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QUANTITATIVE STRUCTURE OF THE SEA ICE MICROALGAE COMMUNITY (RUSSKY ISLAND, PETER THE GREAT BAY, SEA OF JAPAN)

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For the Russian coast of the Sea of Japan, a study of the quantitative structure of sea ice microalgae was carried out for the first time. The investigation covered biotopes of ice core and under-ice phytoplankton of two Russky Island bays during winter season of 2020 and 2021. In total, 88 microalgae species from 50 genera and 7 divisions were identified. As found, the ice microalgae flora was characterized by a greater species richness than the phytoplankton biotope. Out of prevailing species, the most abundant ones were planktonic diatoms *Chaetoceros socialis* f. *radians*, *Nitzschia frigida*, *Thalassiosira nordenskioeldii*, and *Nitzschia* sp. Diatoms formed the basis of the community. Specifically, in 2020, their abundance was 1,861.2 cells·mL^{-1} in the Voevoda Bay and 751.2 cells·mL^{-1} in the Novik Bay; in 2021, the values reached 6,846.3 and 17,143.1 cells·mL^{-1}, respectively. In 2020 in the Voevoda Bay, cell abundance was maximum in the upper layer of the ice core and gradually decreased closer to a border with under-ice water; in the Novik Bay, it was distributed approximately evenly throughout the core. In 2021 in the Voevoda Bay, the opposite pattern was observed: microalgae abundance was minimal in the upper layers of the ice core and gradually increased as moving down, to a border with under-ice water. In the Novik Bay, maximum microalgae abundance was recorded in the upper layer of the ice core, with a relatively uniform distribution over all layers. Thus, the differences are shown in the quantitative structure of ice microalgae depending on a layer of the ice core, year, and study area.

Keywords: quantitative structure, microalgae, phytoplankton, Peter the Great Bay, Russky Island, Sea of Japan

Microalgae (hereinafter MA) are the main biological component of a sea ice cover. There are branched pores and channels in ice, and cells of planktonic and benthic MA get there from under-ice water. Some species prove to be adapted to such extreme habitat conditions and begin to develop rapidly (Buinitskii, 1973 ; Mel'nikov, 1989). This is more pronounced for multi-year ice, but even in an ice cover which is formed in the bays in winter alone, significant differences are sometimes recorded from phytoplankton in terms of MA qualitative and quantitative composition.

In winter, MA production in ice samples can make up to 7.5 % of the total primary production of a water area (Dupont, 2012). During ice cover melting, MA are the main food source for organisms of higher trophic levels. This alone determines the importance of analyzing the structure of ice communities in water areas with a seasonally formed ice cover. In terms of sea ice MA studies, Peter the Great Bay is of significant scientific interest: it is the only water area at this geographical latitude where a stable ice cover can be formed.

Investigations of MA communities in ice of the Sea of Japan are mainly focused on ice physicochemical and production characteristics and the analysis of patterns of ice formation conditions. The first description of ice conditions was made by L. Schrenk in 1869 and covered the Tatar Strait alone. The closest publication in terms of the study object in Peter the Great Bay area is the work on chlorophyll and primary production of ice-related MA for the Amur Bay (Kuznetsov, 1980). In this article, the author both analyzed composition of photosynthetic pigments and provided some data on MA species composition and abundance. In the joint work of the staff of the Pacific Oceanological Institute (POI FEB RAS) and National Scientific Center of Marine Biology (NSCMB FEB RAS) aimed at studying ice production peculiarities in the Razdolnaya River estuary during a freeze-up, it was specified as follows: ice was characterized by a significantly lower species richness than phytoplankton (Zvalinsky et al., 2010).

When studying ice-related MA communities, Russian and foreign researchers mainly focused on polar regions (Ryabushko, 2016 ; Arrigo et al., 2014 ; Kauko et al., 2018 ; Werner et al., 2007). Investigations of the water areas of Peter the Great Bay, as well as other water areas of the Russian coast of the Sea of Japan, are mostly concentrated either on water floristic composition or on ice physicochemical parameters and its production characteristics. To date, scientific data are very scarce on quantitative characteristics of ice-related MA communities for the Russian coast of the Sea of Japan, especially for various ice horizons. Such information is relevant for ice of considerable thickness. Both Voevoda and Novik bays are of great scientific interest due to certain environmental problems. Specifically, there are mariculture farms in the Voevoda Bay that affect the seagrass *Zostera marina* Linnaeus, 1753 growing there, while it is one of the plants contributing to formation of local environmental conditions (Barabanshchikov et al., 2018). The Novik Bay is under certain anthropogenic stress because of domestic wastewater from the Far Eastern Federal University campus. There were several hydrological, hydrochemical, and ecological studies focused on these problems; those, with the data obtained by us, could be expanded in the context of investigating the dynamics of these two water areas under anthropogenic load. So, a fundamental interest arose in the analysis of the quantitative structure of sea ice MA in two Russky Island bays during two winter seasons.

The aim of this work was to study the quantitative structure of MA community in sea ice in two Russky Island bays (the Sea of Japan) during the winter periods of 2020 and 2021.

MATERIAL AND METHODS

The material for the study was ice cores and samples of under-ice water. Sampling was carried out on 18.02.2020 in the Voevoda Bay (43°00′05.6″N, 131°79′30.8″E), 19.02.2020 in the Novik Bay (43°01′38.9″N, 131°88′16.3″E), and 25.02.2021 in both bays at the same coordinate points (Fig. 1).

The meteorological conditions during sampling were as follows: cloudless weather and air temperature about –0.3 °C. In 2020 in the Voevoda Bay water area, there was a snow cover with a depth about 10 cm; in 2021, a depth was about 3 cm. In the Novik Bay water area, there was no snow cover. In the Voevoda Bay in 2020, depth down to the bottom was 3 m; in 2021, a depth was about 2.5 m. In the Novik Bay in 2020, depth down to the bottom was 7 m; in 2021, it was 7.5 m.

