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Current state of zoobenthos in two estuarine bays of the Barents and Kara Seas

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Benthic studies in two seasonally ice-covered Arctic estuaries include description of the faunal composition, biodiversity, quantitative distribution, and biogeographic structure of the fauna. Water temperature and salinity variations, bottom relief, and sediment composition are important features influencing the zoobenthos of Pechora Bay and Ob Bay. The inner parts of the bays are occupied by freshwater and brackish water fauna, while marine species occupy the mouths of the bays. Species diversity increases from the inner parts to the open sea, while the homogeneity of the community reflects the opposite tendency.

Key words: biodiversity, biogeography, Pechora and Ob Bays, species composition, zoobenthos.

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Introduction

The study of the influence of environmental conditions on bottom fauna in estuarine areas has been a topic of several international symposia during recent decades (Skreslet, 1986). There is a great deal of information about the bottom fauna from estuarine areas, especially the Baltic Sea (Andersin *et al.*, 1978). In the Arctic, the influence of fresh water on the functioning of marine ecosystems has been of great interest since the importance of salinity controlled balance of the water exchange in the Greenland Sea was described (Hagaard and Carmaak, 1989).

The interaction between the coastal ocean and the fresh water discharging into the Arctic seas is very important because the severe climate renders the ecosystems sensitive to negative impacts. The processes taking place in the coastal zone of the south-eastern part of the Barents Sea and the Kara Sea are strongly dependent on the processes in the watershed, especially with regard to the freshwater outflow on the ice cover, sedimentation, transportation of organic matter, and biological productivity.

Our aim is to determine the faunal composition, biogeographic structure, and quantitative distribution of the zoobenthic fauna in Pechora Bay and Ob Bay, especially with reference to the salinity gradients. These two bays have certain similarities, and they are geographically located in the Arctic at similar latitudes (Fig. 1). Both are influenced by large outflows of fresh water and characterized by shallow water and the absence of sills towards the open sea. Pechora Bay is located in the south-eastern part of the Barents Sea. The Barents Sea is strongly influenced by warm Atlantic Water, which in the east penetrates the Kara Gate, the strait between the Barents Sea and Kara Sea. The length of the bay in the north-east direction from the Pechora River delta up to the navigable channel between the Gulyaevskiye islands is about 75 km, and the area is 7290 km^2. The annual outflow of the Pechora River into the bay is about 150 km^3. The Ob Bay is located in the southern part of the Kara Sea, which is weakly influenced by Atlantic Water. Only the deep warm water mass penetrates from the North. The length of the bay from the Ob River delta up to the sea area between the White and Shokalskiy islands is about 870 km and the

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area is about 55.600 km^2. The annual outflow of the Ob River into the bay is 500–600 km^3.

The bays differ in configuration. Pechora Bay is shorter and wider than Ob Bay, but both have similar longitudinal bathymetric profiles. The depths do not exceed 6–8 m in the deltas and increase up to 15–25 m at the seaward entrance. Based on multiannual observations, the hydrological regime of both bays exerts a strong seasonal variability in water temperature and salinity (Nadejdin, 1964; Nalimov, 1972; Burenkov and Vasilkov, 1994). In Pechora Bay, the annual variation in water temperature is between -1.12°C in spring and 14.1°C at the end of August. In Ob Bay, the lowest temperature was observed in the middle of June (-1.8°C) and the highest at the beginning of September, varying between 8.5 and 11.5°C.

Our data from Pechora Bay provide for the first time a complete picture of the zoobenthos communities. Earlier publications contain only information about the Korovinskaya inlet in the eastern part (Varushkina, 1967) and a very general description of the entire Bay (Nadezhdin, 1964). Ob Bay has been studied in more detail (Leschinskaya, 1968; Kusikova, 1989). These studies present general information about the biomass of zoobenthos and the main communities. However, quantitative data on zoobenthos from the area immediately outside the mouth of the bay were lacking.

