THE CYANOBACTERIA, GREEN AND EUGLENOID ALGAE IN THE HIGH MOUNTAIN LAKES OF KAÇKAR PROTECTED AREA (RIZE, TURKEY)

Bülent ŞAHIN * and *Sophia BARINOVA* **

* Trabzon University, Department of Biology Education, Fatih Education Faculty, Söğütlü-Trabzon, Turkey, TR-61335, bulentsahin61@gmail.com, ORCID: 0000-0002-5477-9676.
** Institute of Evolution, University of Haifa, Mount Carmel, Abba Khoushi Avenue, 199, Haifa, Israel, IL-3498838, sophia@evo.haifa.ac.il, ORCID: 0000-0001-9915-2503.

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ABSTRACT

Floras of cyanobacteria, chlorophytes and euglenozoa of 14 glacial lakes and a pond in the Kaçkar Mountains National Park collected on 19 July, 28 August and 10 September 2020 comprised 66 species. Cyanobacteria were predominant (46.96%), *Nostoc* (Cyanobacteria) and *Trachelomonas* (Euglenozoa) were the most abundant. Physicochemical analysis and bioindicator species indicate that the studied waters are fresh, with low salinity and near-neutral or low-alkaline pH and are not polluted with organic matter. Statistical analysis of the data showed that algal and cyanobacterial floras are individual in geographically defined habitats.

RÉSUMÉ: Les cyanobactéries, les algues vertes et les euglénoides dans les lacs de haute montagne de la zone protégée de Kackar (Rize, Turquie).

Les flores de cyanobactéries, de chlorophytes et d'euglénozoaires de 14 lacs glaciaires et d'un étang du parc national des monts Kaçkar, collectées les 19 juillet, 28 août et 10 septembre 2020, comptaient 66 espèces. Les cyanobactéries étaient prédominantes (46,96%), dont *Nostoc* (cyanobactéries) et *Trachelomonas* (euglénozoaires) étaient les plus abondantes. L'analyse physicochimique et les espèces bioindicatrices indiquent que les eaux étudiées sont douces, avec une faible salinité et un pH proche de la neutralité ou faiblement alcalin et ne sont pas polluées par des matières organiques. L'analyse statistique des données a montré que les flores algales et cyanobactériennes sont distinctes dans des habitats géographiquement définis.

REZUMAT: Cianobacterii, alge verzi și euglenoide din lacurile de munte înalte ale zonei protejate Kaçkar (Rize, Turcia).

Florele de cianobacterii, clorofite și euglenozoare din 14 lacuri glaciare și un iaz din Parcul Național Munții Kaçkar, colectate la 19 iulie, 28 august și 10 septembrie 2020, au cuprins 66 de specii. Cianobacteriile au fost predominante (46,96%), *Nostoc* (cianobacteria) și *Trachelomonas* (euglenozoae) au fost cele mai abundente. Analizele fizico-chimice și speciile bioindicatoare indică faptul că apele studiate sunt proaspete, cu salinitate scăzută și pH aproape neutru sau scăzut alcalin și nu sunt poluate cu materie organică. Analiza statistică a datelor a arătat că florele algelor și cianobacteriilor sunt individuale în habitate definite geografic.

INTRODUCTION

The Black Sea area has had a very complex dynamic throughout its geological history, with highly variable conditions and extremely varied living organisms (Bănăduc et al., 2023). The part of the Black Sea basin within the borders of Turkey, from the east of the Melet Stream near Ordu to the Georgian border, is called the Eastern Black Sea Region. The region has been interrupted by tectonic movements in the east-west direction and by narrow and deep river valleys in the north-south direction, resulting a rugged geomorphology. The Eastern Black Sea Mountains (Giresun Mountains and Eastern Black Sea Mountains), which rise abruptly from the coast, separate the coastal area from the inland areas. (Atalay and Mortan, 1997) With its abundant rainfall, humid climate and rich biodiversity, the Eastern Black Sea region is one of nature's most remarkable laboratories. It also offers an important chance to study the rich algal flora of the 685 glacial lakes hosted in the mountains system (Anonymous, 2006; Geçen et al., 2018). The unique ecological features of glacial lakes allow different types of algae to develop, contributing significantly to the overall biodiversity of the area.

This study aim was to identify the Cyanobacteria, Chlorophyta, and Euglenozoa species in Kaçkar Mountains National Park glacial lakes and to compare their floras with those of previously studied regional lakes. Then, using ecological preferences through bioindication and statistical methods to determine the primary factors shaping floristic composition.

MATERIAL AND METHODS

Description of study area

The Kaçkar Mountains National Park is located in the eastern Black Sea region of Turkey. In 1994, it was designated as a protected area. The park encompasses an area of 51,550 hectares, and is situated within the administrative boundaries of the provinces of Rize, Artvin. and Erzurum. The geographical coordinates of the location are 40°57'49'' to 40°42'10" north latitude and 41°14'45'' to 40°51'27'' east longitude (Atalay and Mortan, 1997) (Fig. 1).

