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DIVERSITY AND ECOLOGY OF NON-DIATOM ALGAE IN A SWAMPY MOUNTAIN LAKE OF THE SUNTAR-KHAYAT RIDGE (REPUBLIC SAKHA, YAKUTIA, RUSSIA)

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ABSTRACT

The first studied flora of a mountain lake on the Suntar-Khayat ridge was represented by 170 species of non-diatoms in addition to 112 previously studied diatoms. The calculated similarity indices, correlation analysis and bioindication showed the uniqueness of the non-diatom flora, dominated by charophytes in general and species of the genera *Cosmarium* and *Closterium*. The results of the study of flora suggest that the altitude and the lake location in the zone of the Arctic deserts were major factors that affected the process of formation of the unique species composition.

ZUSAMMENFASSUNG: Diversität und Ökologie von Nicht-Kieselalgen in einem versumpften Bergsee des Suntar-Khayat-Kamms (Republik Sacha, Jakutien, Russland).

Erstmalig wurden nach einer vorangegangenen Studie der Algenflora eines Bergsees auf dem Suntar-Khayat-Kamm, bei der 112 Arten von Kieselalgen festgestellt wurden, nun zusätzlich 170 Arten von Nicht-Kieselalgen festgestellt. Die berechneten Ähnlichkeitsindizes, die Korrelationsanalyse und die Bioindikation zeigten die Einzigartigkeit der Nicht-Diatomeen-Flora, die im Allgemeinen von Charophyten im Allgemeinen und sowie Arten der Gattungen *Cosmarium* und *Closterium* dominiert wird. Die Ergebnisse der Untersuchung der Flora deuten darauf hin, dass die Höhe und die Lage des Sees in der Zone der arktischen Wüsten wichtige Faktoren waren, die den Entstehungsprozess der einzigartigen Artenzusammensetzung beeinflussten.

REZUMAT: Diversitatea și ecologia algelor fără diatomee într-un lac de munte mlăștinos de pe creasta Suntar-Khayat (Republica Sakha, Yakutia, Rusia).

Prima floră studiată a unui lac de munte de pe creasta Suntar-Khayat a fost reprezentată de 170 de specii de non-diatomee, față de 112 specii de diatomee studiate anterior. Indicii de similitudine calculați, analiza corelației și bioindicația au evidențiat unicitatea florei de non-diatomee, dominată de carofite în general și specii din genurile *Cosmarium* și *Closterium*. Rezultatele studiului florei sugerează că altitudinea și locația lacului în zona deșerturilor arctice au fost factori majori care au afectat procesul de formare a compoziției unice a speciilor.

INTRODUCTION

The study of the species composition of water bodies located in extreme natural and climatic conditions, in particular, in the territory of the north of the Russian Far East, has been carried out for a number of years (Kopyrina et al., 2020). At present, we are focusing on the division of works on lotic and lentic objects, since conclusions about the influence of water parameters and macroclimatic parameters are based on different bases and reflect the influence of various climatic factors (Denisov and Barinova, 2015, 2016; Barinova, 2017; Gabysheva et al., 2022). However, while river floras are subject to influences associated with currents and changes in latitude, the floras of lentic water bodies of lakes can more accurately characterize the influence of macroclimatic parameters on the formation of algae flora. On the other hand, the study of algae in lentic water bodies in the Arctic can help to reveal the catchment basins input and represent the effect of natural and anthropogenic conditions throughout the entire catchment area over many years, so its ecosystems stay relatively stable.

Of course, floristic studies in such hard-to-reach areas as the Arctic North, first of all, contribute to supplementing the list of species of regional floras. The first information about algae of the lakes in Central Yakutia comes in 1935 (Kiselev, 1935; Komarenko and Vasilyeva, 1975, 1978; Vasilyeva, 1989; Pestryakova, 2008; Troeva, et al., 2010; Kopyrina, 2014).

The objective of the present study was to reveal the non-diatom species in a mountain lake on Suntar-Khayat ridge in Yakutia and compare it to floras of previously studied lakes in the region with the help of ecological preferences by bioindication and statistical methods for defining major factors influenced the floristic formation process.

MATERIAL AND METHODS

Description of study site

The alpine lake (63°03’57”N, 138°48’47”E) is located in the upper reaches of the Vodopadny Stream (left tributary of the Eastern Khandyga River), six km to the south, at an altitude of 1,330 m a.s.l., on Suntar-Khayat ridge (North-East of Yakutia, Russia) (Fig. 1). The lake is flowing, with a length of 120 m, an 80 m width, a surface area about 3.01 ha, and a muddy bottom. Mosses grow in the coastal part of the lake, the water temperature was 13.3°C, and the transparency was up to 1.2 m. Rhododendron-dryad tundra with *Cassiopeia* are described on the slope of the ravine, a narrow strip of sedge-reed grass *Hypnum* swamp runs along the lake shore.

The high-mountainous regions of Suntar-Khayat are characterized by the harsh climate of the Arctic desert. Winter lasts eight months. The height of the snow cover in the mountains is 50-90 cm. The climate varies from sharply continental to cold maritime. The northeastern regions have a sharply continental climate. Here is the Pole of Cold of the Northern Hemisphere – the village of Oymyakon with an absolute minimum of –71.2°C. Winter is long, up to seven months, with little snow. The height of the snow cover in some years does not exceed 25-30 cm. The summer in the mountains is cool and does not last long. It starts from the second half of June and lasts two months. The average daily air temperature is 10°C. (Izyumenko, 1966) The water nutrition of the lakes in this region is mixed, glacial and snow-rain, as well as due to feeding by melting glaciers.

We studied the algal flora of this lake for the first time and identified 112 taxa of rare and new species of diatoms (Potapova et al., 2014).

