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Phytoplankton Communities and Physical-Chemical Properties of Ulaş Lake (Ulaş/Sivas)

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ABSTRACT

This study was conducted between December 2010 and December 2011 to reveal the phytoplanktonic groups present in Ulaş Lake and to assess the lake's physical and chemical properties. A total of 115 species belonging to 7 phytoplanktonic groups were identified in the lake (Chlorophyta: 49, Heterokontophyta: 36, Cyanobacteria: 10, Euglenophyta: 8, Cryptista: 7, Charophyta: 3, and Dinoflagellata: 2). The annual average values for physicochemical parameters were as follows: water temperature: 12°C, dissolved oxygen: 7.5 mg O_2/L, electrical conductivity: 3.59 mS/cm, turbidity: 16.5 NTU, suspended solids: 16 mg/L, pH: 8.6, calcium: 786 mg/L, hardness: 207 mg $CaCO_3$/L, alkalinity: 140 mg $CaCO_3$/L, sulphate: 101 mg/L, silica: 1.6 mg/L, chemical oxygen demand: 47 mg/L, chloride: 314 mg/L, total phosphate: 55.4 µg/L, total dissolved phosphate: 32.1 µg/L, soluble reactive phosphate: 11.6 µg/L, chlorophyll-a: 11 µg/L, ammonium nitrogen: 35 µg/L, nitrate nitrogen: 47 µg/L, and nitrite nitrogen: 9 µg/L.

Keywords: Phytoplankton, Water chemistry, Ulaş Lake

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Introduction

Water, a fundamental requirement for life, has been a focal point for societies since ancient times, with settlements typically established near water sources. Today, water, which is critically important for life, is under pollution pressure due to urbanization, rapid population growth, industry, and intensive agricultural activities, leading to a gradual decline in its quality.

Water also serves as a habitat for aquatic organisms. Plankton, which float in water and move with currents, play a significant role in supporting aquatic life and consist of both animal and plant organisms [1]. The plant-like organisms among them are called phytoplankton. Phytoplankton, which contain chlorophyll, are photosynthetic organisms that play a crucial role in aquatic ecosystems [2] and form the first link in the food chain. Phytoplankton produce organic matter through photosynthesis [3] and play a vital role in the nutrition of other organisms in the system. Additionally, their rapid response to changes in the system and their sensitivity to various physical and chemical parameters, such as nutrient salts (nitrates and phosphates), salinity, and temperature [4], make them important indicators for assessing the productivity and pollution status of lakes and rivers [5]. Indeed, phytoplankton have been used as indicators in numerous studies to determine water quality and the productivity levels of aquatic systems [6]. Due to these characteristics, determining the physicochemical properties of the habitats of phytoplankton, which play a significant role in aquatic systems, is of great importance. This study aims to identify the phytoplanktonic groups present in Ulaş Lake and the physical and chemical properties of the lake water, their living environment. This study is also expected to provide data for future researches on the lake and for scientific researches in many other subjects.

Materials and Methods

Study Area

The lake, located in the Ulaş district of Sivas, is 35 km from the city centre of Sivas. The lake is situated at coordinates 39°26'48.4"N 37°02'52.7"E. Covering an area of 59 hectares, the lake has a shoreline length of 4 km. It is fed by a channel from the Tecer Stream in the southern part, as well as by surrounding surface waters and precipitation. The lake drains into Taşlıdere through a channel on its western side. The deepest part of the lake is approximately 2 meters, with most areas having a depth of around 1 meter.

Geologically, the study area primarily consists of the Upper Cretaceous–Palaeocene-aged Tecer Formation, characterized by blackish grey, highly jointed, porous, thick-layered, algal, and macrofossil-shell-bearing dolomitic limestones, with occasional sandy-clayey levels. Overlying this unit with an angular unconformity is the Eocene-aged Kaleköy Formation, composed of greenish, medium to thick-layered, alternating pyroclastic and epiclastic rocks. Conformably overlying the Kaleköy

Formation are the Yapalı Formation, consisting of medium to thin-layered, greyish-yellow sandstone, claystone, and shale, and the Eocene-aged Bozbel Formation, which includes sandstone, marl, limestone, and laterally transitional gypsum levels. Above these units lies the Oligocene-aged Küçüktuzhisar Formation, conformably deposited, consisting of gray, green, red, and yellowish claystone, siltstone, and fine-grained sandstone, with gypsum layers of varying thickness. Massive gypsum is observed at the base of this formation, while the upper parts contain alternating thick and thin layers of red conglomerate, sandstone, siltstone, and mudstone. Higher up, the fossil-rich limestones of the Selimiye Formation are present. All these units are covered by Quaternary-aged alluvium [7].