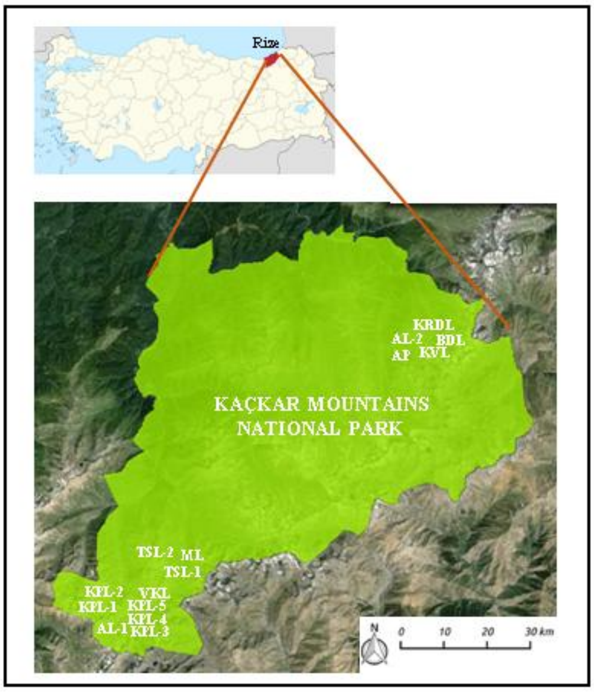

Figure 1: Kaçkar Mountains National Park area (http//national parks of turkey.com – adapted).

This park encompasses a portion of the mountain range that runs parallel to the coastline in the province of Rize, and covers an area of approximately 600 km in length and 200 km in width (Atalay and Mortan, 1997).

The lowest point of the park is the Ayder Plateau, situated at an elevation of 1,150 m, while the highest point is Kaçkar Mountain, which reaches an elevation of 3,932 metres. (Anonymous, 2006) The park is predominantly composed of granitic and volcanic rocks dating from the Late Cretaceous to the Eocene period (Eyüpoğlu et al., 2019). The area is predominantly composed of granodiorite and Cretaceous flysch. In addition, there are isolated occurrences of Neogene sediments. These structures were brought to the surface during the mountain-building process that occurred during the Palaeozoic (1st period) and Cretaceous (3rd period) (Anonymous, 2006). In addition to evidence of Pleistocene glaciers, the Kaçkar Mountains are one of the few locations where ongoing glacial activity can be observed. The region is characterised by a high concentration of glaciers, glacial lakes, glacial valleys, cirques and moraines. The Kaçkar Mountains, which contain approximately 100 glacial lakes, are the fourth highest mountain range in Turkey. (Anonymous, 2006; Kurdoğlu, 2002)

In accordance with the Turkish climate classification system, the studied area is considered to be situated within the domain of the Eastern Blacksea climate (Erinç, 1969). The climate is influenced by relatively cool summers and temperate winters, with precipitation occurring throughout the year. In the lower, northern section of the Kaçkar Mountains National Park, temperatures fluctuate between 0°C and 4°C during the winter months, before rising above 18°C during the summer. At an altitude of over 3,000 m a.s.l. in the southern mountains of the park, temperatures drop to –6°C in winter and range from 6°C to 9°C in summer. Snow cover is typical of high-altitude areas from late September to mid-May. The park receives an annual average precipitation of over 2,000 mm. The park is distinguished by four primary soil types: high mountain meadow soils, limeless brown forest soil, red-yellow soils, and grey-brown soils (Anonymous, 2006). These climatic conditions have resulted in the establishment of a significant biodiversity, particularly in terms of flora and fauna. In his study, Davis (1970) identifies the research area as part of the Colchis region of the Euro-Siberian floristic region. The forest belt is composed of a variety of broad-leaved and conifer tree species, including *Fagus orientalis*, *Castanea sativa*, and *Carpinus* sp. The alpine zone is characterised by a rich flora, with numerous endemic plant species. These include *Papaver lateritium*, *Barbarea trichopoda*, *Cochleria sintenisii*, *Sempervivum furseorum*, *Centaurea appendicigera*, and *Alopecurus laguroides*. This location is noteworthy for being the sole site in Turkey where rhododendrons are able to thrive at an altitude of 3,000 m altitude (Anonymous, 2006). The study area represents one of three significant migratory routes for birds, with the northeast-south route being of particular importance for daytime raptors in the Western Palearctic (Gürpınar, 1987). In light of these geographical and ecological characteristics, the Kaçkar Mountains National Park is among the 200 ecological hotspots that require protection, as recommended by the World Wildlife Fund (WWF) (Anonymous, 2006).

Methods of sampling and laboratory work

Samples of epipelic, epilithic, and epiphytic algae were collected from 14 glacial lakes and one pond situated within the boundaries of Kaçkar Mountains National Park on 19 July, 28 August, and 10 September 2020 (Tab. 1). The epipelic algae were collected with a glass tube. Epilithic samples were obtained by washing randomly collected stones, and epiphytic samples by washing macrophyte plants (*Potamogeton* sp. and *Juncus* sp.) (Sládečková, 1962; Round, 1953). The algae samples were placed in 100 ml plastic bottles and fixed with 4%

formaldehyde. Water temperature, dissolved oxygen concentration, conductivity, and pH were determined concurrently with the collection of algae samples. In order to achieve this, portable measuring devices were utilised, namely the Thermo Orion-4Star pH (Hampton, NH, USA, Marshall Scientific) and the YSI-55 (Letchworth, Hertfordshire, United Kingdom, Xylem Analytics). In the laboratory, a Leica DM 2500 light microscope and a Leica MC170 HD camera (Wetzlar, Germany, Leica Microsystems) were employed for the examination and photography of the algae samples. In order to ascertain the chemical properties of the water samples, assistance was sought from the DSI General Directorate Laboratories, DSI 22nd Regional Directorate Quality Control and Laboratory Branch Directorate.

