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Short Communication

Mesozooplankton in the Kola Transect (Barents Sea): Autumn and winter structure

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ABSTRACT

The spatial distribution of mesozooplankton was investigated in relation to environmental conditions along the Kola Transect (69°30′–79°00′N, 33°30′E) during autumn (September 2011) and early winter (mid-November 2012). Mesozooplankton abundance averaged 964 and 740 individuals m^{-3} and biomass averaged 55 and 32 mg dry mass m^{-3} in 2011 and 2012, respectively. Cluster analysis showed good accordance of the mesozooplankton assemblages with the three main types of water masses present in the region. The first assemblage, dominated by *Calanus finmarchicus* and *Oithona similis*, but including neritic taxa, was associated with Murmansk Coastal Water. The second assemblage, with *Calanus* spp. contributing the majority of the total mesozooplankton biomass, was connected with Atlantic waters. The third assemblage, dominated by *Calanus glacialis,* was associated with cold Arctic waters. Redundancy analysis revealed that the explanatory factors significantly influencing the community structure of mesozooplankton were surface and bottom temperature, and depth of the sampling layer. Almost 64% of the total mesozooplankton fluctuations could be explained by changes in these environmental variables. Inter-seasonal changes in the structure of mesozooplankton were associated with higher abundances of *Calanus hyperboreus*, Copepoda nauplii, *Microsetella norvegica*, *Aglantha digitale*, *Oikopleura vanhoeffenni*, and *Mertensia ovum* and lower numbers of *Oithona atlantica* and young stages of *Paraeuchaeta* spp. in September 2011. Regional and seasonal comparisons of the total mesozooplankton biomass observed in the present study with sample data from the summer of 2003–2012 suggest that the mean values were higher in autumn season of 2011 due to differences in sampling layers.

1. Introduction

The high latitude ecosystems of the Arctic region are characterized by a high degree of environmental variability. The Barents Sea forms the transition zone between the boreal and true Arctic biogeographic regions (Wassmann et al., 2006). The relatively warm Atlantic water that flows into the Barents Sea submerges in many places and continues as an intermediate flow under the lighter Arctic surface water (Jakobsen and Ozhigin, 2011). This mixing and transport makes the export of plankton an important characteristic of the Arctic region (Sakshaug et al., 2009). Climatic variability causes large year-to-year variability in ice and hydrographic conditions, which affects plankton production and fish recruitment (Jakobsen and Ozhigin, 2011).

Zooplanktonic organisms are important food sources for many fishes, sea birds and mammals in the Barents Sea and worldwide (Raymont, 1983; Sakshaug et al., 2009). Many studies have shown copepods and amphipods to be important foods in the diet of the Barents Sea capelin (*Mallotus villosus*) (Orlova et al., 2011). Cod (*Gadus morhua*) is the main predator on capelin in the Barents Sea ecosystem (Wassmann et al., 2006). Cod, polar cod (*Boreogadus saida*), young herring (*Clupea harengus*), ringed seal (*Phoca hispida*), harp seal (*Phoca groenlandica*) and many sea birds consume macrozooplankton such as amphipods and krill (Dalpadado et al., 2001, 2012 and references therein). Many larval fish feed actively on copepods and other crustacean mesozooplankton in the Barents Sea and adjacent waters (Jakobsen and Ozhigin, 2011).

During the period 2003–2010 the mesozooplankton biomass showed a several-fold interannual variation in the Barents Sea (Dvoretsky and Dvoretsky, 2013a, 2014). The fish resources in the Barents Sea have also shown dramatic changes since 1983 (Gjøsæter, 1998; Olsen et al., 2010). These fluctuations may be connected to climatic variability, differences in the intensity of advective transport from the Norwegian Sea to the Barents Sea, and biological interactions, such as predation and food limitation (Wassmann et al., 2006; Stige et al., 2014). The advection of *Calanus* spp. from the Norwegian Sea is an important factor determining *Calanus* species abundance in the

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Barents Sea (Falk-Petersen et al., 2007).

Studies of environmental variability and biota across standard transects provide invaluable information on ecosystem fluctuations from year to year. The Kola Transect is located at the western part of the sea along 30°30′E. There are three main water masses in the Kola Transect (Jakobsen and Ozhigin, 2011): Murmansk Coastal Water (MCW, temperature 1–9 °C, salinity 33.80–34.70 psu), Atlantic Water (AW, temperature 2–8 °C, salinity 34.75–35.00 psu), and Arctic Water (ArW, temperature −2 to +2 °C, salinity 31.35–34.60 psu).

The most extensive and longest time-series containing information on the oceanography and biological resources in the Russian part of the Barents Sea have been collected in the Kola Transect by the Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO) and other scientific organizations (Stige et al., 2014). The first oceanographic studies of the Kola Transect were conducted in 1900. Regular annual hydrographic monitoring of the Kola Transect started in 1951. Previous mesozooplankton data series cover the period 1959–1990 (Nesterova, 1990). These investigations were focused on the spring and summer periods, as were other studies conducted in the Kola Transect after 1990 (Orlova et al., 2011; Dvoretsky and Dvoretsky, 2013a, 2013b, 2014; Stige et al., 2014). As a result, little is known about the structure of the mesozooplankton along the Kola Transect in autumn and winter.

In this study we investigated the composition, distribution and mesozooplankton assemblage structure in the Kola Transect in the mid-autumn and early winter periods. We also attempted to discover how mesozooplankton abundances were related to environmental conditions during this period.

