Original Research Article

Cyanobacteria and microalgae of the shallow mountain lake Paučko, Konjuh Mountain

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ABSTRACT

The mountain lake Paučko is the only natural lake in Protected landscape Konjuh in northeastern Bosnia and Herzegovina. Shallow mountain lakes are highly sensitive to eutrophication. This study presents results on diversity of cyanobacteria and microalgae of the lake Paučko, physical and chemical analysis and evaluation of trophic status. Sampling of net – phytoplankton, periphyton and water for physical and chemical analysis was caried in two seasons in 2018. Light microscopes and immersion objective (magnification 1000x) were used for the identification and quantification of microalgae. Non metric multimensional scaling and Simper analysis were used to describe communities in periphytic and planktic samples. In total, 70 taxa were identified. The most numerous were Bacillariophyta with 52, and Chlorophyta with 7 taxa. Seasonal dynamics in plankton communities were observed in the direction of shift of abundant *Cyclotella meneghiniana*, *Dinobryon divergens*, *Peridinum cinctum* and *Ankistrodesmus fusiformus* in spring season to *Rabdoderma lineare* and *Pantocsekiella comensis* in summer sampling season. Physical and chemical analysis of water revealed high values of total phosphorus, which correspond to the evaluated meso to eutrophic status of the lake calculated by Rott Trophic Index. The lake Paučko is under high pressure caused by the influx and retention of nutrients, which makes it susceptible to eutrophication.

Keywords: cyanobacteria, microalgae, diversity, trophic status, phytoplankton, periphyton, mountain shallow lake

1. INTRODUCTION

Microalgae are unicellular photosynthetic microorganisms, that may exist independently or in colonies, able to uptake CO_2 from both the atmosphere and flue gas emissions, converting it into biomass or other organic compounds, living in saline or freshwater environments [1]. Microalgae are usually characterized by a short generation time, and respond rapidly to environmental changes, what makes them a good indicator of the water quality [2]. Microalgae also include microscopic cyanobacteria. Cyanobacteria are a very diverse group of prokaryotic organisms that were historically considered as “blue-green algae”. In contrast to other prokaryotes (bacteria and archaea), they perform oxygenic photosynthesis and possess chlorophyll-a [3]. Cyanobacteria are among the most abundant and potent primary producers on Earth, occurred in different aquatic and terrestrial habitats [4], whilst diazotrophic cyanobacteria are major players in global nitrogen fixation [5]. Many of cyanobacteria produce unique secondary metabolites, such as toxins [6], and cause blooms, which results from an overabundance of planktic forms, having a large negative impact [7], Cyanobacteria and microalgae are often used in the evaluation of ecological status of freshwaters. The Water Framework Directive 2000/60/EC obliges monitoring of lakes including biological elements as indicators, but smaller lakes are not an integral part of monitoring. Small mountain lakes can have exceptional conservation value, but are highly susceptible to eutrophication.

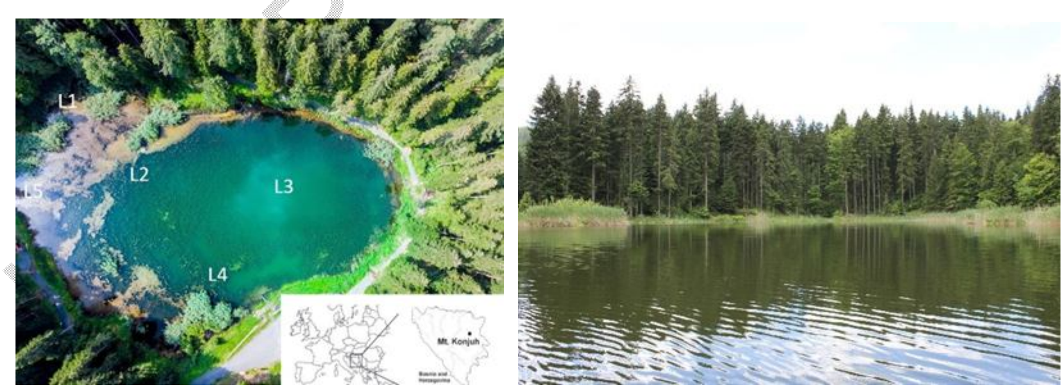
The Paučko lake is a small mountain water body, located in Protected Landscape Konjuh and recognized as an area of natural, landscape and hydrological value in northeastern Bosnia and Herzegovina. The lake is not on the list of monitoring stations due to its small size, and recent studies of macrophytes point to the problem of accelerated overgrowth of the lake with aquatic vegetation of weed taxa *Myriophyllum spicatum* which threatens the disappearance of endangered species in lake [8]. On the other hand, there is a lack of published data on algal research of the lake Paučko on the Konjuh Mt. Algological research on Mt. Konjuh was carried out on springs and streams [9, 10], whilst researches on the lakes and rivers of northeastern Bosnia and Herzegovina have been more frequent in the last few years [11, 12]. Cyanobacteria and microalgae can reflect changes in the environment and indicates changes and the state of the ecosystem.