Taxonomic names of collected species were checked in algaebase.org (Guiry and Guiry, 2021). Bioindicator analysis was performed according to Barinova (2017) with species-specific ecological preferences of revealed indicator taxa (Barinova et al., 2006). The BioDiversity Pro 2.0 program was used for similarity calculation (McAleece, 1997). JASP program was used in the comparative analysis (Love et al., 2019).

Table 1: Geographical coordinates, altitude and surface area information of the studied lakes.

Lakes with abbreviation	Geographic coordinates		Altitude (m)	Area (m^2)
Kapılı Lakes-1 (KPL-1)	40°42’56’’.59N	40°54’51’’.71E	2980	70.529
Kapılı Lakes-2 (KPL-2)	40°43’08’’.70N	40°54’55’’.30E	2973	14.879
Kapılı Lakes-3 (KPL-3)	40°42’34’’.73N	40°54’49’’.02E	3074	35.738
Kapılı Lakes-4 (KPL-4)	40°42’43’’.97N	40°54’47’’.24E	3028	4.732
Kapılı Lakes-5 (KPL-5)	40°42’59’’.03N	40°54’20’’.06E	2926	7.272
Vercenik Kumlu Lake (VKL)	40°43’17’’.91N	40°54’16’’.58E	2864	3.279
Karadeniz Lake (KRDL)	40°52’39’’.19N	41°10’02’’.06E	2782	24.141
Kavron Lake (KVL)	40°52’24’.39N	41°09’45’’.73E	2911	9.007
Büyük Deniz Lake (BDL)	40°52’04’’.60N	41°09’38’’.54E	2922	68.244
Adsız Lake-1 (AL-1)	40°42’39’’.75N	40°54’57’’.65E	3075	16.2
Adsız Lake-2 (AL-2)	40°52’21’’.18N	41°10’06’’.94E	2868	3.842
Moçar Lake (ML)	40°44’11’’.63N	40°56’05’’.36E	2958	22.246
Tatos Sulak Lakes-1 (TSL-1)	40°44’16’’.11N	40°56’42’’.25E	2976	46.421
Tatos Sulak Lakes-2 (TSL-2)	40°44’25’’.50N	40°56’51’’.18E	2940	17.337

The following sources were consulted in order to identify the species of algae: Kadlubowska (2009), Hindak (2008), Komárek and Anagnostidis (2005, 1998), Wołowski and Hindak (2005), John et al. (2003), Huber-Pestalozzi (1969).

The frequencies of algae taxa were determined using a scale based on the number of lakes studied. Very rare (VR): taxa recorded in 1-20% of investigated lakes; rare (R): taxa recorded in 21-40% of investigated lakes; common (C): taxa recorded in 41-60% of investigated lakes; frequent (F): taxa recorded in 61-80% of investigated lakes; very frequent (VF): taxa recorded in 81-100% of investigated lakes (Koçataş, 1992).

RESULTS AND DISCUSSION

Physical and chemical properties of waters

Table 2 shows the results of the physical and chemical analyses of the researched waters. Based on these results, we can say that the water in all the studied lakes was fresh, low saline, acidophilic or circumneutral in pH, and organically unpolluted. It is also understood that there are no eutrophication and acidification problems in these lakes.

Table 2: Averaged physico-chemical data of the 14 high mountain lakes in the Kaçkar Mountains National Park, 2022; (–) Could not be detected as below the determination level.

Parameters	KPL-1	KPL-2	KPL-3	KPL-4	KPL-5	VKL	KRDL
Temperature (°C)	14.2	14.0	14.5	14.0	14.8	22.5	12.5
DO (mg L^{-1})	8.03	8.33	8.14	8.02	8.20	8.18	8.89
pH	6.30	6.30	6.55	6.32	8.21	7.88	6.33
Conductivity (μSm cm^{-1})	23.4	23.2	27.1	26.0	29.30	22.9	36.8
TDS (mg L^{-1})	17.73	15.93	18.72	18.23	20.46	17.86	22.82
Potassium (mg L^{-1})	0.37	0.37	0.50	0.40	0.47	–	–
Total hardness $CaCO_3$ (m L^{-1})	17.96	17.64	19.94	19.70	23.60	–	–
Calcium (mg L^{-1})	5.13	5.00	5.92	5.82	7.17	–	–
Magnesium (mg L^{-1})	–	–	–	–	1.38	–	–
Ammonium (mg L^{-1})	0.31	0.28	0.34	0.23	0.40	0.35	0.17
Chlorine (mg L^{-1})	2.11	1.77	2.20	2.70	1.98	1.51	7.51
Nitrate (mg L^{-1})	–	0.214	0.207	0.232	0.330	–	0.575
Nitrite (mg L^{-1})	–	–	–	–	–	–	–
Phosphate (P_2O_5) (mg L^{-1})	–	–	–	–	0.113	–	–
Parameters	KVL	BDL	AL-1	AL-2	ML	TSL-1	TSL-2
Temperature (°C)	14.7	11.2	17.6	7.1	12.2	13	13
DO (mg L^{-1})	8.55	8.69	7.98	8.97	9.03	9.17	8.90
pH	7.18	6.10	7.30	6.54	7.13	6.9	6.9
Conductivity (μSm cm^{-1})	19.9	71.4	14.1	38.9	46	40	40
TDS (mg L^{-1})	12.34	44.27	9.92	27.34	21.89	20.34	19.84
Potassium (mg L^{-1})	0.38	0.44	0.35	–	–	–	–
Total hardness $CaCO_3$ (mg L^{-1})	–	38.84	–	–	17.59	–	–
Calcium (mg L^{-1})	4.02	12.69	–	7.25	4.52	5.30	5.33
Magnesium (mg L^{-1})	–	1.73	–	–	1.53	–	–
Ammonium (mg L^{-1})	0.76	0.82	0.31	0.13	0.11	0.08	0.12
Chlorine (mg L^{-1})	2.44	1.70	2.02	7.48	7.26	7.03	7.74
Nitrate (mg L^{-1})	–	0.233	0.225	0.515	0.361	0.279	0.218
Nitrite (mg L^{-1})	–	–	–	–	0.020	0.020	–
Phosphate (P_2O_5) (mg L^{-1})	–	–	–	–	–	–	–

