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Ecological features of cyanobacteria and algae communities of the littoral of the meromictic Lake Shira (Khakassia Republic, Russia)

Lira Gaysina
M. Akmullah Bashkir State Pedagogical University

A I. Fazlutdinova
M. Akmullah Bashkir State Pedagogical University

O N. Mukhina
M. Akmullah Bashkir State Pedagogical University

L F. Akhmadeyeva
M. Akmullah Bashkir State Pedagogical University

D Yu Rogozin
Siberian Federal University

See next page for additional authors

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© 2020. L. A. Gaysina[1, 2] ORCID: 0000-0002-0920-6449,
A. I. Fazlutdinova[1] ORCID: 0000-0001-7971-6690, O. N. Mukhina[1] ORCID: 0000-0002-4028-9916,
L. F. Akhmadeyeva[1] ORCID: 0000-0002-6471-3929, D. Yu. Rogozin[3, 4] ORCID: 0000-0002-9350-2936,
A. O. Bul'khin[3, 4] ORCID: 0000-0002-8537-0945, N. V. Sukhanova[1] ORCID: 0000-0002-6130-6172,
J. R. Johansen[5] ORCID: 0000-0002-0794-9417,
[1]M. Akmullah Bashkir State Pedagogical University,
3-a, Okt'yabrskoy revolucii, Ufa, Republic of Bashkortostan, Russia, 450008,
[2]All-Russian Research Institute of Phytopathology,
5, Institute St., B. Vyazyomy, Odintsovo District, Moscow Region, Russia, 143050,
[3]Institute of Biophysics Siberian Branch of RAS,
50, Akademgorodok, Krasnoyarsk, Russia, 660036,
[4]Siberian Federal University,
79, Svobodny Prospekt, Krasnoyarsk, Russia, 660041,
[5]John Carroll University, University Heights,
John Carroll Blvd., Ohio 44118, USA,
e-mail: lira.gaisina@mail.ru

During the study of cyanobacteria and algae from littoral of the meromictic Lake Shira (Republic of Khakassia, Russia) forty-eight taxa were identified: Cyanobacteria – 7, Chlorophyta – 5, and Bacillariophyta – 36 species. Cyanobacteria were represented by cosmopolitan taxa *Leptolyngbya voronichiniana*, cf. *Trichocoleus hospitus* and widely distributed in the freshwater ecosystems species *Phormidium* cf. *paulsenianum*, *Pseudophormidium* cf. *golenkinianum*, *P. pauciramosum*, *Leptolyngbya perforans*, and *L. subtilissima*. Among green algae typical freshwater taxa *Chloroidium saccharophilum*, *Desmodesmus abundans*, *Oocystis lacustris*, *Chlorella* sp., *Stigeoclonium* sp. were detected. Among Bacillariophyta the most frequent species were *Amphora ovalis*, *Cymbella affinis*, *Encyonema silesiacum*, *Eunotia fallax*, *Gomphonella olivacea*, *G. parvulum*, *Kobayasiella subtilissima*, *Navicula minima*, *N. radiosa*, *N. veneta*, *Nitzchia fonticola*, *N. palea*, *Grunowia tabellaria*, *Surirella undulata*. Several rare species cf. *Fragilaria tenera*, *Grunowia tabellaria* and cf. *Ulnaria capitata* were found. In relation to mineralization indifferents was the largest group (73%). In relation to pH, a unique feature of the investigated lake was the predominance of alkaliphilic species of diatoms (56%), such as *Amphora ovalis*, *Cymbella affinis*, *Gomphonema truncatum*, *Hantzschia amphioxys*, *Navicula minima*, *N. veneta*, *Nitzschia* cf. *linearis*, *N. palea*, *Planothidium lanceolatum* and other. In the geographic structure cosmopolitan group included 25 species (69%), boreal group – 4 species (11%), arcto-apline group – 2 species (6%). To obtain more accurate information on the biodiversity of cyanobacteria and algae of Lake Shira further studies using molecular-genetic and electron microscopic methods are needed.

Keywords: meromixia, Bacillariophyta, alkaliphilic species, *Leptolyngbya voronichiniana*, *Pseudophormidium pauciramosum*, *Desmodesmus abundans*, *Oocystis lacustris*, *Amphora ovalis*, *Grunowia tabellaria*, *Surirella undulata*.

