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EXPERIMENTAL ARTICLES

The Distribution of Bacterio- and Mesozooplankton in the Coastal Waters of the White and Barents Seas

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Abstract—The total population density and the biomass of bacterioplankton, mesozooplankton, and phosphate-accumulating bacteria (PAB) were estimated during the 2000–2001 summer–autumn seasons in the coastal waters of the White and Barents Seas, which are subject to the action of tidal and sea currents, the inflow of riverine waters, and anthropogenic impact. In the shallow estuarine waters with salinities of 6.5–32‰ near the Chernaya, Pesha, and Pechora River mouths, the population of PAB fluctuated from 0.1 to 9.1 million cells/ml (0–36% of the total bacterial population). In pelagic seawaters, which are low in phosphates (12–50 μg/l) and are characterized by an increased iron/phosphorus ratio (2.0–3.6), bacterioplankton amounted to 0.1–1.6 million cells/ml and was mainly represented by small organisms with a volume of 0.08–0.15 μm^3, commonly lacking intracellular polyphosphates. In the pelagic zone of the Barents Sea, the biomass of mesozooplankton (B_z) was comparable with that of bacterioplankton (B_b = 39–175 mg/m^3), the B_b/B_z ratio being 1.4–4.6. Off the Varandeiskii, Pechora, and Kolguyev oil terminals, B_b increased to 155–300 mg/m^3 and the B_b/B_z ratio rose to 1.4 to 50.3 (with an average value of 20.9), presumably due to the severe anthropogenic impact on these waters. In this case, the dense population of bacterioplankton (0.9–7.6 million cells/ml) was mainly represented by large cells (0.12–0.76 μm^3 in volume), most of which (3–43% of the total bacterioplankton population) contained polyphosphates. The chemical composition of these waters was characterized by an elevated content of the total phosphorus (65–128 μg/l) and by a low iron/phosphorus ratio (0.9–1.2).

Key words: microbial population density, bacterioplankton biomass, mesozooplankton biomass, phosphate-accumulating bacteria, intracellular polyphosphates, phosphorus, iron, anthropogenic impact, seawater, Barents Sea.

The opening up of an industrial diamond deposit in the Primorskii region of Arkhangelsk oblast and of the coastal Timano-Pechora oil-bearing field has posed an ecological threat in the White and Barents Seas [1, 2]. The threat is mainly due to severe ecological problems in the Pechora Sea (a southeastern extension of the Barents Sea) related to the drilling of oil wells and the construction of oil terminals, which result in heavy oil pollution of the environment. Intense sea currents, the inflow of riverine waters, strong winds, the indented coastline, and the complex topography of the sea bottom in this region make the distribution pattern of oil suspensions and the hydrobiological parameters of seawater very heterogeneous, both spatially and temporally [2, 3].

Earlier microbiological studies in the Barents Sea showed that its bacterioplankton is characterized by a high reproduction rate and daily productivity and a concentration that decreases as one progresses northward [4, 5]. In August 1984, both the population and the daily production of bacterioplankton in the southeast of the Barents Sea were at maxima in coastal and shallow waters [6, 7]. The intricate horizontal distribution pattern of bacterioplankton in this region was explained by the complex dynamics of seawaters and the mixing of sea and riverine waters. The population and the biomass of bacterioplankton were found to be several times higher in the vicinity of islands. Among the planktonic communities occurring in the pelagic zone of the Barents Sea, bacterioplankton plays the most important role, being responsible for the major fraction of the activity of hydrobionts and forming the basis of the trophic chain in this arctic sea [4, 8].

Of great interest is the finding that the phosphorus content in the north of the Atlantic Ocean and in the Arctic Ocean (<1 μg-atom/l) is lower than in the other oceans and in the seas around Antarctica (>2.5 μg-atom/l) [9]. Studies with the radioisotope ^{32}P showed that the rates of phosphorus regeneration and turnover are more important for the maintenance of the biological productivity

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of oceanic waters than phosphorus concentration [10]. Bacteria rapidly utilize orthophosphates present in natural waters, excreting organic phosphates, which are efficiently utilized by phytoplankton [11].

Over the last two decades, much research effort has been devoted to the study of the ecology and physiology of phosphate-accumulating bacteria (PAB), which are able to accumulate intracellular polyphosphates in amounts reaching 20–35% of the dry biomass of cells [12]. Lowering the cultivation temperature diminishes the requirement of PAB for orthophosphate (necessary for cell growth) and stimulates the accumulation of phosphates in cells in the form of polyphosphates [13]. The distribution of PAB in waters of different genesis is considerably influenced by the spatial and temporal dynamics of iron and phosphorus compounds, which are able to aggregate with the formation of phosphorus- and iron-containing precipitates.

However, little is known about the distribution of PAB in coastal marine ecosystems. To fill this gap, this work aimed to study the total population and the biomass of bacterioplankton, mesozooplankton, and PAB in the coastal waters of the White and Barents Seas, which are subject to the action of various natural and anthropogenic factors.

