of the Chukchi shelf and off Point Barrow. In July and August summer period, more than a half of the study area had <50% ice cover and the water column was stratified by temperature and salinity. Over the Chukchi shelf and continental slope of the Beaufort Sea, the phytoplankton abundance and biomass were an order of magnitude higher in July–August than in May–June. The taxonomic diversity of algae also increased due to the appearance of late-spring and summer diatoms, dinoflagellates, and coccolithophorids (*Emiliania huxleyi*). Interestingly, the seasonal differences between phytoplankton abundance and taxonomic composition in the spring and summer periods varied the least over the Chukchi Sea slope and in the deep-water area of the Arctic Ocean. High algae concentrations in summer were located in the lower layers of the euphotic zone, suggesting that the spring bloom on both the Chukchi shelf and in the western part of the Beaufort Sea occurred in late June/early July. In the spring and summer, the microalgal community was characterized by a high abundance of 4–10 μm flagellates, which exceeded the abundance of all other taxonomic groups. In both seasons studied, phytoplankton reached its maximum abundance within restricted areas in the southern part of the Chukchi Sea southwest of Point Hope, in the northern part of the Chukchi shelf between the 50- and 100-m isobaths, on the shelf northwest of Point Barrow, and over the continental slope in the Beaufort Sea. The pronounced spatial difference in the seasonal state was a characteristic feature of the phytoplankton community in the western Arctic.

1. Introduction

The wide (~800 km) shelf of the Chukchi Sea, the narrower shelf of the western Beaufort Sea, and the adjacent continental slope of both seas are among the most productive regions of the Arctic. Primary production in this Arctic region are controlled by seasonal environmental changes, including solar irradiation, ice cover, water temperature, and vertical stratification, as well as the Pacific inflow from the south via the Bering Strait (Aagaard, 1964; Coachman et al., 1975; Coachman and Aagaard, 1988; Weingartner et al., 2005). Of key importance are the nutrient-rich Pacific waters advected northward from the Bering Sea into the Chukchi Sea (Walsh et al., 1989; Codispoti et al., 2005). The warmer Pacific waters from the south influence the timing of the seasonal ice retreat in spring as well as its formation in the fall as compared to other Arctic shelves. The narrow shelf of the Beaufort Sea receives

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considerable coastal runoff, which lowers the salinity of the nearshore waters and supplies a large amount of terrigenous material and nutrients.

These combined environmental conditions are favorable for phytoplankton development, resulting in high primary production that supports high prey biomass and ultimately higher trophic levels in the ecosystem. On the shelf of the Chukchi Sea, primary production can reach 8–15 g C m^{-2} day^{-1} seasonally (Springer and McRoy, 1993; Hill and Cota, 2005), and the average biomass of the underlying benthic infauna can exceed 360 g m^{-2} (Dunton et al., 2005), reaching even 4000 g m^{-2} north in select regions of the Chukchi Sea (Grebmeier et al., 2006). The combination of seasonally variable environmental factors and current flow through Bering Strait results in temporal and spatial variability of water mass characteristics in this region (Coachman et al., 1975; Walsh et al., 1989; Weingartner et al., 2005). The Pacific inflow through Bering Strait varies depending on seasonal and climatic factors; the resulting variable current structure directly influences the ecosystems of the Chukchi shelf and western shelf regions of the Beaufort Sea. The variability of the pelagic environment affects phytoplankton and controls their taxonomy, abundance and biomass, in situ primary production, and successional dynamics. Phytoplankton provides $>90\%$ of the total primary production over the shelf and continental slope in the Chukchi and Beaufort Seas, while ice algae are important only during a short period at the beginning of the vegetation season (Hill and Cota, 2005). Thus, it is essential to evaluate the level of phytoplankton variability and the factors that define it on the shelf and continental slope of the Chukchi and Beaufort Seas, since this region represents a "gateway" for the Pacific water influence over the Arctic Basin (Carmack and Wassman, 2006).

Phytoplankton data in the western Amerasian Arctic are fragmentary (Kiselev, 1937; Shirshov, 1982; Okolodkov, 1986; Bursa, 1963; Horner, 1984; Booth and Horner, 1997). These references describe the dominant species and marine algal groups, abundance, and biomass data, along with some analysis of their spatial distribution. However, to date, the information on seasonal changes in the composition and quantitative measurements within the phytoplankton community has been scarce due to limited access to these ice-covered seas. Exceptions to these limited studies are those undertaken by Shirshov (1982) and Hill et al. (2005). In the latter study, the taxonomic composition of phytoplankton was analyzed based on size fractionation and HPLC analysis of pigments; the quantitative characteristics were estimated only from the chlorophyll *a* concentrations.