Material and methods

In the 1990s, material has been collected during several special summer expeditions in Ob Bay by RV "Academic Karpinskiy" (1991), RV "Dmitriy Mendeleev" (1993), and RV "Kern" (1996), and in Pechora Bay by RV "Geophysic" (1995). The results from 10 sampling stations in Pechora Bay, which were located along one longitudinal transect from the river mouth to the entrance of the bay, were used. Similarly, the results from eight stations in Ob Bay were used, but the transect ran in this case from the central part to the entrance area (Fig. 1, Table 1). Temperature and salinity profiles were measured with a CTD-sond at each station. Depth in the sampling areas varied from 7 to 18 in Pechora Bay and from 12 to 35 m in Ob Bay. Bottom sediments in both bays consisted mainly of muddy clay or sandy mud. Sandy sediments were also registered in Pechora Bay.

The benthic material was collected with a 0.1 m^2 van Veen grab, 0.25 m^2 Ocean, or 0.04 m^2 Petersen grab in 2–6 replicates at each station. The samples were gently flushed through a bag of nylon net with a mesh size of 0.75 mm. Samples were sorted under a microscope. The animals were preserved in 70% alcohol and subsequently identified to species or to practical taxonomic levels. Specimens of each taxon in each sample were weighed (after storage in alcohol). These values were then used for calculating the average biomass of each species and the total average biomass and abundance of benthos at each station.

Shannon diversity (H) and evenness (U) indices (Pielou, 1966) for the bottom communities were calculated on the basis of the abundance values. In addition, the biogeographic characteristics for each marine and brackish water taxon were determined based on the biogeographical principles and regionalization theory of Golikov (1982).

Results

Analysis of hydrographic parameters revealed the presence of frontier zones between freshwater, estuarine, and marine water masses in both bays (Fig. 2). In Ob Bay, fresh water was observed in the southern part, which is located south of Taz Bay. The northern part was characterized by typical estuarine salinity (10–29), while the mouth area had normal marine conditions. In contrast, typical marine salinity was not recorded in Pechora Bay. Neither at the entrance to the bay nor just outside did salinity exceed 28. The frontier zone between fresh water and brackish water was located in the southern part of the bay because of the strong tidal current entering from the narrow northern channel (Fig. 1). Fresh water appeared at Station 14, located near the mainland coast, where the tidal current cannot penetrate because of the large volume of the freshwater input from the Pechora River and the high current velocities therein along the mainland coast.

The temperature variation along the Ob Bay transect was high and varied from 7.2°C in the inner part to -1.8°C at the mouth. In Pechora Bay, the temperature varied between 4.2°C and 11.0°C; no temperatures below zero were observed.

A total of 107 different taxa were recorded in Pechora Bay and 125 in Ob Bay. The study area in Pechora Bay is characterized by the absence of freshwater fauna, except for oligochaetes. The brackish water area was, with only 10 species identified in the innermost part, as poor as the estuarine zone of Ob Bay. In general, however, the faunal composition of the two bays was very similar. The polychaete (*Marenzelleria arctia*), crustaceans (*Monoporeia affinis* and *Saduria entomon*), and the priapulid (*Halicryptus spinulosus*) occupied all stations belonging to the brackish area, and the mollusc (*Macoma balthica*) was found locally in similar parts of the bays.

The number of species increased continually towards the mouth of the bays, except for Stations 5 and 6 in Pechora Bay, where the low species number appears to be caused by the presence of clean, coarse sandy sediments. At the station located near the mouth area, 52 taxa were recorded.