MATERIALS AND METHODS

Water and plankton samples were taken during the integrated expedition on board the research vessel *Poisk* in the White and Barents seas in August–September 2000 and in June–July, July–August, and October 2001 and also near the White Sea Biological Station of the Moscow State University in August 2001 (figure). Seawater was sampled at different depths using a Frantsev-type bottle. Mesozooplankton was caught with a Jedi-type plankton net.

The total phosphorus (P_{tot}) was determined by hydrolyzing samples in a solution of potassium persulfate (0.1 g/10 ml) in 2% H_2SO_4 at 100°C for 1 h. Orthophosphates were quantified spectrophotometrically (590 nm; KFK-2 colorimeter) with ammonium molybdate and potassium antimonyl tartrate in the presence of ascorbic acid. The total iron was determined by measuring the absorbance of the ortho-phenanthroline complex at 490 nm. These analytical methods can be found in the handbook [14].

To determine the total population density and the biomass of bacterioplankton (N_b and B_b, respectively) in samples, they were treated by the standard methods of aquatic microbiology [15]. The quantity N_b and the percent of volutin-containing cells (N_v) were determined by a direct microscopic count of cells retained on 0.2-μm Millipore filters, which were stained for 1.5 days with toluidine blue (a dye that causes a red metachromatic shift in the color of volutin-containing cells). The filters were examined under a Biolar transmission microscope at a magnification of 1500×. Cell sizes were measured using an ocular micrometer. The biomass B_b was calculated accounting for the content of the main bacterial morphotypes and the degree of their shrinkage on the filters (from 1.7 to 2.1). The cell density was taken to be 1.06; the dry biomass of cells was assumed to be 15% of their wet biomass.

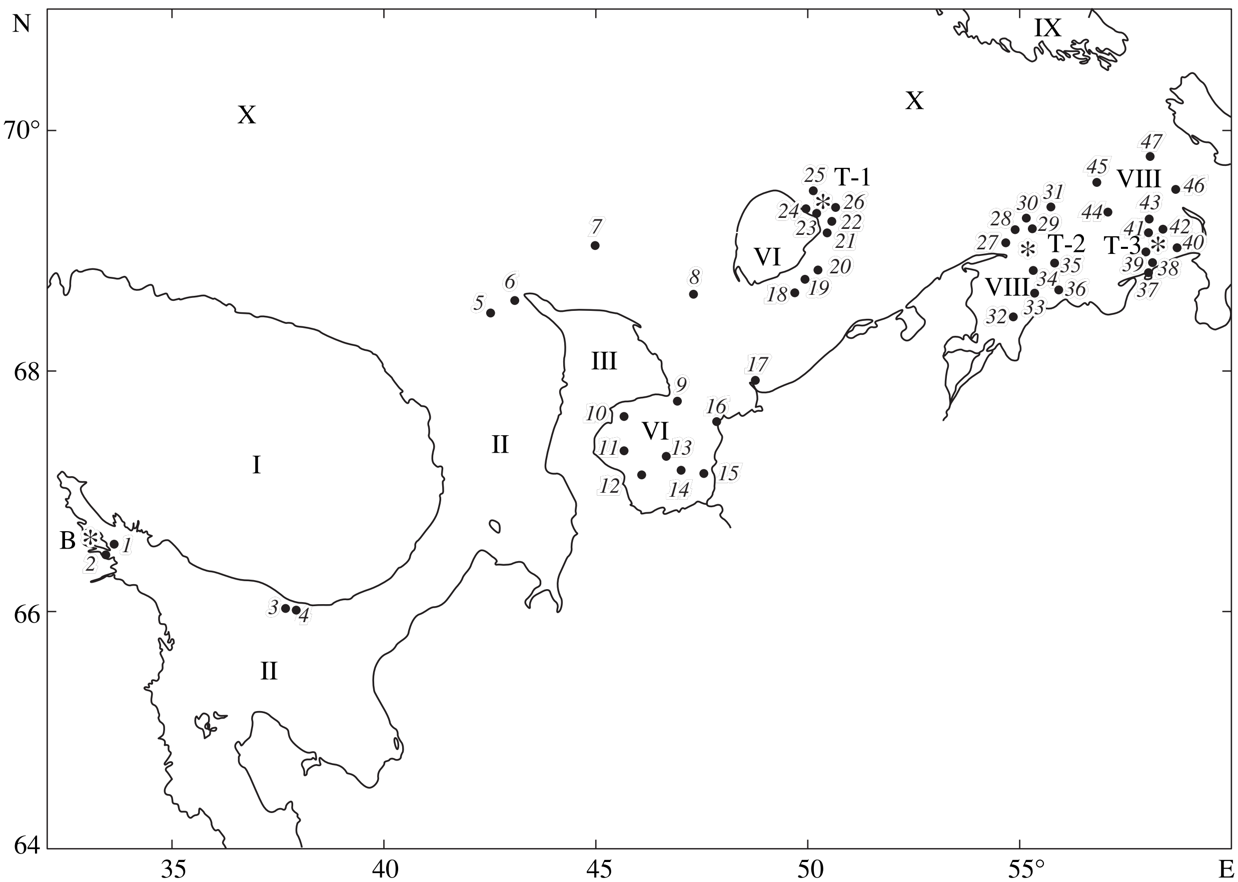
The dark microbial assimilation of carbon dioxide was evaluated by the radiocarbon method [15]. Samples (40 ml) were placed in amber bottles and supplemented with 0.2–0.4 ml of a solution containing 3–6 μCi ^{14}C-labeled sodium bicarbonate. After incubation for 18–24 h, the samples were fixed with formalin and passed through 0.2-μm filters. The filters were washed with 0.3 N HCl to remove the remaining radioactive bicarbonate, and their radioactivity was measured in a Beta-2 scintillation counter. The rate of the dark assimilation of carbon dioxide was used to calculate the productivity of heterotrophic bacteria (P), assuming that the contribution of CO_2 to the biosynthesis of cellular constituents in these bacteria is 6% [15].