Ice cores were sampled using a circular drill with a diameter 15 cm. After sampling, the ice cores were divided into 10-cm-long layers and placed into sterile plastic containers. The length of the ice cores in 2020 in the Voevoda Bay was 44 cm, and in the Novik Bay, 38 cm. The length in 2021 in the Voevoda Bay was 62 cm; in the Novik Bay, it was 64 cm (Fig. 2).

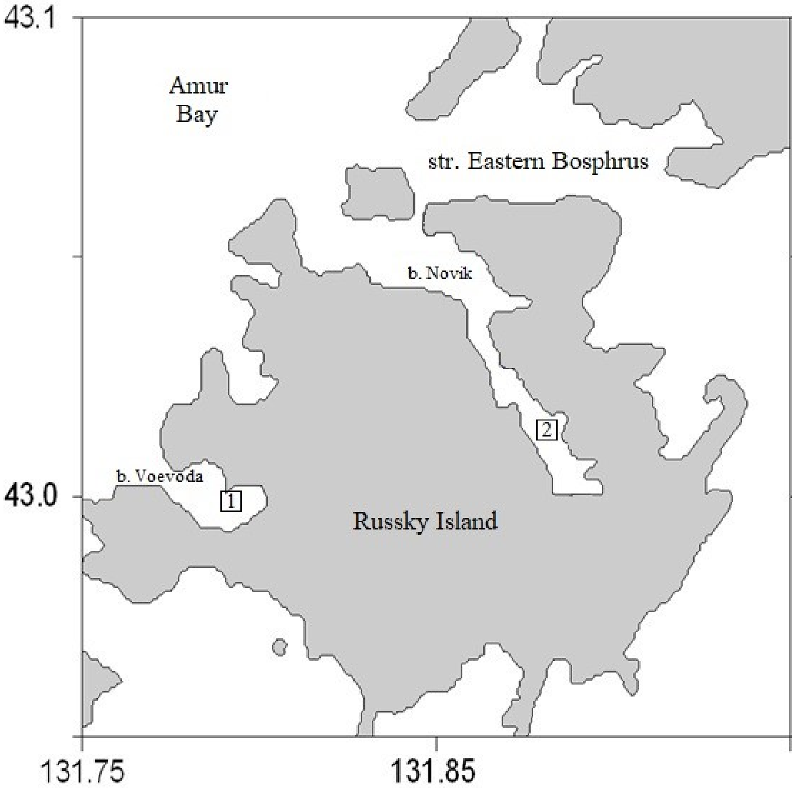

Fig. 1. Ice core and under-ice water sampling stations: 1, the Voevoda Bay; 2, the Novik Bay

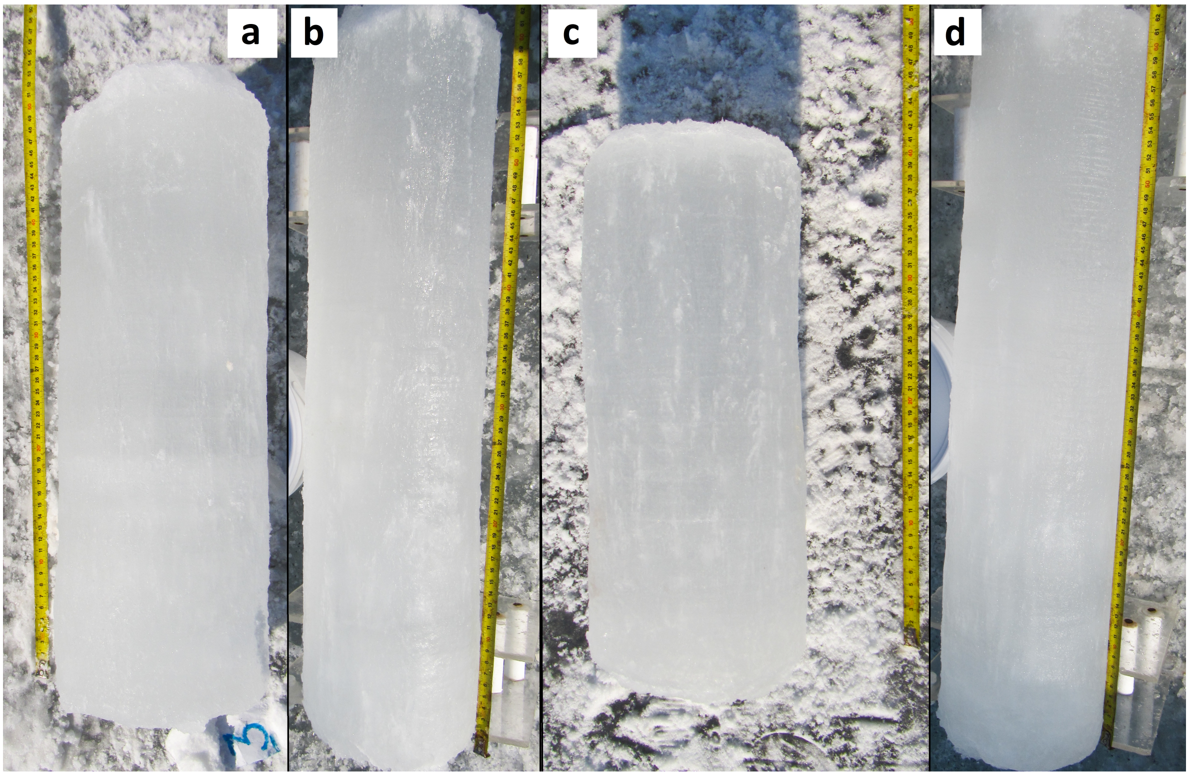

Fig. 2. Ice cores from the Voevoda Bay (a, 2020; b, 2021) and the Novik Bay (c, 2020; d, 2021)

In addition to ice core sampling, under-ice water sampling was carried out using a 5-L Niskin bottle. Hydrochemical composition of the samples was analyzed at POI FEB RAS. Species identification and calculation of MA quantitative characteristics were carried out in the laboratory of marine microbiota of the NSCMB FEB RAS.

The cores were melted at a temperature of +24 °C; melt water was poured into sterile containers. The samples were fixed with 5 % potassium iodide solution in the ratio as follows: 2.5 mL of iodine *per* 1 L of melt water. In accordance with the method of Radchenko (Radchenko et al., 2010), after 12 days, excess water was drained to 100–200 mL of the residue from each layer.