УДК 574.58

Экологические особенности цианобактериально-водорослевых сообществ литорали меромиктического озера Шира (Республика Хакасия, Россия)

**© 2020. Л. А. Гайсина[1], д. б. н., доцент, зав. кафедрой,
А. И. Фазлутдинова[1], к. б. н., доцент, О. Н. Мухина[1], магистрант,
Л. Ф. Ахмадеева[1], магистрант, Д. Ю. Рогозин[3, 4], д. б. н., в. н. с.,
А. О. Бульхин[3, 4], аспирант, Н. В. Суханова [1], д. б. н., доцент, проректор,
Д. Р. Джохансен[5], доктор биологии, профессор,**
[1]Башкирский государственный педагогический университет им. М. Акмуллы,
450008, Россия, г. Уфа, ул. Октябрьской революции, д. 3-а,

[2]Всероссийский научно-исследовательский институт фитопатологии,
143050, Россия, Московская область, Одинцовский район,
р.п. Большие Вяземы, ул. Институт, д. 5,
[3] Институт Биофизики СО РАН,
660036, Россия, г. Красноярск, Академгородок, д. 50,
[4]Сибирский федеральный университет,
660041, Россия, г. Красноярск, пр. Свободный, д. 79,
[5] Университет Джона Кэрролла,
44118, США, Кливленд, Норт Парк бульвар, 20700,
e-mail: lira.gaisina@mail.ru

При изучении цианобактерий и водорослей литорали меромиктического озера Шира (Республика Хакассия, Россия) было обнаружено сорок восемь таксонов: Cyanobacteria – 7, Chlorophyta – 5, Bacillariophyta – 36 видов. Цианобактерии были представлены космополитами *Leptolyngbya voronichiniana*, cf. *Trichocoleus hospitus* и широко распространёнными в пресноводных экосистемах видами *Phormidium* cf. *paulsenianum*, *Pseudophormidium* cf. *golenkinianum*, *Pseudophormidium pauciramosum*, *Leptolyngbya perforans* и *L. subtilissima*. К зелёным водорослям относились также типично пресноводные виды и роды *Chloroidium saccharophilum*, *Desmodesmus abundans*, *Oocystis lacustris*, *Chlorella* sp., *Stigeoclonium* sp. Среди представителей отдела Bacillariophyta наиболее часто встречались виды *Amphoraovalis*, *Cymbella affinis*, *Encyonema silesiacum*, *Eunotia fallax*, *Gomphonella olivacea*, *G. parvulum*, *Kobayasiella subtilissima*, *Navicula minima*, *N. radiosa*, *N. veneta*, *Nitzchia fonticola*, *N. palea*, *Grunowiata bellaria*, *Surirella undulata*. Было обнаружено также несколько редких видов cf. *Fragilaria tenera*, *Grunowiata bellaria* и cf. *Ulnariacapitata*. По отношению к минерализации наиболее многочисленной была группа видов-индиффирентов (73%). По отношению к pH уникальной чертой изученного озера было преобладание алкалифильных видов (56%), таких как *Amphora ovalis*,*Cymbella affinis*, *Gomphonema truncatum*, *Hantzschia amphioxys*, *Navicula minima*, *N. veneta*, *Nitzschia* cf. *linearis*, *N. palea*, *Planothidium lanceolatum* и др. Для получения более точной информации о биоразнообразий цианобактерии и водорослей озера Шира необходимы дальнейшие исследования с использованием молекулярно-генетических и электронно-микроскопических методов.

Keywords: меромиксия, Bacillariphyta, алкалифильные виды, *Leptolyngbya voronichiniana, Pseudophormidium pauciramosum, Desmodesmus abundans, Oocystis lacustris, Amphora ovalis, Grunowia tabellaria, Surirella undulata.*

Meromictic lakes are characterized by a long-term stratification of the water column – meromixia that often causes accumulation of nutrients in the bottom layers of water bodies. This phenomenon affects living organisms [1]. It should be noted, that despite quite a number of publications on meromictic lakes [2–5], insufficient data about cyanobacteria and algae compositions in this type of water bodies exist.

