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EXPERIMENTAL ARTICLES

Communities of Anoxygenic Phototrophic Bacteria in the Saline Soda Lakes of the Kulunda Steppe (Altai Krai)

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Abstract—The saline soda lakes of the Kulunda steppe (Altai krai) are small and shallow; they are characterized by a wide range of salinity and alkalinity, as well as by the extreme instability of their water and chemical regimes. Accumulations of anoxygenic phototrophic bacteria (APB) visible to the unaided eye were noted only in several lakes with high rates of sulfate reduction in their bottom sediments. However, enumeration of APB cells by inoculation revealed their presence in all 17 lakes. APB cell numbers varied from 10^3 to 10^9 CFU cm^{-3}. In the APB communities of all lakes, purple sulfur bacteria of the family *Ectothiorhodospiraceae* were predominant. In 14 out of the 17 lakes, purple nonsulfur bacteria of the family *Rhodobacteraceae* were also detected (10^3–10^7 CFU cm^{-3}). Purple sulfur bacteria of the family *Chromatiaceae* were less abundant: *Halochromatium* sp. (10^4–10^7 CFU cm^{-3}) were found in six lakes, while *Thiocapsa* sp. (10^4 CFU cm^{-3}) were detected in one lake. On the whole, the APB communities of the soda lakes of the Kulunda steppe were characterized by the low diversity and evenness of their species compositions, as well as by the pronounced dominance of the members of the family *Ectothiorhodospiraceae*. There was no correlation between the structures of the APB communities and alkalinity. However, the dependence of the species composition of APB (mainly ectothiorhodospiras) on water mineralization was revealed. High mineralization (above 200 g l^{-1}) was a limiting factor that affected the APB communities on the whole, restricting the APB species diversity to extremely halophilic bacteria of the genus *Halorhodospira*.

Key words: soda lakes, anoxygenic phototrophic bacteria, species diversity, water alkalinity, water mineralization.

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Extreme habitats such as soda lakes have attracted attention of researchers for a long time and continue to be the subject of considerable scientific interest. This is due to the unique properties of haloalkaliphilic microorganisms, among which representatives of a great number of new taxa from virtually all known physiological groups have been detected and described. The attention of researchers is also associated with the hypothesis that the microbial communities of soda lakes are a relict analogue of the terrestrial biota of the early Proterozoic era [1, 2]. The alkaline lakes of Africa and some lakes of western America have been studied in most detail. Narrower-scope studies of a number of soda lakes in Hungary, Mongolia, etc., have also been carried out [2–4]. In Russia, the soda lakes of the Transbaikal region (Buryatia, Chita oblast), Tyva, and Altai krai have been studied [2, 5]. However, data on the anoxygenic phototrophic bacteria (APB) inhabiting the soda lakes of Russia are scarce and mostly pertain to the lakes of the Transbaikal region. In our previous publications, the results of our studies of the structure of the APB communities in the soda lakes of the Transbaikal region are presented; the effect of environmental factors on this structure was analyzed; the adaptation of bacteria to the ambient conditions was demonstrated; and a number of novel APB taxa, including those of the genus level, were described [5, 6]. In Lake Khilganta (the Agin–Buryat autonomous region), we studied the daily dynamics of environmental parameters and the vertical stratification of a microbial mat; the role of the phototrophic microbial community in the production process and detoxification of sulfide was determined as well [7].

Data on the APB inhabiting other soda lakes of Russia are limited to those presented in the works by B.L. Isachenko [2, 8], dealing with the lakes of the Kulunda steppe (Altai krai) and published in the 1930s. Isachenko noted the abundance of purple sulfur bacteria in these lakes and their active role in the sulfur cycle.

At present, intense microbiological studies of the Kulunda lakes are being carried out by a research team guided by D.Yu. Sorokin. The sulfur and nitrogen cycles, as well as microorganisms involved in them, including newly described taxa of alkaliphilic bacteria, have been studied in detail [9, 10]. The rates of the

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production and degradation processes in these lakes have been determined [11, 12].

The aim of the present work was to study the structure of the APB communities inhabiting the soda lakes of the Kulunda steppe and compare them with APB communities of other saline and soda lakes.

MATERIALS AND METHODS

The field studies of 17 saline soda lakes of the Kulunda steppe (Altai krai) and the benthic microbial communities inhabiting them were carried out in July 2006.