Taxonomic species content

A total of 66 algal species, which belong to Cyanobacteria 31 species, Chlorophyta 27 species, and Euglenozoa eight species, were identified from 15 algal samples collected from 14 lakes and one pond in the Kaçkar Mountains National Park. While cyanobacteria made up 46.96% of the species composition, *Nostoc* and *Trachelomonas*, represented by five species each, were identified as the primary genera of the benthic flora. The other genera are represented by one to three species in the flora (Tab. 3). At the end of the study, three species were found to be new records for the freshwater algal flora of Turkey. These species are marked with an asterisk in table 3.

Table 3: Diversity and ecology of Cyanobacteria, Chlorophyta, and Euglenozoa species in 14 lakes and a pond of the Kaçkar Mountains National Park.

Species	H	F	Hab	Oxy	Hal	pH	Tro	Index S
Cyanobacteria								
Anabaena inaequalis Bornet and Flahault 1886	1	VR	P-B	st	–	–	e	1.60
Anabaena sp.	1	VR	P-B	–	–	–	e	–
Aphanocapsa grevillea (Berkeley) Rabenhorst 1865	1	VR	P	–	hb	–	e	1.40
Calothrix parietina Thuret ex Bornet and Flahault 1886	2	VR	B	st-str	–	–	om	1.10
Calothrix sp. 1	3	VR	B	–	–	–	–	–-
Calothrix sp. 2	2	VR	B	–	–	–	–	–
Chroococcus tenax (Kirchner) Hieronymus 1892	3	VR	B	aer	–	–	ot	–
Cyanothece aeruginosa (Nägeli) Komárek 1976	1	R	P-B	aer	–	–	e	0.90
Cyanothece sp.	1	VR	–	–	–	–	–	–
Dolichospermum heterosporum (Nygaard) P. Wacklin, L. Hoffmann and J. Komárek 2009	3	VR	–	–	–	–	–	–
Dolichospermum solitarium (Klebahn) Wacklin, L. Hoffmann and Komárek 2009	3	VR	P	–	–	–	e	1.95
**Johannesbaptistia pellucida* (Dickie) W. R. Taylor and Drouet 1938	3	VR	P-B	–	hlbn t	–	–	–
Kamptonema formosum (Bory ex Gomont) Strunecký, Komárek and J. Smarda 2014	1	R	P-B	st	–	ind	me	3.10
Komvophoron hindakii Hasler and Poulícková 2010	1,2	VR	B	–	–	–	–	–
Lyngbya nigra C. Agardh ex Gomont 1892	1	VR	–	–	–	–	–	–
Merismopedia glauca (Ehrenberg) Kützing 1845	–	F	P-B	–	i	ind	e	–
Merismopedia tranquilla (Ehrenberg) Trevisan 1845	–	R	P-B	–	i	ind	–	2.30
Microcoleus amoenus (Gomont) Strunecky, Komárek and J. R. Johansen 2013	1	R	P-B	st-str	–	alb	–	0.10
Nostoc paludosum Kützing ex Bornet and Flahault 1886	3	VR	P-B	st	–	–	–	–

Table 3 (continued): Diversity and ecology of Cyanobacteria, Chlorophyta, and Euglenozoa species in 14 lakes and a pond of the Kaçkar Mountains National Park.