MA species were identified under an Olympus BX41 transmitted light microscope with an UPLanF1 100×/1.30 objective (Japan). To verify the species composition, the material was examined under a scanning electron microscope Sigma 300 VP (the UK). Diatom shells were cleaned from organic substances by "cold" and "hot" methods of treatment with concentrated sulfuric acid, followed by washing in distilled water (Ryabushko & Begun, 2015).

Cells were counted in a 1-mL Sedgewick–Rafter counting cells. MA biomass was estimated by a volumetric method using original and published data on measurements of cell volume for each species (Biovolumes and Size-Classes, 2006 ; Sun & Liu, 2003). MA divisions are given according to the system adopted in the work of G. Konovalova *et al.* (1989). Species with a density of at least 20 % of the total density were considered prevailing ones (Konovalova, 1984).

For statistical data analysis, Shannon and Pielou indices were applied. The Shannon–Wiener index (H) was calculated as follows:

$$H = -\sum p_i \ln p_i \,,$$

where p_i is the ratio of the i-th species in the total density.

The Pielou evenness index (e) was calculated by the formula:

$$e = H / \ln S \,,$$

where H is the Shannon index;

S is the total species number (Megarran, 1992).

RESULTS

MA of Russky Island bays were represented by 88 species from 7 divisions. In the ice biotope, a greater species richness was recorded than in the phytoplankton biotope: in ice, 80 species from 7 divisions were found; in phytoplankton, 40 species from 5 divisions were identified. In terms of species number, diatom genera *Navicula* Bory, 1822, *Nitzschia* Hassall, 1845, and *Protoperidinium* Bergh, 1881 prevailed, as well as a dinoflagellate genus *Gyrodinium* Kofoid & Swezy, 1921.

Analysis of the quantitative structure of sea ice MA showed that the ratio of diatoms was the highest in terms of abundance and biomass (Table 1). This was evidenced by increased content of silicates in water and ice samples as well: the value reached 3.05 $\mu\text{mol}\cdot\text{L}^{-1}$ in 2020 and 5.53 $\mu\text{mol}\cdot\text{L}^{-1}$ in 2021.

In the ice flora, prevailing diatom species were *Chaetoceros socialis* f. *radians* (F. Schütt) Proshkina-Lavrenko, 1963, *Nitzschia frigida* Grunow in Cleve & Grunow, 1880, *Thalassiosira nordenskioeldii* Cleve, 1873, and an unidentified small-cell *Nitzschia* species. Dinoflagellates were represented less significantly; out of them in 2020, *Amphidinium sphenoides* Wulff, 1919 and *Protoperidinium depressum* (Bailey) Balech, 1974 stood out; in 2021, representatives of green algae (unidentified prasinophytes).

The least contribution was made by a golden alga *Octactis speculum* (Ehrenberg) F. H. Chang, J. M. Grieve & J. E. Sutherland, 2017 and euglena alga *Eutreptiella braarudii* Throndsen, 1969. In phytoplankton of both bays in 2021, the prevalence of cryptophytic algae of the genus *Plagioselmis* Butcher, 1994 was registered. Haptophytes with relatively low quantitative values were found only in the upper ice layers in the Novik Bay in 2021.

Table 1. Quantitative characteristics of algal divisions representatives (N, abundance, cells·mL^{-1}; B, biomass, mg·m^{-3})

Division	The Voevoda Bay				The Novik Bay			
	2020		2021		2020		2021	
	N	B	N	B	N	B	N	B
Chrysophyta	15.5	52.6	76.2	243.4	0.3	1.1	0.2	1.7
Bacillariophyta	1,861.2	9,327.5	6,846.3	53,457.8	751.2	9,851.4	17,143.1	165,143.0
Cryptophyta	0.0	0.0	4,500.0	121.5	0.0	0.0	1,714.3	46.3
Dinophyta	11.8	1,490.3	1.7	15.1	40.5	438.9	2.6	36.3
Chlorophyta	0.0	0.0	578.0	83.0	0.0	0.0	493.6	71.0
Euglenophyta	0.0	0.0	20.4	211.2	3.8	39.3	1.9	20.0
Haptophyta	0.0	0.0	0.0	0.0	0.0	0.0	47.9	4.2
In total	1,888.5	10,870.4	12,022.6	54,132.0	795.8	10,330.7	19,403.6	165,322.5

Analysis of MA quantitative distribution over ice layers showed the following: in 2020 in the Voevoda Bay, cell abundance was maximum in the upper layer of the ice core and gradually decreased closer to a border with under-ice water (Fig. 3a). In the Novik Bay, abundance was distributed approximately evenly throughout the core (Fig. 3b).