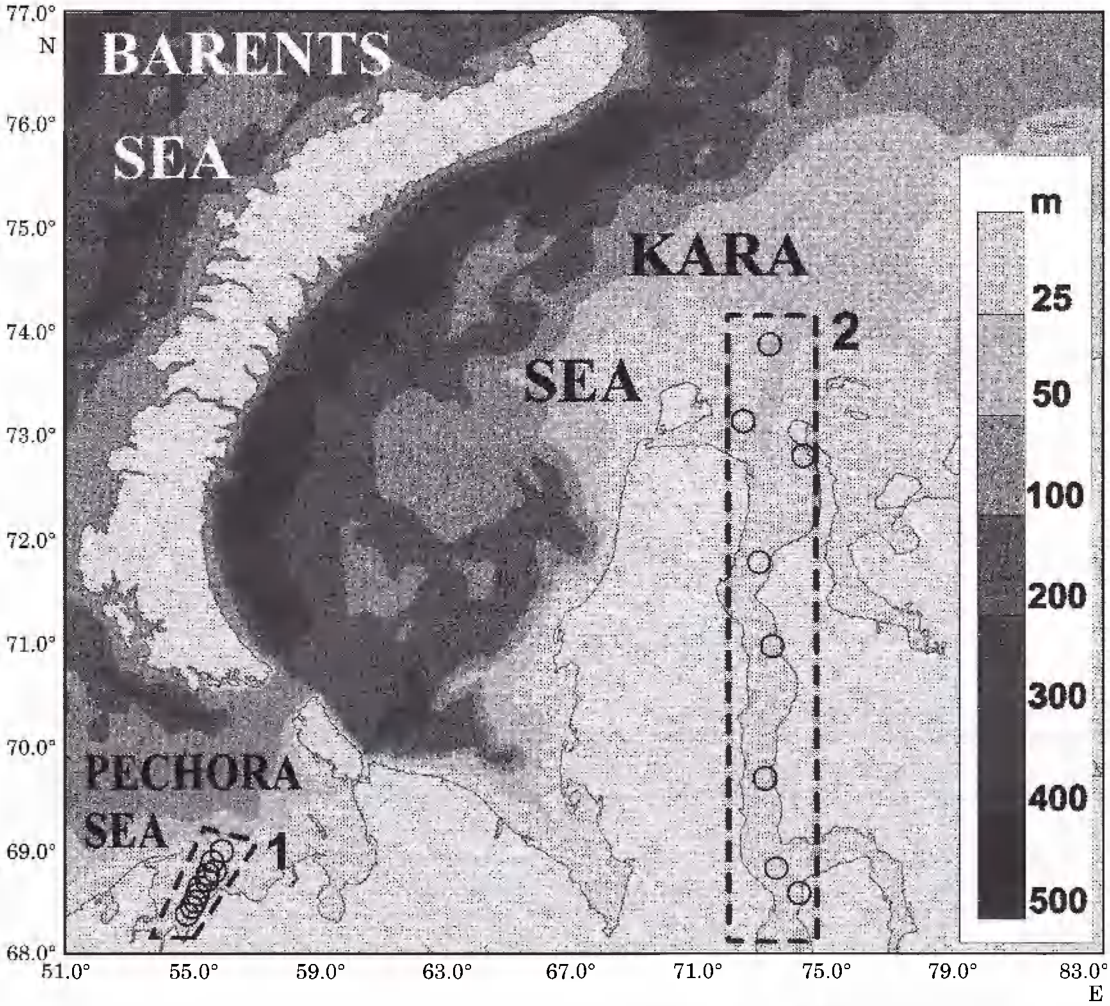

Figure 1. Study area with sampling stations in the Pechora (1) and Ob bays (2).

The southern part of the study area in Ob Bay was inhabited by freshwater fauna, consisting of oligochaetes, chironomids, and bivalves. The number of taxa did not exceed 20 in any sample. To the north of Taz Bay, the freshwater zoobenthos is substituted by the brackish-water faunal complex. The benthic fauna in this region is very poor, and consists of only 3–4 species in each sample, consisting mainly of polychaetes (*M. arctia*), amphipods (*M. affinis*), and priapulids (*H. spinulosus*). The transition from the brackish-water faunal complex towards marine fauna was observed only at the outer section, where depth was gradually increasing. The number of taxa increased towards the mouth of Ob Bay, as in Pechora Bay. The richest fauna, 72 species, was recorded at Station 231 at the mouth of Ob Bay, characterized by mixed muddy clay sediments and by a marine salinity. At the northern and most marine stations of both bays, molluscs, polychaetes, and crustaceans predominate the benthic fauna. In addition, stenohaline systematic groups such as brittle stars, bryozoans, and ascidians were observed.

The Shannon index of diversity in Pechora Bay varied from 1.5 in the inner, brackish waters of the southern part to 4.0 at the entrance (Fig. 2c), while the index in Ob Bay varied from 0.5 to 5.5 and increased towards the delta area and to the mouth (Fig. 2f). The low diversity index corresponds to areas that are clearly influenced by fresh water. The index of fauna homogeneity shows an opposite change in comparison with the diversity.

From a biogeographic point of view, the total benthic fauna in Pechora Bay was composed of 31% truly arctic, 63% boreal-arctic, and only 6% boreal species (Fig. 3c). In the southern part of the bay, half of the species were of Arctic origin, belonging mostly to the so-called estuarine-arctic forms, which are able to live in highly varying hydrological conditions (low salinity, high

Table 1. Sampling stations in the Pechora and Ob bays.

