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Effects of experimentally increased near-bottom flow on meiofauna diversity and community structure in the Arctic Ocean

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A B S T R A C T

Effects of increased near-bottom flow velocities on the sedimentary environment and its associated small biota were studied in a long-term *in situ* experiment at 2500 m water depth at the Deep-Sea Observatory HAUSGARTEN in the eastern Fram Strait. In 2003, the Remotely Operated Vehicle (ROV) "Victor 6000" was used to install a stainless steel flume of about 8.5 m in length, consisting out of a 6 m long passageway with a cross-section of 50 × 50 cm and 3–4 m wide funnel-like doorways to increase bottom currents by a factor of approximately 6. Sediment sampling for biochemical sediment analyses, bacterial studies and meiofaunal investigations (with special focus on the nematode communities) was carried out 4 years after the installation of the flume using the ROV "Quest 4000". The data showed clearly reduced values for parameters indicating organic matter (food) availability in the sediments, and corresponding lower bacterial and meiofaunal densities inside the flume, compared to control sites outside the channel. Results suggest that increased near-bottom currents and food deficiency not only diminish sediment-inhabiting meiofaunal assemblages but also alter the meiobenthic composition. Compared to background sediments, the nematode community inside the flume evidently showed adaptations to the overall reduced food availability and a more heterogeneous environment due to generally increased and more turbulent flow velocities. The variable environmental conditions inside the flume have an effect not only on the number of genera present, but also on the identities of the genera and the functional composition of the nematode community.

1. Introduction

Water movement and associated particle transport affect marine communities at various scales and in many ways. Oceanic circulation patterns determine broad-scale biogeographic patterns (e.g., Sherman and Alexander, 1989; Bailey, 1998; Longhurst, 1998; Spalding et al., 2007). At smaller scales, fluid flow controls sediment dynamics and a multitude of biological and ecological processes (Nowell and Jumars, 1984; Butman, 1987; Abelson and Denny, 1997; Smith and Brown, 2006). Currents determine the flux of nutrients and food particles, but also the spreading of odors attractive to organisms able to detect these scents. Moreover, water flow controls the dispersal of small organisms and developmental stages of larger fauna, thereby contributing to their spreading in the pelagic environment as well as at the seafloor (Levin, 2006). By increasing the recruitment rate of rare species, water flow is a powerful driver of biodiversity in the marine realm (Palardy and Witman, 2010).

Comparing low- and high-energy abyssal sites separated geographically by hundreds to thousands of kilometers, there is evidence that strong near-bottom currents have the potential to affect benthic communities (Thistle, 1988; Aller, 1989; Kaufmann et al., 1989; Levin and Thomas, 1989; Thistle et al., 1991; Levin et al., 1994). However, as other environmental factors (e.g., pressure, sediment type, oxygen concentrations, food availability) will most probably differ between these sites, observed differences in species richness within these communities may also be attributed to variables other than increased flow speeds. Thus, to single out effects of locally enhanced near-bottom flow on benthic communities, *in situ* experimental manipulation of the flow regime is indispensable.

In October 1990, Thistle and Levin (1998) used the manned submersible "Alvin" to install small weirs (20 cm in height, 48 cm in length) at Fieberling Guyot seamount (583 m water depth) west of San Diego (California) to accelerate near-bottom currents.

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Sediment samples to study the impact of increased flow on meiobenthic communities retrieved 6.5 weeks after the deployment showed significantly lower meiofaunal (and macrofaunal) densities, compared to background samples. The present study is basically a development of the Thistle and Levin (1998) experiment. The flume used in the present experiment was 12-times longer and almost twice the width to allow additional sediment sampling for various environmental parameters (sediment characteristics, organic carbon content, food availability) and microbial studies (cell numbers, bacterial biomasses, exo-enzymatic activities). Moreover, the flume was wide enough to insert an acoustic travel time current meter and an autonomous oxygen microprofiler to carry out point flow measurements and to assess oxygen profiles and fluxes in the uppermost sediment layers, respectively. While meiobenthic studies by Thistle and Levin (1998) concentrated on the metazoan meiofauna at major taxa level with special focus on harpacticoid copepods (identified to working species), the present study addresses the total meiofauna, including foraminiferans. This time, special focus was laid on the nematodes, as this group of organisms generally occurs in comparatively large numbers and usually dominates the benthic metazoan meiofauna in deep-sea sediments. Other deviations from the Thistle and Levin (1998) experiment include a much greater water depth of the experimental area (2283 m versus 583 m) as well as considerably lower ambient temperatures (<1 °C versus $+5$ °C) at a polar deep-water site, i.e. the deep-sea observatory HAUSGARTEN in the eastern Fram Strait (Arctic Ocean). The most important difference between the two experiments, however, is the time interval between the installation of the weirs and the flume, respectively, and the sampling for environmental parameters, sediment-bound bacteria, and faunal components. As discussed by Thistle and Levin (1998), the sampling of the initial experiment after only 6.5 weeks might have been near the time of maximum negative effect due to the increased near-bottom flow and thus, too early for the establishment of a new, high-flow-tolerant fauna. The sampling for the present study was carried out a full 4 years after the installation of the flume. After such a long time, expected differences between meiobenthic communities inside the flume and those in the surrounding sediments should be regarded as persistent, reflecting a new equilibrium between the benthic communities and their (altered) environment.