Due to the need to preserve a small mountain lake, the aim of this work is to investigate the structure and ecological characterization of the planktic and periphytic communities of cyanobacteria and microalgae, along with the physical and chemical analysis and the evaluation of the ecological status of the lake.

2. MATERIAL AND METHODS

2.1 Study area

The lake Paučko is a small lake located at 711 m a.s.l. in the catchment area of the Drinjača River in the Protected Landscape Konjuh, northeastern Bosnia and Herzegovina (N 44°14´01.61˝, E 18°36´05.51˝). The maximum length of the lake is 150 meters, and the width is about 100 meters, the maximum depth is 5 meters. The catchment area of the lake is 35.6 ha. The Paučko Lake is fed by an underground water source and a stream into which water gravitates from the basin of the surrounding area Water from the lake flows into a smaller stream. The area is characterized by moderate-continental [13]. Due to torrential flows, the lake is subject to the natural process of filling with sediment.



a) b)

Fig. 1. Study area – Paučko Lake (a - photo by A. Čamdžić, b – photo by J. Kamberović, 2018)

2.2 Methods

Sampling was carried out at 5 locations (L1-L5) in May (marked with a) and August (marked with b) in 2018 (Figure 1). These months were selected based on their hydrologic conditions, where May is typical for higher water precipitation and spring season. In situ measurements of water temperature, pH, conductivity, oxygen concentration and saturation were done with a multimeter HQ 40d, 30d flexy multi, HACH. Physical and chemical analysis of the following parameters were done in the laboratory according to standardized methodology [14]: turbidity, biological oxygen demand (BOD_5), dichromate chemical oxygen demand (COD dichromate), permanganate chemical oxygen demand (COD permanganate), total nitrogen (TN), nitrate ($N\text{-}NO_3^-$), nitrite ($N\text{-}NO_2^-$), ammonium ($N\text{-}NH_4^+$), total phosphorus (TP), orto-phosphate ($P\text{-}PO4_3^-$), total suspended solids (TSS), alkalinity, total hardness, ions of calcium (Ca^{2+}), magnesium (Mg^{2+}), sulphates (SO_4^{2-}), and chloride (Cl^-).

Samples 1 and 5 are phytobenthic samples taken at the inlet and outlet streams of the lake, respectively, using the method BAS EN15708:2011. Phytoplankton samples 2, 3, and 4 were taken using a phytoplankton net with mesh spacing of 25 µm for qualitative analysis, following the methodology described in EN 16698:2015. Samples were preserved with a buffered 4% formaldehyde solution. Non-diatom species were identified in fresh samples, whilst diatoms were acid cleaned [15], and mounted in Naphrax (Brunel Microscopes Ltd., U.K.). Quantitative analysis of phytoplankton samples was determined via relative abundance using a six-step scale (1, 2, 3, 5, 7, 9). Light microscopes (Motic) and immersion objective (magnification 1000x) were used for the identification and quantification of microalgae. Identification of cyanobacteria and microalgae was performed using literature [16-27].

The saprobic status of the lake (Saprobic Index) was calculated on the basis of a list of indicator organisms according to Wegl [28], using the Pantle-Buck Index [29]. Ecological status is determined according to guidelines Official Gazette of Republika Srpska 42/01 [30]. Additionally, the diatom trophic index (TI) by Rott et al. [31] was used in the evaluation of trophic status of the lake ecosystem.

