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Polar Science 6 (2012) 183–195

http://ees.elsevier.com/polar/

Effect of radioactive pollution on the biodiversity of marine benthic ecosystems of the Russian Arctic shelf

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Received 1 August 2011; revised 2 March 2012; accepted 2 April 2012
Available online 24 April 2012

Abstract

This study is the result of many years of research on the ecology of the marine benthos of Russian Arctic seas. We used samples collected at various locations from the Russian continental shelf during 1993–2009 as the basis of our study. Our main aim was to analyze the spatial distribution of taxonomic and quantitative characteristics of the meiobenthos (small bottom-dwelling animals, 0.1–3.0 mm in size). Statistical analysis of the data revealed that the factors determining the spatial distribution of meiobenthic organisms under natural conditions, and conditions impacted upon by human activity, were salinity, water depth, hydrocarbons, heavy metals and radiocaesium volumetric activity. The possible use of the meiobenthos as a tool for environmental impact assessment is proposed and discussed on the level of higher taxa.

Keywords: Arctic seas; Meiobenthos; Marine ecology; Russian continental shelf; Environmental impact assessment

1. Introduction

In response to the ecological decline of recent years we must intensify our efforts to manage the environment to prevent further degradation. To achieve this, an understanding of biodiversity and, in particular, species composition is essential. The conservation of biodiversity is a typical problem for the Arctic seas, in which marine ecosystems were considered to be intact for many years but are now under increasing external pressure from economic activities in the ocean, as well as global environmental changes. Similar changes are also reflected in the structure of marine benthic ecosystems.

Conserving biodiversity consists of two parts: the acquisition of reliable species data and the formulation of adequate measures for their conservation. There are insufficient species data for marine ecosystems because large areas of the seafloor have yet to be analyzed at sufficient spatial and temporal resolution, and in such areas it is difficult to undertake repeated sampling. In addition to compiling taxonomical lists, it is also important to study benthic ecology.

The first species counts in Arctic seas were undertaken by Russian scientists in the middle of the 20th century; for example, Pergament (1944) found 1180 species in the Kara Sea, Ushakov (1952) reported 720 species for the Chukchi Sea, and Zenkevich (1963) reported species numbers for each sea except the East Siberian Sea. The richest of the Eurasian Arctic shelf seas is the Barents Sea, which is inhabited by

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doi:10.1016/j.polar.2012.04.001

3245 invertebrate species. The White Sea supports an impoverished Barents Sea fauna comprising 1817 species. The number of species steadily declines eastwards from the North Atlantic: 1671 species are known for the Kara Sea, 1472 for the Laptev Sea, 1011 species for the East Siberian Sea, and 1168 species for the Chukchi Sea (Buzhinskaja et al., 2001).

Marine benthic organisms can be divided into three groups by size: macro-, meio- and microbenthos. Generally, in marine ecology, the initial focus of attention when studying sea-bottom ecosystems is given to the macrobenthos. The macrobenthos comprises 60% of marine species, the meiobenthos 34%, and plankton 6%. Different benthic groups have been studied to varying degrees, with the study of species diversity starting with large organisms. The meiobenthos (small benthic organisms, 0.1–3.0 mm in size) and the microbenthos (<0.1 mm) are often excluded from marine research, which adds to the uncertainty inherent in investigations of both the biodiversity and functional ecology of sea-bottom ecosystems. Planktonic species are less diverse and more widely distributed compared with benthic animals, and our knowledge of them is more complete. The macrobenthos is, therefore, more frequently studied than the meiobenthos, and meiobenthic groups such as nematodes, turbellarians, harpacticoids, and ostracods are particularly poorly studied.

Meiobenthic organisms are an important part of marine ecosystems: their density can reach hundreds of thousands of individual organisms per square meter; the biomass is often comparable with the biomass of the macrobenthos, especially at greater depths. The meiobenthos feed on the large number of bacteria and bottom-dwelling unicellular algae, and thus consume a significant proportion of primary production, direct consumption of which is either unavailable or energetically unfavorable for many macrofauna. In turn, meiobenthic organisms serve as food for some invertebrates and fish. The meiobenthos play a significant role in the decomposition of organic matter and changes in the physical properties of sediments.

The composition of the meiobenthos includes various taxonomic groups of small multicellular organisms. Their systematic position is sometimes very poorly studied, and limited data are available relating to their ecology. Detailed study of dominant meiobenthic groups and species will enable us to get closer to understanding the ecology of small benthic invertebrates in various areas of the Arctic seas of Russia.

In recent years, interest in the study of the meiobenthos has increased dramatically. The research covers a wide range of subjects: morphology, systematics, the ecology of meiobenthic organisms, and molecular genetic studies. Biogeographic studies of the meiobenthos have also expanded the study of various geographic areas such as the abyssal zone, trenches, hydrothermal vents, as well as the polar regions of both hemispheres, and these are of particular interest. The volume of available information is already quite large, but its rate of accumulation is still high. For the meiobenthos there is a clear lack of review papers that analyze all stored data (such as the work of Higgins and Thiel, 1988; Galtsova, 1991; Giere, 2008; Mokievsky, 2009). Research on the meiobenthos of the Arctic continental shelf is extremely uneven. While the meiobenthos of the Barents, White, and Pechora seas, including the coast of Spitsbergen, has been studied in detail (e.g., Radziejewska and Stankowska-Radziun, 1979; Galtsova, 1991; Szymelfenig et al., 1995), few studies have examined the Eastern (Siberian) sector of the Arctic Ocean.

There have been quantitative studies of the meiobenthos in ecosystems of the Novosibirsk Shallows (Sheremetevskiy, 1987) from the intertidal zone to depths of 30 m; the Chauna Bay of the East Siberian Sea (Golikov et al., 1994); and estuarine areas of the Lena River (Gukov, 2001). Research of the Kara Sea benthos began long ago: it is thought to date back to A.E. Nordenskioeld's expeditions in 1875, 1876, and 1878 (Semenov, 1989). However, the meiofauna of the Kara Sea is now virtually unknown. There are a few taxonomic works that examine the diversity of nematodes in the Kara Sea (e.g., Galtsova and Kulangieva, 1999), and two works dedicated to the study of meiobenthic organisms collected from areas around the former nuclear test site Novaya Zemlya (Galtsova et al., 2004b; Pogrebov et al., 1997). The taxonomic composition and distribution of the meiobenthos in the Abrosimova and Stepovogo inlets, which are nuclear waste disposal sites, were both investigated in detail; samples were collected from depths ranging from 44 to 74 m.

There are two approaches to studying the ecology of marine meiobenthos. The first one concentrates on the ecology of major taxonomic rank (orders, classes). Such studies contribute to the overall picture of the significance of the meiobenthos and its separate component-groups within ecosystems, and aim to establish a common link between the characteristics of these groups and their relationship with the environment. The second one is associated with detailed study of the systematics of major groups and common species. It classifies small benthic organisms and provides keys to the identification of species.