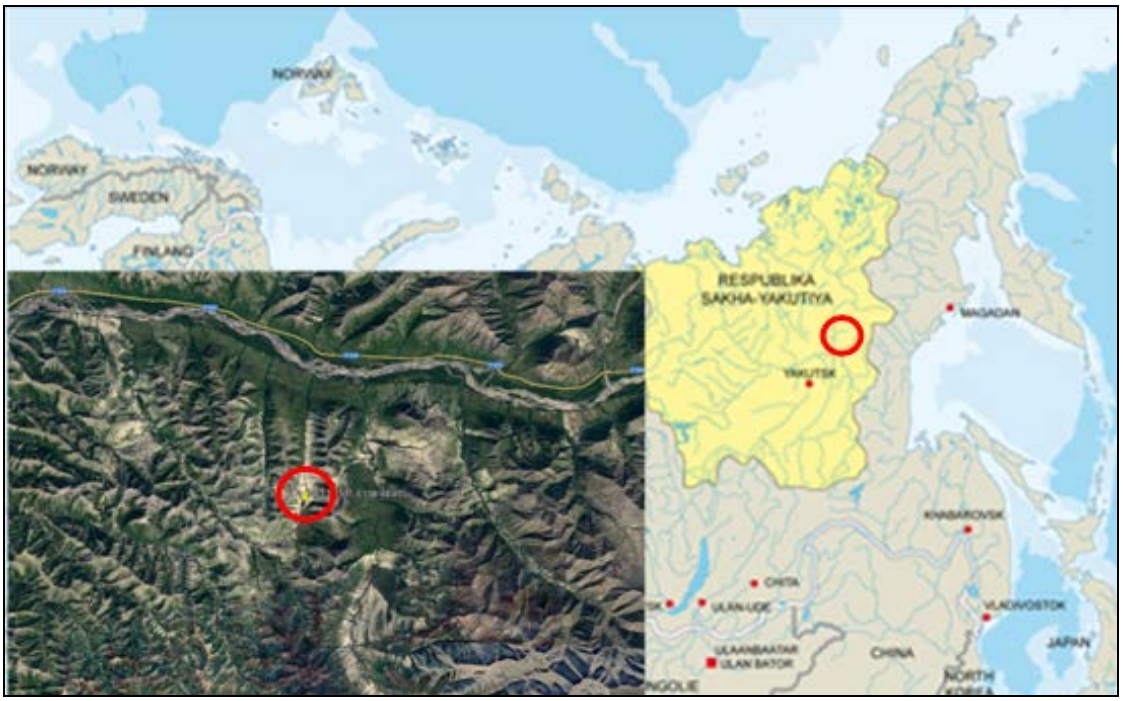

Figure 1: The studied lake in the Suntar-Khayat ridge (red circle)
(Republic Sakha, Yakutia, Russian Far East).

Sampling and laboratory study

The material for the study was eight samples of phytoperiphyton collected from higher aquatic plants and mosses in August 2003. During sampling, the water temperature was measured, and transparency was determined.

The collection of materials was carried out according to the research methods generally accepted in algology (*, 1989; **, 1992; Komulainen, 2003). For further study of the collected material, samples in 15 ml plastic tubes were fixed in a 4% solution of neutral formaldehyde. Identification of non-diatom phytoperiphyton algae was carried out in the Department of Botanical Research of the Institute of Biotechnology of the Siberian Branch of the Russian Academy of Sciences using a Mikmed-6 microscope.

Taxa names are given according to the database (Guiry and Guiry, 2021; http://www.algaebase.org) with the latest additions and clarifications.

Species and varieties within each phylum are arranged alphabetically.

The ecological preferences of the identified species were determined using bioindication methods (Barinova, 2017a; Barinova et al., 2006, 2019).

A similarity tree was calculated and constructed with the help of BioDiversity Pro 9.0 program.

Correlation of species content was calculated with JASP networks (Love et al., 2019).

RESULTS

Physical and chemical variables

Hydrochemical variables are given for the first time. The surface waters of this reservoir have no taste and smell. The water temperature was 16.2°C, the transparency is up to one m, water pH is neutral (7.20), water of the bicarbonate class, calcium group of type three. Bicarbonates (25% equivalent) and calcium ions (37% equivalent) dominate the ionic composition. In terms of TDS, the waters are fresh, have low salinity and are soft.

Taxonomical species content

A taxonomic diversity of 170 species and varieties was identified in the composition of algae and cyanobacteria communities at the end of the short summer period, in August (Tab. 1). They belonged to seven taxonomic phyla. Charophyta (63) dominated, and then Cyanobacteria (38) was significantly less, while Chlorophyta and Ochrophyta accounted for 30 and 29 species, respectively. The remaining three phyla included a total of one to five species (Fig. 2). The richest division of charophytes was dominated by the genera *Cosmarium* Corda ex Ralfs with 18 species and *Closterium* Nitzsch ex Ralfs with nine species. These are usually inhabitants of wetland habitats of shallow clear waters or coastal communities. As can be seen from table 1, the revealed flora of non-diatoms is represented in the majority by typical varieties. We calculated the Ssp/Sp index, which reflects the intraspecific variability of the flora (Barinova, 2011), and it turned out to be only 1.006 for the studied lake, which characterizes the studied flora as practically monotypic with low intraspecific polymorphism. Next, the specific content of the taxonomic list per lake area (species – area index as number of species per one square kilometer) was calculated (Barinova et al., 2011; Barinova and Stenina, 2013). The species per area index turned out to be high, 56.5 species per km^2.

Table 1: Diversity and ecological preferences of non-diatom algae in the lake in the Suntar-Khayat ridge (Republic Sakha, Yakutia). Abbreviations of the Ecological groups: Substrate – S, soil; Ep, epiphytes; B, benthic as a whole; P-B, planktonic-benthic; and P, planktonic. Temperature – eterm, eurythermal. Water disturbance and Oxygenation – aer, aerophiles; str, streaming well-oxygenated waters; st-str, low streaming, mid-oxygenated waters; st, standing, low-oxygenated waters; and H_2S, sulfide indicators. Water pH – acf, acidophiles; ind, pH-indifferents; alf, alkaliphiles; and alb, alkalibiontes. Salinity – hb, halophobes; i, chloride-tolerated (indifferent); hl, halophiles. Class of Water Quality – Classes 1-4 according EU FWD. Trophy – ot, oligotraphentes; om, oligo-mesotraphhentes; m, mesotraphentes; me, meso-eutraphentes; e, eutraphentes.

Taxa	Hab	Temp	OXY	Index S	SAP	HAL	pH	TRO
Charophyta								
Actinotaenium curtum (Brébisson ex Ralfs) Teiling ex Růžička and Pouzar	P-B	–	aer	0.90	x-b	–	ind	om
Actinotaenium cruciferum (De Bary) Teiling	P-B	–	aer	–	–	–	acf	om
Closterium attenuatum Ralfs	–	–	–	–	–	–	–	–
Closterium baillyanum (Brébisson ex Ralfs) Brébisson	B	–	–	–	–	–	ind	om
Closterium leibleinii Kützing ex Ralfs	P-B	–	st-str	2.60	a-o	–	ind	e
Closterium parvulum Nägeli	P-B	–	–	2.00	b	i	ind	m
Closterium peracerosum Gay	–	–	–	–	–	–	–	–

Table 1 (continued): Diversity and ecological preferences of non-diatom algae in the lake in the Suntar-Khayat ridge (Republic Sakha, Yakutia).