When analyzing mesozooplankton, we took into account its species composition, the size distribution of planktonic organisms, and the developmental stages of each planktonic species [16]. Planktonic organisms were counted under a binocular using a Bogorov chamber. Depending on the plankton density, either undiluted or diluted samples were analyzed. The average number of planktonic organisms in cubic meters was calculated from two sets of experimental data. The biomass B_z was evaluated based on the table of the sizes and weights of particular planktonic organisms in the White Sea and southeastern Barents Sea.

RESULTS

The physicochemical characteristics of the sampling region. Seawater in the pelagic zone of the Pechora Sea (figure, stations 7, 22, 26, 31, 45) had a salinity of 30.0–33.9‰ and low contents of total phosphorus (12–14 μg/l) and iron (75–90 μg/l), especially in the surface layer. The iron/phosphorus (Fe : P) ratio (by weight) for this water was 3.5–3.6. In the open White Sea (st. 5 and 6) and Barents Sea, P_{tot} varied from 12 to 50 μg/l, the Fe : P ratio being 2.0–3.6. In estuaries (st. 13–15, 32–36) such as that of the Pechora River, the hydrochemical parameters of seawater fluctuated within wide limits: the water salinity from 6.5 to 32‰, P_{tot} from 45 to 70 μg/l, Fe_{tot} from 120 to 480 μg/l, and the Fe : P ratio from 1.0 to 4.6. Near the oil terminals (st. 27–30, 37–44, 47), the seawater exhibited a high value of P_{tot} (65–128 μg/l) and a low value of the Fe : P ratio (0.9–1.2).

In the samples of bottom water, which contained suspended material and warp, the values P_{tot} and Fe_{tot} increased severalfold, but the Fe : P ratio remained at a level within 2.8–5.3. Off the Tersky coast of the Kola Peninsula (st. 3, 4), the bottom seawater was characterized by P_{tot} and Fe_{tot} as high as 560–710 and 3620–67360 μg/l, respectively. In the water of Chernorechenskaya Guba (Bay) (st. 2), P_{tot} and Fe_{tot} were equal to 2600 and



A map showing the location of water sampling stations: (*1–47*) stations; (T-1, T-2, T-3) Kolguyev, Pechora, and Varandeiskii oil terminals; (B) the Biological Station of Moscow State University; (I) Kola Peninsula; (II) the White Sea; (III) Kanin Peninsula; (IV) Cheshskaya Guba (Bay); (V) the Pomorsky Strait; (VI) Kolguyev Island; (VII) Pechora Bay; (VIII) the Pechora Sea; (IX) Novaya Zemlya; (X) the Barents Sea.

12900 μg/l, respectively. Some microorganisms (6–10% of the total) in these aerated bottom waters were able to accumulate intracellular polyphosphates.

Abnormally high natural concentrations of P_{tot} (1150 μg/l) and Fe_{tot} (3240 μg/l) with an Fe : P ratio equal to 2.4 were revealed in the anaerobic hypolimnion of the stratified Slabosolenoe ("slightly saline") Lake (st. 1), which has a limited connection with the sea. In the reductive mud of this lake, insoluble ferric hydroxide probably converts into gel-like ferrous hydroxide, which coprecipitates with the phosphates present in the bottom water. The abundant microbial community of the hypolimnion, which amounts to up to 61.5 million cells/ml, does not contain bacterial cells with volutin. This finding is in agreement with our earlier studies on the ecology and physiology of PAB [12, 13].

The population density and the biomass of bacterio- and mesozooplankton. In the middle of August, the vertical distributions of temperature and oxygen in the shallow Slabosolenoe Lake exhibited maxima in the metalimnion (Table 1). In the lower layer of the chemo- and thermocline, bacterioplankton was dense (13500–26270 mg/m^3) and mainly composed (65–70%) of large cocci with an average cell volume of 1.1–1.3 μm^3. As is evident from the low specific activity of the dark assimilation of CO_2, the fraction of actively reproducing heterotrophic bacteria in the hypolimnion was considerably smaller than that in the surface water. Correspondingly, the P/B_b ratio was 17–20 times higher in the surface water than in the bottom water.