2. Material and methods

A 1000-km transect across the Barents Sea was sampled during two cruises from 23 to 29 September 2011 and from 10 to 19 November 2012 on board R/V Dalnie Zelentsy (Fig. 1, Table S1 in Supplementary material). The cruises ran northward from the Murmansk coast to the Perseus Bank. Sampling was performed at 18 and 19 stations in 2011 and 2012, respectively. Stations were distributed every 0.5° (ca. 30 nautical miles).

Vertical profiles of temperature and salinity were obtained using a Sea-Bird Electronic 19 PLUS CTD. Zooplankton was collected from near the bottom (5–10 m above) to the surface using Juday nets (50 cm mouth diameter) with 168 μm mesh and equipped with filtering cod ends. Vertical hauls were conducted at a speed of 1 m s^{-1}. No flowmeters were used but special care was taken while sampling to keep the cable vertical by controlling an angle of the wire during catching. The volume sampled by the net was then calculated based on the depth of the tow and the surface area of the opening of the net (0.11 m^2). Due to wire time constraints sampling was performed at different times of day and night. The cod-end content of the nets was directly preserved in 4% buffered formalin-seawater solution for later taxonomic identification and abundance measurements.

Taxonomic identification and counts of mesozooplankton were conducted on shore in the laboratory using a MBS-10 dissecting stereo microscope. Common taxa were counted in subsamples (1/32 or 1/64); the entire sample was examined for either rare species and/or large organisms (krill, amphipods, medusae). Identification of the copepods was made at the level of species and developmental stage. Sex was also determined for the most abundant species. Copepodite stages of *Calanus finmarchicus* and *C. glacialis*, as well as young stages of *C. hyperboreus*, were distinguished by measurements of the prosome length (for details see Dvoretsky, 2011). *Pseudocalanus* species were identified according to Frost (1989).

Mesozooplankton abundance was expressed as number of individuals per cubic meter. Biomass of the mesozooplankton was calculated using the abundance data and published individual dry masses and length-mass regressions (for details see Dvoretsky and Dvoretsky, 2009a, b, 2012, 2013a, b). Wet mass (WM) was converted to dry mass (DM) using a conversion factor of 0.04 for gelatinous zooplankton and 0.2 for other groups (Harris et al., 2000). All the means are presented with standard error.

Multivariate analysis of the mesozooplankton was performed using PRIMER 5.0 software (Clarke and Warwick, 1994). Abundance data were square root transformed. Cluster analysis based on the Bray-Curtis similarity index (group average linkage) was applied to test similarities in the mesozooplankton assemblage among stations. Analysis of similarities (ANOSIM) based on the Bray-Curtis similarity matrix of mesozooplankton abundance was used to test for differences between clusters (Clarke and Gorley, 2001). The SIMPER procedure was used to reveal the contribution (in %) of each zooplankton taxon to the total similarity within the different clusters.

Redundancy analysis (RDA) was used to examine the distribution of zooplankton taxa in relation to environmental variables (time of sampling, latitude, longitude, depth of the sampling layer, averaged temperature and salinity in the sampling layer). RDA is a direct gradient analysis of taxon data, in which the axes are constrained by a linear model, i.e. by linear combinations of environmental variables (ter Braak and Smilauer, 2002). Before analyses, the abundance data were transformed using a square-root transformation so as to allow the less important taxa to influence the species patterns (ter Braak and Smilauer, 2002). A Monte Carlo permutation test with 499 permutations was carried out to find out which environmental variables significantly ($p < .05$) explained the species distribution. The analysis ranks the environmental variables according to their quantitative importance by forward selection. The analyses were carried out using the program Canoco v. 4.5.

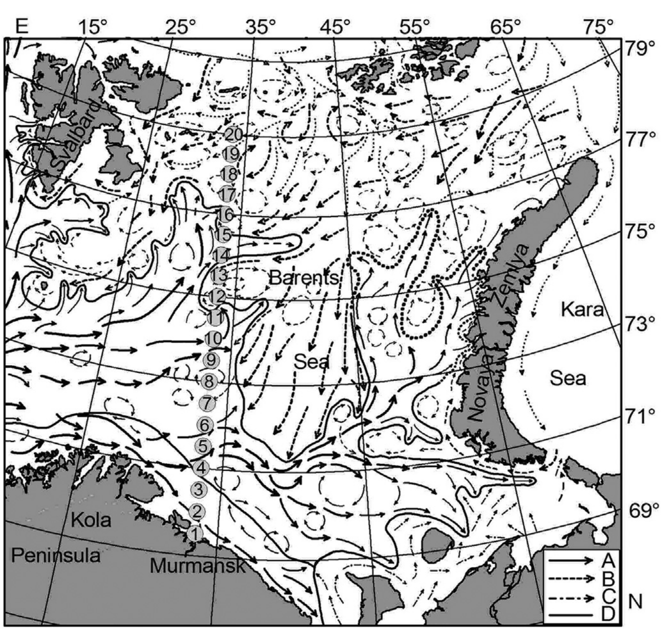

Fig. 1. Location of the sampling area in the Barents Sea in September 2011 and November 2012. A – warm currents, B – cold currents, C – coastal currents, D – boundary of the frontal zones.

3. Results

3.1. Hydrography

The September 2011 cruise took place during the stratified period. Stations 1–14 showed a surface layer (0–50 m) with temperatures above 6 °C and up to 9 °C at st. 1 and st. 4 (Fig. S1 in Supplementary material). Intermediate waters (50–150 m) displayed temperatures between 2 and 3 °C, with warmer waters southwards. Stations 15–18 were