Taxa	Hab	Temp	OXY	Index S	SAP	HAL	pH	TRO
Charophyta								
Closterium pritchardianum W. Archer	P-B	–	–	–	–	–	ind	m
Closterium setaceum Ehrenberg ex Ralfs	P-B	–	–	–	–	hb	acf	om
Closterium siliqua West and West	P	–	st-str	–	–	–	–	–
Closterium striolatum Ehrenberg ex Ralfs	P-B	–	–	1.20	o	–	acf	om
Cosmarium asphaerosporum Wittrock	B	–	–	–	–	i	acf	ot
Cosmarium botrytis Meneghini ex Ralfs	P-B	-	st-str	1.90	o-a	i	ind	m
Cosmarium conspersum Ralfs	–	–	–	–	–	–	–	–
Cosmarium dentiferum Corda ex Nordstedt	–	–	–	–	–	–	acf	m
Cosmarium exiguum W. Archer	–	–	–	–	–	–	–	–
Cosmarium hornavanense Gutwinski	B, aer	–	aer	1.00	o	-	acf	m
Cosmarium humile Nordstedt ex De Toni	P-B	–	–	1.10	o	i	ind	m
Cosmarium margaritatum (P. Lundell) J. Roy and Bisset	B	–	–	–	–	–	acf	m
Cosmarium monomazum P. M. Lundell	–	–	–	–	–	–	–	–
Cosmarium ochthodes Nordstedt	B	–	–	1.20	o	–	ind	m
Cosmarium pokornyanum (Grunow) West and G. S .West	B, aer	–	aer	–	–	hl	acf	m
Cosmarium pseudoholmii O. Borge	P	–	–	–	–	i	ind	m
Cosmarium sp.	–	–	–	–	–	–	–	–
Cosmarium subcrenatum Hantzsch	B, aer	–	aer	1.10	o	–	acf	m
Cosmarium sublatereundatum West and G. S. West	–	–	–	–	–	–	–	–
Cosmarium subprotumidum Nordst.	P-B	–	st-str	1.90	o-a	–	ind	me
Cosmarium subquadrans West and G. S. West	–	–	–	–	–	–	acf	m
Cosmarium subundulatum Wille	–	–	–	–	–	–	acf	m
Cosmarium turpinii Brébisson	P-B	–	–	0.70	o-x	i	ind	me
Cosmarium undulatum var. wollei West	–	–	–	–	–	–	–	–
Cylindrocystis brebissonii (Ralfs) De Bary	B, S	–	st, aer	0.80	x-b	–	acf	om
Desmidium graciliceps (Nordstedt) Lagerheim	–	–	–	–	–	–	–	–
Desmidium swartzii C. Agardh ex Ralfs	B	–	–	0.60	o-x	i	ind	m
Euastrum ansatum Ehrenberg ex Ralfs	P-B	–	–	0.50	x-o	–	acf	ot
Euastrum bidentatum Nägeli	P-B	–	–	0.60	o-x	hb	ind	m

Table 1 (continued): Diversity and ecological preferences of non-diatom algae in the lake in the Suntar-Khayat ridge (Republic Sakha, Yakutia).

Taxa	Hab	Temp	OXY	Index S	SAP	HAL	pH	TRO
Charophyta								
Euastrum binale Ehrenberg ex Ralfs	B	–	–	0.60	o-x	–	acf	ot
Euastrum crassicolle P. Lundell	B	–	aer	0.50	x-o	–	acf	om
Euastrum cuneatum Jenner	P-B	–	–	0.50	x-o	–	acf	m
Euastrum tumoriferum (Kossinskaja) Van Westen and Coesel	–	–	–	–	–	–	–	–
Gonatozygon monotaenium De Bary	B	–	st-str	0.80	x-b	hb	acf	me
Gonatozygon pilosum Wolle	–	–	–	–	–	–	–	–
Mougeotia laetevirens (A. Braun) Wittrock	B	–	–	1.00	o	–	–	–
Mougeotia notabilis Hassall	–	–	–	–	–	–	–	–
Mougeotia scalaris Hassall	B	–	–	1.50	o-b	i	–	–
Netrium digitus (Brébisson ex Ralfs) Itzigsohn and Rothe	P-B	–	–	0.50	x-o	i	acf	om
Penium spirostriolatum J. Barker	B	–	–	0.50	x-o	–	acf	om
Penium cylindrus Brébisson ex Ralfs	B	–	–	0.40	x-o	–	acf	om
Pleurotaenium truncatum (Brébisson ex Ralfs) Nägeli	B	–	–	0.80	x-b	–	acf	m
Spirogyra varians (Hassall) Kützing	P-B	–	–	2.10	b	oh	–	–
Spirogyra protecta H. C. Wood	B	–	–	1.10	o	–	–	–
Staurastrum bieneanum Rabenhorst	B	–	–	–	–	–	acf	m
Staurastrum cyrtocerum var. inflexum (Brébisson) Coesel and Meesters	–	–	–	–	–	–	–	–
Staurastrum pachyrhynchum Nordstedt	–	–	–	–	–	–	acf	m
Staurastrum paradoxum Meyen ex Ralfs	P	–	st	–	–	i	ind	ot
Staurastrum platycerum Joshua	–	–	–	–	–	–	–	–
Staurastrum polytrichum (Perty) Rabenhorst	B	–	–	1.60	b-o	–	acf	m
Staurastrum saxonicum Bulnheim ex Rabenhorst	–	–	–	–	–	–	–	–
Temnogyra punctiformis (Transeau) Yamagishi	–	–	–	–	–	–	–	–
Xanthidium aculeatum Ehrenberg ex Ralfs	P-B	–	–	0.60	o-x	–	acf	om
Xanthidium smithii W. Archer	–	–	–	–	–	–	acf	ot
Zygnema pectinatum (Vaucher) C. Agardh	B	–	st-str	1.00	o	oh	–	–
Zygnema cruciatum (Vaucher) C. Agardh	B	–	–	0.80	x-b	–	–	–

Table 1 (continued): Diversity and ecological preferences of non-diatom algae in the lake in the Suntar-Khayat ridge (Republic Sakha, Yakutia).