There was a correlation between the horizontal and vertical distributions of mesozooplankton and its bacterial food. In autumn, the water near the Tersky coast (st. 3, 4) was characterized by almost the same average biomasses of bacterio- and mesozooplankton in the surface and bottom layers (Table 2). At the same time, at depths of 30–60 m, the biomass of mesozooplankton was almost twice as high as that of bacterioplankton, presumably due to a considerable content of large hydromedusas and sagittas from 3 to 30 cm in size. The nauplii of copepods 0.3–0.5 mm in size were detected only in the surface water, whereas the mature males and females of *Oithona similis, Pseudocalanus elongatus, Acartia bifilosa, A. longiremis,* and *Temora longicornis* were encountered at all depths. The copepod *Oithona* was dominant in the surface (0–30 m) water layer,

Table 1. The vertical distribution of bacterioplankton in the coastal waters of the White Sea near the Biological Station of Moscow State University (August 2001)

Parameter	Chernorechenskaya Guba (Bay)		Slabosolenoe Lake				
	0 m	3 m	0 m	1.8 m	3.0 m	3.6 m	4.0 m
Temperature, °C	15	14	18	21	16	13	11
Salinity, ‰	20	24	15	22	23	24	24
Dissolved O_2, % of surface value	100	92	100	147	152	105	0
Total bacteria, million cells/ml	0.44	2.1	3.2	6.0	9.4	16.0	61.5
Average cell volume, μm^3	0.15	0.29	0.32	0.24	1.28	1.10	0.54
Bacterial biomass, mg/m^3	84	784	816	1355	11660	13500	26270
CO_2 fixation (μg C/day) per:							
liter	1.1	4.5	10.9	20.8	12.2	29.2	20.3
billion cells	2.5	2.1	2.8	3.5	1.3	1.8	0.3
Bacterial production, mg/(m^3 day)	183	750	1817	3467	2034	4868	3384
$P : B_b$ ratio	2.18	0.96	2.23	2.56	0.17	0.36	0.13

while the copepod *Pseudocalanus* dominated in the lower layers. The copepods *Acartia* and *Temora* can be considered satellite species.

The B_b/B_z ratio fluctuated the most in the water of Cheshskaya Guba (Bay) in the early summer, when seawater warms to 3–6°C (Table 3). In the west of the bay, where the water salinity was 31.3–32.3‰ due to the influx of salt seawater, the population density and the biomass of mesozooplankton were considerably lower than they are in the east of the bay, where seawater is partially diluted with riverine water and has a salinity of 27.1–32.1‰. The maturing mesozooplankton in the west of the bay was dominated by small nauplii and larvae of cirripedes (*Balanus balanoides* and *Balanus* spp.) and, in the surface horizon, by the protozoans *Tintinnopsis beroidea* and *T. tubulosa*. The mesozooplankton in the east of the bay was dominated by the larval and adult forms of *Acartia*, *Pseudocalanus*, and *Temora*, as well as by relatively large hydromedusas and sagittas, whose population was the most dense in the bottom layer of the bay region adjacent to the Pomorsky Strait. In the biotopes mentioned, the B_b/B_z ratio fluctuated from 0.1 to 1.1, indicating that the biomass of mesozooplankton could considerably exceed (sometimes by an order of magnitude) the biomass of bacterioplankton.

In spite of the described differences in the population and the biomass of mesozooplankton in the western and eastern areas of the Cheshskaya Guba in the early summer of 2001, bacterioplankton was distributed fairly uniformly over the water of this bay and remained at a level typical of 1984 [6, 7]. The only exception was that the percent of PAB with intracellular polyphosphates in the west of the bay comprised 1–24% of the total bacterial population (94 to 490 thousand cells/ml), while only 0–4% of the total bacterial population (163 to 250 thousand cells/ml) in the east of this bay.

In the early autumn, the estuarian water near the mouth of the Pechora River had a temperature of 7.7–8.2°C and salinity varying from 6.5 to 21.7‰ and exhibited microbiological parameters that fluctuated over wide limits: the average volume of cells fluctuated from 0.09 to 0.78 μm^3; the total bacterial population, from 0.8 to 9.1 million cells/ml; the percent of volutin-containing cells, from 4 to 36% of the total bacteria; B_b, from 289 to 1980 mg/m^3; and the B_b/B_z ratio, from 0.5 to 12.5 (Table 4). The high content of bacterial food resulted in a high population (N_z = 2.7–15.3 thousand organisms/m^3; B_z = 39–661 mg/m^3) of *P. elongatus*, *Limnocalanus grimaldii*, *O. similis*, *A. bifilosa*, *Metridia longa*, and freshwater-loving rotifers. In open waters with temperatures of 6.0–8.8°C and salinities of 24.5–33‰, dominant planktonic organisms (in terms of both number and biomass) were *Oithona* spp. and the *Fritillaria borealis* larvae. However, the seawater in the northern, deeper, area of the Barents Sea (surface temperature 9.1°C, bottom temperature –0.6°C, and salinity 30.6–34.3‰) was dominated by the large copepods *Calanus finmarchicus*, *C. glacialis*, and *C. hyperboreus* (7% by number and 78% by biomass), whereas oithonas constituted 50% by number and only 2% by biomass. The B_b/B_z ratio varied within relatively narrow limits: from 1.5 to 7.6 in the water of the Pomor-