Species	H	F	Hab	Oxy	Hal	pH	Tro	Index S
Nostoc sp. 1	3	VR	B	–	–	–	–	–
Nostoc sp. 2	3	VR	B	–	–	–	–	–
Nostoc sp. 3	1	VR	B	–	–	–	–	–
Nostoc sp. 4	1	VR	B	–	–	–	–	–
Oscillatoria princeps Vaucher ex Gomont 1892	1	VR	P-B	st-str	–	ind	–	–
Oscillatoria tenuis C.Agardh ex Gomont 1892	–	F	P-B	st-str	hl	–	–	–
Oscillatoria sp.	1	VR	B	–	–	alf	–	–
Planktothrix agardhii (Gomont) Anagnostidis and Komárek 1988	1	VR	P-B	st	hl	-	-	-
Pseudanabaena galeata Böcher 1949	1	VR	B	–	–	–	e	3.30
Scytonema mirabile Bornet 1889	3	VR	–	–	–	–	–	–
Spirulina major Kützing ex Gomont 1892	1	VR	P-B	st	hl	–	–	–
Synechocystis aquatilis Sauvageau 1892	3	VR	P-B	–	–	alb	–	–
Chlorophyta								
Ankistrodesmus falcatus (Corda) Ralfs 1848	3	VR	P	–	–	–	e	–
Bulbochaete mirabilis Wittrock ex Hirn 1900	2	VR	B	–	–	–	–	1.10
Coelastrum astroideum De Notaris 1867	1	VR	P	st-str	–	–	e	2.20
Coelastrum microporum Nägeli 1855	1	VR	P-B	st-str	i	ind	e	2.30
Coelastrum sphaericum Nägeli 1849	1	VR	P-B	st-str	i	–	e	1.40
Coenococcus nygaardii (Komárek) Hindák 1984	2	VR	–	–	–	–	–	–
Coenocystis planctonica Korshikov 1953	1	VR	P	–	i	–	–	2.00
Coenocystis subcylindrica Korshikov 1953	1,3	VR	P	–	i	–	–	–
Desmodesmus abundans (Kirchner) E. H. Hegewald 2000	1,3	VR	P-B	st-str	–	alf	–	–
Desmodesmus brasiliensis (Bohlin) E. Hegewald 2000	1	VR	P-B	st-str	–	–	–	2.00
Gloeotila subconstricta (G. S. West) Printz 1964	2,3	VR	–	–	–	–	–	–
* *Monoraphidium flexuosum* Komárek 1974	1	VR	P	–	–	–	–	–
Oedogonium sp. 1	–	R	–	–	–	–	–	–
Oedogonium sp. 2	1,2	VR	B	–	–	alb	–	–
* *Palmodictyon varium* (Nägeli) Lemmermann 1915	1	VR	–	–	–	–	–	–

Table 3 (continued): Diversity and ecology of Cyanobacteria, Chlorophyta, and Euglenozoa species in 14 lakes and a pond of the Kaçkar Mountains National Park.

Species	H	F	Hab	Oxy	Hal	pH	Tro	Index S
Pediastrum duplex Meyen 1829	1	VR	P	st-str	i	ind	e	–
Pseudopediastrum boryanum (Turpin) E. Hegewald 2005	–	F	P-B	st-str	i	ind	e	2.10
Scenedesmus acutus var. *Globosus* Hortobágyi 1954	1	VR	P	–	–	–	e	2.20
Scenedemus quadricauda (Turpin) Brébisson 1835	2	VR	P-B	st	–	–	e	2.10
Sphaerocystis planctonica (Korshikov) Bourrelly 1974	1,2	VR	P	–	i	–	e	1.00
Stauridium privum (Printz) Hegewald 2005	3	VR	–	–	–	–	–	–
Stauridium tetras (Ehrenberg) E. Hegewald 2005	1,3	VR	P-B	st-str	i	ind	om	–
Tetradesmus obliquus (Turpin) M. J. Wynne 2016	1	VR	P-B	st-str	i	ind	ot	2.40
Tetraëdron lobulatum var. *polyfurcatum* G. M. Smith 1916	2	VR	–	–	–	–	–	–
Ulothrix zonata (F. Weber and Mohr) Kützing 1833	2	VR	P-B	st-str	i	ind	–	1.80
Uronema confervicola Lagerheim 1887	1,3	VR	B	st-str	–	–	–	2.10
Euglenozoa								
Euglena gracilis G. A. Klebs 1883	1	VR	P-B	st	oh	ind	–	2.00
Euglena granulate (G. A. Klebs) F. Schmitz 1884	1	VR	P-B	st-str	mh	ind	e	2.25
Phacus curvicauda Svirenko 1915	1	VR	P-B	st	i	ind	–	–
Trachelomonas crenulatocollis Maskell 1887	1	VR	–	–	–	–	–	–
Trachelomonas lacustris Drezepolski 1925	1	VR	P	–	hb	–	–	1.50
Trachelomonas volvocina (Ehrenberg) Ehrenberg 1834	1,2	R	P-B	st-str	i	ind	–	2.00
Trachelomonas sp. 1	1	VR	P	–	–	–	–	2.30
Trachelomonas sp. 2	1	VR	P	–	–	–	–	2.30

Note: Ecological groups abbreviation: Habitat (P – planktonic, P-B – plankto-benthic, B – benthic); oxygenation and water moving (Oxy) (aer – aerophiles, st-str – low streaming water, st – standing); Salinity ecological groups (Hal) according to Hustedt (1938-1939) (hb – oligohalobes-halophobes, i – oligohalobes-indifferent, hl – halophiles; mh – mesohalobes; hlbnt – halobiontes; oh – oligohalobes); pH preferences groups (pH) according to Hustedt (1957) (alb – alkalibiontes; alf – alkaliphiles, ind – indifferent); trophic state indicators (Tro) (Van Dam et al., 1994) (ot – oligotraphentic; om – oligomesotraphentic; me – mesoeutraphentic; e – eutraphentic); Index S, species-specific index saprobity according to Sládeček (1986) (Class of Water Quality).

While 57 species were identified as very rare (VR) in the flora, the number of frequent (F) and rare (R) species identified was three and six respectively (Tab. 3). *Oscillatoria tenuis* and *Merismopedia glauca* were observed as frequent (F) species within the phylum Cyanobacteria. *Oscillatoria tenuis* is an inhabitant of benthic and metaphytic habitats of fresh waters, while *Merismopedia glauca* is found in the littoral zones of clean ponds and lakes (Komárek and Anagnostidis, 2005, 1998). The data obtained at the end of the research confirm this information. *Pseudopediastrum boryanum*, which is cosmopolitan and prefers nutrient-rich waters (meso-eutrophic), was a common (F) species of Chlorophyta (John et al., 2003).