The lake bottom and particularly its shallow shores are densely covered with *Myriophyllum* sp. and *Potamogeton* sp. species. The lake is designated as a nationally important wetland and is home to notable bird species, including *Oxyura leucocephala* (white-headed duck), *Tadorna ferruginea* (ruddy shelduck), *Tadorna tadorna* (common shelduck), *Fulica atra* (common coot), *Egretta garzetta* (little egret), *Ardea cinerea* (grey heron), and *Aythya nyroca* (ferruginous duck).

Phytoplankton Sampling and Identification

Samples were collected from a single sampling station at the lake's centre and preserved with Lugol's solution [8]. The samples were settled in hydro-bios sedimentation cells, and counts were performed under a microscope. For species that could not be identified during counting, temporary slides were prepared, and identification was conducted using an Olympus Vanox research microscope. Species identification was based on references from Komarek and Fott; Komarek and Anagnostidis; John and Whitton; Brook; Krammer and Lange-Bertalot; Ettl; Prescott; Wehr and Sheath [9–20].

Physical Measurements

Throughout the study, pH, dissolved oxygen, water temperature, and electrical conductivity measurements were taken during sampling using Consort C932/C933 devices. Visibility was measured using a Secchi disk, and turbidity was determined on-site using a Lovibond turbidity meter.

Chemical Analyses

Water samples for analysis were collected from 30–40 cm below the surface in dark-coloured bottles. Analyses were conducted within the first 24 hours after sample collection, using standard methods [21]. Chlorophyll-a was determined using the 90% acetone method [22].

Results

Physical and Chemical Composition

The annual averages, as well as the minimum and maximum values for physical measurements and chemical analyses, are presented in Table 1. The average water temperature in the lake was 12°C, ranging from 1.5°C to 24°C during the sampling period. The lowest temperature was recorded in February 2011, and the highest in July 2011 (Figure 1c). The annual average dissolved oxygen was 7.5 mg/L, with concentrations ranging from 4.4 to 10.2 mg/L during the study. The highest dissolved oxygen level was 10.4 mg/L in December 2010, and the lowest was in July 2011 (Figure 1c). The annual averages for sulphate, calcium, water hardness, chloride, and electrical conductivity (EC) were 101 mg/L, 786 mg/L, 207 $mgCaCO_3/L$, 314 mg/L, and 3.59 mS/cm, respectively. Sulphate concentrations ranged from 66 to 131 mg/L, with the highest value in October 2011 and the lowest in March 2011 (Figure 1d). Calcium concentrations ranged from 591 to 950 mg/L, with the highest value in October 2011 and the lowest in February 2011 (Figure 1d). Hardness values ranged from 141 to 246 $mgCaCO_3/L$, with the highest value in December 2011 and the lowest in February 2011 (Figure 1d). Chloride concentrations ranged from 248 to 389 mg/L, with the highest in October 2011 and the lowest in February 2011 (Figure 1d). EC values ranged from 2.77 to 4.15 mS/cm, with the highest value in October 2011 and the lowest in February 2011 (Figure 1d). The lake's pH values ranged from 8.03 to 9.22, with the highest value in July 2011 and the lowest in February 2011 (Figure 1b). Total alkalinity (TA) values ranged from 105 to 180 $mgCaCO_3/L$, with the highest value in July 2011 and the lowest in August 2011 (Figure 1b). Three phosphate fractions were measured in the lake: total phosphate (TP), total dissolved phosphate (TDP), and soluble reactive phosphate (SRP). During the sampling period, TP ranged from 16.7 to 115 µg/L, TDP from 5.5 to 90 µg/L, and SRP from 3.3 to 25 µg/L. TP was highest in May 2011 at 115 µg/L and lowest in September 2011 at 16.7 µg/L. TDP was highest in May 2011 at 90 µg/L and lowest in December 2011 at 5.5 µg/L. SRP was highest in February 2011 at 25 µg/L and lowest in August 2011 at 3.3 µg/L (Figure 1e). Nitrogen analyses included nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), and ammonium nitrogen (NH_4-N). The annual average concentrations were nitrate: 47 µg/L, nitrite: 9 µg/L, and ammonium: 35 µg/L. During the sampling period, NO_3-N ranged from 10 to 85 µg/L, NO_2-N from 3 to 35 µg/L, and NH_4-N from 7 to 75 µg/L. The highest NO_3-N value was 85 µg/L in November 2011, and the lowest was 10 µg/L in December 2010. The lowest NO_2-N value was 3 µg/L in February/March 2011, and the highest was 35 µg/L in July 2011. For NH_4-N, the highest value was in June 2011, and the lowest was in February 2011. The annual variations of nitrogen fractions are shown in Figure 1f. Silica (SiO_2) ranged from 0.3 to 6 mg/L, with an annual average of 1.6 mg/L. The highest silica value was 6 mg/L in December 2010, and the lowest was 0.3 mg/L in September/October 2011. The chemical oxygen demand (COD) averaged 47 mgO_2/L, ranging from 9 to 128 mgO_2/L, with the lowest value in February 2011 and the highest in December 2010. The annual average chlorophyll-a value was 11 µg/L, with the highest value of 25 µg/L in October 2011 and the lowest of 2 µg/L in July 2011 (Table 1). The annual average suspended solids

