Oceanologia (2017) xxx, xxx–xxx

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.journals.elsevier.com/oceanologia/

ORIGINAL RESEARCH ARTICLE

Impact of shelf-transformed waters (STW) on foraminiferal assemblages in the outwash and glacial fjords of Adventfjorden and Hornsund, Svalbard

Natalia Szymańska *, Joanna Pawłowska, Małgorzata Kucharska, Agnieszka Kujawa, Magdalena Łącka, Marek Zajączkowski

Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

Received 11 July 2016; accepted 11 April 2017

KEYWORDS
Arctic;
Fjords;
Foraminifera

Summary A new dataset of benthic foraminiferal assemblages from Adventfjorden (tributary fjord of Isfjorden, West Spitsbergen) was compared with the results of a study conducted by Zajączkowski et al. (2010) in Hornsund (West Spitsbergen). According to Nilsen et al. (2016), Atlantic water inflow to the Isfjorden Trough occurs more readily than to anywhere else along the shelf of Spitsbergen; thus, we compared the foraminiferal assemblages of the outwash Adventfjorden fjord, located in the Isfjorden system, with glacial Hornsund, located in southwest Spitsbergen. Despite the juxtaposition of Adventfjorden and Hornsund the data revealed varying impacts of shelf-transformed water (STW) on the benthic foraminiferal assemblages. Outer and central Adventfjorden was dominated by *Adercotryma glomerata*, *Recurvoides turbinata* and *Spiroplectammina* sp., reflecting the presence of STW, while abundant *Melonis barleeanus* in the central area of the fjord indicated a large flux of unaltered organic matter. Only the head of the fjord was dominated by the glaciomarine taxa *Cassidulina reniforme* and *Elphidium clavatum*. Foraminiferal fauna characteristic of STW-influenced environments (i.e., *Nonionellina labradorica* and *R. turbinata*) were also observed in outer Hornsund. However, the glacier-proximal taxa *E. clavatum* and *C. reniforme* were dominant throughout the fjord, demonstrating the impacts of meltwater and high sedimentation. Therefore, it is likely that in Hornsund, glacial impact is a major environmental factor, which is stronger than the influence of STW.

* Corresponding author at: Powstańców Warszawy 55, 81-712 Sopot. Tel.: +48 (58) 7311661.
E-mail address: natalia@iopan.gda.pl (N. Szymańska).
Peer review under the responsibility of Institute of Oceanology of the Polish Academy of Sciences.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.oceano.2017.04.006

1. Introduction

Foraminifera are widely used in micropaleontology in the reconstruction of diverse past and present marine ecosystems owing to their sensitivity to environmental parameters and the preservation of their hard shells throughout geological time (Murray, 2006). The geochemical composition (e.g., $\delta\ ^{13}C$, $\delta\ ^{18}O$) of foraminifera tests and the changes in foraminiferal assemblages, abundance and diversity are used as proxies of temperature, salinity, oxygen availability and water mass properties (e.g., Hald et al., 2007; Rasmussen et al., 2012; Ślubowska-Woldengen et al., 2008).

The climate and oceanography of West Spitsbergen are shaped primarily by Atlantic water (AW) inflow. A recent study conducted by Nilsen et al. (2016) found that AW flows into the Isfjorden Trough more easily than anywhere else along the shelf of Spitsbergen. They conclude that barotropic water movement in the Spitsbergen shelf depends on January–February wind stress, which accelerates and expands the WSC over its average flow layer of 500-m-long isobaths. Further transport of warm and saline water to Isfjorden is topographically guided. Therefore, Isfjorden is potentially the most AW-impacted fjord of West Spitsbergen, and AW may reach its innermost inlets, including Adventfjorden. Fjords south of Isfjorden, such as Hornsund, receive less AW and thus experience Arctic-like conditions. According to Nilsen et al. (2016), the inflow of AW to Hornsund is limited by the depth of the mouth of the fjord and wind stress that is weaker than that in Isfjorden Trough. In contrast, Adventfjorden is the outwash arm of Isfjorden, with a wide and relatively deep entrance; thus, rapid water exchange with the Spitsbergen shelf occurs.

In the recent years, a growing influence of Atlantic Water on the hydrographic regime of the European Arctic was observed (Arthun et al., 2012). This phenomenon, so-called 'atlantification', affects the functional properties of the Arctic ecosystems (Carmack and Wassmann, 2006). In the light of the latest findings of Nilsen et al. (2016), Adventfjorden may serve as a fjord model for studying the correlation between foraminiferal assemblages and the outreach of STW. Despite the fact that foraminiferal assemblages in the fjords of European Arctic have been widely studied (e.g., Hald and Korsun, 1997; Korsun and Hald, 2000; Skirbekk et al., 2016), there is a need to validate and refine the results of these studies, in the context of contemporary hydrographic and environmental changes.

