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MARINE BIOLOGY

Current State of Macrobenthic Communities in Baydaratskaya Bay (Kara Sea)[1]

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Abstract—Macrobenthic communities in Baydaratskaya Bay were studied before and after the seafloor pipeline was begun to be laid out in the year 2011. Materials were collected during three surveys in 2007, 2012, and 2013. Ordination of the data based on community structure and composition revealed a clear depth-related zonality of the communities. Stations deeper than 10 meters were dominated by bivalves, while shallower stations were dominated by nephtyid polychaetes. This structure persisted though the whole period studied, without any pronounced temporal trends. However, several deep-water stations near the pipeline path in the year 2013 revealed a distinct shift in the structure of macrofauna, with large bivalves disappearing, an increased abundance of small polychaetes, and a decrease in total biodiversity. Moreover, macrofauna were absent at one of these stations. We conclude that the structure and distribution of communities are relatively stable and mainly driven by depth. However, there are some local but evident disturbance effects, probably caused by recent human activity (dumping of dredged sediments).

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INTRODUCTION

Macrobenthic communities are widely used as indicators of the state of the environment [22]. Such studies are of current interest in the Arctic since the intensity of anthropogenic activity has increased significantly over the past decades. Moreover, the combination of human impacts and climate shifts may cause more severe environmental changes in the region [24].

Baydaratskaya Bay, situated in the southwestern part of the Kara Sea, is an example of area with low level of human activities. However, the Yamal–Center pipeline crossing the bay, the construction of which began in 2011, may significantly influence the benthic habitat. The comparison of benthic data collected before and after the construction of the pipe may serve as an estimation of the impact of construction on the environment.

MATERIAL AND METHODS

Study area. The characteristic feature of Baydaratskaya Bay hydrology is the low level of freshwater runoff and consequently, high water salinity. Bottom water temperature during summer varies between +9.42°C at a 15-m depth and +1.43°C at 18 m; the bottom water salinity varies within 28.83–34.42‰ ([3], 2007 data). The fine sands are a primary type of sediments, while sandy silts and fine silts are less common [8]. The ice-coverage period is prolonged, and ice gouges occur across the whole range of depths [29].

Material was collected in three surveys between 2007 and 2013 (Table 1, Fig. 1). A 0.1 m^2 grab was used for sampling at 32 stations in 2007, 4 stations in 2012, and 9 stations in 2013 (three samples per station in 2007 and 2012 and a single sample in 2013, Table 1). Samples were sieved through 0.5 mm mesh on board and preserved in 4% formaldehyde. In the laboratory, samples were sorted and transferred to alcohol. Macrofauna was counted and identified to the lowest taxon possible using stereo microscope. Biomass was identified using laboratory balance with 0.001 g precision.

To estimate the **role of species in a community** we used its relative respiration rate [6, 12]:

$$R_i = A_iQ_i/\sum A_iQ_i = A_iB_i^{0.75}N_i^{0.25}/\sum A_iB_i^{0.75}N_i^{0.25},$$

where A_i is the taxon-specific coefficient of respiration intensity, B_i is the taxon's biomass and N_i is the taxon's

Table 1. Number of stations and samples in different surveys

Year	Research vessel	Number of stations	Number of samples
July 2007	*Professor Boyko*	32	96
September 2012	*Muromets*	4	12
September 2013	*Lazurit*	9	9

[1] The article was translated by the authors.