(SSM) was 16 mg/L, and turbidity was 16.5 NTU (Table 1). During the study, SSM ranged from 9.2 to 27.4 mg/L, and turbidity ranged from 6.3 to 37 NTU. The highest SSM value was 27.4 mg/L in June 2011, and the lowest was 9.2 mg/L in February/December 2011 (Figure 1a). The highest turbidity value was 37 NTU in June 2011, and the lowest was 6.3 NTU in December 2011 (Figure 1a). Due to the lake's shallow nature, visibility extended to the lake bottom throughout the study, as confirmed by Secchi disk measurements.

Table 1. Numerical data for physical measurements and chemical analyses of Ulaş Lake

	Temperature (°C)	Dissolved Oxygen (mgO_2/L)	pH	EC (mS/cm)	Turbidity (NTU)	Calcium (mg/L)	Hardness (mg $CaCO_3$/L)	Sulphate (mg/L)	SSM (mg/L)	Total Alkalinity (mg $CaCO_3$/L)
Mean	12	7.4	8.6	3.59	16.5	786	207	101	16.0	140
Minimum	1.5	4.4	8	2.77	6.3	591	141	66	9.2	105
Maximum	24	10.2	9.2	4.15	37.0	950	246	131	27.4	180

	Silica (mg/L)	COD (mg/L)	Chloride (mg/L)	TP (µg/L)	TSP (µg/L)	SRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	NO_2-N (µg/L)	Chl- a (µg/L)
Mean	1.6	47	314	55.4	32.1	11.6	35	47	9	11
Minimum	0.3	9	248	16.7	5.5	3.3	5	10	3	2
Maximum	6.0	128	389	115.0	90.0	25.0	75	85	35	25