Lake Shira is located in the north of the Republic of Khakassia (Russia). It is a brackish water body with sulfate-chloride-sodium-magnesium mineral composition [6, 7]. Average salinity in mixolimnion (upper water layer) during the summer stratification period in 2002–2017 years was approximately 15 g/L, and in monimolimnion it was approximately 19 g/L [4]. Despite the uniqueness of Lake Shira, the biodiversity of cyanobacteria and algae in this reservoir remains unstudied. The aim of this work was to study the biodiversity and ecology of cyanobacterial and algal communities in the littoral zone of Lake Shira.

Material and methods

Samples were taken from the littoral of the lake (to a depth of 1 m) on October 21, 2018 by simply scooping them into 5 L plastic bottles. Pebbles and sand from a depth about 0.5 m were also added into the water sample.

For isolation of clonal cultures of cyanobacteria and algae dilution technique was used [9]. Isolates were cultivated on solidified Z8 medium [10] at room temperature 20–25 °C on with illumination of 40 μmol/m^2 per second provided by 18W cool fluorescent tubes with 12 h:12 h light:dark regime. Pure cultures in tubes on 1.5% agar-solidified media slants were then stored at 4 °C in a refrigerator with transparent door at natural daylight regime. Observations of cyanobacteria were conducted using a Zeiss Axio Imager A2 microscope with DIC optics and AxioVision 4.9 visualization system. Microphotographs were taken with an Axio Cam MRc camera on magnifications ×400 and ×1000. For identification of the taxa and classification, the relevant reference sources were used [11–17]. For clarification the names of cyanobacteria and algae the Algaebase database was used [18].

Results and Discussion

Forty-six taxa were identified: Cyanobacteria – 7, Chlorophyta – 5, Bacillariophyta – 36 species.

Among cyanobacteria cosmopolitan taxa *Leptolyngbya voronichiniana* Anagnostidis & Komárek and cf. *Trichocoleus hospitus* (Hansgirg ex Gomont) Anagnostidis were detected. Besides *Phormidium* cf. *paulsenianum* J.B. Petersen (Fig., 1, see color insert)., *Pseudophormidium* cf. *golenkinianum* (Gomont) Anagnostidis (Fig., 2), *P. pauciramosum* (Anissimova) Anagnostidis, *Leptolyngbya perforans* (Geitler) (Fig., 3) Anagnostidis & Komárek, и *L. subtilissima* (Kützing ex Hansgirg) Komárek in Anagnostidis (Fig., 4) were found. The latter two species are typical inhabitants of the littoral zone of the freshwater bodies [12].

Green algae comprised taxa characterized by a wide distribution in freshwater ecosystems: *Chloroidium saccharophilum* (W. Krüger) Darienko, Gustavs, Mudimu, Menendez, Schumann, Karsten, Friedl & Proschold, *Desmodesmus abundans* (Kirchner) E. H. Hegewald, *Oocystis lacustris* Chodat (Fig., 5), *Chlorella* sp., *Stigeoclonium* sp. (Fig., 6).

Bacillariophyta was the most diverse group. In total, 36 species and intraspecific taxa of diatoms were found in this lake. Among them are representatives of the common freshwater genera – *Achnanthidium* Kützing, *Amphora* Ehrenberg ex Kützing, *Cocconeis* Ehrenberg, *Cymbella* C. Agardh, *Eunotia* Ehrenberg, *Fragilaria* Lyngbye, *Gomphonema* Ehrenberg, *Hantzschia* Grunow, *Navicula* Bory, *Nitzschia* Hassall, *Pinnularia* Ehrenberg, *Staurosira* Ehrenberg, *Surirella* Turpin, and *Ulnaria* (Kutzing) Compère.

