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Export fluxes of biogenic matter in the presence and absence of seasonal sea ice cover in the Chukchi Sea

Catherine Lalande[a,*], Jacqueline M. Grebmeier[a], Paul Wassmann[b], Lee W. Cooper[a], Mikhail V. Flint[c,d], Valentina M. Sergeeva[c]

[a]*Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN, 37932, USA*
[b]*Norwegian College of Fishery Science, University of Tromsø, N-9037 Tromsø, Norway*
[c]*Shirshov Institute of Oceanology, Russian Academy of Sciences, Nakhimovsky Prospect 36, Moscow, 117997, Russia*
[d]*Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, P.O. Box 757220, Fairbanks, AK, 99775, USA*

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Abstract

Drifting sediment traps were deployed at 9 stations in May-June (ice-covered conditions) and July-August (ice-free conditions) 2004 in the Chukchi Sea to investigate the variability in export fluxes of biogenic matter in the presence and absence of sea ice cover. Measurements of chlorophyll-*a* (Chl-*a*), particulate organic carbon (POC), particulate nitrogen (PN), phytoplankton, zooplankton fecal pellets, and the stable carbon isotope composition (δ^{13}C) of the sinking material were performed along Barrow Canyon (BC) and a parallel shelf-to-basin transect from East Hanna Shoal (EHS) to the Canada Basin. POC export fluxes were similarly high in the presence ($378 \pm 106\,\mathrm{mg\,C\,m^{-2}\,d^{-1}}$) and in the absence of ice cover ($442 \pm 203\,\mathrm{mg\,C\,m^{-2}\,d^{-1}}$) at the BC stations, while fluxes were significantly higher in the absence ($129 \pm 98\,\mathrm{mg\,C\,m^{-2}\,d^{-1}}$) than in the presence of ice cover ($44 \pm 29\,\mathrm{mg\,C\,m^{-2}\,d^{-1}}$) at the EHS stations. The C/N ratios and δ^{13}C values of sinking organic particles indicated that POC export fluxes on the Chukchi continental shelf were mostly composed of freshly produced labile material, except at the EHS stations under ice cover where the exported matter was mostly composed of refractory material probably advected into the EHS region. Chl-*a* fluxes were higher under ice cover than in ice-free water, however, relatively low daily loss rates of Chl-*a* and similar phytoplankton carbon fluxes in ice-covered and ice-free water suggest the retention of phytoplankton in the upper water column. An increase in fecal pellet carbon fluxes in ice-free water reflected higher grazing pressure in the absence of ice cover. Elevated daily loss rates of POC at the BC stations confirmed other indications that Barrow Canyon is an important area of carbon export to the basin and/or benthos. These results support the conclusion that there are large spatial and temporal variations in export fluxes of biogenic matter on the Chukchi continental shelf, although export fluxes may be similar in the presence and in the absence of ice cover in highly productive regions.

Keywords: Arctic Ocean; Chukchi Sea; Sediment traps; Export flux; Particulate organic carbon; Ice cover

*Corresponding author. Tel.: +1 418 656 5917; fax: +1 418 656 2339.
E-mail address: catherine.lalande.1@ulaval.ca (C. Lalande).

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1. Introduction

The Chukchi Sea is one of the most productive Arctic shelves when the ice edge recedes, with an estimated production up to $430\,g\,C\,m^{-2}\,yr^{-1}$ in some regions (Sakshaug, 2004; Hill and Cota, 2005). Since there is a constant input of nutrient-rich waters through the Bering Strait, the major factor constraining primary production on the Chukchi Sea shallow continental shelf and slope, when incident radiation is sufficient, is the seasonal variation in ice cover (Springer and McRoy, 1993; Gosselin et al., 1997; Hill and Cota, 2005). A declining trend in seasonal sea ice extent is currently ongoing in the Arctic, with record ice minima observed in September 2002, 2003, 2004 and 2005 (Serreze et al. 2003; Stroeve et al., 2005; Meier et al., 2005). In addition, satellite data obtained from 1978 to 2000 indicate that the Arctic perennial sea ice cover declined at a rate of $8.9 \pm 2.0\%$ per decade, with the largest variations in ice concentrations occurring in the Beaufort and Chukchi Seas (Comiso, 2002). Since the timing and magnitude of primary production depend largely on light conditions and thereby on ice cover in the Chukchi Sea, an earlier melting of sea ice following the increase in light irradiation in spring is likely to enhance annual primary production by extending the growth season (Sakshaug, 2004). Increased primary production in scenarios of reduced ice cover is expected to subsequently increase the vertical export of biogenic matter on the Arctic continental shelves (Wassmann et al., 2004). However, because of the highly seasonal and episodic nature of primary production on the Arctic shelves, the retention or export of biogenic matter is determined by the match or mismatch between the seasonal dynamics of the phytoplankton community and the grazing impact by zooplankton (Peinert et al., 1989; Wassmann et al., 1996; Wassmann, 1998; Sakshaug, 2004; Wassmann et al., 2004; Grebmeier and Barry, 2007). Significant changes in bloom development and thus phytoplankton production, standing stock, and composition may therefore affect the vertical flux of biogenic matter through changes in the food web structure (Wassmann et al., 2004).

Various investigations of vertical flux of biogenic matter using either short-term or long-term moored sediment traps have been conducted in the Arctic Ocean (e.g. Wassmann et al., 2004 and references therein), however the work presented here is the first one conducted in the Chukchi Sea using short-term drifting sediment traps. A previous study of export fluxes derived from $^{234}Th/^{238}U$ disequilibria over the Chukchi Sea shelf indicated that high primary production rates in the absence of ice cover contributed to elevated particulate organic carbon (POC) export fluxes, with POC fluxes increasing approximately 4-fold from ice-covered to ice-free conditions (Moran et al., 2005). In addition to the estimation of the magnitude and seasonal variability of POC export fluxes, the deployment of sediment traps over the Chukchi Sea shelf and slope allowed the determination of the composition of the export fluxes, which may vary considerably as a result of a reduction in seasonal ice cover. The objective of this study was to compare the magnitude and the composition of the export fluxes in the presence and absence of ice cover to provide insight on the processes affecting the vertical flux of biogenic matter over the Chukchi Sea shelf and slope.

2. Material and methods

2.1. Sampling

Drifting sediment traps were deployed at 5 stations in May-June (ice cover) and at 4 stations in July–August (ice-free) 2004 as part of the Western Arctic Shelf-Basin Interactions (SBI) process cruises on board the USCGC *Healy*. Stations sampled were located along the East Hanna Shoal (EHS) and Barrow Canyon (BC) transects (Fig. 1; Table 1). A drifting array of sediment traps deployed at five depths (30, 40, 50, 60, and 100 m) was anchored to an ice floe for deployments in ice cover and drifted attached to a buoy equipped with a reflector and a beacon during ice-free deployments. The sediment trap array was deployed for periods ranging from 11 to 20 h; variations were due to the ship operations schedule and sometimes difficult weather conditions (Table 1). The propellers were not in operation during ice-covered deployments and the drifting array was deployed away from the ship and recovered using a small boat during ice-free deployments to prevent particle collection to be affected by the turbulence created by the ship. The sediment traps (KC Denmark, Silkeborg, Denmark) consisted of four detachable cylindrical tubes with lead weights at the bottom (diameter: 7.2 cm × height: 45 cm; height/diameter ratio: 6.25) mounted in a cross frame to ensure the vertical position of the tubes during deployment.