The total mineralization and pH of the lake water were measured with a portable pH meter and a conductometer (Trans Instruments, Singapore). Carbonate alkalinity was determined by titration with a 0.1 M HCl solution [13]. Cyanobacterial mats or the loose upper layer of sediments containing phototrophic microorganisms were used for inoculation.

APB were enumerated by natural samples dilution series inoculation using agar-shake method . Mineralization and alkalinity of the media corresponded to those of the lakes under study. In addition to NaCl, $NaHCO_3$, and Na_2CO_3, the cultivation media (pH 9.5) contained the following (g l^{-1}): KH_2PO_4, 0.5; NH_4Cl, 0.5; $MgCl_2 \cdot 6H_2O$, 0.2; sodium acetate, 0.5; sodium malate, 0.5; yeast extract, 0.1; $Na_2S \cdot 9H_2O$, 0.2; trace element solution, 1 ml l^{-1}; and vitamin B_{12}, 20 μg l^{-1}. Inoculated media were incubated in a luminostat at a light intensity of about 2000 lx and 25°C.

The morphology of bacterial cells was studied under an Olympus BX-41 light microscope (Japan) with a phase-contrast device.

RESULTS AND DISCUSSION

The soda lakes of the Kulunda steppe are located in the southern part of Altai krai, along its southwestern border with Kazakhstan, 320 km southwest of Barnaul. So many small shallow lakes are located in a zone 25 km in diameter that many of them do not have official names. The physicochemical conditions of the Kulunda lakes vary within a wide range; however, these lakes are mainly hypersaline with high levels of carbonate alkalinity, which makes them different from the majority of low-mineralized soda lakes of other areas of southern Siberia.

In July 2006, during an expedition to the Kulunda steppe, we studied 17 saline soda lakes with different physicochemical parameters (table). The average depths of the studied lakes measured during our field studies were small, 10–50 cm, except for Lake Iodnoe, which is several meters deep. The total mineralization ranged from 15 to 280 g l^{-1}; the total alkalinity was 0.01–2.8 g-equiv l^{-1}. The pH values varied from 8.1 to 10.3. On the whole, the studied lakes are small and shallow; they are characterized by wide salinity and alkalinity ranges, as well as by the extreme instability of their water and chemical regimes.

Properties of the phototrophic communities. In most of the lakes, phototrophic microorganisms were present as a part of the benthic communities and developed in the form of thin (0.5–3 mm) cyanobacterial mats or loose, pigmented layers on the surface of sediment deposits. In the lakes with moderately mineralized water (less than 100 g l^{-1}), filamentous green algae occurred. Massive development of planktonic forms of unicellular green algae (presumably belonging to *Chlorella* sp.), the so-called water bloom, was observed in only one lake (Iodnoe), which is several meters deep and polluted with industrial wastes. In some highly mineralized lakes, the microalga *Dunaliella viridis* and halobacteria were detected; however, green or red water coloration due to massive development of these microorganisms was not observed. In most lakes, a high number of crustaceans of the genus *Artemia* was noted.

Accumulations of APB, visible to the unaided eye as pink-lilac layers within bacterial mats, occurred only in some lakes—namely, Petukhovo, Gorchina-1, and Gorchina-2, with a water mineralization of 60–200 g l^{-1}, an alkalinity level of 0.9–2.8 g-equiv l^{-1}, and active processes of sulfate reduction in sediments. However, APB enumeration revealed their presence in all of the studied lakes. The APB cell numbers in the soda lakes of Altai krai (table), determined by natural samples dilution series inoculation, varied from 10^3 to 10^9 CFU cm^{-3}. In all lakes, purple sulfur bacteria of the family *Ectothiorhodospiraceae* prevailed among anoxygenic phototrophs. Their numbers in cyanobacterial mats and in the surface layer of loose near-bottom depositions ranged from 10^7 to 10^9 CFU cm^{-3}. In 14 out of the 17 studied lakes, spheroidene-containing purple nonsulfur bacteria of the family *Rhodobacteraceae* (10^3–10^7 CFU cm^{-3}) were also present. Purple sulfur bacteria of the family *Chromatiaceae* were less abundant; *Halochromatium* sp. (10^4–10^7 CFU cm^{-3}) were detected in six lakes, while *Thiocapsa* sp. (10^4 CFU cm^{-3}) were detected in one lake.

