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Distribution patterns of Canadian Beaufort Shelf macrobenthos

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Abstract

Variation in macrofaunal composition in relation to sediment and water variables was analysed in nine regions of the western Canadian Arctic on the Beaufort Shelf and in Amundsen Gulf. We hypothesized that benthic community composition was distinctive (1) in a recurrent polynya in Amundsen Gulf and (2) in upwelling regions (Cape Bathurst and Mackenzie Canyon) and (3) changed in a linear gradient across the Beaufort Shelf. Analysis was based on 497 taxa >0.4 mm from 134 samples at 52 stations sampled over 2002–4 in 11–1000 m water depth. Abundance ranged from 490.7 m^{-2} in eastern Amundsen Gulf to 17,950 m^{-2} off Cape Bathurst. (1) Community composition in Amundsen Gulf was not significantly different from the Beaufort Shelf at similar depth, indicating a lack of benthic effect of the polynya in Amundsen Gulf. (2) The Mackenzie Canyon macrofauna, although abundant and diverse, were similarly indistinct from the shelf community at similar depth. However, there was a 10-fold increase in inshore abundance in the upwelling region of Cape Bathurst due to large numbers of the amphipod *Ampelisca macrocephala* and the polychaete *Barantolla americana,* species that were not abundant elsewhere. (3) In the inshore fast ice and flaw lead regions of the Beaufort Shelf, under the influence of ice scour, storm effects, coastal erosion and the Mackenzie River, the macrofauna were dominated by the bivalve *Portlandia arctica* and the polychaete *Micronephthys minuta.* Offshore, where these influences were less and upwelling of deep Atlantic water occurred, the polychaete *Maldane sarsi* dominated. Faunal distribution across the Beaufort Shelf correlated with depth, water and sediment changes but was not significantly linear.

Keywords: Benthos; Community structure; Polynya; Upwelling; Fast ice; Flaw lead; Canadian Arctic; Beaufort Shelf; Amundsen Gulf; Cape Bathurst

1. Introduction

Arctic benthic communities can be highly productive when closely coupled to the pelagic system (Highsmith and Coyle, 1990) and respond rapidly to external forces (Renaud et al., 2007a). They can be essential food resources for diving sea birds (Dickson and Gilchrist, 2002) and large mammals such as gray whales, walrus and bearded seals (Frost and Lowry, 1984). Soft

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sediment benthic communities have numerous impacts on their surroundings (Pearson, 2001). They affect sediment microbiology (e.g. Papaspyrou et al., 2006), meiofaunal (e.g. Peachey and Bell, 1997) and macrofaunal (e.g. Callaway, 2006) composition, modify sediment chemistry (e.g. Norling et al., 2007), alter sediment stability and near-bed hydrodynamics (e.g. Norkko et al., 2001), release and draw down oxygen, nutrients and particulates from the water column (e.g. Kamp and Witte, 2005), supply and consume pelagic organisms (e.g. Snelgrove et al., 2001) and break down and recycle detritus and primary production (e.g. Duchêne and Rosenberg, 2001). They can rework the sediment to >20 cm depth (Dauwe et al., 1998). Although Arctic benthic communities can be abundant and diverse, they can also be sensitive to disturbance, such as from ice scour and be slow to recover (Conlan and Kvitek, 2005).

In the Canadian Beaufort region, benthic studies were spurred by hydrocarbon exploration during the 1970′s and 1980′s (Wacasey et al., 1977; Atkinson and Wacasey, 1989) but syntheses in the primary literature have been sparse until the recent review by Cusson et al. (2007). With the collapse of the Mackenzie gas pipeline development following the Berger Enquiry (Berger, 1977), benthic studies lapsed until settlement of Inuvialuit land claims and resumption of hydrocarbon exploration in this decade.

With improved logistic capabilities for widespread study of the Beaufort coastal region, such as the Canadian Arctic Shelf Exchange Study (CASES), Joint Western Arctic Climate Studies (JWACS) and the CCGS *Nahidik* programs and the development of improved multivariate analytical methods for benthic study (Clarke and Warwick, 2001), it is now possible to statistically test hypotheses of local community pattern in relation to environmental variation. Our purpose is to examine links in benthic macrofaunal community composition on the Beaufort Shelf to regional differences in geography, oceanography and ice processes.

The Canadian Beaufort Shelf is a broad platform extending over 64,000 km^2 to the 200 m isobath (O'Brien et al., 2006). The shelf is bordered by the Mackenzie Canyon to the west, the Amundsen Gulf to the east, the Mackenzie River delta to the south and the Beaufort Sea to the north (Fig. 1). The immense quantities of fresh water delivered by the Mackenzie River (~333 km^3 yr^{-1}) make it the most estuarine of all the shelves. The Mackenzie River's sediment load (~127 million Mt yr^{-1}) exceeds the combined annual sediment load of all other rivers entering the Arctic Ocean (O'Brien et al., 2006). Most of this load is delivered between late May and the end of August. Riverine discharge contributes both particulate (POC) and dissolved (DOC) organic carbon (Dunton et al., 2006) but the fate of this terrigenous carbon in the shelf ecosystem remains poorly understood. Beaufort Shelf sediments consist essentially of silts and clays discharged by the Mackenzie River or released by coastal erosion (Forest et al., 2008). Sand and gravel are largely confined to <10 m depth; coarse-grained sediments at greater depths are derived from drowned beaches or by ice-rafting (Héquette et al., 1995; Carmack and Macdonald, 2002). The upper waters to 220 m depth are mainly supplied by the relatively nutrient-rich Pacific. The water below 220 m is Atlantic in origin (Carmack et al., 2004).

Ice cover is markedly variable inter-annually (Carmack and Macdonald, 2002). Generally freeze-up begins in mid-October, break-up begins in late May and the shelf can be clear of ice by mid-July depending on winds. Winter landfast ice extends to about the 20 m isobath, bordered by a stamukhi zone of grounded ice and pressure ridges. Offshore of the stamukhi zone are intermittent open flaw leads and over the outer shelf, pack ice that tends to drift westward with the Beaufort Gyre. The flaw lead to the east widens into the Cape Bathurst polynya system centered at the mouth of Amundsen Gulf (Fig. 1). The flaw lead and polynya system are vital to marine mammals and migratory birds (Harwood and Stirling, 1992; Dickson and Gilchrist, 2002). The polynya, however, is markedly variable in the timing, extent and persistence of open water (Arrigo and van Dijken, 2004). Over 1998–2000, sustained open water in the polynya occurred over June–Oct (maximally Apr–Nov) with sea ice cover varying ±40% over an area maximally of 25,000 km^2 (Arrigo and van Dijken, 2004). This variation results in variable intensities, timing and duration of phytoplankton blooms, resulting in variable carbon supplies to the benthos, provided that supply is not circumvented by the microbial loop or zooplankton grazing (see Tremblay et al., 2006). Another potential effect of the polynya on the benthos is increased vertical mixing due to wind effects and brine release by newly forming sea ice. This would be manifested by greater flux of carbon to the seafloor than in summer-stratified waters where carbon production would be intercepted by zooplankton (Arrigo and van Dijken, 2004). Grebmeier and Cooper (1995) documented the enhanced flux of organic carbon to the benthos associated with brine release and convective mixing within a polynya in the central Bering Sea. That the benthos is responsive to surface processes was demonstrated by Renaud et al.