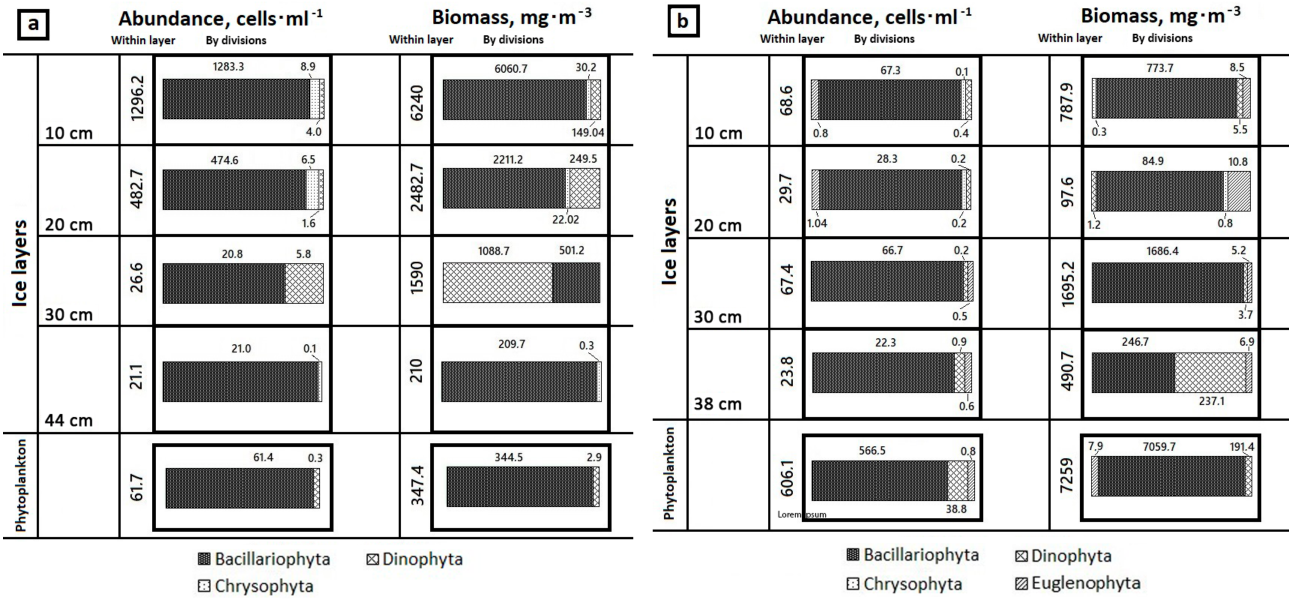

Fig. 3. Diagrams of the distribution of microalgal divisions abundance and biomass by ice layers and in phytoplankton in the Voevoda Bay (a) and the Novik Bay (b) in 2020

At the same time, abundance of sea ice MA in the Novik Bay was almost an order of magnitude lower than in the Voevoda Bay, whereas in phytoplankton, abundance was an order of magnitude higher.

In the Voevoda Bay in 2021, the pattern was in general opposite to that of the previous year: cell abundance was minimal in the upper layers of the ice core and gradually increased as moving down, to a border with under-ice water (Fig. 4a). MA abundance in ice exceeded the value of the previous year by almost three times; in phytoplankton, by three orders of magnitude.

In the Novik Bay, MA abundance was maximum in the upper layer of the core; at the same time, it was relatively evenly distributed over the ice layers (Fig. 4b). Compared to the values of 2020, MA abundance in ice and phytoplankton was an order of magnitude higher. At the same time, cell abundance in ice was an order of magnitude higher than the values for the Voevoda Bay, while cell abundance in phytoplankton was comparable.

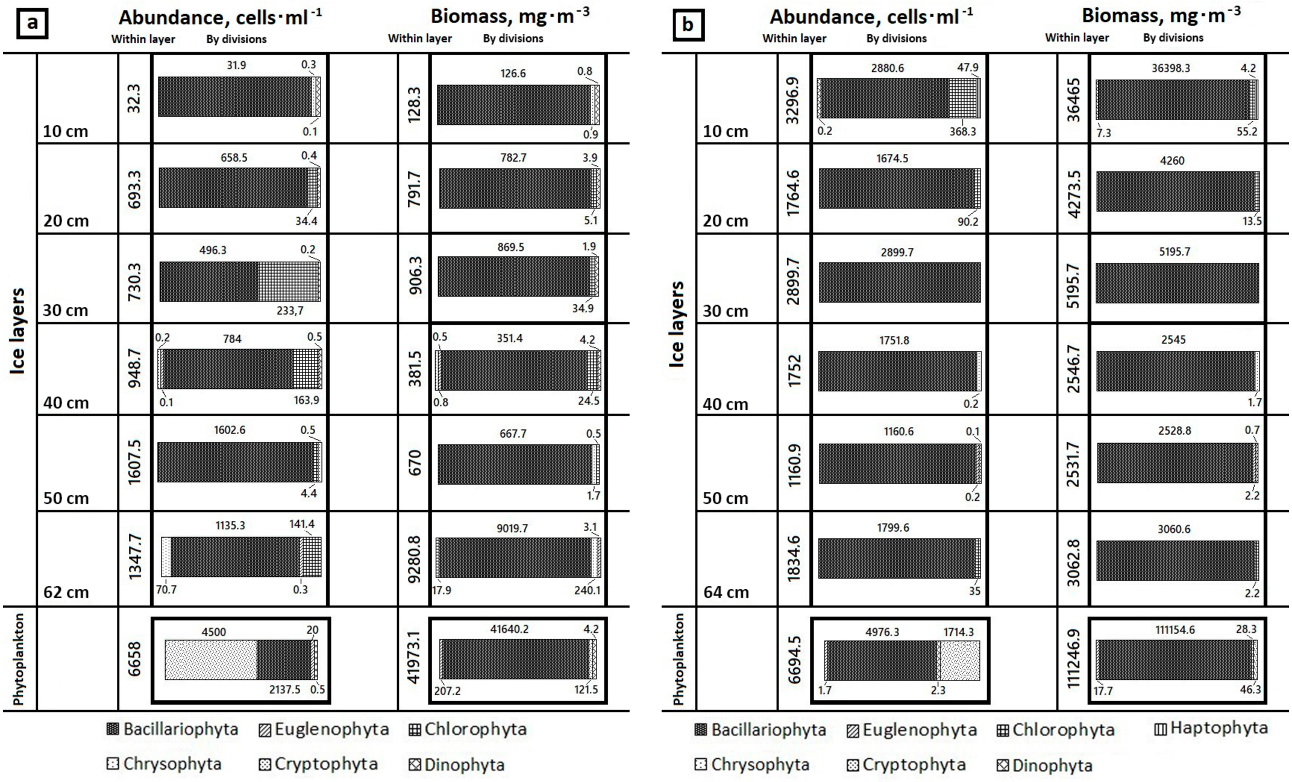

Fig. 4. Diagrams of the distribution of microalgal divisions abundance and biomass by ice layers and in phytoplankton in the Voevoda Bay (a) and the Novik Bay (b) in 2021

Analysis of the quantitative structure of sea ice MA in two Russky Island bays in 2020 and 2021 showed more or less significant differences in the values of the total abundance and biomass for the main prevailing species (Figs 5–8).