Statistical analysis was performed in package Primer 7.0 [32]. All data were transformed by using the square root function prior to statistical analyses. Non-metric multidimensional scaling (nMDS) and hierarchical group average clustering based on scale abundance were used for ordering locations. The ordination was conducted on the Bray-Curtis similarity matrix of species data. Simper analysis were conducted for determination of contribution of taxa to assemblages caused by different factors. Diversity of cyanobacteria and microalgae was calculated by using species richness (S) as the number of identified taxa, and the Shannon index of species diversity *H'*(ln).

3. RESULTS

3.1 Physical and chemical variables of the lake Paučko

The physical and chemical variables measured at the sampling location are shown in Table 1. The water temperature in the Lake (L2-L4) varied between the lowest measured in May (15.2 °C) to the highest measured in August (23.8 °C). The lake Paučko is a weakly alkaline to alkaline (pH varied among 8.48 – 9.11) shallow lake with moderate conductivity, good oxygen saturation, high alkalinity, mostly low content of total nitrogen and nitrogen oxides, sulphates and chlorides. However, high values of total phosphorus and orthophosphates were measured in both sampling series corresponding to the polytrophic status of the Lake. Inlet stream (L1) is characterized by the lower temperature and higher values of total nitrogen in comparison to the outlet stream (L5).

Table 1. Physical and chemicals variables of water measured at the sampling locations on the lake Paučko

Location code	L1a	L1b	L2a	L2b	L3a	L3b	L4a	L4b	L5a	L5b
Temperature °C	10	14.1	16.8	21.9	17.9	23.7	15.2	23.8	18.4	19.2
pH	9.33	8.48	9.01	8.68	8.96	8.49	9.11	8.63	9.36	8.61
Cond (µS cm^{-1})	275	376	420	439	397	458	418	405	265	436
Turbidity (NTU)	2.13	1.49	2.71	5.6	2.86	3.87	3.34	3.92	3.54	4
Secchi depth (m)			2	1.3	2	1	1.2	1		
Oxygen (mgL^{-1})	10.07	9.41	8.46	12.04	10.51	6.79	11.37	11.03	10.67	9.66
O_2 saturation (%)	97.1	99.2	96.2	149.5	120.8	87.3	129.4	142.4	123.6	113.5
BOD_5 (mgL^{-1})	1.01	0.93	2.14	1.37	2.17	3.36	2.32	1.2	2.32	1.5
COD dichromate (mgL^{-1})	7.98	10.49	9.12	12.14	10.83	14.9	11.4	9.94	11.97	11.59
COD permanganate (mgL^{-1})	2.4	3.2	3.6	4.16	3.92	5.68	4.48	2.4	4.48	4
TN (mgL^{-1})	1.001	1.059	0.256	0.425	0.174	0.276	0.145	0.319	0.144	0.235
$N\text{-}NO_3^-$ (mgL^{-1})	0.99	1.05	0.24	0.33	0.16	0.21	0.13	0.27	0.13	0.19
$N\text{-}NO_2^-$ (mgL^{-1})	0.011	0.009	0.016	0.015	0.018	0.016	0.015	0.019	0.03	0.015
$N\text{-}NH_4^+$ (mgL^{-1})	0.02	0.01	0.03	0.08	0.03	0.05	0.04	0.03	0.03	0.03
$P\text{-}PO_4^{3-}$(mgL^{-1})	0.178	0.543	0.07	0.11	0.06	0.11	0.13	0.11	0.01	0.09
TP (mgL^{-1})	0.05	0.28	0.174	0.209	0.4	0.191	0.555	0.114	0.271	0.174
TSS (mgL^{-1})	10	0.5	10	3.8	6	2.8	8	12.4	9.8	2.6
Alkalinity (mg $CaCO_3$ L^{-1})	170	170	205	220	200	220	205	220	205	205
Total hardness (mg $CaCO_3$ L^{-1})	66	76	66	72	70	72	70	70	66	72
Ca^{2+} (mgL^{-1})	24.05	28.06	24.05	25.65	25.65	25.65	25.65	24.85	24.05	25.65
Mg^{2+} (mgL^{-1})	1.46	1.46	1.46	1.94	1.46	1.46	1.46	1.94	1.46	1.94
SO_4^{2-}(mgL^{-1})	3.6	4.7	5.3	6.2	5.9	6.9	5.3	6.6	5.4	6.4
Cl^- (mgL^{-1})	6.13	6.6	5.19	6.13	4.71	5.19	4.71	5.19	4.71	5.19