Lake Shira is characterized by intensive growth of diatoms, but biodiversity of this group was not very high. The most abundant species were *Amphora ovalis* (Kützing) Kützing, *Cymbella affinis* Kützing, *Encyonema silesiacum* (Bleisch) D.G. Mann, *Eunotia fallax* A. Cleve, *Gomphonella olivacea* (Hornemann) Rabenhorst, *G. parvulum* (Kützing) Kützing, *Kobayasiella subtilissima* (Cleve) Lange-Bertalot, *Navicula minima* Grunow (Fig., 7), *N. radiosa* Kützing, *N. veneta* Kützing, *Nitzschia fonticola* (Grunow) Grunow, *N. palea* (Kützing) W. Smith, *Grunowia tabellaria* (Grunow) Rabenhorst (Fig., 8), *Surirella undulata* (Ehrenberg) Ehrenberg (Fig., 9). Species *Amphora libyca* Ehrenberg, *Diploneis* cf. *modicahassiaca* H. Lange-Bertalot & A. Fuhrmann, *Nitzchia sinuata* var. *delognei* (Grunow) Lange-Bertalot, *Karayevia clevei* (Grunow) Bukhtiyarova, *Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot, *Staurosira construens* Ehrenberg (Fig., 10) were sporadic.

Several rare species of diatoms were found: cf. *Fragilaria tenera* (W. Smith) Lange-Bertalot, *Grunowia tabellaria*, cf. *Ulnaria capitata* (Ehrenberg) Compère.

In relation to mineralization, two groups were distinguished: indifferent and halophobe species. Indifferent taxa comprised the largest group (73%) while the halophobes encountered only three species living in slightly salted reservoirs: *Craticula submolesta* (Hustedt) Lange-Bertalot, *Eunotia fallax* (Fig., 11) и cf. *Fragilaria tenera* (W. Smith) Lange-Bertalot.

The diatoms species, which were found in the littoral zone of Lake Shira, were adapted to different life condition and included bottom, planktonic, littoralic, epiphytic-littoral and epiphytic species. Among these the bottom and epiphytic species were the most numerous (47 and 28%, respectively). The epiphytic-littoral group included 14% of the species, 6% of species belong to littoralic group and 3% of species belong to planktonic group.

In relation to pH several ecological groups were found. A unique feature of the investigated lake was the predominance of alkaliphilic diatoms species (56%) such as *Achnanthes conspicua* Ant. Mayer, *Amphora ovalis, A. libyca*, *Cocconeis placentula* Ehrenberg, *Cymbella affinis, Gomphonema truncatum* (Fig., 12), *Fragilaria tenera*, *Hantzschia amphioxys* (Ehrenberg) Grunow, *Navicula veneta, Nitzschia palea* (Kützing) W. Smith, *Fragilaria ulna* (Nitzsch) Lange-Bertalot, *Ulnaria delicatissima* (W. Smith) Aboal & P. C. Silva. Indifferent to pH species like *Achnanthidium lineare* W. Smith, *Gomphonema parvulum*, *Navicula radiosa* Kützing, and *Pinnularia montium* Y. Liu, Kociolek & Q.X.Wang were also found (14%). *Eunotia fallax, Kobasiella subtilisima, Craticula submolesta* belong to acidophilic species (8%), *Gomphonella olivaceae* and *Nitzschia fonticola* – to alkalibiont species (6%).

The geographic structure of the composition of diatoms in the studied lake also has its own specificity. The most abundant were cosmopolitan species – 25 species and interspecific taxon (69%), including *Amphora ovalis*, *Cocconeis placentula*, *Eunotia fallax*, *Fragilaria ulna*, *Gomphonema parvulum*, *Hantzschia amphioxys*, *Navicula minima*, *N. veneta*, *Nitzschia fonticola*, *N. linearis*, *N. palea*. Boreal group were represented by 4 species (11%) – *Achnanthes conspicua*, *Diploneis* cf. *modicahassica*, *Gomphonella olivacea*, *Navicula radiosa*. Two species (6%) – *Grunovia tabellaria* and cf. *Fragillaria tenera* – belong to arcto-alpine group.

Conclusion

Thus, a preliminary analysis of the species composition of the cyanobacterial algal com-

munities of the littoral of Shira Lake revealed the predominance of diatoms. To obtain more accurate information on the biodiversity of cyanobacteria and algae of Lake Shira further studies using molecular-genetic and electron microscopic methods are needed.