MA abundance in ice samples from the Voevoda Bay in 2020 was 1,826 cells·mL^{-1}, with a diatom *N. frigida* prevailing (93.12 % of the total abundance). In phytoplankton, the value was 62 cells·mL^{-1}, with the prevalence of diatoms *Nitzschia* sp. (40.91 %) and *Cylindrotheca closterium* (Ehrenberg) Reimann & J. C. Lewin, 1964 (31.25 %) and the sub-prevalence of *N. frigida* (10.80 %). The biomass in the ice core was 10,522.8 mg·m^{-3}; in phytoplankton, 347.5 mg·m^{-3}.

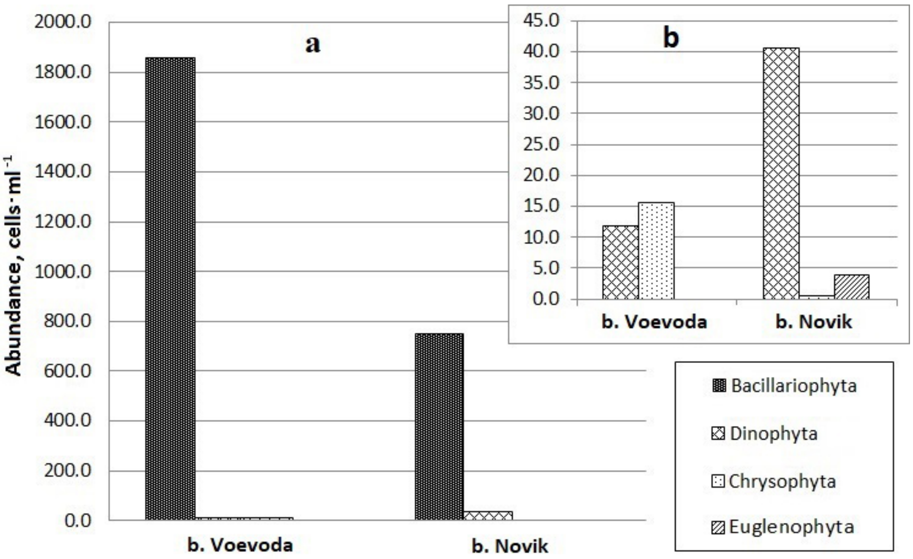

Fig. 5. Diagrams of microalgal divisions abundance in 2020: a, for representatives of prevailing divisions; b, for representatives of small divisions

Low species richness and structural evenness of the MA community in both biotopes are evidenced by the values of species diversity index (1.7 and 1.6 for ice and phytoplankton, respectively) and evenness index (0.4 and 0.5, respectively).

In ice of the Novik Bay in 2020, an order of magnitude lower MA abundance was recorded than in the Voevoda Bay (189 cells·mL^{-1}). A diatom *T. nordenskioeldii* prevailed, with a ratio of 22.63 % of the total abundance – higher than the ratio in the Voevoda Bay (5 %). The sub-prevailing species were *Pseudo-nitzschia pungens* (Grunow ex Cleve) Hasle, 1993 (19.12 %), *N. frigida* (16.32 %), and *C. closterium* (12.90 %). In phytoplankton, cell abundance was 606 cells·mL^{-1} – an order of magnitude higher than the value in the Voevoda Bay; a diatom *Thalassiosira gravida* Cleve, 1896 prevailed (88.83 % of the total abundance).

In the Novik Bay in 2020, the total MA biomass in the ice core and phytoplankton was similar to the value in the Voevoda Bay. In the ice core, the biomass was 3,071.7 mg·m^{-3}, and this was much lower than that in the Voevoda Bay. The biomass in the bay phytoplankton was 7,259.1 mg·m^{-3} – an order of magnitude higher than the values obtained for the Voevoda Bay.

MA species richness in the Novik Bay turned out to be significantly higher in ice than in phytoplankton; this is confirmed by the Shannon–Wiener index values (2.6 and 0.6 for ice and phytoplankton, respectively). Moreover, a considerable difference was observed in the Pielou index values (0.8 and 0.2, respectively) indicating a higher level of structural evenness in ice than in phytoplankton.

In the Voevoda Bay in 2021, the total cell abundance was an order of magnitude higher than in 2020. Specifically, it was 5,360 cells·mL^{-1} in the ice core – an order of magnitude higher than the values obtained for ice of this bay in the previous year. A diatom *Chaetoceros socialis* f. *radians* prevailed (46.22 % of the total abundance). *Navicula granii* (Jørgensen) Gran, 1908 (12.29 %), *Nitzschia* sp. (11.34 %), and unidentified prasinophytes (9.93 %) were the sub-prevailing species. Cell abundance in phytoplankton was 6,658 cells·mL^{-1} which was two orders of magnitude higher than the value for this biotope in 2020. The prevailing species was a cryptophyte *Plagioselmis* sp. (67.59 %); significant contribution was made by diatoms *T. nordenskioeldii* (11.26 %) and *Nitzschia* sp. (7.5 %).

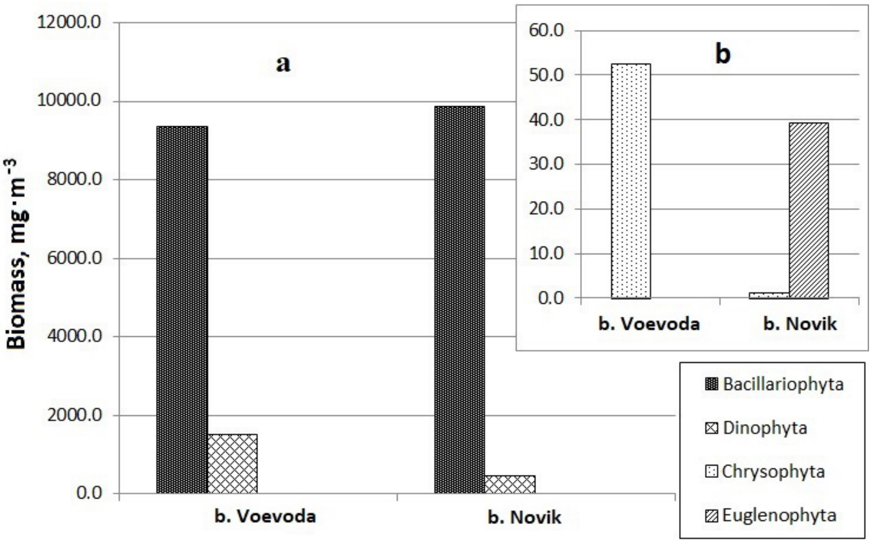

Fig. 6. Diagrams of microalgal divisions biomass in 2020: a, for representatives of prevailing divisions; b, for representatives of small divisions