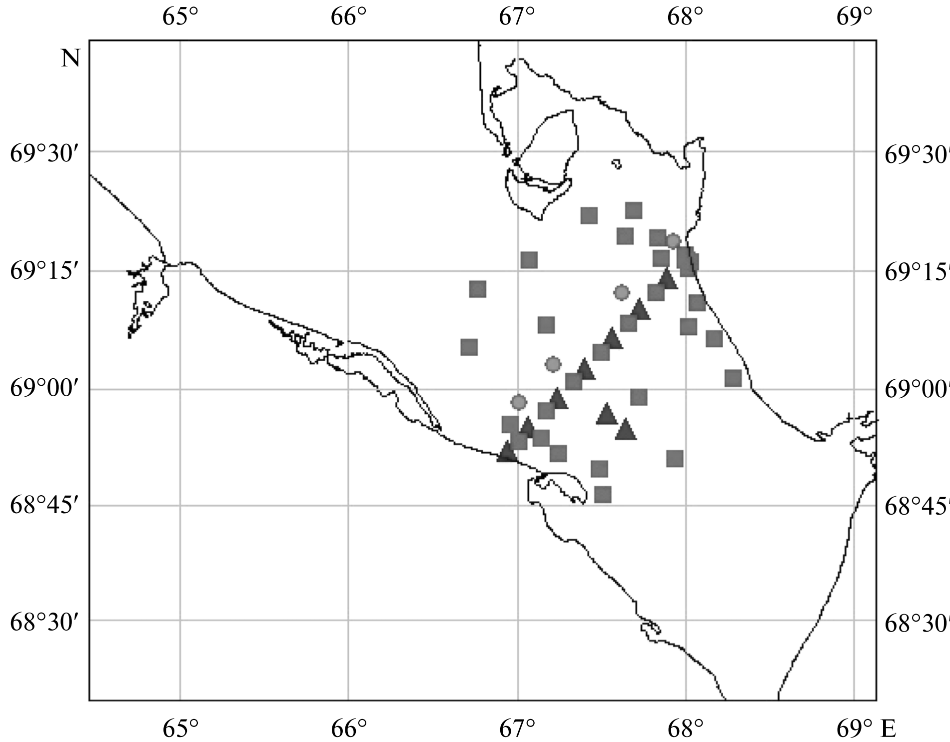

Fig. 1. Schematic map of sampling stations. Squares—stations of 2007, circles—2012, triangles—2013.

abundance. The values of taxon-specific coefficient of respiration intensity were taken from literature [4].

The analysis of data was performed using software packages PRIMER v. 6 and PAST. To calculate the similarity between the samples, we used the Bray–Curtis index [14]:

$$I_{jk} = 1 - \sum [x_{ij} - x_{ik}] / \sum (x_{ij} + x_{ik}),$$

where x_{ij} and x_{ik} are the ith species relative respiratory rate in samples j and k. The resulting similarity matrix was used to perform the ordination using nonmetric multidimensional scaling (nMDS). This ordination was used for both raw and fourth-root transformed data, the latter of which is less sensitive to dominant species. The ANOSIM routine was used to testify the reliability of the factors affected the ordination [16].

To estimate species diversity we used the expected species number per 200 individuals—ES(200). This index is suitable for comparison in case of different sampling efforts [16].

The size structure of communities was estimated using the ABC (abundance/biomass comparison) method, which is sensitive to changes in the community associated with pollution or disturbance [32]. To compare ABC curves we used a W index [15]:

$$W = \sum (B_i - A_i) / [50(S - 1)],$$

where B_i and A_i are the cumulative sums of the first i species ranked by biomass and abundance, respectively, and S is the total number of species. This index takes values from –1 to 1, with negative values indicating the predominance of numerous small organisms, and positive values indicating the dominance of larger ones.

RESULTS

In total, 178 macrobenthic taxa were revealed in three surveys. In 2013, at one station at a depth of 19 m, macrofauna were absent except for few nematodes, so the station was excluded from further analysis.

The ordination of untransformed data is presented in Fig. 2. Stations collected in different years tend to group together, without any obvious differences among years. At the same time, stations were grouped by depth. An ANOSIM test confirmed that the differences among three depth ranges were significant although the R-statistic value was not very high ($R = 0.55$; $p = 0.001$).

The ordination of the fourth-root transformed data, which is less sensitive to dominant species, revealed a similar pattern, but some of the stations 2013 stand apart from the others (Fig. 3). A two-way ANOSIM, with depth and year as grouping factors against a background of bathymetric differences (depth factor) (Table 2), showed that the effect of depth was highly significant. Also, the difference between the 2007 and 2013 surveys was also significant across all depth ranges.

