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Long-term patterns of rocky bottom macrobenthic community structure in an Arctic fjord (Kongsfjorden, Svalbard) in relation to climate variability (1980–2003)

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Abstract

We investigated temporal variations in marine macrobenthic community structure from 1980 to 2003 in high-arctic Kongsfjorden (Svalbard) based on analysis of annual photographs at a permanent rocky bottom station. Abundance and area covered by macrobenthic organisms were estimated based on image analysis of high-resolution photographs, and community summary parameters were calculated as the basis for examination of interannual patterns. Interannual variability in abundance and species diversity were related to climate variability. 45% of the variability of the benthic community in Kongsfjorden could be attributed to environmental factors linked to the North Atlantic Oscillation Index (NAOI) and its local manifestations. The temperature of the West Spitzbergen Current (WSC) was a link between the NAOI and the benthic community. Biodiversity was negatively correlated to the NAOI. Severe changes in the benthic community were observed between 1994 and 1996 coinciding with a shift of the NAOI from a positive to a negative mode. The increase in biodiversity during this period was accompanied by a decline of actinarians and the appearance of dense carpets of brown algae.

Keywords: Svalbard; Benthos; Image processing; Climate variability; North Atlantic Oscillation; Arctic climate regime; Redundancy analysis

1. Introduction

The marine macrozoobenthos is commonly regarded as a good indicator for long-term ecosystem changes (Kröncke, 1995). Most of the fauna are sessile or have little motility as adults compared to plankton and many taxa have life spans of years to decades. These characteristics provide the potential for benthic fauna, individually or collectively as a community, to integrate environmental influences over long time scales (Underwood, 1996). Thus, the study of patterns of variation in benthic communities in relation to environmental variables can provide insight into the biophysical linkages and mechanisms by which communities are maintained.

Shallow marine rocky bottom habitats (including the intertidal) are well-suited to directly examine the dynamic relations between organisms and their physical and biological environment because of their

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accessibility, well-described species compositions and interactions. Further, gradients in environmental parameters such as temperature, nutrient concentration, and turbidity tend to be amplified in these shallow habitats compared to deeper water because of the proximity to the surface ocean and its atmospheric drivers (Paine, 1966; e.g. Connell, 1972; Underwood, 1996 and references therein). Therefore, the detection of long-term changes in shallow benthic communities can lead to inferences about the physical forcing mechanisms which drive these ecological patterns (Barry et al., 1995; Kröncke, 1995; Kröncke et al., 1998, 2001; Sagarin et al., 1999).

The North Atlantic Oscillation Index (NAOI) (Hurrell, 1995) is the dominant signal of the interannual variability in the atmospheric circulation across the North Atlantic with a cyclical component of ≈ 7.9 years. The NAOI is usually measured as the mean deviation from the average atmospheric sea level pressure (SLP) between Iceland and the Azores, but variations of the index using Lisbon or Gibraltar as southern stations are also common. It influences the temperature and the current regime of the entire North Atlantic (Tunberg and Nelson, 1998). The northernmost extension of the North Atlantic Current is the West Spitsbergen Current (WSC), which has a major influence on the hydrographical regime in western Svalbard fjords, including Kongsfjorden (79°N). Strong interannual fluctuations in WSC temperature were revealed in a time series of subsurface hydrographical data from 1970 to 1997, which were related to variations in large-scale atmospheric patterns, as indicated by the NAOI (Saloranta and Haugan, 2001).

Two alternating (cyclonic and anticyclonic) wind-driven circulation regimes have been described for the Arctic Ocean, with each regime persisting for 5–7 years (Proshutinsky and Johnson, 1997; Mysak and Venegas, 1998). These regimes are associated with different patterns in Arctic SLP (Johnson et al., 1999) and sea ice concentration (Mysak and Venegas, 1998), while the shifts from one regime to the other are forced by changes in the location and intensity of the Icelandic low and Siberian high pressure systems (Proshutinsky and Johnson, 1997; Mysak and Venegas, 1998). The resulting Arctic Climate Regime Index (ACRI) may help explain cyclical variations in the Arctic Ocean's temperature and salinity structure and thus changes in biological systems. The ACRI should reflect more specifically the shifting atmospheric pattern in the Arctic than the Arctic Oscillation Index (AOI), which covers a broader range of the Northern Hemisphere. We therefore use the ACRI and compare it to the NAOI in order to determine how these indices of atmospheric forcing are related to the variations in the benthic community.

Alterations of the atmospheric circulation may result in changes of the trophic system on an ocean-wide scale (Arntz and Fahrbach, 1991; Stenseth et al., 2002) with major impacts on the distribution on phyto- and zooplankton. Benthic communities may have a delayed response due to time lags related to the propagation of external forcing through the production and settlement of organic matter from the plankton to the benthos and to changes of reproductive rates of the benthos (Gray and Christie, 1983). Andersin et al. (1978) document abundance cycles of 6–7 years for the amphipod *Pontoporeia affinis* in the Bothnian Sea, while Svane and Lundälv (1982) identify a 10–11 year cycle for the ascidian *Pyura tessulata* in the Skagerak. Several studies provide evidence of relationships between atmospheric circulation indices and benthic populations. The NAOI was used to explain community variations in the North Sea and the Skagerak (Carpentier et al., 1997; Tunberg and Nelson, 1998; Hagberg and Tunberg, 2000; Nordberg et al., 2000; Kröncke et al., 2001; Schroeder, 2005). The ACRI was linked to variations in bivalve growth in a high-arctic fjord from Northeast Svalbard (Ambrose et al., in press).

In the high-arctic, few studies have investigated interannual variations in composition of arctic macrobenthic communities on rocky bottom habitats. The relationship between climate indices, local environmental parameters and changes in benthic communities is poorly understood compared to pelagic ecosystem components (phytoplankton and zooplankton) (Beaugrand et al., 2002; Drinkwater et al., 2002). In this study, we examine interannual patterns of benthic community structure over a 23-year period spanning positive and negative modes of major oscillatory climate indices and investigate how climate indices and their related environmental factors explain the observed variations in a benthic community in Kongsfjorden.

2. Materials and methods

2.1. Study area

The study area is situated near Kvadehuken at the outer part of Kongsfjorden on the northwest corner of the Svalbard archipelago (Fig. 1). Our permanent station (78° 58.6′N, 11° 30.1′E) is located at 15 m depth on horizontal bottom, about 300 m from shore. The bottom surface at the station is characterised by bedrock, with smaller and larger pebbles.