3.2 Cyanobacteria and microalgae of the lake Paučko

In total, 70 taxa were identified in both sampling series. The most numerous were Bacillariophyta with 52, and Chlorophyta with 7 taxa. Cyanobacteria, Pyrrophycophyta, Xanthophyta, Charophyta were represented with only a few taxa (Table 2). The greatest number of taxa was found in the net-phytoplankton sample in the spring season (L2a – 28 taxa), and lowest number were identified in plankton sample L3b in summer season (8 taxa). The following taxa were identified with high abundance in at least one sample: *Rhabdoderma lineare*, *Achnanthidium minutissimum*, *Cyclotella meneghiniana*, *Cymbella dorsenotata*, *Encyonopsis microcephala*, *Odontidium mesodon*, *Planothidium lanceolatum* and *Staurosira construens*.

Table 2. The list of idientified cyanobacteria and microalge of the Paučko Lake

Locations/taxa	L1a	L1b	L2a	L2b	L3a	L3b	L4a	L4b	L5a	L5b	Per. Fr.	Pl. Fr.	Spring Fr.	Summer Fr.
Cyanobacteria														
Aphanocapsa sp.							3	2				2	1	1
Chroococcus dispersus (Keissler) Lemmermann			3	1	2	2	2					5	3	2
Rhabdoderma lineare Schmidle & Lauterborn			2	2			3	5				4	2	2
Spirulina major Kützing ex Gomont					1		1					2	2	
Pyrrophycophyta														
Dinococcus oedogonii (P.Richter) Fott				1			1					2	1	1
Peridinium cinctum (O.F.Müller) Ehrenberg			2	1	2	1	2					5	3	2
Chrysophyta														
Dinobryon divergens O.E.Imhof			2		3		2					3	3	
Xanthophyta														
Vaucheria sp.	3										1		1	
Bacillariophyta														
Achnanthidium affine (Grunow) Czarnecki										2	1			1
Achnanthidium minutissimum (Kützing) Czarnecki	1	2	2		2				5	7	4	2	4	2
Achnanthidium neomicrocephalum Lange-Bertalot & F.Staab			2				2	2	3		1	3	3	1
Amphipleura pellucida (Kützing) Kützing	1								1		2		2	
Amphora copulata (Kützing) Schoeman & R.E.M.Archibald	1								1		2		2	
Amphora pediculus (Kützing) Grunow	1									1	2		1	1
Amphora stechlinensis Levkov & Metzeltin			1									1	1	
Brachysira neoexilis Lange-Bertalot				1						1	1	1		2
Cocconeis pediculus Ehrenberg								1				1		1
Cocconeis placentula Ehrenberg	2	1	1	2				1		2	3	3	2	4
Cocconeis pseudolineata (Geitler) Lange-Bertalot		3									1			1
Cyclotella meneghiniana Kützing			7	1	7	3	7		1		1	5	4	2
Cymbella dorsenotata Østrup			2	5	1	1	2	3	2	2	2	6	4	4
Cymbella excisa Kützing										3	1			1
Cymbella vulgata Krammer				2	1	1						3	1	2
Cymbopleura inaequalis (Ehrenberg) Kram			3	2	1		2	2	1		1	5	4	2
Denticula tenuis Kützing				1	1		1	1		1	1	4	2	3
Encyonema minutum (Hilse) D.G.Mann	1		1	2		2	2		3		2	4	4	2
Encyonopsis microcephala (Grunow) Krammer			1	1				2		5	1	3	1	3
Epithemia adnata (Kützing) Brébisson			1	1				1	1	1	2	3	2	3
Eucocconeis flexella (Kützing) Meister				1					1		1	1	1	1
Eunotia tenella (Grunow) Hustedt			1		1		1	1				4	3	1
Fragilaria acus (Kützing) Lange-Bertalot										1	1			1
Fragilaria gracilis Østrup								1				1		1
Gomphonema auritum A.Braun ex Kützing				1						3	1	1		2
Gomphonema parvulum (Kützing) Kützing	1								2	3	3		2	1
Gomphonema pumilum (Grunow) E.Reichardt & Lange-Bertalot		1									1			1