Table 2. The vertical distribution of bacterio- and mesozooplankton in the coastal waters of the White Sea off the Tersky coast of the Kola Peninsula (October 2001)

Parameter	Water horizons			
	0–30 m	30–60 m	60–70 m	70 m (bottom water with warp)
Temperature, °C	6.2 ± 0.4	6.6 ± 0.1	6.7 ± 0.02	6.7 ± 0.01
Salinity, ‰	27.0 ± 0.5	27.5 ± 0.1	27.6 ± 0.02	27.6 ± 0.01
Total content (μg/l) of:				
iron	170 ± 10	135 ± 25	160 ± 5	5190 ± 1570
phosphorus	54 ± 24	35 ± 5	39 ± 1	635 ± 75
Bacterioplankton:				
Abundance, thousand cells/ml	177 ± 57	92 ± 11	75 ± 28	12900 ± 5100
Volutin-containing cells, % of total	1 ± 1	0	1 ± 1	8 ± 2
Biomass, mg/m^3	36.7 ± 13.3	13.7 ± 0.9	11.2 ± 0.2	6700 ± 2400
Mesozooplankton:				
abundance, thousand organisms/ml	2.8 ± 1.5	2.1 ± 0.4	0.54 ± 0.04	–
biomass, mg/m^3	34.2 ± 21.0	28.6 ± 1.4	10.6 ± 0.3	–
$B_b : B_z$ ratio	1.1 ± 0.5	0.5 ± 0.1	1.1 ± 0.1	–
Major planktonic organisms (percent abundance/percent biomass)	*Oithona* (72/38)	*Pseudocalanus* (26/41)	*Pseudocalanus* (45/55)	
	Pseudocalanus	*Oithona* (60/20)	*Sagitta* (0.1/15)	
	Acartia (6/13)	*Hydromedusae* (0.3/15)	*Oithona* (36/11)	
	Temora (3/7)	*Sagitta* (0.1/10)	*Temora* (6/9)	
	Fritillaria (2/3)	*Acartia* (5/6)	*Acartia* (4/3)	
	nauplii Copepoda (4/1)	*Temora* (2/3)	*Calanus* (1/2)	

sky Strait and from 1.4 to 4.6 in the pelagic zone of the Barents Sea. The surface waters of the open seas were dominated by small microorganisms with an average cell volume of 0.08–0.15 μm^3 and contained virtually no bacterial cells with intracellular polyphosphates.

In contrast, the areas of water off the Varandeiskii, Pechora, and Kolguyev oil terminals exhibited widely fluctuating and, on average, higher values of planktonic parameters. Namely, the total population of bacterioplankton ranged from 0.9 to 7.6 million cells/ml; the average cell volume, from 0.12 to 0.76 μm^3; the biomass, from 155 to 3400 mg/m^3; and the percent of bacterial cells with intracellular polyphosphates, from 3 to 43% of the total N_b. The biomass of mesozooplankton lagged significantly behind the biomass of bacterioplankton, due to which the average value of the B_b/B_z ratio increased to 20.9, fluctuating from 1.4 to 50.3.

DISCUSSION

It is known that bacteria involve organic matter in the food chain. Small invertebrate filter feeders eat bacterioplankton as it is, while large filter feeders can eat bacterioplankton only if it forms aggregates larger than 5 μm^3 in volume [17]. The ability to form aggregates with particulate material is typical of PAB, which are widespread in bodies of water with intense navigation, often polluted with oil products and suspended bottom sediments [18]. Among PAB, there are hydrocarbon-oxidizing bacteria, which are able to remove oil products, phosphorus, and metals from natural and waste waters [19].

According to our investigations, the concentration of PAB and other bacteria was elevated near the Varandeiskii, Pechora, and Kolguyev oil terminals, where bacterioplankton was dominated by large cells and cells with intracellular polyphosphates, whose high abundance was likely due to the high concentration of total phosphorus and the small Fe : P ratio (Table 4).

Table 3. The distribution of bacterio- and mesozooplankton in the surface and bottom waters of Cheshskaya Guba (Bay) (June–July 2001)