66 species of non-diatom algae belonging to Cyanobacteria, Chlorophyta, and Euglenozoa were found in the 14 lakes and one pond in the Kaçkar Mountains National Park. Since the samples were collected in July, August, and September, which are suitable months for algal growth in this region, and the detailed seasonal study of the lakes, it is possible to assume that the identified species composition represents the maximum species richness of the flora. For this reason, we believe that the results of this study are comparable with the species composition of the same algal groups in high-mountain lakes in similar climatic regions.

It is not surprising that the taxonomic composition of the Cyanobacteria, Chlorophyta, and Euglenozoa in these lakes is consistent with that of previously studied lakes in the region and the lake on the Suntar-Khayat ridge (northeast Yakutia, Russia), since the terrain structure, the macroclimatic conditions and the water properties of the lakes are similar (Şahin and Barinova, 2025; Kopyrina et al., 2022; Şahin et al., 2020). This similarity in flora is also a sign that these algae are competitive under climatic stress conditions (Barinova and Alster, 2021).

Cyanobacteria, Chlorophyta, and Euglenozoa flora of 14 lakes and one pond in the Kaçkar Mountains National Park is mostly represented by typical species variants (Tab. 3). The Ssp/Sp index value, which indicates the intraspecific variability of the flora, was found to be 1.031 (Barinova, 2011). The flora is monotypic with low intraspecific polymorphism. The specific content of the taxonomic list for each area of the lakes (species/area index as the number of species per km^2) was also calculated (Barinova and Stenina, 2013; Barinova et al., 2011). The highest value was found in KPL-1 (7.05 species per km^2) and the lowest in VKL (0.4 species per km^2). Although AP (28 species) has the most species, the species area index could not be calculated because its area was unknown. This index can be used as reference for future monitoring of biodiversity in purpose safety and stability assessment.

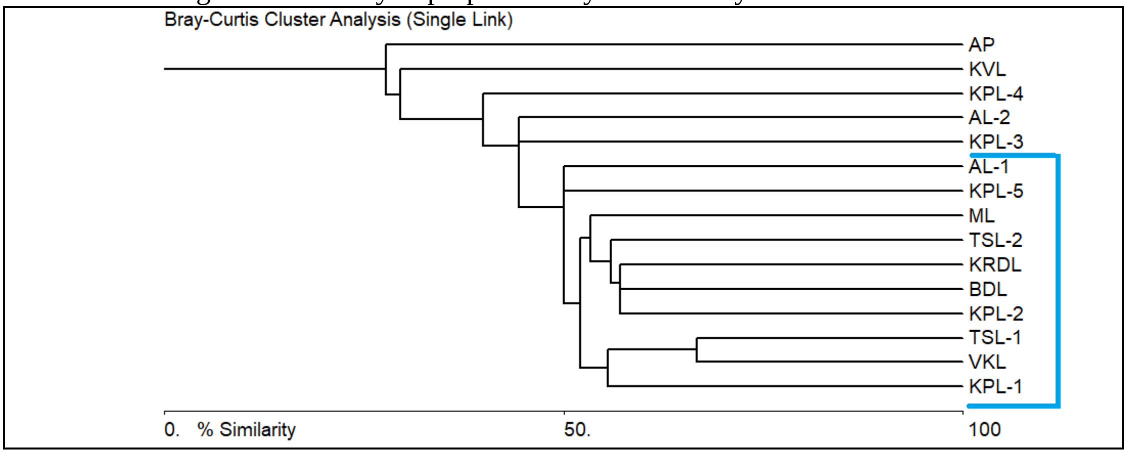

Figure 2: Similarity of the of Cyanobacteria, Chlorophyta, and Euglenozoa algal flora in 14 lakes and one pond of Kaçkar Mountains National Park.

The similarity of species composition of Cyanobacteria, Chlorophyta, and Euglenozoa in 14 lakes and one pond in the Kaçkar Mountains National Park was calculated using the Bray-Curtis statistical method. According to this, 10 lakes formed a cluster with more than 50% similarity. The other five lakes and one pond could not form their own cluster (Fig. 2). This fact shows that these species composition belongs to a single flora, on the other hand it emphasises that some floras (KPL-3, AL-2, KPL-4, KVL, AP) have a high individuality.

Statistical comparison of data about species content (Tab. 3) and chemical variables in studied lakes (Tab. 2) with help of the JASP Network plot construction shows four groups of lakes that diveded on the base of the links value (Fig. 3). In this analysis, when not only the floristic composition of communities in lakes but also water quality parameters are included in the calculation, we analyze the similarity of the entire lake ecosystem. Figure 3 shows that the lakes are divided into four clusters, each of which combines habitats and floras concentrated in groups of lakes according to their position on the landscape. Thus, this analysis clarifies the comparison of only the species composition and shows the influence of the climatic gradient on the formation of floras of the studied water bodies in the protected area of the Kaçkar Park.