Bacteria of the families *Ectothiorhodospiraceae* and *Rhodobacteraceae* were represented by more than one species. However, since genetic analysis is required for determination of their species affiliation, the term "morphotype" should be used at this stage of the investigation.

Despite their high morphological variability, members of the family *Ectothiorhodospiraceae* inhabiting the soda lakes of the Kulunda steppe can be divided into four main morphotypes.

(1) The first morphotype, designated as *Halorhodospira* sp. 1, includes thin spirilla, 0.5–0.8 μm in diameter, phenotypically closest to the extremely halophilic *Halorhodospira halophila* [14].

(2) Bacteria belonging to the second morphotype, *Halorhodospira* sp. 2, represented by large curved rods

Physicochemical conditions and APB cell numbers in the soda lakes of Kulunda steppe

Station no.	Lake name*	Mineralization, g l^{-1}	H_2S in sediments	pH	Alkalinity, g-equiv l^{-1}		APB number, log CFU cm^{-3}									Number of morphotypes
					total	CO_3^{2-}	total APB number	*Halorhodospira* sp. 1	*Halorhodospira* sp. 2	*Ectothiorhodospira* sp. 1	*Ectothiorhodospira* sp. 2	*Rhodobacteraceae* 1	*Rhodobacteraceae* 2	*Halochromatium* sp.	*Thiocapsa* sp.	
11KL-06	N. Karagay	**15**		10.0	0.10	0.09	6	–	–	–	6	4	5	–	–	**3**
9KL-06	Bezymyannoe-1	**30**		10.2	0.20	0.15	3	–	–	–	3	2	2	–	–	**3**
12KL-06	Bezymyannoe-2	**30**		9.8	0.01		4	–	–	3	4	3	–	–	–	**3**
14KL-06	Bezymyannoe	**40**		10.2	0.21	0.15	6	–	–	3	6	5	–	–	4	**4**
1KL-06	Petukhovo	**60**	+	10.3	0.90	0.85	8	–	–	8	5	6	4	–	–	**4**
18KL-06	Gorchina-3	**60**	+	10.6	0.67	0.62	8	–	–	8	–	7	5	7	–	**4**
17KL-06	Gorchina-2	**80**	+	10.3	1.25	1.05	9	–	–	9	–	8	–	5	–	**3**
10KL-06	Zhivopisnoe	**90**		10.1	0.50	0.45	6	–	–	6	–	5	4	5	–	**4**
6KL-06	Tanatar-III	**112**	+	10.1	1.13	0.90	7	–	–	7	–	5	–	–	–	**2**
7KL-06	Iodnoe	**120**		9.6	0.35	0.20	5	–	–	5	–	5	3	4	–	**4**
13KL-06	Nikolaev Bereg	**120**		9.4	0.03	0.02	6	–	3	6	–	6	-	4	–	**4**
16KL-06	Gorchina-4	**160**	+	9.2	2.55	1.88	7	7	–	6	–	6	5	5	–	**5**
4KL-06	Tanatar-I	**200**	+	10.0	1.57	1.30	8	8	–	6	–	–	–	–	–	**2**
15KL-06	Gorchina-1	**200**	+	10.2	2.83	2.25	9	9	–	–	–	–	8	–	–	**2**
8KL-06	Pechatnoe	**200**		9.5	0.17	0.10	5	5	–	–	–	3	–	–	–	**2**
3KL-06	Kochkovoe	**240**		8.5	0.01	0	3	2	3	–	–	–	–	–	–	**2**
2KL-06	Lomovoe	**280**		8.1	0.01	0	3	–	3	–	–	–	–	–	–	**1**

* The lakes in the list are arranged in the order of increasing lake water mineralization.

or spirilla 1.5–2 μm in diameter and producing extracellular sulfur, were detected only in three highly mineralized lakes with high alkalinity levels. No complete phenotypic analogues of these bacteria exist among known species; however, they should be classified into the genus *Halorhodospira* on the basis of their preference for extremely saline habitats.

(3) Bacteria belonging to the third morphotype, *Ectothiorhodospira* sp. 1, are represented by vibrios or short spirilla, 0.9–1.2 × 2–2.5 μm, with a morphology resembling *Ectothiorhodospira haloalkaliphila* [14] and the recently described bacterium *Ect. variabilis,* whose habitats include Kulunda lakes [15]. The cells of the latter species may or may not contain gas vacuoles; no gas vacuoles were observed in the strains occurring in the Kulunda lakes.