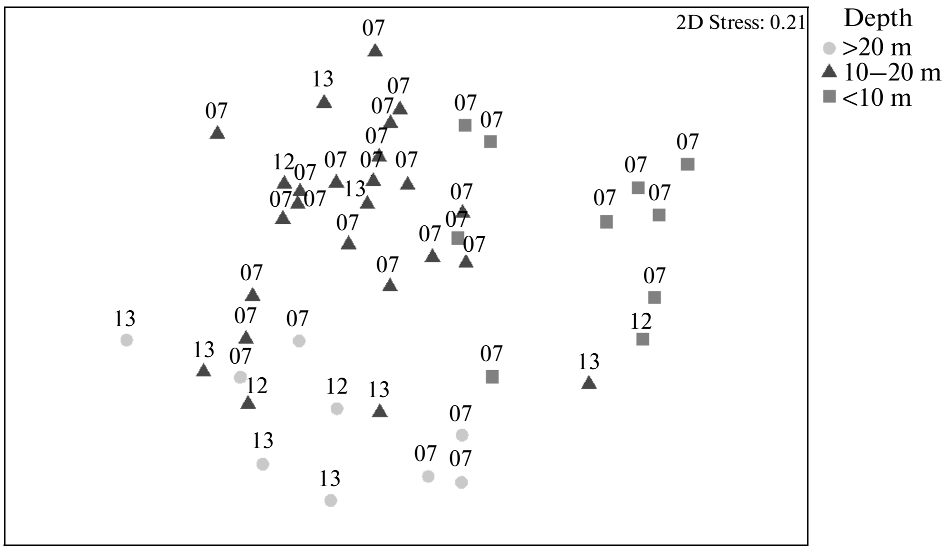

Fig. 2. MDS Ordination based on untransformed data of species relative respiration rate. Numbers indicate the year of sampling.

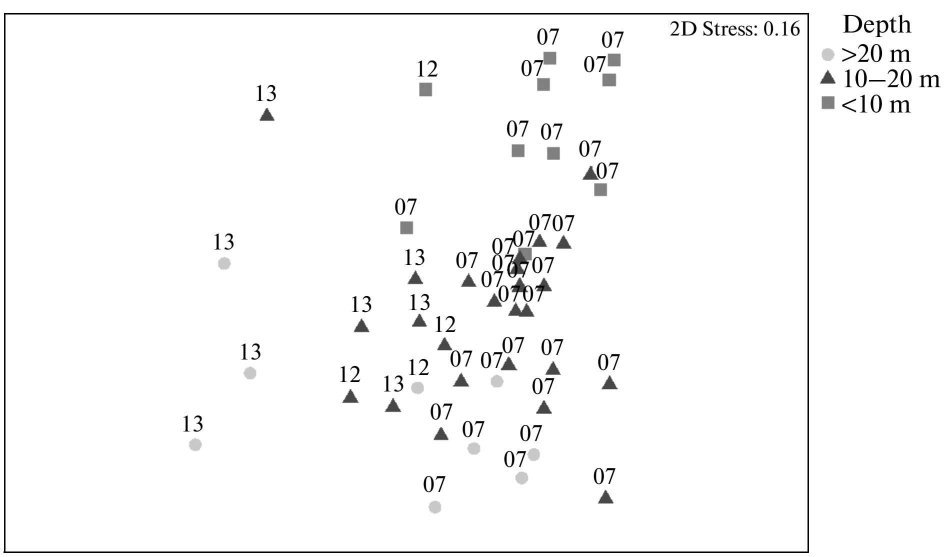

Fig. 3. MDS ordination based on fourth root transformed data of species relative respiration rate. Numbers indicate the year of sampling.

Thus, the results show a distinct shift in the structure of macrofauna on the deepest (>20 m) stations in 2013. From the ordination of transformed data (Fig. 3) it was clear that one middle-depth station was rather similar to these three deepest. An ANOSIM test confirmed that these four 2013 stations significantly differed from the others ($R = 0.69$, $p = 0.001$). A SIMPER test revealed that over 60% of the similarity among these four stations was due to the relatively high abundance of small polychaetes *Micronephtys minuta, Cirratulidae* spp., *Cossura* sp., *Ampharete* gr. *lindstroemi* and bivalve *Mya truncata* (represented there by juveniles only) and absence of large bivalves (*Astarte borealis, Yoldia hyperborea*) and isopod *Synidothea bicuspida*. The *Micronephtys minuta* was the most abundant species at all of these four stations.