Gomphonema pumilum var. *elegans* E.Reichardt & Lange-Bertalot							1					1	1	
Gomphonema subclavatum (Grunow) Grunow				1								1		1
Gomphonema truncatum Ehrenberg								1		1	1	1		2
Gyrosigma acuminatum (Kützing) Rabenhorst				1								1		1
Halamphora veneta (Kützing) Levkov				1			1					2	1	1
Meridion circulare (Greville) C.Agardh	1										1		1	
Navicula oblonga (Kützing) Kützing				1								1		1
Navicula radiosa Kützing								1	1		1	1	1	1
Navicula sp.					1							1	1	
Navicula tripunctata (O.F.Müller) Bory	1	1									2		1	1
Navicula veneta Kützing		1								1	2			2
Nitzschia denticula Grunow			1									1	1	
Nitzschia lacuum Lange-Bertalot			1	1								2	1	1
Nitzschia linearis W.Smith	3										1		1	
Nitzschia sp.					1	1	1					3	2	1
Odontidium mesodon (Kützing) Kützing	5										1		1	
Pantocsekiella comensis (Grunow) K.T.Kiss & E.Ács			2		2	1		2		1	1	4	2	3
Pinnularia sp.			1									1	1	
Pinnularia subgibba Krammer		1									1			1
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	3	5									2		1	1
Rhopalodia gibba (Ehrenberg) Otto Müller			1					1				2	1	1
Stauroneis smithii Grunow									1		1		1	
Staurosira construens Ehrenberg			3	3	2		5	5	1	1	2	5	4	3
Ulnaria capitata (Ehrenberg) Compère					1		1	1				3	2	1
Ulnaria ulna (Nitzsch) Compère			1	1			1	1	1	1	2	4	3	3
Chlorophyta														
Ankistrodesmus fusiformis Corda			3		3		3	2				4	3	1
Celochaete sp.			1									1	1	
Chaetomorpha linum (O.F.Müller) Kützing				2				2				2		2
Desmodesmus communis (E.Hegewald) E.Hegewald			1		1		1					3	3	
Pediastrum boryanum			1		1		1	1				4	3	1
Scenedesmus acuminatus (Lagerheim) Chodat			1				1					2	2	
Sphaerocystis schroeteri Chodat			2				1					2	2	
Charophyta – Zygnematophyceae														
Staurastrum polymorphum Brébisson				1								1		1
Closterium moniliferum Ehrenberg ex Ralfs				3								1		1
Klebsormidiaceae							1	1				2	1	1
Number of taxa	13	8	28	26	19	8	26	23	15	18	36	52	52	52

*L1, L5 – periphyton samples, L2, L3, L4 – plankton samples; Per. Fr. – frequency as number of periphyton samples, Pl. Fr. – frequency as number of phytoplankton samples

Hierarchical group average clustering and the non-metric MDS identified 3 assemblages (Figure 2), mainly related to sample type: two groups of periphyton of inlet (L1a, L2b) and outlet stream (L5a, L5b), and one group of phytoplankton samples of both seasons of sampling (L3ab – L4ab). Simper analysis of samples according to sample type revealed 25.26% similarity among periphytic samples, and 43.6% similarity among phytoplankton samples. Periphytic samples were characterized by following taxa with cumulative contribution up to 70%: *Achnanthidium minutissimum*, *Cocconeis placentula*, *Gomphonema parvulum*, *Planothidium lanceolatum* and *Navicula tripunctata*. Crenophile diatom species *Odontidium mesodon* was dominant in spring season of inlet stream. In the outlet stream, in addition to the abundant *A. minutissimum* and *Encyonopsis microcephala*, common taxa for the plankton of the lake were found. Phytoplankton samples were characterized by following taxa with cumulative contribution up to 70%: *Cymbella dorsenotata*, *Cyclotella meneghiniana, Staurosira construens*, *Chroococcus dispersus*, *Peridinium cinctum*, *Cymbopleura inaequalis*, *Ankistrodesmus fusiformis*, *Pantocsekiella comensis*, *Encyonema minutum*, *Rhabdoderma lineare* and *Denticula tenuis*.