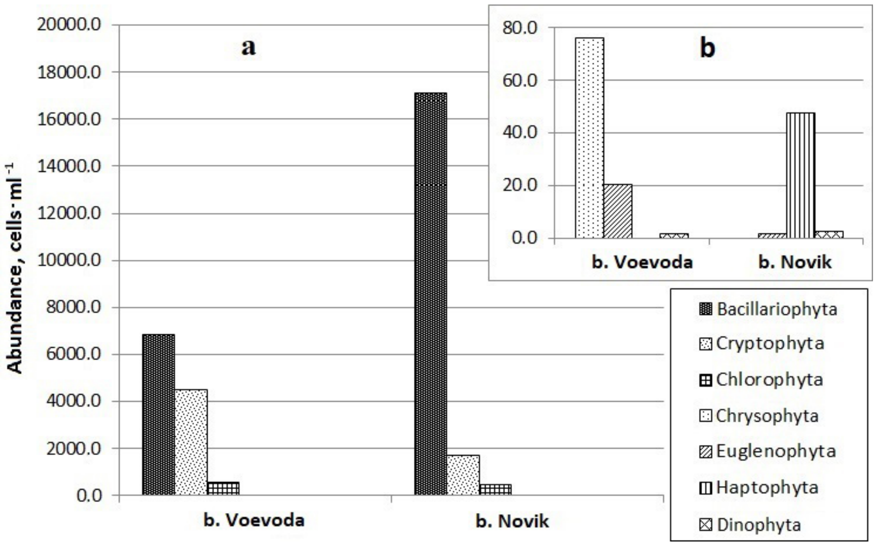

Fig. 7. Diagrams of microalgal divisions abundance in 2021: a, for representatives of prevailing divisions; b, for representatives of small divisions

In ice samples, MA biomass was 12,158.8 mg·m^{-3}; in phytoplankton, it was 41,973.1 mg·m^{-3}. Compared to phytoplankton, ice was characterized by higher species richness (the Shannon–Wiener index values were 2.8 and 1.2, respectively) and evenness (the Pielou index values were 0.7 and 0.4, respectively).

In the Novik Bay in 2021, the total cell abundance in ice and phytoplankton was an order of magnitude higher than in 2020. Abundance in the ice core was 12,709 cells·mL^{-1}; algae *Nitzschia* sp. and *N. frigida* prevailed (51.90 and 28.43 %, respectively). Less significant contribution was made by the species *Entomoneis gigantea* var. *decussata* (Grunow) Nizamuddin, 1982 (5.96 %), *Navicula septentrionalis* Cleve, 1896 (4.59 %), and unidentified prasinophytes (3.61 %). In phytoplankton, abundance was 6,694 cells·mL^{-1}. *T. nordenskioeldii* (34.14 %) and *Plagioselmis* sp. (25.61 %) were the prevailing species, while *N. septentrionalis* (11.95 %), *N. granii* (7.34 %), and *N. frigida* (5.12 %) were the sub-prevailing ones.

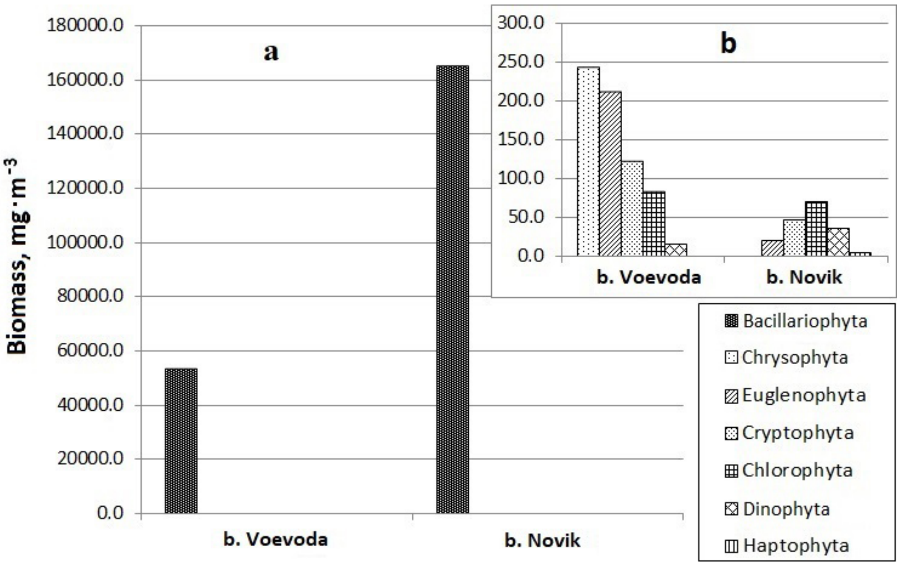

Fig. 8. Diagrams of microalgal divisions biomass in 2021: a, for representatives of prevailing divisions; b, for representatives of small divisions

MA biomass in ice was 54,075.6 mg·m^{-3}; the value in phytoplankton was 111,247 mg·m^{-3}. As in 2020, species richness and its evenness in 2021 in the ice biotope were higher (the values of the indices were 2.8 and 0.8, respectively) than in the phytoplankton biotope (the values were 1.8 and 0.6, respectively).

DISCUSSION

Study of sea ice and under-ice phytoplankton in Russky Island bays was carried out during two winter periods and showed more or less significant differences in the quantitative structure of the MA community. The most considerable differences in the quantitative structure were revealed by the years of the investigation: in 2020, MA communities were generally characterized by low species richness. A difference was recorded in terms of quantitative characteristics of the ice and phytoplankton biotopes between the studied bays as well. Specifically, in the Voevoda Bay, MA abundance and biomass in ice significantly exceeded the values for phytoplankton; in the Novik Bay, the opposite pattern was recorded. The total cell abundance in the Novik Bay was two times lower than the value in the Voevoda Bay, while the total biomass was comparable.