Station	RV	Year	Latitude	Longitude	Depth (m)	N**
1	"Geophysic"	1995	69°00'44	56°00'75	7	5 vV
2	"Geophysic"	1995	68°54'35	55°42'98	9.7	4 vV
3	"Geophysic"	1995	68°48'65	55°48'08	17.8	4 vV
5*	"Geophysic"	1995	68°47'00	55°34'00	8	6 Pt
6*	"Geophysic"	1995	68°43'42	55°32'17	8	6 Pt
9	"Geophysic"	1995	68°39'37	55°17'93	9.6	4 vV
10	"Geophysic"	1995	68°35'28	55°14'54	10.2	4 vV
13	"Geophysic"	1995	68°31'12	55°09'27	7.7	4 vV
14	"Geophysic"	1995	68°27'74	55°03'28	6.9	4 vV
15	"Geophysic"	1995	68°23'79	54°54'13	7.0	4 vV
4414	"D. Mendeleev"	1993	73°49'93	73°30'05	26	2 Oc
231	"Ac. Karpinsky"	1991	73°05'90	72°40'04	15	2 Oc
234	"Ac. Karpinsky"	1991	72°45'75	74°34'90	16	2 Oc
4416	"D. Mendeleev"	1993	71°45'01	73°09'38	18	2 Oc
4417	"D. Mendeleev"	1993	70°56'83	73°33'94	20	2 Oc
4417	"D. Mendeleev"	1993	69°40'98	73°19'40	13.5	2 Oc
4418	"D. Mendeleev"	1993	68°49'61	73°40'64	13	2 Oc
96	"Kern"	1996	68°35'06	74°24'21	10.4	3 vV

*Sampling from a rubber boat.
**vV: van-Veen grab (0.1 m^2); Pt: Petersen grab (0.04 m^2); Oc: Ocean grab (0.25 m^2).

temperature in summer and below 0°C in winter). In the northern part and outside the bay, the proportion changes and the number of boreal-arctic species increases and becomes higher than the number of arctic species.

In Ob Bay, the biogeographic structure of the total fauna was as follows: arctic species 20%, boreal-arctic species 77%, and boreal species 3% (Fig. 3f). There was a similar tendency to that in Pechora Bay in the variation of the biogeographic structure from the inner part to the mouth. In the brackish area, arctic species predominated (60%). Further northwards, their importance decreased with the appearance of a high number of widespread boreal-arctic species, while some boreal forms were also observed at most marine stations. The most important boreal species were *Obelia longissima* (Hydroidea), *Pleurogonium spinissimum* (Isopoda), and *Phyllodoce mucosa* (Polychaeta), while the most important arctic species were *M. arctia* (Polychaeta), *H. spinulosus* (Priapulida), *Saduria sibirica* (Isopoda), and *Diastylis sulcata* (Cumacea). In general, boreal species were observed in both bays in areas with salinities higher than 20.

In the estuarine zone of Pechora Bay, abundance (number of organisms) varied from 345 to 10 180 m^{-2} and biomass from 4.9 to 85.1 g m^{-2} (Fig. 3a,b). In comparison, both abundance (1500 m^{-2}) and biomass (2.5 g m^{-2}) of the benthic fauna were very low in the fresh water areas of Ob Bay (Fig. 3d,e). In the brackish water areas (salinity 6–10) of Ob Bay, abundance varied between 710 and 1200 m^{-2}, and total biomass between 7.4 and 12.4 g m^{-2}. In both bays, the typical inhabitants of these areas were polychaetes (*M. arctia*), amphipods (*M. affinis*), and priapulids (*H. spinulosus*). In addition, *M. balthica*, which does not penetrate to the eastern part of the Kara Sea, dominated the biomass in Pechora Bay. The biomass of these species together represented about 80% of the total biomass.

The marine part of Pechora Bay was characterized by a lower abundance (870–1106 m^{-2}) and biomass (20.0–27.4 g m^{-2}) than the inner part. Outside the estuarine zone at the mouth of Ob Bay, abundance increased to about 3000 m^{-2}; the total biomass exceeded 100 g m^{-2}. Among all systematic groups, bivalves along with polychaetes dominated the biomass, forming about 50% of the total biomass.