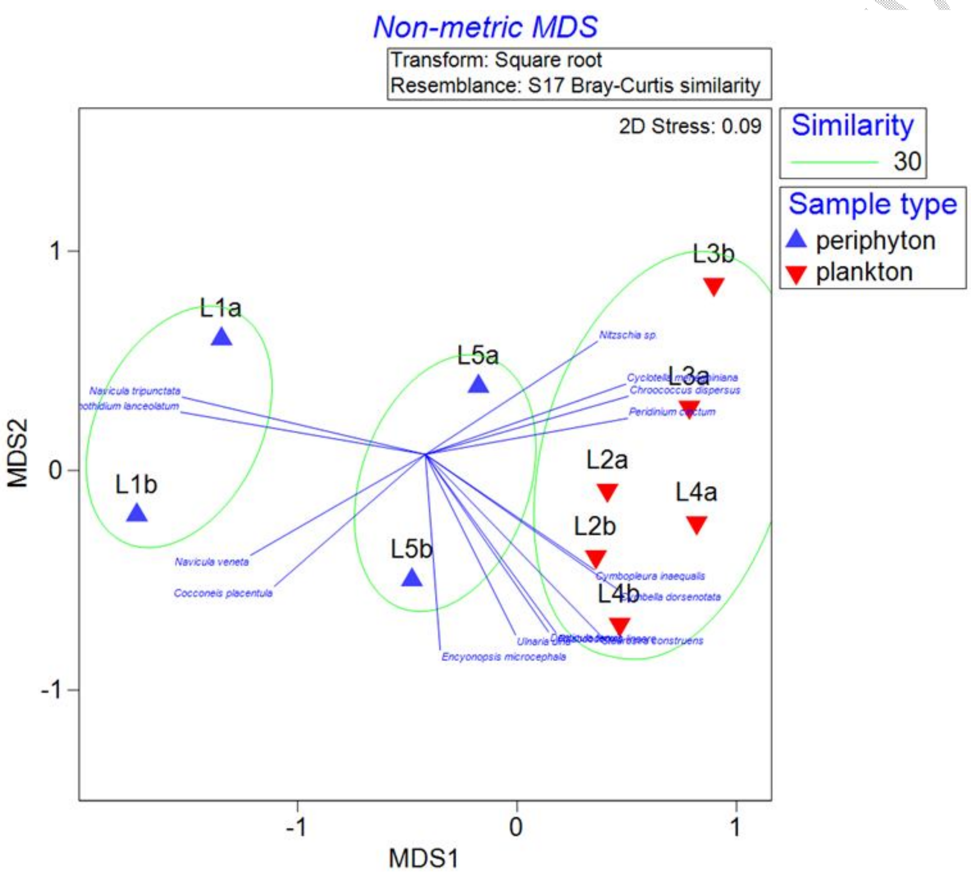


Fig. 2. Non-metric multidimensional scaling (nMDS) overlayed with clusters of group average clustering (30% of similarity) of locations based on Bray-Curtis matrix of similarities of microalgal assemblages in relation to sample type and Pearson correlation index of taxa (r>0.7).

In the analysis of the seasonal aspect, the following species were represented in the spring, and less common in the summer*: Cyclotella meneghiniana*, *Peridinium cinctum*, *Dinobryon divergens*, *Ankistrodesmus fusiformis* and *Chroococcus dispersus*. On the contrary, summer samples are typical for more abundant cyanobacteria *Rhabdoderma lineare* and diatom *Cymbella dorsenotata* (Figure 3). The frequent species *Staurosira contruens* remains more or less equally abundant in both sample series.