Taxa	Hab	Temp	OXY	Index S	SAP	HAL	pH	TRO
Chlorophyta								
Actinastrum aciculare Playfair	P	–	–	–	–	–	–	–
Ankistrodesmus spiralis (W. B. Turner) Lemmermann	P	–	–	2.10	b	–	–	e
Ankistrodesmus fusiformis Corda	P-B	–	st-str	2.00	b	i	–	e
Blidingia marginata (J. Agardh) P. J. L. Dangeard ex Bliding 1963	B	–	–	–	–	–	–	–
Bulbochaete setigera C. Agardh ex Hirn	B	–	–	1.30	o	–	–	–
Bulbochaete nana Wittrock ex Hirn	B	–	–	1.30	o	–	–	–
Chaetophoropsis elegans (Roth) B. Wen Liu, Qian Xiong, X. Dong Liu, Z. Yu Hu and G. Xiang Liu	B	–	–	1.20	o	–	–	–
Characiochloris apiculata Korshikov	–	–	–	–	–	–	–	–
Cladophora fracta (O. F. Müller ex Vahl) Kützing	P-B	–	st-str	2.30	b	–	–	e
Cladophora glomerata (Linnaeus) Kützing	P-B	–	st-str	1.90	o-a	i	alf	e
Geminella interrupta Turpin	B	–	–	1.30	o	–	–	–
Gloeotila scopulina (Hazen) Heering	B	–	–	–	–	–	–	–
Koliella longiseta (Vischer) Hindák	P	–	st	2.00	b	i	–	–
Monoraphidium griffithii (Berkeley) Komárková-Legnerová	P-B	–	st-str	2.20	b	i	–	e
Oedogonium oblongum Wittrock ex Hirn	B	–	–	–	–	oh	–	–
Oedogonium pringsheimii C. E. Cramer ex Hirn	B	–	–	1.40	o-b	–	–	–
Oedogonium undulatum A. Braun ex Hirn	B	–	–	–	–	i	–	–
Palmodictyon varium (Nägeli) Lemmermann	–	–	–	–	–	–	–	–
Planctococcus sphaerocystiformis Korshikov	P	–	st	–	–	–	–	–
Prasiola sp.	–	–	–	–	–	–	–	–
Prasiola subareolata Skuja	–	–	–	–	–	–	–	–
Prasiola velutina (Lyngbye) Trevisan	–	–	–	–	–	–	–	–
Pseudocharacium obtusum (A. Braun) Petry-Hesse	B, Ep	–	st	–	–	i	–	–
Pseudopediastrum kawraiskyi (Schmidle) E. Hegewald	P	–	–	1.40	o-b	–	–	–
Siderocelis ornate (Fott) Fott	P-B	–	st-str	2.20	b	i	–	–
Stigeoclonium amoenum Kützing	–	–	–	–	–	–	–	–

Table 1 (continued): Diversity and ecological preferences of non-diatom algae in the lake in the Suntar-Khayat ridge (Republic Sakha, Yakutia).

Taxa	Hab	Temp	OXY	Index S	SAP	HAL	pH	TRO
Chlorophyta								
Ulothrix implexa (Kützing) Kützing	–	–	–	–	–	–	–	–
Ulothrix oscillarina Kützing	B, aer, S	–	st-str	–	–	–	–	–
Ulothrix zonata (F. Weber and Mohr) Kützing	P-B	–	st-str	1.80	o-a	i	ind	–
Ulothrix albicans Kützing	B	–	–	1.30	o	–	–	–
Cyanobacteria								
Anabaena sp.	P-B	–	–	–	–	–	–	e
Anabaena catenula Kützing ex Bornet and Flahault	P-B	–	–	–	–	–	–	m
Chlorogloea microcystoides Geitler	Ep, B, S	–	aer	–	–	–	–	–
Gloeocapsa violacea Kützing	S	–	–	–	–	–	–	–
Gloeocapsopsis magma (Brébisson) Komárek and Anagnostidis ex Komárek	S	–	–	–	–	i	ind	–
Gloeothece palea (Kützing) Nägeli	Ep, B, S	–	aer	–	–	–	–	–
Gloeotrichia echinulata P. G. Richter	P-B	–	–	1.50	o-b	–	–	m
Gomphosphaeria aponina Kütz.	P-B	–	st-str	1.20	o	hl	alf	ot
Limnothrix guttulata (Goor) I. Umezaki and M. Watanabe	P-B	–	st,H2 S	3.00	a	–	–	–
Lyngbya kuehniana Migula	–	–	–	–	–	–	–	–
Lyngbya sp.	B	–	–	–	–	–	–	–
Merismopedia smithii De Toni	P-B	–	–	1.50	o-b	i	–	ot
Nodularia spumigena Mertens ex Bornet and Flahault	P-B, S	–	–	1.80	o-a	–	–	e
Nostoc kihlmanii Lemmermann	P	–	–	1.40	o-b	i	–	ot
Nostoc linckia Bornet ex Bornet and Flahault	P-B, Ep	–	–	1.60	b-o	–	–	–
Nostoc paludosum Kützing ex Bornet et Flahault f. *paludosum*	P-B, S	–	st	1.60	b-o	–	–	m
Nostoc punctiforme Hariot	P-B, S	–	aer	1.60	b-o	–	–	–
Oscillatoria limosa C. Agardh ex Gomont	P-B	–	st-str	2.60	a-o	hl	alf	e
Oscillatoria rupicola (Hansgirg) Hansgirg ex Forti	P-B, S	–	aer	–	–	–	–	–
Oscillatoria simplicissima Gomont	P-B	–	st-str	–	–	i	–	ot
Oscillatoria sp.	B	–	–	–	–	–	alf	–
Phormidium ambiguum Gomont	B, S	eterm	st-str	2.30	b	i	ind	me
Phormidium deflexoides (Elenkin and Kossinskaja) Anagnostidis and Komárek	–	–	–	–	–	–	–	–

Table 1 (continued): Diversity and ecological preferences of non-diatom algae in the lake in the Suntar-Khayat ridge (Republic Sakha, Yakutia).

Taxa	Hab	Temp	OXY	Index S	SAP	HAL	pH	TRO
Cyanobacteria								
Phormidium granulatum (N. L. Gardner) Anagnostidis	P-B	–	st-str	–	–	–	alf	–
Phormidium irriguum (Kützing ex Gomont) Anagnostidis et Komárek	B, Ep	–	aer	–	–	–	–	me
Phormidium schroeteri (Hansgirg) Anagnostidis	P-B, S	–	st	3.10	a	–	–	–
Planktothrix prolific (Gomont) Anagnostidis and Komárek	P	–	–	–	–	–	alf	–
Plectonema tomasinianum Bornet ex Gomont	B, S	–	st-str	0.80	x-b	–	–	ot
Pseudophormidium radiosum (Gomont) Anagnostidis and Komárek	–	–	–	–	–	–	–	–
Snowella lacustris (Chodat) Komárek and Hindák	P	–	–	1.60	b-o	i	alb	me
Snowella rosea (J. W. Snow) Elenkin	P	–	–	1.70	b-o	–	–	–
Stigonema mamillosum C. Agardh ex Bornet and Flahault	S, B	–	aer	–	–	–	–	–
Stigonema ocellatum Thuret ex Bornet and Flahault	B	–	–	0.60	o-x	–	–	–
Stigonema informe Kützing ex Bornet and Flahault	S, B	–	aer	–	–	–	–	–
Tolypothrix tenuis Kützing ex Bornet and Flahault	B, S	–	st	1.00	x-b	i	–	ot
Tolypothrix distorta Kützing ex Bornet and Flahault	B, S	–	–	0.95	x-b	–	–	ot
Trichodesmium lacustre Klebahn	P	–	st	–	–	–	–	–
Woronichinia compacta (Lemmermann) Komárek and Hindák	P-B	–	–	–	–	–	–	om
Euglenozoa								
Phacus striatus France	–	–	–	–	–	–	–	–
Trachelomonas curta A. M. Cunha	P	–	–	2.10	b	–	–	–
Trachelomonas hispida (Perty) F. Stein	P-B	eterm	st-str	2.20	b	i	acf	–
Trachelomonas volvocina (Ehrenberg) Ehrenberg	P-B	eterm	st-str	2.00	b	i	ind	–
Miozoa								
Glenodiniopsis steinii Wołoszyńska	P	–	st-str	1.20	o	–	–	–
Gymnodinium latum Skuja	P	–	–	1.50	o-b	–	–	–
Parvodinium inconspicuum (Lemmermann) Carty	P	–	–	–	–	–	–	–
Parvodinium lubieniense (Woloszynska) Carty	P	–	–	1.00	o	–	–	–
Peridinium sp.	P	–	–	1.40	o-b	–	ind	–