The present study aims to test whether persistently increased bottom currents have a permanent effect on the density, diversity and structure of meiobenthic communities. Our investigations were done at major taxon level, but also in great detail by focusing on the dominant metazoan group in deep-sea sediments, the nematodes. Based on the various trophic positions that nematodes occupy in the marine benthic food web (Heip et al., 1982) and their variety in life history traits and stress tolerance (Bongers, 1990; Bongers et al., 1991), nematodes are characterized as an ecologically extremely heterogeneous group of organisms. Therefore, nematodes are a useful tool to investigate the implications of increased bottom currents and concomitant changes in environmental conditions.

2. Material and methods

2.1. Experimental area and flume set up

The stainless steel flume was installed during RV "*Polarstern*" expedition ARK-XIX/3 in summer 2003 at station S-3 (78°36′N, 05°04′E; 2283 m water depth) of the HAUSGARTEN observatory in Fram Strait west of Svalbard (Soltwedel et al., 2005). Station S-3 represents an abyssal plain site in the southern-most part of the HAUSGARTEN area, characterized by unstructured fine-grained deep-sea sediments. Visual observations with remotely operated vehicles and towed camera systems revealed no larger elevations in the surroundings. During the experiment, bottom-water temperatures in the area were fairly constant at -0.85 °C.

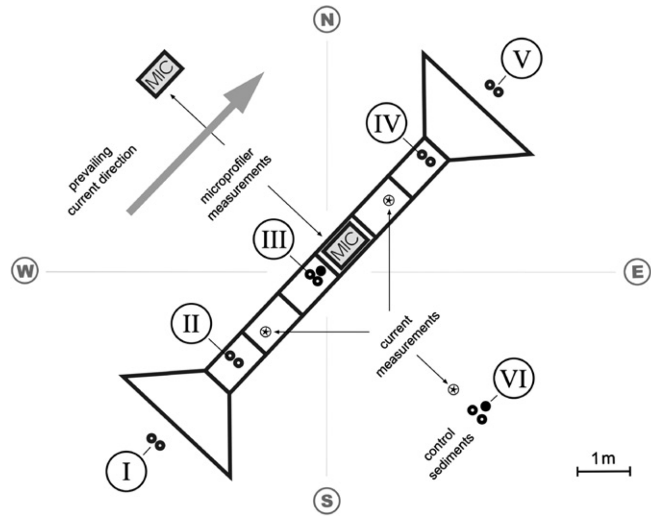

Fig. 1. Schematic top view of the flume showing positions for current meter measurements during RV "*Polarstern*" expedition ARK-XIX/3 in summer 2003, as well as sites for the push-coring of surface sediments (I–VI) and *in situ* microprofiler measurements (MIC) during RV "*Polarstern*" cruise ARK-XXII/2 in summer 2007 (open circles: sediment samples for benthic parameters; closed circles: sediment samples for *ex situ* microprofiler measurements).

The flume installed at this site has a total length of approximately 8.5 m and consists of a 6 m long passageway with a cross-section of 50 × 50 cm and 3–4 m wide funnel-like entry ways at both ends (Fig. 1). Whereas the complete passageway was lowered to the seafloor on a wire, apertures of the flume were assembled using the French Remotely Operated Vehicle (ROV) "Victor 6000".

The channel was designed to significantly increase the current velocity of the water flowing through it. The structure was covered with lids (Fig. 2A and B) to prohibit a logarithmic decrease in flow velocities with increasing distance from the seafloor due to interactions between water masses inside the channel and overlying waters outside the channel and to ensure maximum acceleration of bottom-waters over the entire height of the flume. According to previous near-bottom current data from the region (Premke, unpubl. data), the flume was orientated roughly in a SW to NE direction. Continuous current measurements conducted during the experiment (see below) confirmed the proper orientation of the flume in the prevailing currents.

2.2. Flow measurements

The general current regime in the study area during the experiment was continuously monitored with RCM11 current meters moored at ~15 m above the seafloor and approximately 300 m away from the flume. The instruments registered and stored flow velocities and directions at 20-s intervals. Current meters were regularly exchanged in summer months during our yearly cruises to HAUSGARTEN observatory. No data could be obtained for the time period mid-2003 till mid-2004, due to technical problems.

Local flow measurements around the flume were carried out by means of a MAVS-3 acoustic current meter (NOBSKA) following the installation of the channel in 2003. The current meter, measuring across four acoustic axes (two vertical and two