Discussion

The benthic fauna found in the two bays reveals certain similarities, but differs substantially from Arctic areas with a smaller influence of freshwater outflow from rivers. For instance, in the Svalbard area, meltwater from glaciers plays a major role in the formation of the estuarine zone but influences only the top of the bays (Weslawski *et al.*, 1995). In contrast, the estuarine zones dominate the Pechora and Ob bays. Species richness in the Svalbard area is correspondingly higher than in our study. In fact, species composition in these bays is similar to that of the Baltic Sea (Andersin *et al.*, 1978; Andersin and Sandler, 1991). The poor fauna may be explained by low temperatures, a short summer period, a large outflow of fresh water and a high rate of mineral

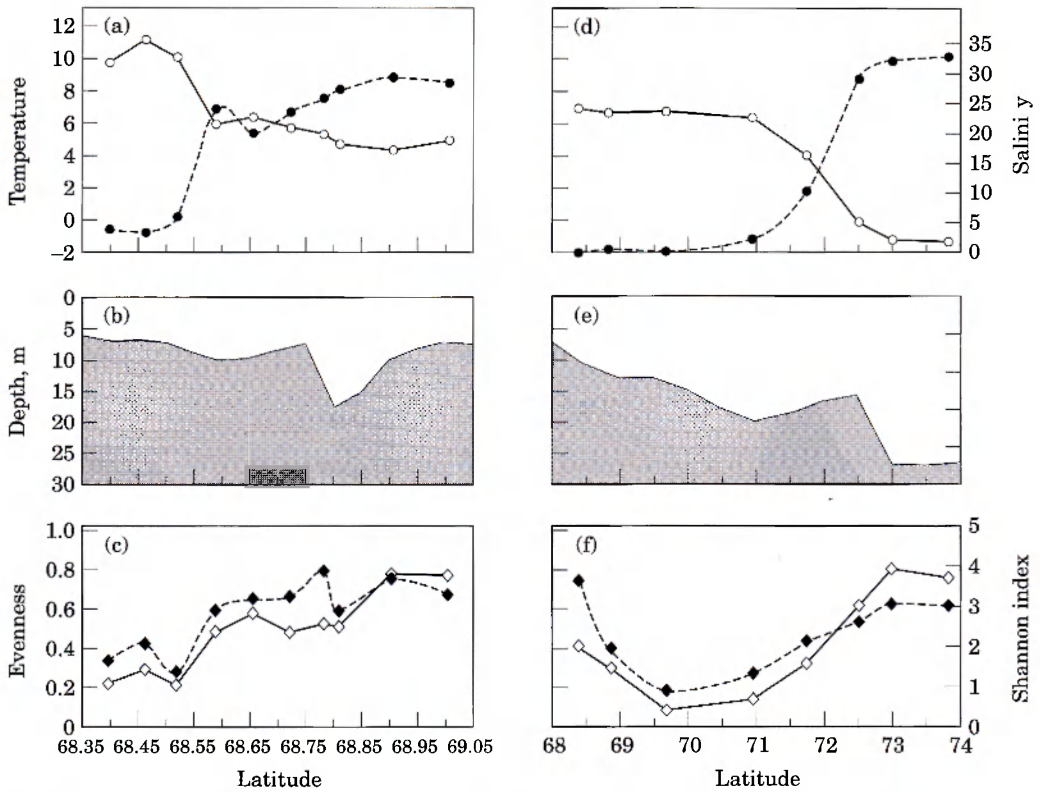

Figure 2. Pechora Bay (left panels) and Ob Bay (right panels): a, d: Bottom temperature (°C, circles), salinity (‰, dots); b, e: depth; and c, f: evenness (closed symbols), and Shannon (open symbols) along the sampling transect.

sedimentation (Lisitsyn, 1994). This concurs with the postulate about the negative influence of the "critical" salinity of 5–8 (Remane and Schlieper, 1971; Khlebovich, 1974) on freshwater species and marine species.

The analysis of the faunal composition has made it possible to define several benthic communities, communities which have mostly fresh and brackish-water characteristics. In both bays, the locations of these faunal complexes shows a strong dependence on environmental conditions, especially freshwater outflow and grain-size composition of the bottom sediments. Also, the variations in the Shannon index along the transects reflect certain similarities: low values in the inner parts with brackish water and a gradual increase towards the open sea. The increase in diversity in the inner part of Ob Bay is evidence of favourable conditions for freshwater species.