Table 1 (continued): Diversity and ecological preferences of non-diatom algae in the lake in the Suntar-Khayat ridge (Republic Sakha, Yakutia).

Taxa	Hab	Temp	OXY	Index S	SAP	HAL	pH	TRO
Ochrophyta								
Bumilleria borziana N. Wille	–	–	–	–	–	–	–	–
Characiopsis borziana Lemmermann	Ep	–	–	–	–	–	–	–
Characiopsis falx Pascher	–	–	–	–	–	–	–	–
Characiopsis grandis Pascher	–	–	–	–	–	–	–	–
Characiopsis pyriformis (A. Braun) Borzì	Ep	–	–	–	–	–	–	–
Characiopsis saccata N. Carter	–	–	–	–	–	–	–	–
Characiopsis sublinearis Pascher	–	–	–	–	–	–	–	–
Characiopsis korschikovii Matvienko	–	–	–	–	–	–	–	–
Chloropedia plana Pascher	–	–	–	–	–	–	–	–
Codonodendron ocellatum Pascher	–	–	–	2.00	b	–	–	–
Derepyxis dispar (A. Stokes) Senn	Ep	–	–	1.50	o-b	–	–	–
Dinobryon borgei Lemmermann	P	–	–	1.20	o	–	–	–
Dinobryon cylindricum O. E. Imhof	P-B	–	–	1.20	o	i	–	–
Dinobryon eurystoma (A. Stokes) Lemmermann	P-B	–	–	1.20	o	–	–	–
Dinobryon sertularia Ehrenberg	P-B	–	–	1.30	o	i	–	–
Dinobryon sociale (Ehrenberg) Ehrenberg	P	–	–	1.20	o	i	–	–
Dinobryon asymmetricum D. G. Hilliard and B. C. Asmund	P	–	–	1.20	o	–	–	–
Ducellieria chodatii (Ducellier) Teiling	–	–	–	–	–	–	–	–
Epipyxis utriculus (Ehrenberg) Ehrenberg	Ep	–	–	1.20	o	–	–	–
Mallomonas spinulosa Conrad	–	–	–	–	–	–	–	–
Mallomonas teilingii Conrad	P	–	–	1.60	b-o	–	–	–
Ophiocytium parvulum (Perty) A. Braun	B	–	–	1.30	o	oh	–	–
Salpingoeca gracilis H. J. Clark	–	–	–	–	–	–	–	–
Stokesiella epipyxis Pascher	–	–	–	–	–	–	–	–
Trachychloron ellipsoideum (Pascher) Pascher	–	–	–	–	–	–	–	–
Tribonema crassum Pascher	–	–	–	–	–	–	–	–
Tribonema spirotaenia Ettl	–	–	–	–	–	–	–	–
Tribonema ulotrichoides Pascher	B	–	–	1.30	o	–	–	–
Tribonema vulgare Pascher	P-B	–	–	1.40	o-b	i	–	–
Rhodophyta								
Audouinella chalybea (Roth) Bory	B	–	str	1.00	x-o	–	alf	–

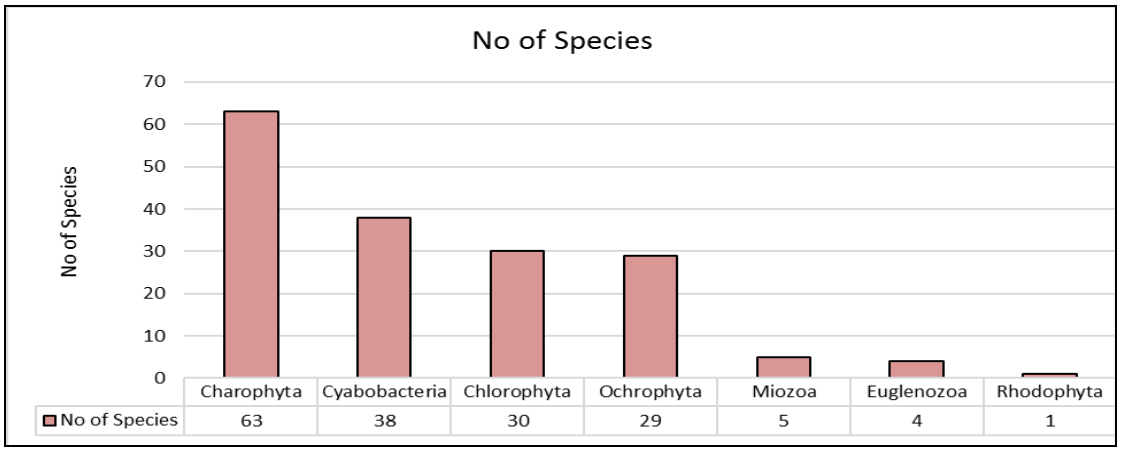

Figure 2: Species distribution over taxonomic phyla of non-diatom algae in the studied area.