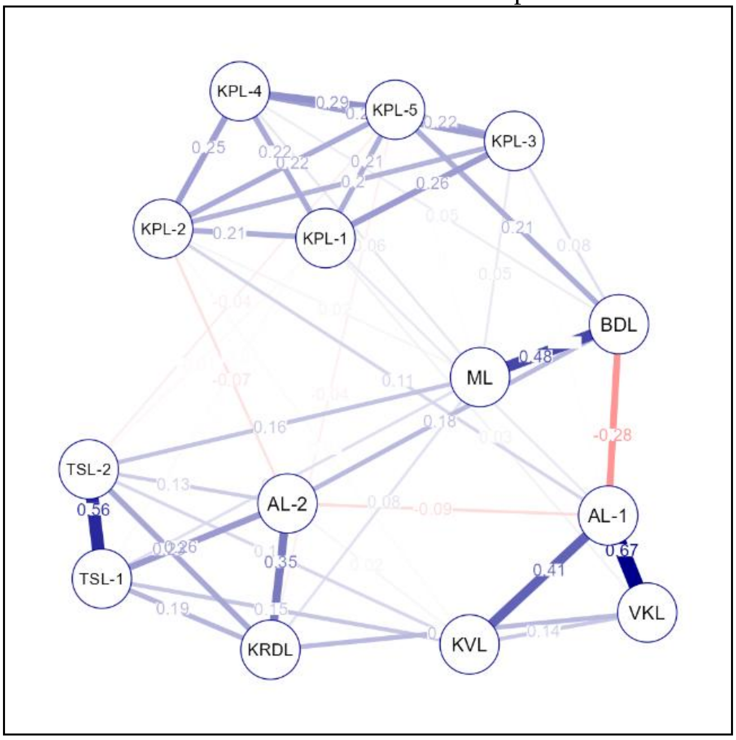

Figure 3: JASP Network plot for the comparison of taxonomic species content and chemical variables in 14 lakes and one pond of Kaçkar Mountains National Park. The thickness of the lines is proportional to the strength of the connection, indicated by the numbers. Blue lines – positive correlation, red lines – negative correlation.

CONCLUSIONS

The algal flora of 14 of the 100 glacial lakes and one pond in the Kaçkar Mountains National Park is studied for the first time. It is seen that macroclimatic conditions, in addition to the physical and chemical properties of the water, are effective in shaping the flora. The lakes, the almost pristine lakes, maintain diverse and valuable benthic algal floras, making them important sites in Turkey’s ecological network.

REFERENCES

1. Anonymous, 2006 – Kaçkar Dağları Milli Parkı uzun devreli gelişme planı analitik etüt ve sentez raporu, Doğa Koruma ve Milli Parklar Genel Müdürlüğü, Ankara, 251. (in Turkish)
2. Atalay İ. and Mortan K., 1997 – Türkiye Bölgesel Coğrafyası, İnkılap Kitapevi, İstanbul. (in Turkish)
3. Barinova S., 2011 – The effect of altitude on distribution of freshwater algae in continental Israel, *Current Topics in Plant Biology*, 12, 89-95.
4. Barinova S., 2017 – Essential and practical bioindication methods and systems for the water quality assessment, *International Journal of Environmental Sciences & Natural Resources*, 2, 1-11, DOI: 10.19080/IJESNR.2017.02.555588.
5. Barinova S. S., Kukhaleishvili L., Nevo E. and Janelidze Z., 2011 – Diversity and ecology of algae in the Algeti National Park as a part of the Georgian system of protected areas, *Turkish Journal of Botany*, 35, 729-774.

6 Barinova S.S., Medvedeva L. A. and Anissimova O. V., 2006 – Diversity of algal indicators in environmental assessment, *Pilies Studio Publisher*, Tel Aviv, Israel, 498. (in Russian)

7. Barinova S. and Stenina A., 2013 – Ecological adaptation of diatoms in the Arctic lakes of the Kostyanoi Nos Cape (Nenezky Natural Reserve, Russian North), *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology*, 147, 2, 397-410.
8. Barinova S. and Alster A., 2021 – Algae and cyanobacteria diversity and bioindication of long-term changes in the Hula Nature Reserve, Israel, *Diversity*, 13, 11, 583.
9. Bănăduc D., Afanasyev S., Akeroyd J. R., Năstase A., Năvodaru I., Tofan L., Curtean-Bănăduc A., 2023 – The Danube Delta: the Achilles heel of Danube River-Danube Delta-Black Sea region fish diversity under a Black Sea impact scenario due to sea level rise – a prospective review, *Fishes*, 8, 7, 1-27.
10. Davis P. H. 1970 – Flora of Turkey and the east Aegean Islands, Edinburg University Press, Edinburgh, 1-9.
11. Eyüpoğlu Y., Dudas F. O., Zhu D., Liu Z. and Chatterjee N. 2019 – Late cretaceous I- and A-type magmas in eastern Turkey: magmatic response to double-sided subduction of Paleo- and Neo- Tethyan lithospheres, *Lιthos*, 326, 39-70.
12. Erinç S. 1969 – Klimatoloji ve Metodları, İstanbul Üniversitesi Coğrafya Fakültesi Yayınları, İstanbul, 540. (in Turkish)
13. Uherkovich G., Ács É. and Schmidt, A., 1995 – The green algal genera Scenedesmus (Chlorococcales, Chlorophyceae) with special attention to taxa occurring in Hungary, *Magyar Algológiai Társaság, Budapest*.1-234.
14. Geçen R., Toprak V. and Tonbul S., 2018 – Glacial lakes on eastern Blacksea Mountain, their distribution and morphometric properties, in 3rd International Geography Symposium on the 30th Anniversary of TUCAUM, 1057, Ankara, Turkey.
15. Guiry M. D. and Guiry G. M., 2021 – AlgaeBase, World-wide electronic publication, Galway, Ireland, National University of Ireland, Galway (online), http://www.algaebase.org (accessed January 2021).
16. Gürpınar T., 1987 – Kuş Göçü Acısından Türkiye'nin Önemi, Türkiye ve Balkan ÜlkelerindeYaban Hayatı, Uluslararası Sempozyumu Bildiriler Kitabı, Eylül, İstanbul, Turkey, 16-20. (in Turkish)
17. Hindák F., 2008 – Colour atlas of cyanophytes, VEDA, Publishing House of the Slovak Academy of Sciences, Bratislava, 253.
18. Huber-Pestalozzi G., 1969 – Das Phytoplankton des Süßwassers, *Systematik und Biologie Band* XVI, 4, E. Schweizerbart'sche Verlagsbuchhandlung (Nägele u. Obermiller), Stuttgart, 606. (in German)
19. Hustedt F., 1957 – Die Diatomeen flora des Flußsystems der Weser im Gebiet der Hansestadt Bremen, *Abhandlungen des Naturwissenschaftlichen Vereins zu Bremen*, 34, 3, 181-440. (in German)