The index of species evenness with the Shannon index clearly shows the areas where the freshwater benthic complex is transformed to the estuarine complex. Also, the borders between the estuarine complex and the marine complex can be clearly seen (Fig. 2c,f). Moreover, the differences between the values of the two indices for the two bays are indicative of the impact of the different amounts of freshwater outflow from the Ob and Pechora rivers. The influence was considerably stronger in Ob Bay than in Pechora Bay.

The strong influence of the Arctic is reflected in the biogeographic structure of the fauna. Although the arctic species predominate in both bays, the proportion of boreal species in Pechora Bay is larger than in Ob Bay, and they are observed virtually along the whole transect. This may be explained by a stronger influence of Atlantic Waters in the Barents Sea than in the Kara Sea.

Parallel with the changes in fauna richness, changes in benthic productivity are apparent. The presence of the boreal mollusc *M. balthica* caused higher biomass values in the brackish zone of Pechora Bay, while an increase in zoobenthos biomass in Ob Bay is restricted to the mouth where arctic euryhaline bivalves appear. The observed differences in zoobenthos, and especially the lower abundance and biomass in Ob Bay, appear to be caused by a more severe climate and, consequently, a more severe environment in the latter.

Leschinskaya (1962) and Kusikova (1989) have noted considerable seasonal variations in the biomass of bottom animals. Causes of these fluctuations might lie in variations in the hydrological regime. In winter, the flow