In 2021, species richness and evenness, as well as the quantitative structure, were characterized by higher values in both bays. Differences in MA abundance in the Voevoda Bay were insignificant between the ice biotope and the phytoplankton one, while the value of biomass in under-ice water was three times higher than that in ice. A slightly different pattern was observed in the Novik Bay: cell abundance in ice was two times higher than in phytoplankton, and the value of biomass in phytoplankton was two times higher than that in ice. In total, MA flora in the Novik Bay was characterized by higher values of the quantitative indicators in both biotopes than in the Voevoda Bay. Phytoplankton was the exception: its abundance was comparable for two bays.

Importantly, during sampling (in February), the ice cores had no visual coloration indicating MA mass development. However, according to V. Buinitskii (1973) who carried out similar studies in the Antarctic in 1962, MA abundance is not always reflected in ice color intensity. In our case, the lack of coloration can be explained by significant thickness of the ice cover over which algae are distributed during its formation. In 2020 and 2021, considerable thickness of the ice cover in Russky Island bays was recorded (38 to 64 cm), and these values are not typical for most studies of young ice in polar regions. Specifically, according to the recent investigation of young Arctic ice by Norwegian researchers (Kauko et al., 2018), the ice cover was about 27 cm thick.

The results obtained are consistent with the literature data on the quantitative structure of MA communities in Peter the Great Bay in winter. According to the material published, the basis of the ice and under-ice algae community is formed by the diatoms – in terms of both species composition and quantitative structure. In various works, due to differences in meteorological, hydrochemical, and other conditions for specific water areas, different data are given on their quantitative ratio in a community (50 to 100 % of the total abundance). In the ice biotope, flagellate algae – mainly dinoflagellates – are usually less abundant; in 2020, their quantitative contribution was similar to that from the literature (Kauko et al., 2018). In 2021, representatives of green algae were the second in terms of abundance (following diatoms). The ratios of golden and euglena algae were the lowest, and this is also consistent with the results of the original study.

Many MA species prevailing and sub-prevailing in ice of Russky Island bays were registered in other works focused on phytoplankton in winter. Specifically, high abundance of a planktonic diatom *Chaetoceros socialis* f. *radians* was repeatedly noted in February in the southeastern Sea of Japan (Konovalova et al., 1989), *inter alia* in the Amur Bay (Orlova et al., 2009). A benthic–planktonic diatom *Cylindrotheca closterium* was previously reported for phytoplankton (Konovalova et al., 1989) and for microphytobenthos of Peter the Great Bay (Ryabushko, 1990 ; Ryabushko et al., 2019). Another prevailing species of the ice flora – a planktonic diatom *Nitzschia frigida* – was recorded among the prevailing representatives of the Arctic ice biotope as well (Kauko et al., 2018). Its mass development was observed in Peter the Great Bay water areas (Begun et al., 2011 ; Ponomareva, 2017). Moreover, representative of this genus – *Nitzschia* sp. – was also reported among prevailing ice-related MA species in the Amur Bay of the Sea of Japan (Kuznetsov, 1980).

Out of prevailing MA of the sea ice in Russky Island water areas, a planktonic diatom *Thalassiosira nordenskioeldii* should be noted. This species prevailed in under-ice phytoplankton in winter and spring and reached its maximum blooming force at low and negative water temperatures in some Peter the Great Bay water areas (Begun et al., 2011 ; Konovalova et al., 1989 ; Shevchenko et al., 2020), *inter alia* in the Paris Bay (Ponomareva, 2017). In winter, a diatom *Thalassiosira gravida* and the species of the genus *Pseudo-nitzschia* were recorded as prevailing ones in Peter the Great Bay coastal areas (Konovalova et al., 1989 ; Orlova et al., 2009 ; Ponomareva, 2017) and in young Arctic ice (Kauko et al., 2018). Less abundant species of the ice and plankton biotopes of Russky Island – a dinoflagellate *Protoperidinium depressum* and a diatom *Coscinodiscus oculus-iridis* Ehrenberg, 1840 – were noted in Peter the Great Bay water areas in late winter and in spring (Konovalova et al., 1989).

For the first time for phytoplankton of Peter the Great Bay, the prevalence of representatives of the division Cryptophyta – *Plagioselmis* species – was registered. According to the literature data, cryptophytic algae of this genus prevailed in the Golden Horn Bay in September (Stonik, 2018). Moreover, *Plagioselmis* species were recorded among MA of the Amur Bay plankton, but those were not the prevailing ones (Orlova et al., 2009).

Other MA registered in ice during our study were mentioned in the composition of the prevailing MA in the work of L. Kuznetsov on ice MA of the Amur Bay (1980). Among them, there were a golden alga *Octactis speculum* and a diatom *Entomoneis paludosa* (W. Smith) Reimer, 1975 representing the same genus as *Entomoneis gigantea* var. *decussata* which was found by us in small abundance.

According to the literature data (Kauko et al., 2018), during the sea ice formation, MA cells present in the water column become incorporated into ice composition due to complex processes of turbulent mixing. However, several researchers showed that not only phytoplankton, but also benthos is a source of replenishment for the ice biotope (Olsen et al., 2017 ; Ratkova & Wassmann, 2005). According to some authors (Okolodkov, 1992 ; Niemi et al., 2011), as young ice develops, centric diatoms become more abundant than pennate ones. In accordance with other data (Campbell et al., 2018 ; Galindo et al., 2017), during the sea ice formation, centric diatoms begin to quantitatively prevail over pennate ones or dinoflagellates. There are also investigations indicating the following: in general, the prevalence of pennate diatoms is the main stage of succession during the blooming of the representatives of ice flora communities (Leeuwe et al., 2018 ; Leu et al., 2015).