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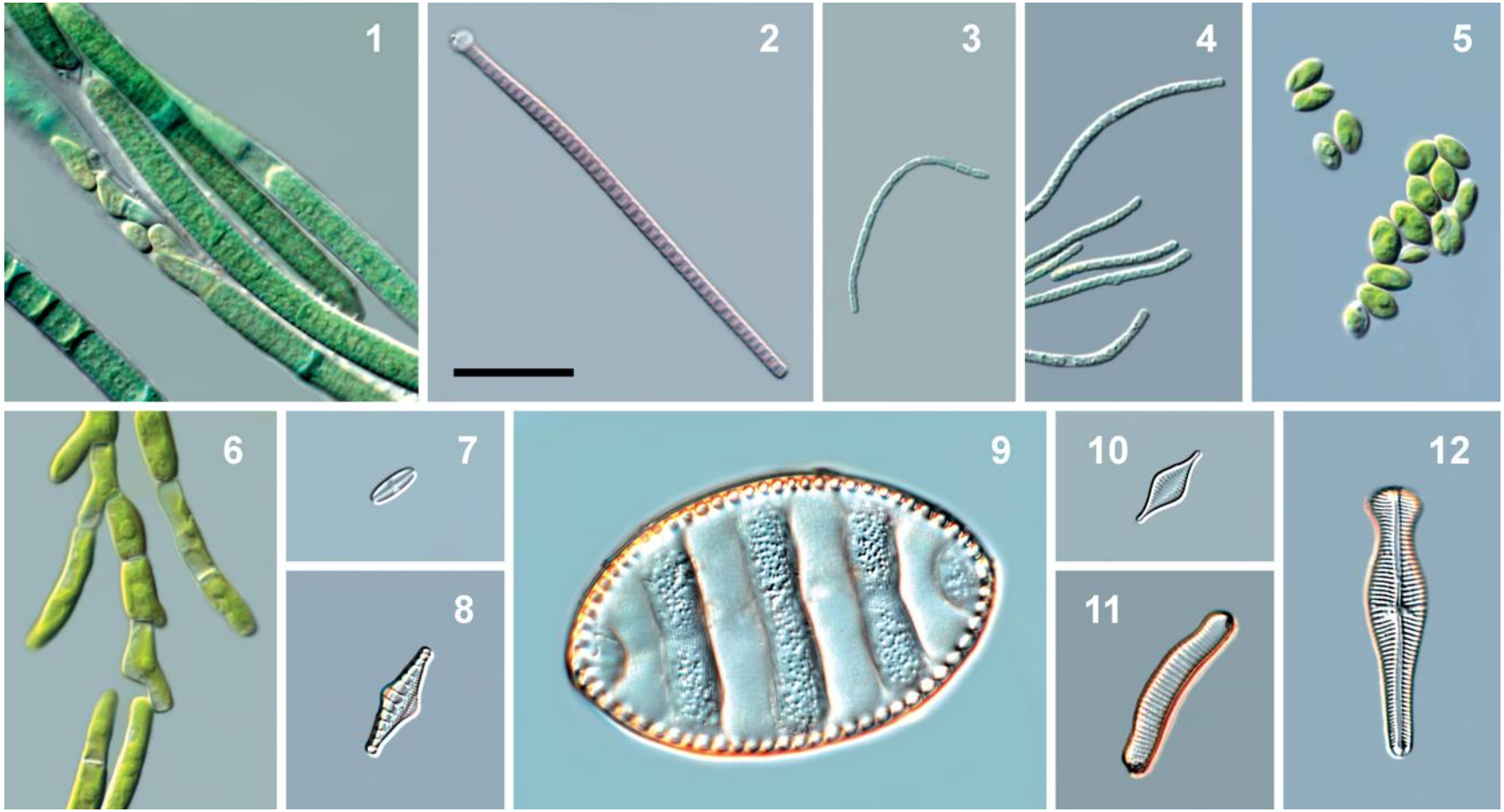

Fig. Cyanobacteria and algae of the littoral zone of Lake Shira: 1 – *Phormidium* cf. *paulsenianum*; 2 – *Pseudophormidium* cf. *golenkinianum*; 3 – *Leptolyngbya perforans*; 4 – *L. subtilissima*; 5 – *Oocystis lacustris*; 6 – *Stigeoclonium* sp.; 7 – *Navicula minima*; 8 – *Grunowia tabellaria*; 9 – *Surirella undulata*; 10 – *Staurosira construens*; 11 – *Eunotia fallax*; 12 – *Gomphonema truncatum*. Scale bar is 10 μm length