Bioindicators

Algae form the basis of the trophic pyramid. Each species is able to survive only under certain environmental parameters. The maximum development of the species is achieved in the amplitude of the optimum parameter of the environment. Bioindication methods are based on this (Dokulil, 2003; Barinova, 2017a). If a species is found in a community of organisms inhabiting a particular water body, then the ecological amplitudes of the identified species can be used to characterize their habitat. Thus, the indication of environmental parameters for the organisms inhabiting it is based on the ecological amplitude of the environmental parameters within which a particular species survives, as well as the community in which it enters. Indication systems have been developed for several environmental parameters. For a species that is an indicator of a specific environmental parameter, the parameters of its optimal development are determined. Since the ecological preferences of species are species-specific, groups of species whose optimums correspond to certain intervals of the environmental index constitute groups of indicators. Thus, the identified species belongs to the group of indicators that develop in certain values of the environmental parameter. If we have identified representatives of this group of species, then, consequently, the amplitude of the parameter of the environment in which the species was found is determined. Each species of algae can indicate several environmental parameters. Thus, a species community can indicate the amplitudes of several environmental parameters and thus characterize the amplitudes of environmental parameters in which the community lived.

The ecological preferences of species can help characterize the habitat conditions for such remote and little explored mountain lakes as the lake on the Suntar-Khayat ridge. From table 1 it can be seen that more than 95% of the identified list of species were indicators. As can be seen from the distribution of indicators by ecological groups, benthic and planktonic-benthic species prevailed; however, planktonic species were also represented in the lake community (Fig. 3a). A very unusual distribution was observed among indicators of water saturation with oxygen (Fig. 3b). Slowly moving water species, moderately enriched with oxygen, dominated, but aerophilic species were in second place. They are adapted to living in waters with high oxygen saturation, that is, they characterize the waters of the lake as well aerated. Among water pH indicators, acidophiles predominated (Fig. 3c), but indifferent were also fairly well represented. The waters of the lake can be characterized as strictly fresh by the predominance of salinity indicators from the group of indifferent (Fig. 3d).

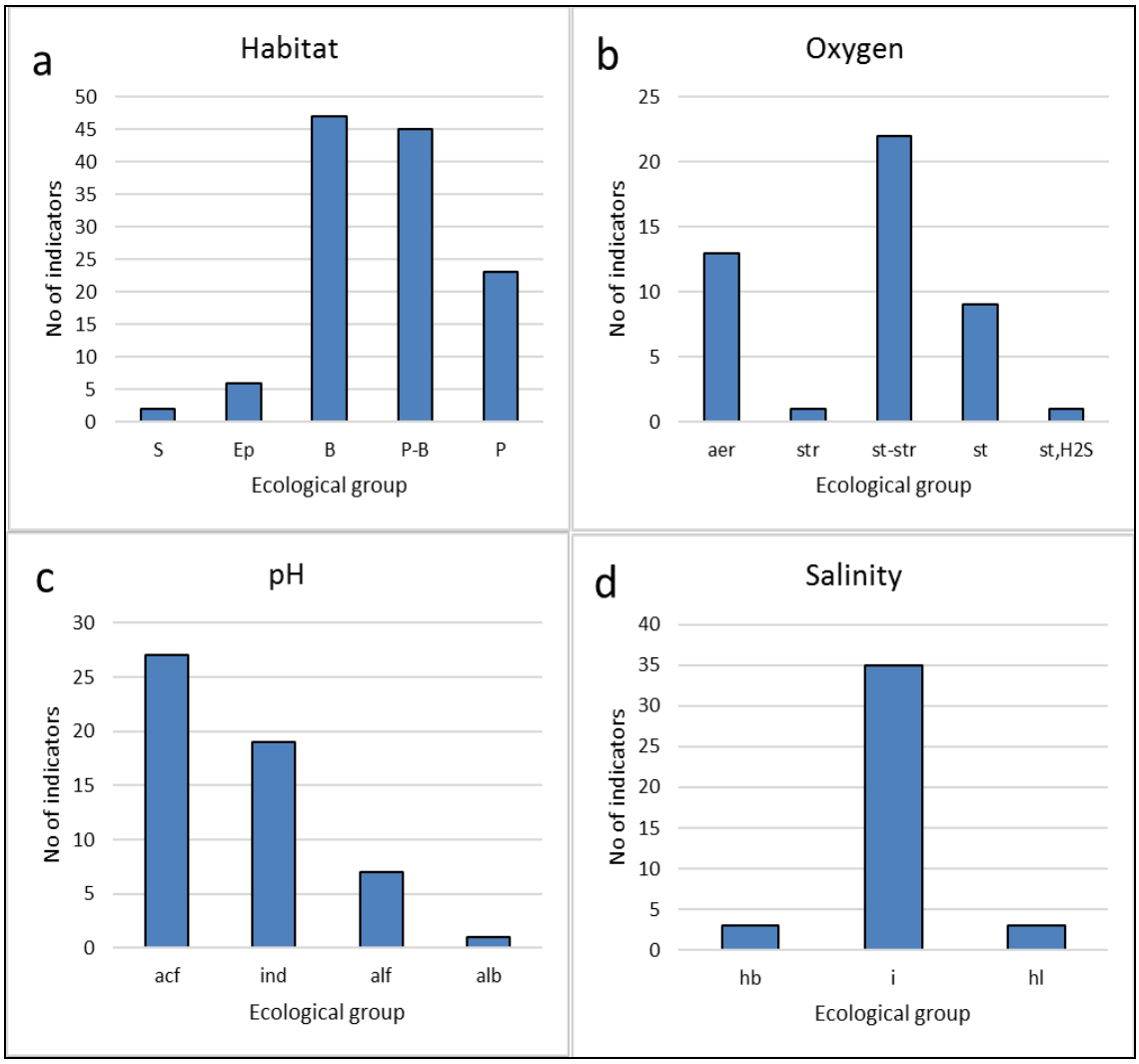

Figure 3: Indicator species distribution over ecological groups of habitats (a), oxygenation (b), water pH (c), and salinity (d) in the of non-diatom algae of the lake in the Suntar-Khayat ridge, (Republic Sakha, Yakutia).

Considerable interest arises in the analysis of the saturation of lake waters with organic matter and its trophic state.

As can be seen from figure 4a, the distribution by water quality classes calculated from the species-specific saprobity indices from table 1 characterizes the waters of the lake as weakly saturated with organic matter, 2 purity classes.

Groups of trophic indicators show the mesotrophic state of the lake (Fig. 4b).