Thus, according to data obtained in 2012–2013, on the part of the studied area there were no changes in the macrobenthic structure, and the same types of community were present. Shallow depths below 10 m were dominated by polychaete *Nephtys longosetosa* and lacked large bivalves. Depths between 10 and 20 m were characterized by the dominance of bivalves *Serripes groenlandicus*, sometimes along with *Ciliatocardium ciliatum*. The latter was found among the domi-

Table 2. Two-way ANOSIM results (grouping factors are depth and year) for fourth root transformed data

Groups	*R*	Significance level
2012, 2013	0.003	45.2%
2007, 2012	0.312	9.6%
2007, 2013	0.47	0.3%

nants at the deepest stations, along with *Astarte borealis* and *Yoldia hyperborea*.

The integral parameters of benthic assemblages by year and depth ranges are presented in Table 3. At depths up to 20 m, the values were similar over the whole period of research. The deepest stations of the year 2013, however, showed a noticeable decrease in total biomass and species diversity. Low biomass was caused by the disappearance of large bivalves, while the high abundance was caused by an abrupt increase in abundance of small polychaetes species. Consequently, these changes resulted in negative value of the *W*-index. Interestingly, different species contributed to the high abundances at each station from this group (Table 4).

DISCUSSION

The depth zonality of macrobenthic communities in Baydaratskaya Bay was shown for the first time by material collected in 1987–1988. The central deep part differed from shallow parts both in species composition and higher biomass and diversity [10]. Later surveys in 1992–1993 confirmed this vertical zonality [1]. Three types of benthic communities were described: 1—a shallow one (5–6 m) with low biomass dominated by *N. longosetosa* and *Acrybia islandica*; 2—community at 10–12 m depths, with biomass up to 177 g/m^2, dominated by *Serripes groenlandicus*—*Stegophiura nodosa*—*N. longosetosa*; and 3—the deepest community (>20 m), dominated by *Astarte borealis*—*Stegophiura nodosa*—*Synidothea bicuspida*. This pattern is in accordance with that found in 2007–2013 and described above.

Benthic surveys in 1990–1991 in the inner part of Baydaratskaya Bay revealed eight different communities, but two of them were represented by a single station each [2]. Stations with a predominance of *Astarte borealis* were found close to the open sea at depths of 8–37 m, while stations along the western coast were dominated by *Serripes groenlandicus* and *Ciliatocardium ciliatum*. This spatial pattern matches our data. However, two communities (Ascidiacea gen. sp.–*Myriothrochus rinckii* and *Portlandia arctica*–Amphipoda), which were described near the east coast, had not been found since 1990–91. This is most probably due to scarce sampling and the extremely patchy distribution of benthos near the east coast. Stations with a predominance of *Micronephtys minuta* and Cumacea gen. sp. are of particular interest since we also found *M. minuta* as dominant species in 2013. However, at the beginning of the 1990's these stations were taken at 11 m depth near the Kara Bay but not along the track of pipe.

Thus, the overall distribution of benthic communities in Baydaratskaya Bay remained relatively stable in 2007–2013, with the only exception being some stations of 2013 located along the southern border of the dredging area. Bottom fauna on these stations was characterized by the predominance of small polychaetes, the almost complete disappearance of large bivalves, and low diversity and biomass. Moreover, at one station in this area, macrofauna was completely absent. The most likely reason for such catastrophic changes is dredging during pipe building, which commonly results in the increase of resuspended matter in water and then intensive sedimentation [7, 9].

Most benthic organisms are not adapted to such rapid changes of environment. First of all, the increase of inorganic suspended matter in near-bottom water negatively affects filter-feeding mollusks since their filtration structures are adapted to the certain concentration of suspended matter [21]. In general, benthic

Table 3. Integral parameters of macrobenthos from different depth ranges. Bold type highlights the values for the deepest stations of 2013