Station (depth)	N_b, thousand cells/ml	N_v, % of N_b	N_z, organisms/m^3	B_z, mg/m^3	$B_b : B_z$ ratio	Planktonic organisms (dominants are marked by asterisks)
Western area of the bay						
9 (10 m)	140/280	24/17	492	8.8	6.4/19.7	*Pseudocalanus*, **lrv. Cirripedia*, *Acartia*, *Infusoria*
10 (14 m)	85/134	2/10	810	15.1	1.5/2.5	Ditto
11 (10 m)	141/126	1/10	332	5.1	5.1/3.7	*Pseudocalanus*, *Hydromedusae*, *Acaxtia*, **lrv. Cirripedia*, *Infosoria*
13 (38 m)	140/94	0/20	443/501	8.1/12.7	1.7/4.1	**lrv. Cirripedia*, *Pseudocalanus*, *Acartia*, *Infusoria*
12 (38 m)	490/240	10/14	128/348	1.5/7.7	132.5/10.2	*Pseudocalanus*, *lrv. Cirripedia*, *Acartia*, **Infusoria*
Eastern area of the bay						
15 (29 m)	225/167	4/0	1122/1003	14.1/14.4	6.5/1.1	**Acartia*, *Pseudocalanus*, *lrv. Cirripedia*, *Nauplii cop. Infosuria*
14 (32 m)	124/250	0/0	843/778	15.5/34.5	1.6/0.6	**Pseudocalanus*, *Sagitta*, *lrv. Cirripedia*, *Temora*
16 (12 m)	190/163	0/1	6036	117	0.4/0.4	**Acartia*, *Hydromedusae*, *Pseudocalanus. lrv. Cirripedia*, *Temora*
12 (29 m)	290/217	0/1	1658/3614	46/329	1.2/0.1	*Hydromedusae*, **Acartia*, *Sagitta*, *Pseudocalanus*, *lrv. Cirripedia*, *Temora*

In the open White and Barents seas, where the average volume of bacterial cells and the total phosphorus content were low, while the Fe : P ratio was high, the concentration of microorganisms with intracellular polyphosphates was insignificant (Tables 2, 4). The relative abundance of PAB (and their average cell volume) fluctuated from 0 to 36% of the total bacterial abundance (0.1–9.1 million cells/ml) in the Chernaya, Pesha, and Pechora River estuaries with a water temperature of 8.0–8.2°C and a widely fluctuating water salinity (6.5–32‰) and Fe : P ratio. These data suggest that the phosphorus and iron cycles strongly influence the abundance and the distribution of PAB near the islands and in the coastal waters of the White and Barents seas, where hydrochemical conditions favor the formation of gel-like ferrous hydroxide, which coprecipitates with phosphates, detritus, and microorganisms.

The elevated values of bacterial abundances and the average cell size near the oil terminals provide for the high biomass of bacterioplankton (B_b = 155–3400 mg/m^3), which exceeds that of mesozooplankton by a factor of 20.9. In the river estuaries, which are characterized by the mixing of marine and riverine waters and the related processes of suspending and redeposition of bottom sediments and bacteriobenthos, the biomass of bacterioplankton and the B_b/B_z ratio fluctuate widely (B_b from 14 to 1980 mg/m^3). At the same time, in the pelagic zone of the Barents Sea, these parameters are considerably more stable, B_b fluctuating from 39 to 175 mg/m^3 and the B_b/B_z ratio ranging from 1.4 to 4.6.

In the early summer, the B_b/B_z ratios at two stations in the Cheshskaya Guba drastically differed (132.5 and 0.1). The minimum B_b/B_z ratio (0.1) was observed in the lower horizon of the station located near the outlet from the bay, where mesozooplankton was dominated by various copepods, larvae of benthic invertebrates with the mixed type of feeding, and the large predators sagittas (chaetognaths) and hydromedusas (coelenteratas) (Table 3). The maximum B_b/B_z ratio was detected in the upper horizon of the station located in the mixing zone of sea and riverine waters, where mesozooplankton was dominated by protozoan tintinnids 0.1–0.25 mm in size, while maturing filter feeders were very scarce. The

Table 4. The distribution of bacterio- and mesozooplankton in the surface waters of the southeastern Barents Sea (August–September 2000)