(4) Bacteria belonging to the fourth morphotype, *Ectothiorhodospira* sp. 2, were represented by ovoid cells or short rods, sometimes slightly curved, 1.3–1.5 μm in diameter, phenotypically resembling halotolerant or slightly halophilic strains usually assigned to *Ect. shaposhnikovii* [14].

Molecular biological studies demonstrated differences of the species level between isolates from different habitats similar to *Ect. haloalkaliphila*–*Ect. variabilis* or to *Ect. shaposhnikovii* (i.e., to our morphotypes *Ectothiorhodospira* sp. 1 and *Ectothiorhodospira* sp. 2) [15]. Thus, the diversity of *Ectothiorhodospira* species inhabiting soda lakes is probably greater than the number of species described so far.

Purple nonsulfur bacteria of the family *Rhodobacteraceae* were represented by two morphotypes, *Rhodobacteraceae* 1, thin elongated rods, 0.4–0.6 × 1.5–2.5 μm, and *Rhodobacteraceae* 2, shorter and thicker rods or ovoid cells, 0.8–1.1 × 1.3–2 μm. Genetic studies are required to definitely establish the generic affiliation of these bacteria. Thus far, purple nonsulfur bacteria of two morphologically similar genera, *Rhodovulum* and *Rhodobaca* [15, 16, 20], have been found in soda lakes; we also cannot rule out that there exist new genera of these bacteria that remain to be discovered. In the soda lakes of the Transbaikal region and Mongolia, which we have studied previously, bacteria of the first morphotype (*Rhodobacteraceae* 1) are widespread. According to the results of phylogenetic analysis, these microorganisms belong to two new species of the genus *Rhodovulum* [16]. Thus, among purple nonsulfur bacteria, like among ectothiorhodospiras, there likely exist morphologically similar but phylogenetically distinct taxa. Studies of the taxonomic status of purple nonsulfur bacteria isolated from the soda lakes of the Kulunda steppe are currently in progress.

In all lakes, purple sulfur bacteria of the genus *Halochromatium* were represented by one morphotype that did not show complete similarity with the known species of this genus and most probably belonged to a new species of alkaliphilic bacteria that remains to be described. Their cells are ovoids or short rods (1.5–2.0 × 2.5–3.5 μm), motile, and often containing intracellular sulfur globules. The cells of *Thiocapsa* sp. (nonmotile cocci about 1.5 μm in diameter) were noted only in one lake.

Thus, it is obvious that the observed phenotypic diversity of APB, which was revealed without genetic analysis, is lower than their phylogenetic diversity and, accordingly, than the actual number of species. However, even taking into consideration this possibility, it is clear that, on the whole, the APB communities inhabiting soda lakes of the Kulunda steppe are characterized by low diversity and evenness of their species compositions, with pronounced dominance of the family *Ectothiorhodospiraceae* members.

The effect of the total water mineralization on the structure of the APB communities. Our previous studies of the Kulunda lakes showed a positive correlation between the primary production values and water alkalinity [11]. We did not observe any correlation between productivity and water mineralization in the range of 30–200 g l^{-1}, whereas an increase in salinity above 200 g l^{-1} suppressed the phototrophic community. Anoxygenic photosynthesis was recorded only in 5 of the 12 lakes studied. The obtained data correlate with the results of the APB enumeration. Anoxygenic photosynthesis was revealed in the lakes where the number of APB was 10^7–10^9 CFU cm^{-3} and was not detected in the lakes where the APB number was below 10^7 CFU cm^{-3}.

No correlation between the structure of the APB community and alkalinity was revealed. At the same time, dependence of the species composition of APB, primarily that of ectothiorhodospiras, on water mineralization was recorded.