Depth	Year	Biomass (g/m^2)	Abundance (ind/m^2)	ES (200)	*W*-index
Below 10 m	2007	19.6 ± 16.7	584 ± 330.7	50.32 ± 3.42	0.149
	2012	44.5	810	31.97 ± 1.26	0.298
	2013	–	–	–	–
From 10 to 20 m	2007	117.4 ± 103.7	1579.1 ± 1469.9	48.29 ± 3.6	0.103
	2012	180.3 ± 172.2	2943.3 ± 1376.5	33.36 ± 2.78	0.157
	2013	143.8 ± 122.7	3742 ± 1523.8	37.02 ± 2.99	0.15
Over 20 m	2007	93.8 ± 52.5	942.7 ± 839.5	45.31 ± 3.57	0.112
	2012	73.4	2383.3	38.03 ± 2.8	0.154
	2013	**16.7 ± 12**	**5656.7 ± 2570**	**15.74 ± 2.24**	**–0.116**

Table 4. Abundances (ind/m^2) of species contributing over 9% to overall abundance at some stations of 2013

Station (depth)	4 (21 m)	6 (22 m)	8 (20.5 m)	12 (13 m)
Micronephtys minuta	**1370 (16.6%)**	**2290 (40.5%)**	**2450 (79.3%)**	**1000 (69.4%)**
Aricidea nolani	770 (9.4%)	450 (7.9%)	0	0
Mya truncata juv.	50 (0.6%)	60 (1.1%)	20 (0.65%)	**130 (9%)**
Cossura sp.	**3250 (39.5%)**	**1230 (21.7%)**	**440 (14.2%)**	0
Galothowenia oculata	1150 (14%)	20 (0.3%)	0	0
Levinsenia gracilis	920 (11.2%)	680 (12.0%)	0	0

fauna is adapted to some natural rate of sedimentation. If this rate increases drastically (e.g., in the case of dredging), depletion of fauna or even complete extinction can occur because of burial by sediments [27]. The survival of benthic organisms in this situation depends on their ability to restore contact with the bottom water layer [13, 21]. There is some evidence that organisms with similar life modes behave in a similar way when they are exposed to dredged sediments [30]. It seems that stations of 2013 with depleted or absent macrofauna were directly affected by a trencher that started to operate in late 2011. The results of computer modelling [11] prove that the most intensive sedimentation is likely to happen in this narrow (1–2 km) area to the south of the pipeline track. Stations of 2012 are located to the north of the track, so the macrobenthos there was apparently less affected by dredging.

The early stages of community recovery after disturbance are generally considered to be dominated by *r*-strategy species [28]. Typically, this results in an increase in abundance but a decrease in biomass (i.e., negative *W*-index values) as well as a low species richness [16]. In case of Baydaratskaya Bay, the stations of 2013 with disturbed communities were dominated by few species of small polychaetas, mainly *Micronephtys minuta*. This species is considered to be an *r*-strategist, which can rapidly form very dense local aggregations [20]. Probably, the high reproductive potential and high motility allow it to recolonize disturbed areas. For instance, on the Beaufort Sea shelf, *M. minuta* predominates in the inshore fast ice (below 20 m) and flaw lead (20–40 m) areas, which are highly influenced by ice scouring and coastal erosion [18]. Another species, whose abundance has increased significantly, is polychaete *Cossura* sp. Similar increase in the abundance of polychaetes, in particular belonging to the Cossuridae family, was described after the dumping of sediments in the Baie des Chaleurs [23]. In our case, the observed changes in the abundances of other species can probably be explained by the fact that stations were affected by trencher with some time lag, and so they are on different stages of progressive succession.

After a single anthropogenic impact, rapid community restoration is possible. For example, in the Western Baltic Sea the benthic parameters returned to an initial state two years after the experimental dumping [31]. Pipeline construction in the Cnolakilty Bay, Ireland, has lead to the complete extinction of macrofauna at the impacted site. The first recolonization by the polychaete *Hediste diversicolor* happened six months later, and one year later the site was recolonized by the bivalve *Scrobicularia planta*. Both species are typical dominants for the area [25, 26]. Apparently, the recolonisation of soft sediments in the Arctic happens much more slowly. According to some estimates, it can take up to twelve years for the community to be restored [19]. For instance, the macrofauna of the Barrow strait sites exposed to ice scour did not completely recover until after nine years of observation [17]. All things considered, we can state that pipeline building had a local but evident negative effect on the macrobenthos in Baydaratskaya Bay. It can take years for the benthic communities to be restored. Thus, benthic communities in the southwestern part of the Kara Sea, earlier considered as stable [5], are in danger of severe disturbance due to increasing human activities on Arctic shelf.

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