20. Hustedt F., 1938-1939 – Systematische und Ökologische Untersuchungen über die Diatomeenflora von Java, Bali und Sumatra, *Archiv für Hydrobiologie, Suppl.*, 15, 131-177, 393-506, 638-790, 16, 1-155, 274-394. (in German)
21. John D. M., Whitton B. A. and Brook A. J., 2003 – The freshwater algal flora of the British Isles: an identification guide to freshwater and terrestrial algae, Cambridge University Press, Cambridge, 702.
22. Kadlubowska J. Z., 2009 – Freshwater flora of Central Europa, Chlorophyta, 8, 8, Conjugatophyceae 1, Zygnemales, Heidelberg, Spektrum Akademischer Verlag, Heidelberg, 532.
23. Koçataş A., 1992 – Ekoloji (Çevre Biyolojisi), Ege Üniversitesi Matbaası, Turkiye, İzmir, 564. (in Turkish)
24. Komárek J. and Anagnostidis K., 1998 – Freshwater flora of Central Europe, Cyanoprokaryota 1, 1, Chroococcales, Spektrum Akademischer Verlag, Heidelberg, 548.
25. Komárek J. and Anagnostidis K., 2005 – Freshwater flora of Central Europe, Cyanoprokaryota 2, 2, Oscillatoriales, Spektrum Akademischer Verlag, Heidelberg, 759.
26. Kopyrina L., Pshennikova E. and Barinova S., 2022 – Diversity and ecology of non-diatom algae in a swampy mountain lakes of the Suntar-Khayat Ridge (Republic Sakha, Yakutia, Russia), *Transylvanian Review of Systemetical and Ecological Research*, 24, 17-34.
27. Kurdoğlu O., 2002 – Kackar Dağları Milli Parkı ve Yakın Çevresinin Doğal Kaynak Yönetimi Acısından İncelenmesi, Ph.D. Thesis, KTU Fen Bilimleri Enstitüsü, Orman Mühendisliği Ana Bilim Dalı, Trabzon, Turkey. (in Turkish)
28. Love J., Selker R., Marsman M., Jamil T., Dropmann D., Verhagen J. A., Ly A., Gronau F. Q., Smira M., Epskamp, S., Matzke D., Wild A., Knight P., Rounder J. N., Morey R. D. and Wagenmakers E., 2019 – JASP: Graphical statistical software for common statistical designs, *Journal of Statistical Software*, 88, 1-17.
29. McAleece N., Gage J. D. G., Lambshead P. J. D., Paterson G. L. J., 1997 – BioDiversity Professional statistics analysis software, Jointly developed by the Scottish Association for Marine Science and the Natural History Museum London.
30. Round F. E., 1953 – An investigation of two benthic algal communities in Malharm Tarn, Yorkshire, *Journal of Ecology*, 41, 174-197.
31. Sládečková A., 1962 – Limnological investigation methods for the periphyton (Aufwuchs) community, *Botanical Review*, 28, 286-350.
32. Şahin B., Akar B. and Barinova S., 2020 – Non-diatom algae of the high mountain protected lakes in the Artabel Lakes Nature Park, Gümüşhane, Turkey, *Botanica Pasifica*, 9, 1-10.
33. Şahin B. and Barinova S., 2025 – Diversity and ecology of non-diatom algae in two high-mountain lakes of Çamlihemşin (Rize, Turkey), *Botanica Pacifica*, 14, 1, 1-9.
34. Sládeček V., 1986 – Diatoms as indicators of organic pollution, *Acta Hydrochimica et Hydrobiologica*, 14, 555-566.
35. Van Dam, H., Mertens A., Sinkeldam J., 1994 – A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands, *Netherlands Journal of Aquatic Ecology*, 28, 1, 117-133, DOI: 10.1007/BF02334251.
36. Wołowski K. and Hindak F., 2005 – Atlas of Euglenophytes, VEDA Publishing House of the Slovak Academy of Sciences, Bratislava, 136.