First of all, it should be noted that representatives of the family *Ectothiorhodospiraceae* dominated among anoxygenic phototrophs in all the lakes studied. In the lakes with water mineralization of 15–200 g l^{-1}, nonsulfur and sulfur purple bacteria of the families *Rhodobacteraceae* and *Chromatiaceae* were also present in the APB communities. *Rhodobacteraceae* were detected at a salinity of up to 200 g l^{-1}; *Halochromatium* sp. occurred in the lakes with a water mineralization of 60–160 g l^{-1}; *Thiocapsa* sp. were detected in one lake with a water mineralization of 40 g l^{-1}. No distributional patterns of both *Rhodobacteraceae* morphotypes as dependent on water mineralization were observed. This is most probably due to the presence of more than two species of the family *Rhodobacteraceae,* morphologically similar, but with different physicochemical optima. An increase in salinity above 200 g l^{-1} restricted the APB species diversity. In the lakes with the water mineralization of 240 and 280 g l^{-1}, the APB communities consisted exclusively of *Ectothiorhodospiraceae* members.

With an increase in the water salinity, changes in the distribution of various members of the family *Ectothiorhodospiraceae* occurred. In lakes with minimal mineralization (15–30 g l^{-1}), only halotolerant bacteria of the morphotype *Ectothiorhodospira* sp. 2 were detected. At a salinity of 30–60 g l^{-1}, these microorganisms were detected along with moderately halophilic bacteria of the morphotype *Ectothiorhodospira* sp. 1. With further increase in the water salinity to up to 120 g l^{-1}, *Ectothiorhodospira* sp. 1 were the only representatives of the family *Ectothiorhodospiraceae* in the APB community; at 120–200 g l^{-1}, they were found along with the extremely halophilic *Halorhodospira* sp. 1. Finally, in soda lakes with the highest water salinity (above 200 g l^{-1}), only *Halorhodospira* representatives were present. It should be noted that *Halorhodospira* sp. 2 were detected only in hypersaline lakes (120–280 g l^{-1}) with a relatively low alkalinity (0.01–0.03 g-equiv l^{-1}). It is obvious that they differ from *Halorhodospira* sp. 1 in their preference for less alkaline conditions and are probably closely related to the recently described neutrophilic halophilic bacterium *Hlr. neutriphila* [17].

Thus, an increase in the water mineralization affected, first of all, the species composition of ectothiorhodospiras, resulting in the succession of the dominants from halotolerant species to halophilic and then extremely halophilic ones. High mineralization (above 200 g l^{-1}) was a limiting factor that affected the APB communities on the whole and restricted their species compositions to extremely halophilic species of the genus *Halorhodospira*.

Our previous studies of the phototrophic communities of the low-mineralized soda lakes of the Transbaikal region demonstrated that changes in the salinity level within a range from 5 to 40 g l^{-1} did not affect the structure of the APB communities [5]. A water mineralization lower than 5 g l^{-1} was a limiting factor for the APB communities. In the present work, we show that 200 g l^{-1} is the upper boundary after which mineralization becomes a limiting factor. Although an increase in the water salinity from 15 to 200 g l^{-1} was accompanied with changes in the APB species composition (primarily in the species composition of the members of the family *Ectothiorhodospiraceae*), it hardly affected the APB species diversity, which depended on other environmental factors. Thus, summarizing the data on the soda lakes of the Transbaikal region and Kulunda steppe, we conclude that, on the whole, the salinity level ranging from 5 to 200 g l^{-1} is favorable for the APB development. A water mineralization below 5 and above 200 g l^{-1} is a limiting factor for the development of the haloalkaliphilic APB communities. Ectothiorhodospiras were predominant in the APB communities of all the lakes with a water mineralization above 5 g l^{-1}.

If we compare the studied soda lakes and the saline lakes of marine origin (the Crimean steppe) [18, 19], the predominance and monopoly of *Ectothiorhodospiraceae* in the latter was observed only at a salinity level of more than 200–250 g l^{-1}. The simultaneous effect of two or more extreme factors results in the reduction of their limiting thresholds. The two main limiting factors characteristic of soda lakes, salinity and alkalinity, have a similar effect on their APB communities and result in the prevalence of *Ectothiorhodospira* species. Therefore, the level of water mineralization that promotes the predominance of bacteria of the family *Ectothiorhodospiraceae* in the APB communities is much lower (5 g l^{-1}) in soda lakes than that in neutral saline lakes of marine origin (200–250 g l^{-1}).