In the Vostok Bay (the Sea of Japan) in January 1980 at a depth of 0.5 m and a water temperature of −1.2 °C during the ice cover formation on rocky soils, maximum biomass of diatoms reached 2,576 $mg \cdot m^{-2}$ due to benthic–planktonic species *Odontella aurita* (Lyngbye) C. Agardh, 1832 and *Melosira moniliformis* (O. F. Müller) C. Agardh, 1824. Those – along with pennate diatoms *Tabularia tabulata* (C. Agardh) Snoeijs, 1992 and *Licmophora abbreviata* C. Agardh, 1831 and a small-cell species *Diatomella salina* var. *septata* (Nikolaev) I. V. Makarova, 1968 – formed a massive accumulation at the very ice edge (Ryabushko, 1990). The listed species were also found by us in MA communities of the studied bays, but in contrast to the above-mentioned investigations, our study showed that the basis of ice MA in Russky Island bays was formed by planktonic diatoms from the classes Coscinodiscophyceae and Bacillariophyceae. Apparently, this is due to climatic peculiarities of different years manifesting during ice formation and due to specific abiotic environmental characteristics of local habitats in each water area studied.

The data obtained by us do not allow drawing conclusions on succession processes of sea ice, since the material was sampled once – in February. At the same time, in the ice flora in Russky Island water areas, one can observe a mixed composition of MA life forms which are the basis of the quantitative structure of ice studied.

As a result of the study carried out during the ice period of 2020 and 2021, differences were registered in the quantitative structure of sea ice MA and under-ice water MA in the Voevoda and Novik bays (sometimes, by more than an order of magnitude). The differences in the total MA abundance and biomass in the ice biotope depended on the year of the study, water area, and ice layer. Those could be related to the peculiarities of the hydrometeorological regime formed in Peter the Great Bay water areas in different years, as well as to specifics of hydrological and hydrochemical parameters of the aquatic environment in each water area studied.

Conclusion. For the first time for the latitude of Peter the Great Bay (the Sea of Japan), the quantitative structure of sea ice microalgae communities in the Voevoda and Novik bays of Russky Island was studied. In total, 88 species from 50 genera and 7 divisions were identified. The ice biotope was characterized by a higher species richness compared to the phytoplankton biotope: in ice, 80 species from 7 divisions were recorded; in phytoplankton, 40 species from 5 divisions were registered.

In the MA communities in ice, diatoms *Chaetoceros socialis* f. *radians*, *N. frigida*, *T. nordenskioeldii*, and *Nitzschia* sp. prevailed. For the first time for Peter the Great Bay, the prevalence of a cryptophytic algae *Plagioselmis* was registered in the under-ice phytoplankton.

The study covered the main quantitative characteristics of MA of two biotopes and ice core horizons in two Russky Island bays. A sufficiently high level of quantitative abundance in the ice cover of the Voevoda and Novik bays was established. In the first year of the study, the MA communities were characterized by considerably lower MA abundance and biomass compared to those of the second year. Diatoms formed the basis of the quantitative structure of the community, with abundance values reaching 1,861.2 cells·mL^{-1} for the Voevoda Bay and 751.2 cells·mL^{-1} for the Novik Bay in 2020. In 2021, the values were 6,846.3 and 17,143.1 cells·mL^{-1}, respectively.

In the Voevoda Bay in 2020, cell abundance was maximum in the upper layer of the ice core and gradually decreased closer to a border with under-ice water, while in the Novik Bay, it was distributed approximately evenly throughout the core. In the Voevoda Bay in 2021, the opposite pattern was recorded: microalgae abundance was minimal in the upper layers of the ice core and gradually increased as moving down, to a border with under-ice water. In the Novik Bay, maximum MA abundance was registered in the upper layer of the ice core, with a relatively uniform distribution over all layers.

Thus, the differences are shown in MA quantitative structure in ice samples of two bays depending on a layer of the ice core, year, and study area. Further investigation of sea ice in Peter the Great Bay is required – first of all, in the seasonal aspect: at this geographical latitude, a stable ice cover can be formed only in this water area.

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КОЛИЧЕСТВЕННАЯ СТРУКТУРА СООБЩЕСТВА МИКРОВОДОРОСЛЕЙ МОРСКОГО ЛЬДА (ОСТРОВ РУССКИЙ, ЗАЛИВ ПЕТРА ВЕЛИКОГО, ЯПОНСКОЕ МОРЕ)

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Впервые для российского прибрежья Японского моря изучена количественная структура сообщества микроводорослей морского льда. Исследованием охвачены биотопы льда и подлёдного фитопланктона двух бухт острова Русский в зимний период 2020 и 2021 гг. Идентифицировано 88 видов микроводорослей из 50 родов и 7 отделов. Установлено, что сообщество микроводорослей льда характеризовалось бо́льшим видовым богатством, чем подлёдный фитопланктон. Среди доминирующих видов наиболее многочисленными были планктонные диатомовые водоросли *Chaetoceros socialis* f. *radians*, *Nitzschia frigida*, *Thalassiosira nordenskioeldii* и *Nitzschia* sp. Диатомеи составляли основу сообщества, достигая в 2020 г. численности 1861,2 кл.·мл$^{-1}$ в бух. Воевода и 751,2 кл.·мл$^{-1}$ в бух. Новик, а в 2021 г. — 6846,3 и 17143,1 кл.·мл$^{-1}$ соответственно. В 2020 г. в бух. Воевода численность клеток была максимальной в верхнем слое ледового керна и постепенно снижалась ближе к границе с подлёдной водой; в бух. Новик она была распределена почти равномерно по всему керну. В 2021 г. в бух. Воевода отмечена противоположная закономерность: в верхних слоях керна численность микроводорослей была минимальной, а по ходу продвижения вниз, к границе с подлёдной водой, она постепенно возрастала. В бух. Новик максимум численности зарегистрирован в верхнем слое керна, притом что распределение по всем слоям было относительно равномерным. Таким образом, показаны различия в количественной структуре микроводорослей льда в зависимости от слоя ледового керна, года и места исследования.

Keywords: quantitative structure, microalgae, phytoplankton, Peter the Great Bay, Russky Island, Sea of Japan