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Environmental baselines and reconstruction of Atlantic Water inflow in Bjørnøyrenna, SW Barents Sea, since 1800 CE

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ABSTRACT

Metal concentrations, sediment properties and benthic foraminiferal assemblages were investigated in sediment cores in the SW Barents Sea, to reconstruct environmental baselines and natural variability of Atlantic Water inflow since 1800 CE. Metal concentrations correspond to no effect levels and do not influence the foraminifera. Increased Hg and Pb was linked to inflow of Atlantic Water. The data set is considered to reflect the pre-impacted environmental baseline and range in natural variability of the study area. The foraminiferal assemblages in the SW part of the study area showed warming and presence of Atlantic Water towards 1900 CE. The NE part of the region indicate presence of cold Artic Water influenced conditions. Between 1900 and 1980 CE, the SW region indicates reduced inflow of Atlantic Water. From 1980 CE towards the present the assemblages of the entire study area show warming of Atlantic Water and northward retreat of the Arctic Front.

1. Introduction

The Barents Sea is a unique and highly sensitive shallow water polar ecosystem, highly susceptible to changes in converging ocean currents (Sakshaug, 1997). The Barents Sea is one of the world's most productive seas, in particular around the oscillating ice edge (Sakshaug, 1997). In recent decades, the Barents Sea has experienced a fast growth in human activities, which is expected to continue and further diversify in the coming years. Of particular concern are activities related to the petroleum industry, including release of drill cuttings to the seafloor. Drill cuttings are by-products of both oil- and gas drilling and contain fine-grained slurry of rock and heavy metals. It is of importance that such deposits are accurately monitored and managed. One way of monitoring environmental impact is by assessing changes in the seafloor fauna (bio-monitoring) (WFD, 2000). Following the EU legislation, the impact of enhanced environmental pressure is assessed by the extent of deviation of the benthic community from reference conditions (WFD, 2000). Reference conditions correspond to *"biological, chemical and morphological conditions associated with no or very low human pressure"* (WFD, 2000). It is therefore of great relevance to not only understand the local impact of petroleum activity, but also to establish reliable reference conditions reflecting the pre-impacted environmental baseline, especially in areas not yet opened for petroleum production. This will serve as future reference to monitor the environmental impact of anthropogenic activity. Although monitoring changes in these reference conditions can indicate the environmental impact of increased anthropogenic activity in the Barents Sea, effects of natural environmental changes will be superimposed on these anthropogenic induced changes. The applicability of an environmental baseline must therefore always take the natural variability of the processes and organisms involved into account, which therefore must be adequately investigated during the relevant time interval (Wassmann et al., 2011).

Definition of environmental baselines is challenging, as the marine environment often has been impacted by human activities or climate change for many years (Hinz et al., 2011). Benthic foraminifera can be a helpful tool to reconstruct in-situ reference conditions. Benthic foraminifera are unicellular organisms (meiofauna, 45–1000 μm) living on top of and within the first centimeters of the seafloor sediment. Foraminifera are widely used as indicators for climatic and environmental changes and have a shell that fossilizes in the sediment, providing an archive of past changes. By studying live and fossilized foraminiferal assemblages in sediment cores, the method enables reconstruction of pre-impacted reference conditions in already impacted areas, present-day ecosystem impact, and monitoring of ecosystem recovery after environmental pressure has diminished (Dolven et al., 2013; Polovodova Asteman et al., 2015). Additionally, studying foraminifera in sediment cores will provide multiannual to decadal-scale records of natural environmental change, providing a record of the area's natural variability. Recent development and standardization of new bio-monitoring methods based on foraminifera (Aagaard-Sørensen et al., 2017;

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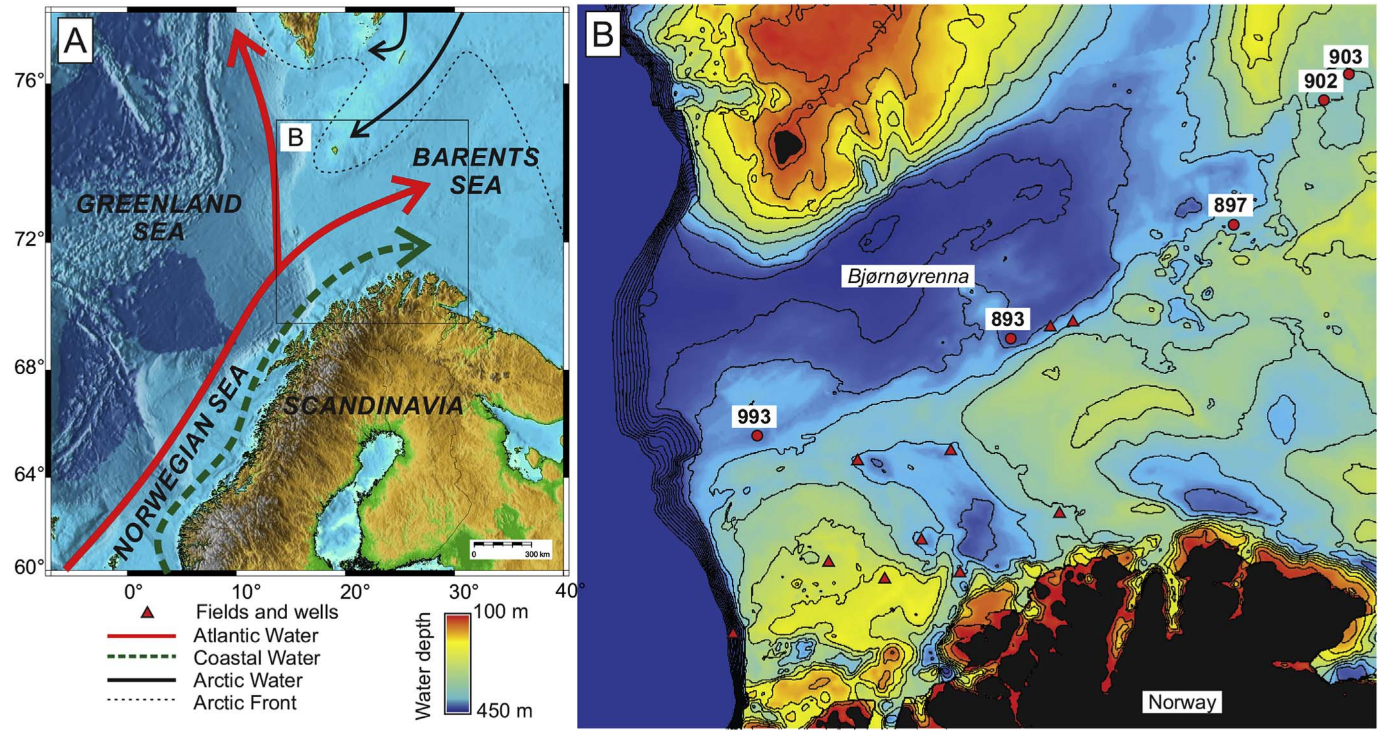