Station (depth)	Salinity, ‰	N_b, thousand cells/ml	N_v, % of N_b	B_z, mg/m^3	N_z, organisms/m^3	$B_b : B_z$ ratio	Planktonic organisms (dominants are marked by asterisks)
Pechora Bay (western area near the Pechora estuary)							
32 (4 m)	6.5	9100	4	1980	2730	12.5	**Pseudocalanus*, *Acartia*, *Limnocalanus*, *Rotatoria*
33 (7 m)	10.6	2600	36	1128	3016	2.7	**Limnocalanus*, *Metridia*, *Pseudocalanus*, *Acartia*
36 (7 m)	16.9	1500	6	333	15341	0.5	**Pseudocalanus*, *Limnocalanus*, *Acartia*, *Rotatoria*
35 (10 m)	20.2	2200	8	647	2916	7.0	*Limnocalanus*, *Metridia*, *Pseudocalanus*, **Oithona*
34 (14 m)	21.7	757	32	289	4540	7.5	*Pseudocalanus*, **Olthona*, *Acartia*
Pechora Sea off the Pechora and Varandenskii oil terminals near Pechora Bay							
27 (13 m)	28.6	407	22	155	7948	1.4	**Pseudocalanus*, *Acartia*, *Oithona*, *Temora*
28 (20 m)	29.7	926	3	156	10192	3.2	* *Oithona*, *Pseudocalanus*
29 (20 m)	28.5	478	38	202	5500	2.6	**Oithona*, *Pseudocalanus*, *Fritillaria*
30 (23 m)	27.6	1500	14	744	3708	42.8	**Oithona*, *Fritillaria*
44 (17 m)	27.1	990	2	125	4222	8.5	**Oithona*, *Fritillaria*
47 (21 m)	29.9	26700	3	501	2406	32.7	*Acartia*, **Fritillaria*, *Oithonoa*, *Pseudocalanus*
43 (20 m)	29.3	937	11	320	2646	17.6	*Acartia*, **Oithona*, *Fritillaria*, *Pseudocalanus*
42 (19 m)	27.5	1300	3	194	2128	12.2	*Acartia*, **Oithona*, *Fritillaria*, *Pseudocalanus*
41 (16 m)	27.2	2340	3	4001	4360	13.7	*Pseudocalanus*, *Acartia*, **Oithona*, *Fritillaria*
39 (15 m)	24.5	1240	13	437	1290	26.6	*Pseudocalanus*, *Acartia*, **Oithona*
38 (13 m)	25.0	1270	14	418	2162	15.5	**Pseudocalanus*, *Acartia*, *Oithona*
40 (8 m)	30.4	7600	1	1125	4643	15.1	Ditto
37 (5 m)	27.2	1140	43	573	1628	50.3	**Oithona Pseudocalanus*, *Acartia*
Water area near the Kolguyev oil terminal off the Kolguyev Island							
21 (7 m)	32.7	3900	4	1082	13180	9.8	*Acartia*, **Oithona*
22 (6 m)	32.7	7400	21	3395	4430	49.0	*Acartia*, *Temora*, **Oithona*
23 (7 m)	32.8	2300	27	967	3615	15.2	**Acartia*, *Oithona*
24 (7 m)	32.7	5900	29	1810	4200	20.0	Ditto
Pomorsky Strait							
20 (25 m)	33.0	230	2	27	580	7.6	*Pseudocalanus*, **Oithona*
19 (39 m)	32.8	290	0	30	1638	1.5	*Pseudocalanus*, *Calanus*, *Oithona*, **Microsetella*
18 (30 m)	32.8	850	0	75	7722	2.0	*Acartia*, **Fritillaria*
8 (55 m)	32.5	495	1	82	4242	2.9	**Oithona*, *Fritillaria*
Pelagic zone of the Barents Sea							
7 (50 m)	32.7	670	0	83	5700	1.5	**Oithona*, *Pseudocalanus*, *Fritillaria*
22 (34 m)	32.8	750	0	70	5824	1.4	**Oithona*, *Fritillaria*
26 (32 m)	32.8	170	0	78	2610	4.6	Ditto
31 (21 m)	30.5	395	0	39	5592	1.5	Ditto
45 (24 m)	29.9	565	0	50	4426	1.8	**Oithona*, *Pseudocalanus*, *Fritillaria*

high values of the B_b/B_z ratio may be due to the fact that the plankton net we used to catch mesozooplankton (gauze 55) was unable to catch microzooplankton smaller than 0.1 mm in size, such as protozoans and larvae of bottom and planktonic invertebrates, which are known to actively eat bacterial cells suspended in water [20].

Thus, in the summer of 2000, the coastal waters in the southeastern Barents Sea were characterized by high values of the total and relative content of P_{tot}, the average volume of bacterial cells, the concentration of polyphosphate-containing PAB, and the density and biomass of bacterioplankton, the latter considerably exceeding the biomass of mesozooplankton (Tables 2–4). This situation seems to be related to the superposition of unfavorable hydrodynamic conditions in this region and the heavy anthropogenic and technogenic loads on this region because of the opening up of the coastal Timano–Pechora oil field. The data obtained in this study (Table 1) are in agreement with those reported by other researchers on bacterial production in cold Arctic waters [4–8].