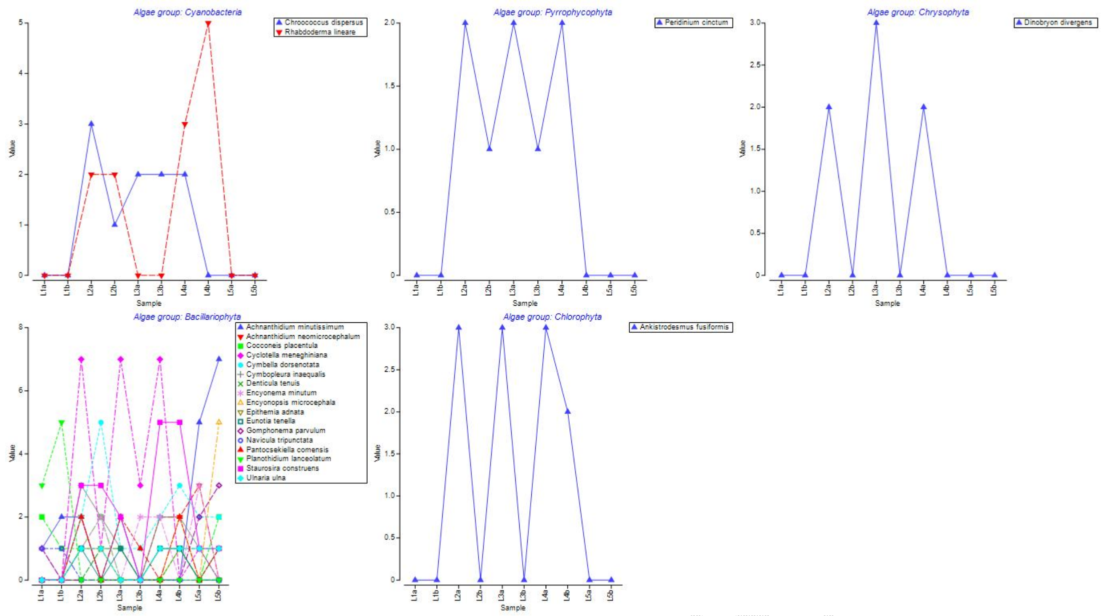


Fig. 3. Abundance of the most typical algal taxa per season fluctuation and sample locations according to the algal groups

Shannon index of diversity varied from 1.86 to 3.15 indicating moderate to high diversity of taxa, with slightly higher average value in spring (*H´*= 2.77) in comparison with summer samples (*H´*=2.51).

In total, 45.7 % of microalgal taxa were indicators according to Rott et al. (1999). The trophic index (TI) indicates the meso to eutrophic and eutrophic status of the lake Lake Paučko. Saprobic index (SI) by Pantle – Buck (1955) included 48.57 indicator taxa and varied among 1.69 – 2.19, with an average of 1.91, corresponding mostly to the betamesosaprobic level, and indicating good ecological status (Table 3).

Table 3. Diversity, trophic (TI) and saprobic (SI)/ecological status of the lake Paučko

Locations	*H´*	TI Rott	Trophic status	SI	Ecological status according to SI
L1a	2.37	2.023	Meso- to eutrophic	1.69	good
L1b	1.86	2.32	Meso- to eutrophic	1.95	good
L2a	3.15	2.49	Meso- to eutrophic	1.91	good
L2b	3.11	2.12	Meso- to eutrophic	1.86	good
L3a	2.73	2.56	Eutrophic	2.03	good
L3b	1.98	2.7	Eutrophic	2.19	good
L4a	3.05	2.54	Eutrophic	1.98	good
L4b	2.96	2.00	Mesotrophic	1.73	good
L5a	2.52	2.00	Mesotrophic	1.95	good
L5b	2.65	1.1	Oligo- to mesotrophic	1.86	good

** H´ - Shannon diversity index, TI Rott – Trophic Index Rott 1999, SI; Saprobic Index Pantle Buck, 1955*

4. DISCUSSION

In the analysis of community of cyanobacteria and microalgae, more taxa were found in plankton samples of the lake in comparison to periphytic samples of inlet and outlet streams. Many species of planktic cyanobacteria are well known as bloom formers and toxin producers in freshwaters [33]. Cynobacterial taxa specific for toxic bloom such as *Dolichospermum circinalis, Aphanizomenon flos–aquae, Cylindrospermopsis raciborskii, Microcystis aeruginosa* were not found in Paučko Lake, and only frequent cynobacteria in planktic sample were *Rhabdoderma lineare* and *Chroococcus dispersus*. *Rhabdoderma lineare*, previous known as *Synechococcus linearis* is a freshwater, planktic cynobacteria typical for oligo- to mesotrophic water bodies and common in temperate zones [34], whilst *Chroococcus is* distributed over the world. In the spring season, in planktic sample were abundant dinophyte *Peridinium cinctum*, and chrysophyte *Dinobryon divergens*. *Peridinium cinctum* is a common generalist species in freshwater ecosystems, characterized as oxyphilic inhabiting shallow mesotrophic to eutrophic water bodies [35]. Although most species of the genus *Dynobrion* are specific to oligotrophic and water with neutral pH, *D. divergens* can occasionally be found in water with high phosphate concentrations [36], which is the case with Paučko Lake.