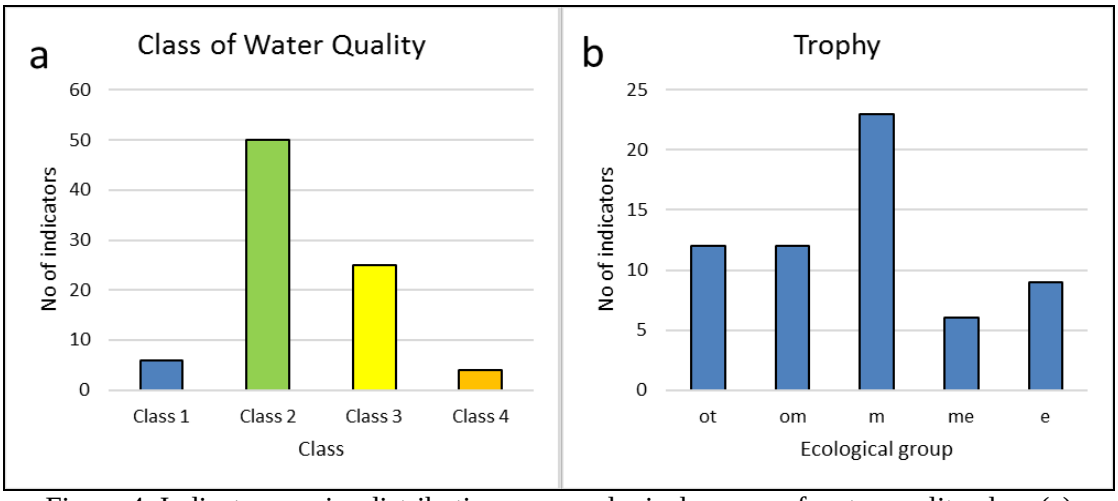

Figure 4: Indicator species distribution over ecological groups of water quality class (a) and trophic state (b) of non-diatom algae of the lake in the Suntar-Khayat ridge.

Comparative statistics

In order to understand what place the revealed flora of non-diatoms belongs among other previously studied lacustrine floras of Yakutia, a comparative floristic analysis was carried out. The comparison included only non-diatoms from nine lakes studied in detail (Kopyrina et al., 2020) and lakes on the Suntar-Khayat ridge. A general list was compiled with the reduction of the species composition to modern taxonomy. Thus, 489 species of non-diatoms from 10 lakes were included in this calculation (Tab. 2).

Table 2: Distribution of the number of non-diatom species in the floras of the studied lakes of Yakutia.

Lake	Code	Terraces	No. of non-diatom species
Suntar-Khayat	S-Kh	Suntar-Khayat	170
Aalah	B-Aal	Bestyakhskaya	174
Kurelah	B-Kur	Bestyakhskaya	98
Sullah	B-Sul	Bestyakhskaya	33
Dyiere	B-Dyi	Bestyakhskaya	52
Ynah	T-Yna	Tyungulyunskaya	109
Nal Tungulu	T-NalT	Tyungulyunskaya	65
Tungulu	T-Tun	Tyungulyunskaya	68
Abalah	A-Aba	Abalahskaya	53
Nidzhili	L-Nid	Lena-Viluyskaya	57

The flora of Lake Aalah on the Bestyakhskaya terrace near the Lena River was the most similar in terms of species richness of non-diatoms to the flora of Lake Suntar-Khayat (Tab. 2). Lake Aalakh is located approximately at the same latitude (63°3'N) as the lake under study (63°0'N), and also has a close surface area (0.052 km^2), moreover, the number of non-diatoms in it (174) is close to the studied lake (170), as well as the number of species per lake

area (64.7). Despite the similarity of the general floristic parameters, both lakes differ significantly in the species composition of non-diatoms, since in the Aalakh, charophytes make up less than a third, along with green and cyanobacteria. The index of intraspecific polymorphism in Lake Aalakh is also higher (1.034) than in the studied lake (1.006). That is, the flora of Suntar-Khayat Lake differs markedly from the floras of the lakes studied earlier.

Comparison of the species composition according to Bray-Curtis (Fig. 5) of the floras of non-diatom algae from 10 lakes of Yakutia demonstrated five clusters. The flora of the lakes located on the terraces of the Lena River (clusters 1-3) was the most similar, but the flora of the Nidzhili Lake was differed from them and located to the north (cluster 4). The studied flora occupies a special place in the tree, forming cluster 5 with a similarity level of less than 10%.

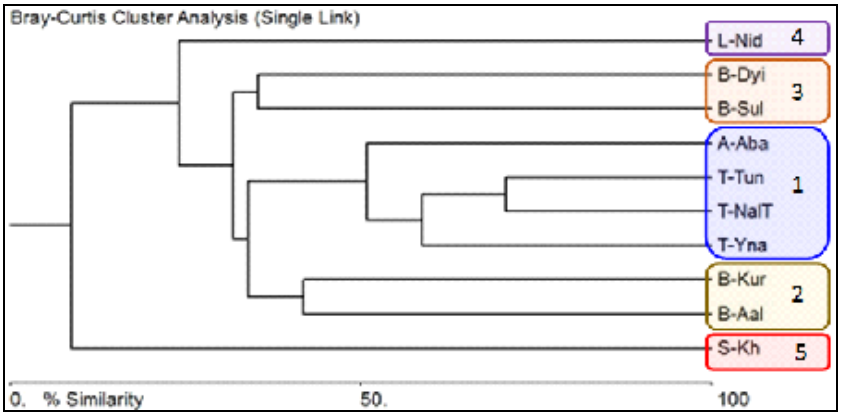

Figure 5: Similarity three of the of non-diatom algae in nine lakes of Yakutia and the lake in the Suntar-Khayat ridge.

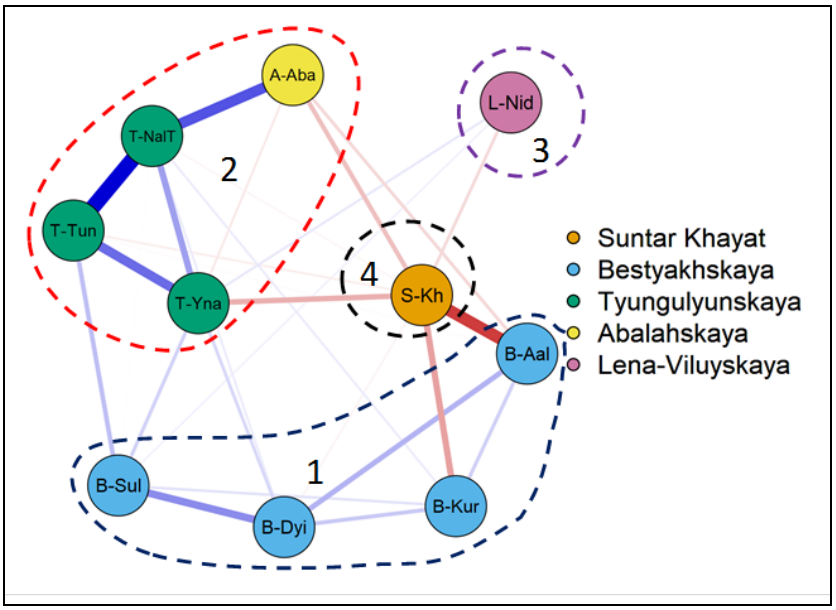

Figure 6: JASP network plot for correlation of the non-diatom algae species in nine lakes of Yakutia and the lake in the Suntar-Khayat ridge; dashed lines outlined the clusters, blue lines are positive correlation, and red lines are the negative correlation; the lines thickness reflects of the correlation power.