REFERENCES

1. Glavatskikh, S.P., Gubaidullin, M.G., Titenko, A.P., and Shcherbakova, V.V., The Ecological Aspects of the Diamond Industry Development in the Arkhangelsk Region, in *Litosfera i gidrosfera evropeiskogo severa rossii: Geoekologicheskie problemy* (The Lithosphere and Hydrosphere of the European Russian North), Ekaterinburg, 2001, pp. 385–400.
2. Gubaidullin, M.G., Korobov, V.B., and Yudakhin, F.N., The Development of the Ecologically Safe Oil Transportation System from the Northern Timano-Pechora Oil Field, in *Litosfera i gidrosfera evropeiskogo severa rossii: Geoekologicheskie problemy* (The Lithosphere and Hydrosphere of the European Russian North), Ekaterinburg, 2001, pp. 358–384.
3. Leshchev, A.V., Khomenko, G.D., Matyushenko, V.A., and Lukin, L.R., The Ecological Monitoring of Russian Arctic Seas by Optimal Methods, in *Sever: Ekologiya* (North: Ecology), Ekaterinburg, 2000, pp. 90–109.
4. Teplinskaya, N.G., Bacterial Production in the Barents Sea, in *Sovremennye problemy gidrobiologii Barentseva morya* (The Modern Hydrobiological Problems of the Barents Sea), Apatity: Kol'sk. Filial AN SSSR, 1988, pp. 34–40.
5. Savvichev, A.S., Rusanov, I.I., Pimenov, N.V., Mitskevich, I.N., Bairamov, I.T., Lein, A.Yu., and Ivanov, M.V., Microbiological Explorations in the Northern Part of the Barents Sea in Early Winter, *Mikrobiologiya*, 2000, vol. 69, no. 6, pp. 819–830.
6. Baitaz, O.N., A Comparative Analysis of Bacterioplankton in Dal'nezelenetskaya Guba (Bay) and the Southeastern Barents Sea, in *Ekologiya i biologicheskaya produktivnost' Barentseva morya* (The Ecology and Bioproductivity of the Barents Sea), Moscow: Nauka, 1990, pp. 78–87.
7. Baitaz, V.A., Baitaz, O.N., and Mishustina, I.E., The Biometric Parameters, Abundance, and Biomass of the Major Morphological Groups of Bacterioplankton in the Barents Sea, *Okeanologiya*, 1996, vol. 36, no. 6, pp. 883–887.
8. Teplinskaya, N.G., The Role of Bacterioplankton in the Formation of Food Chains in the Barents Sea, in *Ekologiya i biologicheskaya produktivnost' Barentseva morya* (The Ecology and Bioproductivity of the Barents Sea), Moscow: Nauka, 1990, pp. 17–22.
9. Gulbransen, R.A. and Roberson, C.E., Inorganic Phosphorus in Seawater, in *Fosfor v okruzhayushchei srede* (Phosphorus in the Environment), Moscow: Mir, 1977, pp. 141–164 (Russian translation).
10. Sorokin, Y.I., Phosphorus Metabolism in Planktonic Communities of the Eastern Tropical Pacific Ocean, *Mar. Ecol. Prog. Ser.*, 1985, vol. 27, no. 14, pp. 87–97.
11. Currie, D.J. and Kalff, J., 1. A Comparison of the Abilities of Freshwater Algae and Bacteria to Acquire and Retain Phosphorus. 2. The Relative Importance of Bacterioplankton in Freshwater, *Limnol. Oceanogr.*, 1984, vol. 29, no. 2, pp. 298–310, 311–321.
12. Saralov, A.I., Chikin, S.M., Bannikova, O.M., Kozlova, G.A., and Solomennyi, A.P., Distribution of Phosphate-accumulating Bacteria in Phosphorite-bearing Rocks and Surface and Ground Waters of the Ural Region, *Mikrobiologiya*, 1999, vol. 68, no. 3, pp. 407–417.
13. Saralov, A.I., Mol'kov, D.V., Bannikova, O.M., Solomennyi, A.P., and Chikin, S.M., Intracellular Accumulation of the Monomeric Precursors of Polyphosphates and Polyhydroxyalkanoates in *Acinetobacter calcoaceticus* and *Escherichia coli* Cells, *Mikrobiologiya*, 2001, vol. 70, no. 6, pp. 737–744.
14. Lur'e, Yu.Yu., *Analiticheskaya khimiya promyshlennykh stochnykh vod* (Analytical Chemistry of Industrial Sewage Waters), Moscow: Khimiya, 1984.
15. Kuznetsov, S.I. and Dubinina, G.A., *Metody izucheniya vodnykh mikroorganizmov* (Methods for Studying Aquatic Microorganisms), Moscow: Nauka, 1989.
16. Mikheeva, V.N. and Benevolenskii, G.F., Sampling of Marine Plankton and Sample Pretreatment, in *Rukovodstvo po metodam biologicheskogo analiza morskikh vod i donnykh otlozhenii* (Manual of Methods for the Biological Analysis of Seawater and Bottom Sediments), Leningrad: Gidrometeoizdat, 1980, pp. 122–133.
17. Sorokin, Yu.I., On the Trophic Role of Microflora in the Coral Reef Biocenosis, *Dokl. Akad. Nauk SSSR*, 1971, vol. 1997, no. 6, pp. 1424–1427.
18. Kvasnikov, E.I. and Klyushnikova, T.M., *Mikroorganizmy – destruktory nefti v vodnykh basseinakh* (Microbial Degraders of Oil in Bodies of Water), Kiev: Naukova Dumka, 1981.
19. Saralov, A.I., Berdichevskaya, M.V., Bannikova, O.M., and Chikin, S.M., Accumulation of Polyphosphates in the Initial Growth Phase of *Acinetobacter calcoaceticus* and *Rhodococcus maris*, *Mikrobiologiya*, 1995, vol. 64, no. 4, pp. 446–452.
20. Sorokin, Yu.I., Vshivtsev, V.S., and Domnikov, V.S., Microzooplankton, in *Tekhnogennoe zagryaznenie i protsessy estestvennogo samoochishcheniya Prikavkazskoi zony Chernogo morya* (Technogenic Pollution and Natural Purification Processes off the Caucasian Coast of the Black Sea), Moscow: Nedra, 1996, pp. 277–291.