Fig. 1. Study area.
(a) Ocean surface currents of the Norwegian Sea and western Barents Sea. Dashed line indicates an estimation of the present-day position of the Arctic front (after Loeng, 1991). (B) Close up of the western Barents Sea showing core locations along transect in the Bjørnøyrenna trough. Red triangles indicate locations of oil industry exploration wells. Color scale reflects water depth; the contour interval is 50 m. Coordinates of the coring locations are given in Table 1.

Alve et al., 2016; Barras et al., 2014; Bouchet et al., 2012; Schönfeld et al., 2012), has led to consideration to include the foraminiferal method in the EU legislation. Additionally, the Norwegian authorities now recommend using foraminifera to reconstruct in situ environmental baseline conditions (Veileder02:2013, 2015).

The main objective of this study is to determine the pre-impacted environmental baseline and natural variability of foraminiferal assemblages and sediment properties for the SW Barents Sea since 1800 CE. Variability in Atlantic Water inflow has a strong influence on the seafloor environment of the SW Barents Sea, as it transports both heat (Loeng and Drinkwater, 2007), nutrients (Knies and Martinez, 2009) and metals (e,g, AMAP, 1998; Junttila et al., 2014) toward the region. To establish reliable baselines for the area, it is therefore of importance to additionally improve our understanding of the variability in Atlantic Water inflow toward the Barents Sea. Five sediment cores were investigated following the pathway of Atlantic Water to the northeast through the Bjørnøyrenna trough (Fig. 1). Benthic foraminiferal assemblages, grain size distribution, total organic carbon and heavy metal concentrations were analyzed. An age model was obtained by the ^{210}Pb dating method. Our findings will serve as a robust dataset of baseline conditions and natural variability that can be used for future reference to monitor environmental impact of anthropogenic activities in the Barents Sea. This will be of great importance with the opening of new blocks for petroleum exploration in more northern and eastern parts of the Barents Sea (NorwegianPetroleumDirectorate, 2017). In addition, it will serve as baseline to monitor impact of other environmental change, including climate change and Atlantification of the Barents Sea (Wassmann et al., 2011).

2. Oceanography

Cores were collected in the glacially eroded Bjørnøyrenna trough (Andreassen et al., 2008) located in the Barents Sea (Fig. 1). The present day sedimentary environment is dominated by undisturbed silty clay deposits (Wilson et al., 2011). Three main water masses prevail in the Barents Sea: Atlantic Water (AW), Arctic Water (ArW) and Coastal Water (CW) (Fig. 1). Additionally, a mixture of AW and ArW can form the local Barents Sea Water (BSW) (Hopkins, 1991), with temperatures around 0 °C and salinities of 34.4–35. CW (> 2 °C, < 34.7) (Loeng, 1991) is transported northwards along the Norwegian coast and is confined to the south western part of the Barents Sea. AW is characterized by higher salinities and temperatures (> 35; > 3 °C) (Loeng, 1991). ArW enters the Barents Sea from the north and has low salinities (34.3 and 34.8) and temperatures (−1.5 °C), resulting in seasonal formation of sea ice (Loeng, 1991). In the Barents Sea, dense AW descends under the colder ArW, resulting in the formation of the oceanic Arctic Front (AF). At the AF, high nutrient availability results in increased primary production, especially just south of the front (Sakshaug and Slagstad, 1992). The maximum sea ice extent occurs between February and March, while the Barents Sea might be completely ice free from late summer to autumn (Vinje and Kvambekk, 2001). The inflow of AW, and hence salinity and heat, as well as variations in sea ice extent and location of the AF, have large effects on the Barents Sea ecosystem (Loeng and Drinkwater, 2007).

3. Material and methods

3.1. Samples

Cores were collected at 5 locations in the SW Barents Sea following the pathway of AW up north. Core locations were chosen in basins at deeper water depths where sediment accumulation rates are expected to be highest, improving chances of undisturbed cores with a high temporal resolution (Fig. 1, Table 1). Cores were collected during different years, i.e. July 2012 (893, 897, 902 and 903) and June 2015 (core 993) (Table 1). Sediment cores were retrieved by a multi-corer. Six sediment cores maximum half a meter apart from one another, were retrieved simultaneously with one multi-corer cast. Three sediment