Previous studies conducted in Adventfjorden have revealed high sensitivity of the fjord to climatic (Zajączkowski et al., 2004) and ecological changes (Pawłowska et al., 2011) and have shown that benthic foraminiferal assemblages reflect past and present environmental variability, largely steered by the inflow of AW (Majewski and Zajączkowski, 2007). However, according to Beszczyńska-Möller et al. (1997), water formed over the Spitsbergen shelf is a mixture of AW, Arctic water (ArW) transported from the Barents Sea and local glacial meltwater that has reached the shelf area, termed shelf-transformed water (STW). Recent changes in AW inflow and associated heat transport to West Spitsbergen have resulted in the creation of large ice-free areas in northern and western Svalbard (Cottier et al., 2007), leading to changes in the productivity and biodiversity of the Arctic ecosystems (Pawłowska et al., 2011). Therefore, linking faunal changes with local oceanographic data may aid in understanding and predicting environmental responses to the changing climate. The aim of this study is to investigate the impact of STW inflow on the foraminiferal assemblages in a glacial (Hornsund) and an outwash (Adventfjorden) fjord. In these two types of fjords, the location of glacial or glaciofluvial outflow in the inner fjord causes environmental gradients in turbidity, suspended organic matter concentration and sediment stability (Syvitski et al., 1987). According to Zajączkowski (2008), the sedimentological regime is consistent between these two types of fjords, however, outwash fjords exhibit more pronounced horizontal gradients in water density than do glacial fjords. Herein, we have compared a new dataset of foraminiferal assemblages from Adventfjorden with the results of a study conducted by Zajączkowski et al. (2010) in Hornsund. Analysed were datasets from late summer (August), for which there are recent, well-developed foraminiferal tests, representing the average conditions of the studied fjords.

2. Study area

The oceanographic regime off West Spitsbergen is shaped by two coastal currents: the West Spitsbergen Current (WSC), carrying AW and the East Spitsbergen Current (ESC), carrying a mixture of Arctic (ArW) and Polar waters (PW; e.g., Cottier et al., 2005). The classification of water masses proposed by Swift (1986) and Hopkins (1991) defines the temperature and salinity of AW as $>3^{\circ}C$ and >34.9, respectively. The ArW is fresher and colder than AW; however, its temperature and salinity vary according to the outflow from land. In the shelf off West Spitsbergen, AW, ArW and glacial water converge and mix, forming STW over the AW and ArW mixing line (Cottier et al., 2005; Saloranta and Svendsen, 2001). Based on the intensities of AW and ArW inflow, the waters on the shelf and in the adjacent fjords shift from Arctic to Atlantic dominance in annual cycles (e.g., Aagard et al., 1987; Svendsen et al., 2002).

This study was conducted in Adventfjorden, one of the southern arms of Isfjorden located on the west coast of Spitsbergen (Svalbard; Fig. 1). The wide and more than 100 m deep entrance of Adventfjorden allows for water exchange with the central part of Isfjorden, the largest fjord system on Spitsbergen. Adventfjorden is 8.3 km long and 3.4 km wide and is located between 78°13′ and 78°17′N and 15°25′ and 15°46′E. In the innermost area, there is a 0.7-km-wide tidal flat. The tides are semidiurnal and have a range of 159 cm (Zajączkowski and Włodarska-Kowalczuk, 2007).

The fjord is a marine coastal system, receiving freshwater and terrigenous material of primarily glacial origin. The Adventelva and Longyearelva rivers are the greatest contributors of sediment and freshwater. Freshwater discharge in summer is $3.18\ m^3\ s^{-1}$, with a sediment load of 131–151 mg dm^{-3}. Because the rivers remain frozen in winter, this water supply is cut off for 243 days of the year. Sediment accumulation decreases down-fjord from 1.87 to 0.87 cm $year^{-1}$ (Węsławski et al., 1999; Zajączkowski et al., 2004).

The water salinity is approximately 6 near the tidal flat, and at 1.5 km from the flat, it reaches 28. Since 2005, the fjord has remained ice-free during the winter (Zajączkowski et al., 2010). The climate of the region is warmer than expected from its high latitude owing to the influence of

Please cite this article in press as: Szymańska, N., et al., Impact of shelf-transformed waters (STW) on foraminiferal assemblages in the outwash and glacial fjords of Adventfjorden and Hornsund, Svalbard. Oceanologia (2017), http://dx.doi.org/10.1016/j.oceano.2017.04.006