Comparison of the Kulunda steppe lakes with other soda and saline lakes in terms of the APB community structure. So far, no comparative investigations of the structure of the APB communities of soda lakes or enumeration of APB cells therein have been carried out, with the exception of our studies of the lakes of the Transbaikal region [5–7]. For some other soda lakes, there are data on dominant species (members of the family *Ectothiorhodospiraceae*), or communications devoted to isolation and description of new APB taxa. It should be noted that the microbial communities inhabiting soda lakes are quite unique and to a large extent consist of autochthonous organisms that cannot be found in other ecosystems. That is why investigations into the microflora of soda lakes usually results in the description of new microorganisms of various physiological groups. This is also true for anoxygenic phototrophs inhabiting soda lakes, the majority of which were identified as new taxa. Green bacteriochlorophyll *b*-containing *Halorhodospira* species, *Hlr. halochloris* and *Hlr. abdelmalekii,* were isolated from the soda lakes of Wadi Natrun (Egypt) [14]; *Rhodobaca bogoriensis* was isolated from the lakes of the Great Rift Valley in east Africa [20]; *Ectothiorhodosinus mongolicus, Ectothiorhodospira variabilis*, and *Ect. magna* were isolated from Mongolian lakes [15]; *Thiorhodospira sibirica, Thioalkalicoccus lumnaeus, Heliorestis daurensis, Hrs. baculata*, and *Rhodobaca barguzinensis* were isolated from the soda lakes of the Transbaikal region [5, 15]; and the description of two more novel species of the genus *Rhodovulum* is to be published in the near future [16]. The taxonomic status of the APB inhabiting the Kulunda lakes has yet to be determined; however, according to our preliminary results, some of them belong to new taxa, including those of the genus level.

Comparison of the Kulunda lakes and the low-mineralized soda lakes of the Transbaikal region reveals that the APB communities inhabiting these lakes have much in common: the benthic type of development, predominance of bacteria of the family *Ectothiorhodospiraceae,* and the absence of green sulfur bacteria. However, the soda lakes of the Kulunda steppe differed from the lakes of the Transbaikal region by lower diversity and lower evenness of the APB species composition and a more pronounced predominance of *Ectothiorhodospira* species. In the Kulunda lakes, we did not detect any members of the genera *Thiorhodospira, Thioalkalicoccus, Oscillochloris*, or *Heliorestis,* which were present in low-mineralized soda lakes of the Transbaikal region. Moreover, purple sulfur bacteria of the family *Chromatiaceae* are much more widespread in the lakes of the Transbaikal region [5]. It is obvious that this is due to the higher mineralization level of the Kulunda lakes, which inhibits the growth of many species, even halophilic ones, and gives the advantage to species of the family *Ectothiorhodospiraceae.*

A similar distributional pattern of bacterial species within the APB communities was observed in another region of Central Asia, northern Mongolia. Although enumeration of APB in Mongolian lakes was not performed, a considerable diversity of these microorganisms was noted in the lakes with a water mineralization of up to 60 g l^{-1}; the monopoly of ectothiorhodospiras was observed at a salinity of 165 g l^{-1} and higher (no data are available on lakes with a water salinity of 60–165 g l^{-1}) [3].

Of interest is also comparison of the APB communities of soda lakes with those of shallow-water saline lakes of marine origin, also characterized by the benthic type of development of phototrophic communities. As mentioned above, in neutral saline lakes of the Crimean steppe, members of the family *Ectothiorhodospiraceae* were dominant among APB at a water mineralization above 200–250 g l^{-1} [18, 19]. However, at a lower mineralization, the APB communities of the

Crimean saline lakes differ significantly from those of soda lakes by the greater species diversity, the presence of green sulfur bacteria, as well as by the alternating predominance of various APB groups and high evenness of the species composition.

Thus, the diversity and evenness of the APB species composition in saline and soda lakes decrease as the effects of extreme environmental factors (salinity and pH) increase: the greatest species diversity was observed in saline neutral lakes, the species diversity in low-mineralized soda lakes was lower, and the lowest diversity was detected in hypersaline alkaline lakes.

Summarizing the results obtained in the present work, we conclude that, on the whole, the APB communities of the soda lakes of the Altai krai are characterized by low diversity and low evenness of their species compositions, as well as by the pronounced dominance of the members of the family *Ectothiorhodospiraceae*. No correlation between the structure of the APB community and the water alkalinity was observed. At the same time, the dependence of the species composition of APB, primarily that of ectothiorhodospiras, on the water mineralization was revealed. Mineralization higher than 200 g l^{-1} is a limiting factor that affects the whole APB community, restricting the APB species diversity to extremely halophilic species of the genus *Halorhodospira*.

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