The calculation of the correlations of the species composition of 10 lakes showed (Fig. 6) that cluster 1 is formed by the species compositions of the lakes of the Bestyakhskaya terrace, which are in similar natural conditions, including Lake Aalakh. Cluster 2 is composed of correlating species compositions of non-diatom floras from the lakes of the Tyungulun terrace and Lake Abalakh. Cluster 3 corresponds to the unique flora of Lake Nidzhili. The flora of non-diatoms of the studied lake on the Suntar-Khayat ridge show not only a difference from all the floras of 9 lakes (cluster 4), but its species composition also significantly negatively correlates with the species composition of Lake Aalakh, which is similar in general floristic parameters. Thus, the non-diatom flora of the lake on the Suntar-Khayat ridge can be characterized as peculiar, unique in species composition, and with low species polymorphism.

DISCUSSION

Preliminary studies carried out on a lake located in the Suntar-Khayat ridge allowed to identify 170 species of non-diatoms in addition to 112 diatoms (Potapova et al., 2014). Thus, the total floristic composition of the studied lake reached 282 species. Since the survey of this hard-to-reach lake was carried out once, we can assume that its flora can be significantly replenished in the course of further research. However, even at this initial stage, it can be seen that the species composition is quite large and comparable with the floras of previously studied non-diatom lakes in a similar climatic zone or high-mountain habitats (Denisov and Barinova, 2015; Krupa et al., 2016; Barinova and Niyatbekov, 2018; Tsarenko et al., 2021). It is possible that the species richness of the studied samples represents practically the maximum species composition, since the lake was surveyed in detail and during the most favorable period for the development of algae in this region, in August.

The most significant differences in the studied flora were the predominance of charophyte algae with the dominance of the species composition of the genera *Cosmarium* and *Closterium* (Tab. 1). This is comparable to the distribution of the generic composition of the flora in the Artabel Lakes, located at 2,600-3,000 m a.s.l. in northeastern Turkey (Şahin et al., 2020). Here, among 73 species of charophytes, 37 *Cosmarium* and seven *Closterium* species are represented. For other floras studied in the altitude gradient, it turned out that the increase in habitat or desertification leads to similar trends in the structure of the algae flora, namely, an increase in the role of non-diatoms in general and charophytes and greens in particular. This allows us to confirm that non-diatoms are more competitive under conditions of climatic stress (Barinova et al., 2011; Barinova and Alster, 2021). The revealed structure of the taxonomic composition of the lake flora on the Suntar-Khayat ridge can be considered evidence of a climatic impact on the process of formation of lake floras in the Arctic climatic conditions stress previously shown for river floras (Barinova et al., 2015; Barinova, 2017).

Even only, the high saturation of the algal flora with the genera *Cosmarium* and *Closterium* can characterize the flora of the lake as unique. However, besides this, calculations of general floristic parameters were carried out in order to confirm this. It turned out that the intraspecific polymorphism of non-diatoms in the studied lake is at an extremely low level, amounting to only 1.006. That is, the flora is practically monospecific. This drew attention to other methods for comparing its species composition with the floras of previously studied lakes in the region (Kopyrina et al., 2020). Whereas the total species richness of non-diatoms was close in the studied lake and Lake Aalakh, the first terrace of the Lena River, located at the same latitude, the actual species composition differed significantly. The calculations of the similarity (Fig. 5) and correlation (Fig. 6) of the species composition of 10 non-diatom lakes revealed the uniqueness of the flora of the studied lake.

Moreover, the correlation analysis showed a strong negative correlation even between lakes similar in other floristic parameters, such as Suntar-Khayat and Lake Aalakh. That is, the flora of the studied lake remains so unique in this region that it does not reveal the influence on its species composition of general climatic influences characteristic of the terraced lakes of the Lena River. Previously, it was shown that floras are similar in lakes located on terraces that are, having a common origin (Kopyrina et al., 2020). However, the lake under study is located at an altitude of 1,300 m a.s.l. and thus differs in its origin precisely in this parameter. Identification of uniqueness has been made possible with the use of new or rarely used variables, such as indices of the number of species per unit area, intraspecific polymorphism index and statistical methods, actively developed for floristic and hydrobiological studies (Dedić et al., 2020).

In order to identify the characteristics of the environment in which the studied flora develops, a bioindicator analysis was carried out in addition to the measured parameters of the environment. Due to lake inaccessibility, the chemical parameters were determined in a very limited composition and characterized the waters of the lake as neutral pH (7.2), fresh, hydrocarbonate class, with a temperature of 16.2°C, and a transparency of about one m. However, bioindication helped us significantly supplement the characteristics of the environment of the studied lake. It turned out that algae most of all mastered the benthic and plankton-benthic lifestyle, however, planktonic species were also found. Groups of acidophiles, low salinity, and eurythermal inhabitants dominated and characterized the waters of the lake as mesotrophic Class 2 of water quality, which is, weakly saturated with organic matter. The uniqueness of the identified flora was manifested in an unusually high proportion of aerophiles that prefer waters significantly enriched with oxygen. Thus, bioindication helped to characterize the waters of the lake as clean, fresh and slightly saturated with organic matter, neutral or slightly acidic pH and moderate in temperature, and the lake itself as mesotrophic with a unique species composition of non-diatom algae.

CONCLUSION

The study of the species composition of the lentic water bodies of Yakutia has been carried out for a number of years. The floras of lakes can more accurately characterize the influence of macro climatic parameters on the process of the flora formation, while river floras are subject to influences associated with the flow and change of latitude. The flora of the lake on the Suntar-Khayat ridge turned out to be rich, including 170 species of non-diatom algae, comparable in richness to the flora of Lake Aalakh, but differing so much in the composition of the identified species that even unlike it, it formed a special cluster among the 10 compared lake floras. The uniqueness was formed by the dominance of the species composition of Charophytes in general and the genera *Cosmarium* and *Closterium*, in particular. Bioindicator characteristics demonstrated a significant number of aerophilic species that prefer oxygen-enriched waters. The calculation of floristic parameters showed a uniquely low intraspecific polymorphism with an index Ssp/Sp = 1.006, comparable with the desert and mountain floras of Israel and the Caucasus. Thus, the monospecificity of the flora and its adherence to waters enriched with oxygen revealed the influence of the mountainous desert climate on the formation of the flora of non-diatoms, and the Charophytes genera *Cosmarium* and *Closterium*, as the most adapted to these conditions.

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