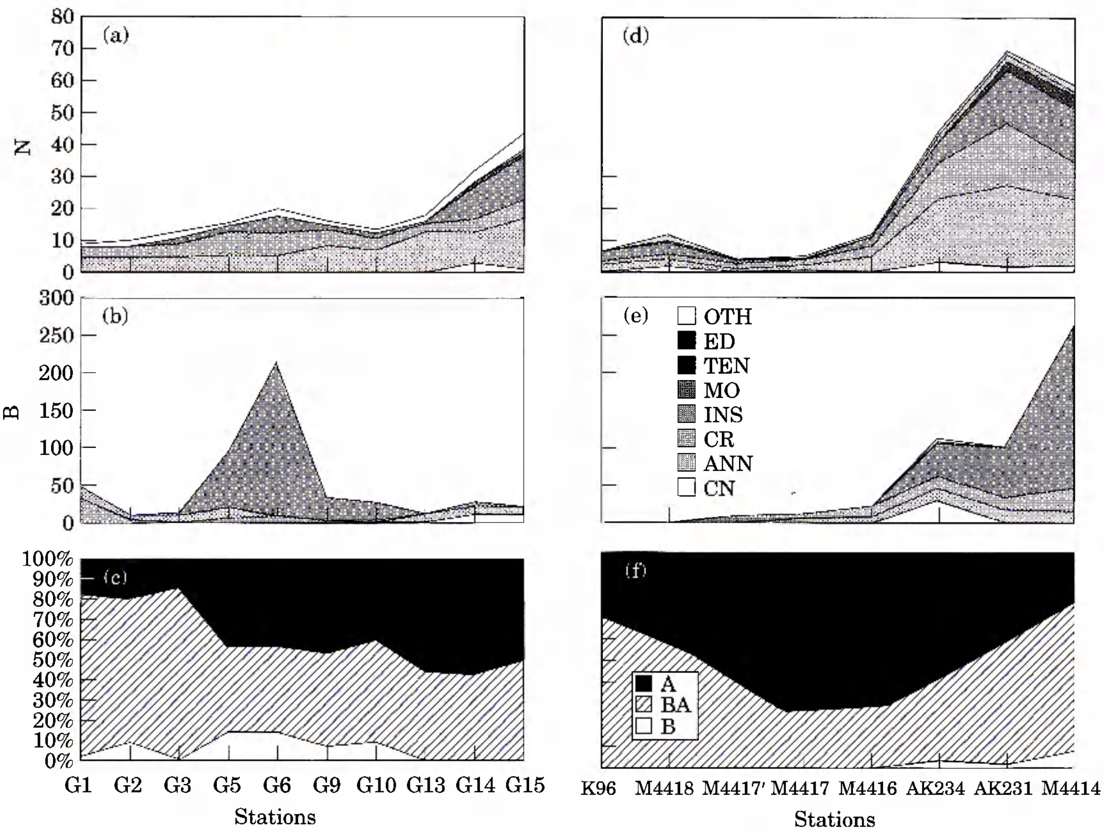

Figure 3. Pechora Bay (left panels) and Ob Bay (right panels): abundance of different systematic groups in (a, d) number 0.25 m^{-2} and (b, e) biomass (g m^{-2}) along the sampling transects (CN: *Coelenterata*; ANN: *Annelida*; CR: *Crustacea*; INS: *Insecta*; MO: *Mollusca*; TEN: *Tentaculata*; ED: *Echinodermata*; OTH: other; see legend in panel e); and c, f: biogeographical structure of the benthic fauna (A: arctic; BA: boreal-arctic; B: boreal).

of the Ob River decreases and salinity of the water in the bay increases, allowing the introduction of brackish species while reducing survival of freshwater species. Another factor, one which must influence the benthic communities, is the severity of the winters. Large parts of the shallow areas of Ob Bay as well as Pechora Bay are frozen to the bottom with a consequent destruction of the bottom fauna. A periodical destruction of the bottom fauna by ice scouring is also possible, even in deeper areas. However, sometimes interannual variations have been caused also by inaccurate positioning of the sampling stations.

While a comparison of our results with previous studies reflects a doubling of the species list for Ob Bay (Leschinskaya, 1962), the biomass values are similar. According to data from the 1960s (Leschinskaya, 1962) and 1980s (Kusikova, 1989), the average total biomass varied in the range of 3.3–4.4 g m^{-2} (wet weight), while maximum values of 11–12 g m^{-2} were observed at some stations. We obtained approximately the same values.

In both bays, a noticeable increase in species number was observed at stations where bottom salinity exceeds 25. Simultaneously, a fast increase in biomass was observed in zones where salinity rapidly increases to 22–30. According to Lisitsyn (1994), intensive biological uptake of dissolved and suspended organic matter discharged by the rivers takes place under these conditions. In Pechora Bay, a high biomass is built up by the boreal-arctic bivalve mollusc *M. balthica*, which is well adapted to brackish-water conditions. In Ob Bay, *M. balthica* is absent as its distribution area eastwards is limited to the north-west coast of the Baydaratzkaya Bay. Instead, a similarly high biomass is formed by the arctic bivalve mollusc *Portlandia arctica*. At the entrance, a big increase in biomass is formed by a typical marine bivalve mollusc with cosmopolitan distribution, *Hiatella arctica*.

A comparison of our results with earlier studies (Leshchinskaya, 1962; Kusikova, 1989; Nadezhdin, 1964) shows that the biomass in the two bays varies between years. Leshchinskaya (1962) explained the variations in the Ob Bay by the great variability in the long-term thermal regime. Correlation of the biomass in Pechora Bay with average annual water temperatures in the Barents Sea (Adrov and Denisenko, 1996) during different periods has shown that the zoobenthos reacts by an increase in biomass to the rise of temperature with a delay of 3 years. In Ob Bay, the zoobenthos reacts by an increase in biomass to the rise of temperature with a delay of 1 year (Leshchinskaya, 1962). These differences between the bays may be explained by the fact that in Pechora Bay periodic biomass observations are available only for the brackish zone, where the relatively large and long-lived *M. balthica* dominates. In Ob Bay, zoobenthos data are available only for the central part, which in practice is fresh water. Here, small-sized short-living oligochaetes, bivalve molluscs and crustaceans dominate, which react faster to varying thermal conditions.

The analysis of the 1996 survey allows the separation of three zoobenthic communities in the sublittoral zone of the central part of Ob Bay. According to previous studies (Kusikova, 1989), only one community was observed, dominated by oligochaetes and bivalves. The communities with crustacean and bivalve dominance were not noticed, either because they occupy only small areas or, more likely, because sampling methodology and/or the definition of communities differed. Comparisons cannot be made because published data for Pechora Bay (Nadezhdin, 1964) are so scarce.

The material obtained forms a solid baseline for future monitoring of the two bays, especially within the framework of the current oil and gas prospecting programmes. Furthermore, the results may be used for evaluations of fish productivity, as the majority of the commercial fish in these bays are benthos feeders, and zoobenthos may form up to 65% of all the food for fish (Greze, 1957; Podlesniy, 1958).

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