Analyzing the composition of diatoms, *Cyclotella meneghiniana*, *Staurosira construens* and *Cymbella dorsenotata* were most abundant, first species during the spring, and other two species independent of the sampling series. *C. meneghiniana* can causes diatom bloom, which has been observed in the shallow middle reaches of the Hunter River, Australia. Optimal conditions for bloom are water temperature in the range of 23°C to 28°C, long retention time in the extended period for at least 12 days [37]. In this study, the abundance of C. *meneghiniana* was lower in the summer period with higher water temperature. Fragilarioids *Staurosira construens* is benthic/tychoplanktonic diatoms with a wide range of ecological preferences, capable of growing in shallow aquatic environments and littoral areas of flowing waters and deep lakes [38] with affinity for habitats covered with macrophytes [39]. The Paučko lake is inhabited with aquatic submerged competitive macrophyte species *Myriophyllum spicatum*, which covers almost the entire bottom of the lake in the summer aspect [8], which may be one of the reasons for the continued presence of fragilaroid forms of diatoms. Diatom *Pantocsekiella comensis* is occurred frequently in summer season in planktic samples. Previous studies revealed that this species occurred at high abundance in the plankton communities of alkaline montane lakes with high surface temperatures (>18°C), lover concentration of phosphorous and higher values of Ca^{2+} [40], Water temperature and weakly alkaline reaction could cause higher frequency of this taxa, despite the high phosphorous concentrations in the lake Paučko.

Chlorophyte such as *Ankistrodesmus* can overgrow freshwaters under high nutrient enrichment, and sometimes cause oxygen depletion in ponds and sheltered lake coves [41], *A. fusiformus* is identified in spring seasone in Paučko lake with moderate abundance.

Seasonal dynamics in plankton communities were observed in the direction of shift of abundant *C. meneghiniana, D. divergens, P. cinctum* and *A. fusiformus* in spring season to the R. *lineare* and *Pantocsekiella comensis* in the summer.

The lake is located in a forest area and is occasionally used by the local community as a picnic spot. However, it is characterized by a very high values of total phosphorus and low values of total nitrogen, which points to the enrichment of the lake with phosphorus through the infiltration of the forest land and the long-term retention of phosphorus in the lake due to accelerated growth and decomposition of plant mass. High values of total phosphorus correspond to the evaluated eutrophic status using trophic index.

The lake Paučko is under high pressure caused by gradual shallowing. Shallow lakes usually have a small volume and weak capacity to dilute input nutrients, resulting in high sensitivity to anthropogenic forcing. One of the threats that disrupt the ecosystem structure of the lake Paučko is the influx of nutrients, mostly through surface flows which encourage the development of macrophyte vegetation that rapidly overgrows the lake and reduces the surface of the water mirror. Bearing in mind the high value of nutrients in the lake, there is a risk of water bloom in the future, which implies undertaking restoration measures.

5. CONCLUSION

The lake Paučko is a weakly alkaline to alkaline shallow lake with moderate conductivity, good oxygen saturation, high alkalinity, mostly low content of total nitrogen and nitrogen oxides, and high concentrations of total phosphorus. In total, 70 cyanobacterial and microalgal taxa were identified in planktic and periphytic samples. The most numerous were Bacillariophyta with 52 taxa. Non metric multidimensional scaling and hierarchical clustering classified samples into three groups, mostly based on sample type (planktic and periphytic) on 30% similarity. Simper analysis in planktic samples revealed most contributive taxa: *Cyclotella meneghiniana, Staurosira construens, Cymbella dorsenotata, Chroococcus dispersus, Peridinium cinctum, Cymbopleura inaequalis, Ankistrodesmus fusiformis, Pantocsekiella comensis, Encyonema minutum, Rhabdoderma lineare* and *Denticula tenuis*. Highest contribution to periphytic samples had *Achnanthidium minutissimum, Cocconeis placentula, Gomphonema parvulum, Planothidium lanceolatum* and *Navicula tripunctata*. Seasonal dynamics in plankton communities were observed in the direction of shift of abundant *C. meneghiniana, Dinobryon divergens, P. cinctum* and *A. fusiformus* in spring season to the R. *lineare* and *Pantocsekiella comensis* in summer season. The trophic index pointed to the meso to eutrophic and eutrophic status of the lake Paučko, and saprobic index to the beta-mesosaprobic status. Although located in an uninhabited mountainous area, the lake Paučko is under high pressure caused by the influx and retention of nutrients, especially phosphates, what makes it highly susceptible to eutrophication and potential algal bloom

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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