The data presented here address the distribution and temporal changes of the phytoplankton community, which directly relate to one of the principal objectives of the Western Arctic Shelf–Basin Interactions (SBI) Program (Grebmeier, 2003; Grebmeier and Harvey, 2005). One of the main objectives of the SBI project is to evaluate the distribution and dynamics of the major ecosystem components over the shelf, continental slope, and adjacent regions of the deep-water Arctic basin. Our paper describes the phytoplankton taxonomy, size composition, and seasonal variability associated with varying abiotic factors during both spring and summer 2002 in the Chukchi and Beaufort Seas.

2. Materials and methods

The data were collected in 2002 during two research surveys in the eastern part of the Chukchi Sea and the western part of the Beaufort Sea aboard the icebreaker USCGC *Healy* during two seasons: spring, from May 10 to June 13 (cruise HLY-02-01) and summer, from July 19 to August 21 (cruise HLY-02-03). The study region encompassed an area between 67°N and 74°N, and 151°W and 169°W. The samples were collected in three broad regions: the shallow-shelf system at depths <50 m to the outer shelf, the continental slope area, and the deep-water Arctic basin to depths >2000 m. During the spring cruise (HLY-02-01), phytoplankton samples were collected at 28 stations whereas during the summer expedition (HLY-02-03), 32 stations were sampled (Fig. 1). Multiple 30-L Niskin water bottles were used for collections, and water was sampled from two depth layers: the subsurface layer (2–3 m) and the layer of the maximum fluorescence (or the maximum vertical density gradient) determined from the fluorescence sensor on the CTD profiler. Temperature, salinity, density, and fluorescence data were collected using a SeaBird 911 CTD profiler, with additional discrete water-collections for chlorophyll measurements made with a standard Wetlabs fluorometer. Nutrient samples were collected using Niskin water bottles and processed using Alpkem Model 300 automated nutrient analyzer

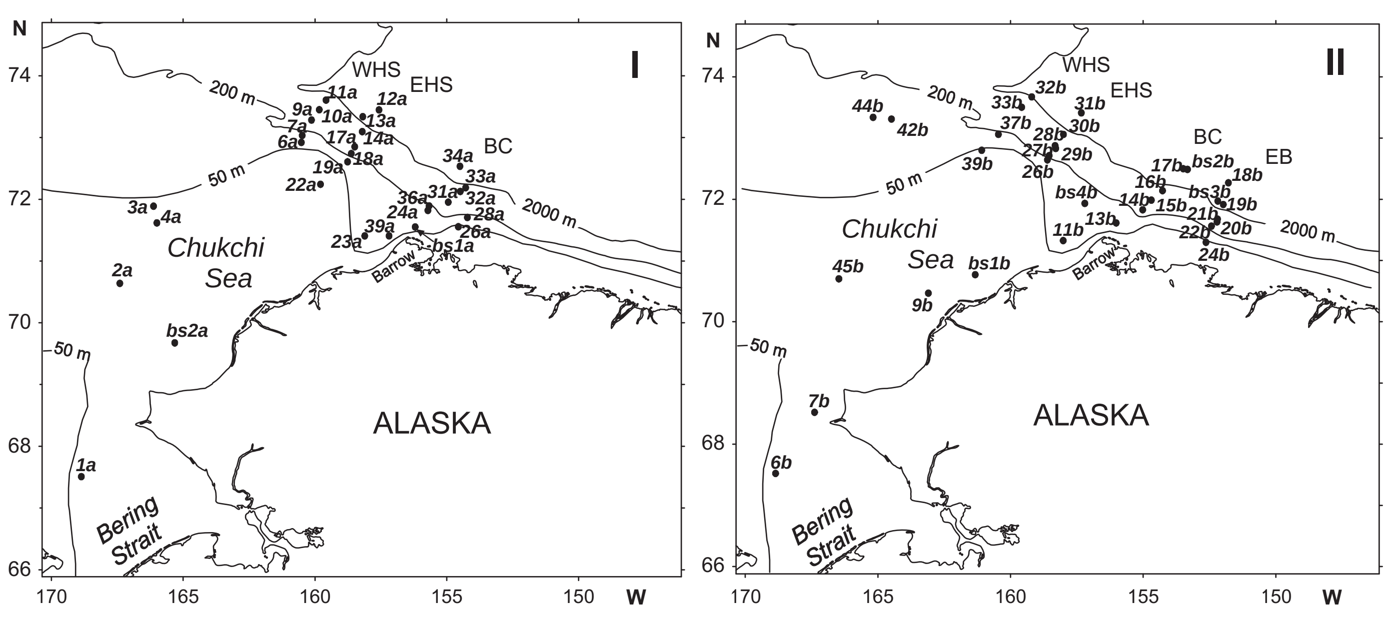

Fig. 1. Sampled stations. I—May–June; II—July–August. Transect labels: WHS—West Hanna Shoal, EHS—East Hanna Shoal, BC—Barrow Canyon, EB—East Barrow.