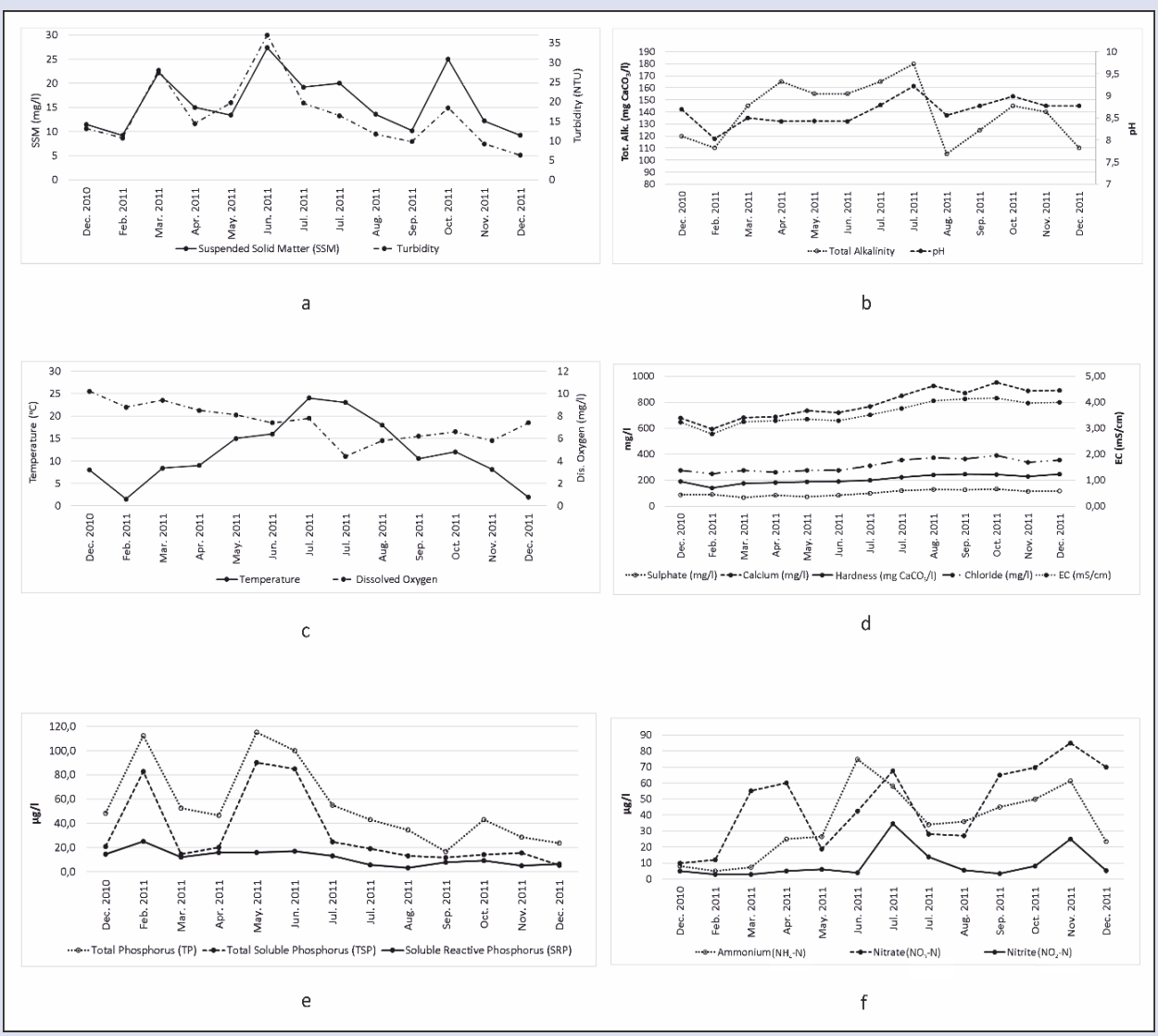

Figure 1. Annual variation of physicochemical parameters of Ulaş Lake. a) suspended solids (SSM) and turbidity, b) total alkalinity and pH, c) dissolved oxygen and temperature, d) sulphate, calcium, hardness, chloride, and EC, e) Total phosphate (TP), total dissolved phosphate (TDP), and soluble reactive phosphate (SRP), f) ammonium (NH_4-N), nitrate (NO_3-N), and nitrite (NO_2-N)

Phytoplankton Composition

A total of 115 species belonging to 7 phytoplanktonic groups were identified in the study (Table 2). Of these, 49 belong to Chlorophyta, 36 to Heterokontophyta, 10 to Cyanobacteria, 8 to Euglenophyta, 7 to Cryptista, 3 to Charophyta, and 2 to Dinoflagellata. Throughout the sampling period, members of the Chlorophyta, Cryptista, Heterokontophyta, and Cyanobacteria groups were consistently present in the lake. The group with the highest species diversity was Chlorophyta. This group showed particularly high organism counts in March, May, June, and July (March: 3551 org/mL; May: 4011 org/mL; June: 3902 org/mL; July: 6183 org/mL). Chlorophyta accounted for 47% of the total organisms in March, 69.1% in May, 63.1% in June, and 77.1% in July. Within this group, *Monoraphidium tortile*, *Monoraphidium contortum*, *Monoraphidium griffithii*, and *Coenochloris fottii* were the dominant species. The Heterokontophyta group, the second most diverse, showed increases in February, August, and October 2011, with organism counts of 1044 org/mL, 1529 org/mL, and 1404 org/mL, respectively. These counts represented 24.6% of the total organisms in February, 62.7% in August, and 29% in October. Within this group, *Fragilaria capucina*, *Chaetoceros muelleri*, and *Nitzschia acicularis* were dominant. The Cyanobacteria group was represented by 10 species and was particularly abundant in July, with 4303 org/mL, accounting for 57% of the total organisms. *Chroococcus dispersus* and *Chroococcus minor* were the dominant species in this group. The Cryptista group showed numerical increases in April and October, with 2799 org/mL in April (43.5% of total organisms) and 2532 org/mL in October (54.9% of total organisms). *Cryptomonas marssonii* and *Rhodomonas minuta* were the dominant species in this group. The Euglenophyta group was numerically significant only in November 2011, with 501 org/mL, representing 10.5% of the total organisms. *Euglena viridis* and *Phacus pyrum* were the prominent species in this group. In other sampling periods, Euglenophyta members were consistently present but not numerically significant. The Dinoflagellata group was significant only in February 2011, with 376 org/mL, accounting for 13.8% of the total organisms. After this period, Dinoflagellata members were rarely observed and did not reach significant numerical levels. The Dinoflagellata group was represented by *Gymnodinium* sp. and *Palatinus pseudolaevis*. The Charophyta group did not reach significant numbers throughout the sampling period and was represented by *Closterium setaceum* and *Cosmarium granatum*. The annual variation of the dominant phytoplanktonic groups (Chlorophyta, Heterokontophyta, Cyanophyta, and Cryptista) is shown in Figure 2.

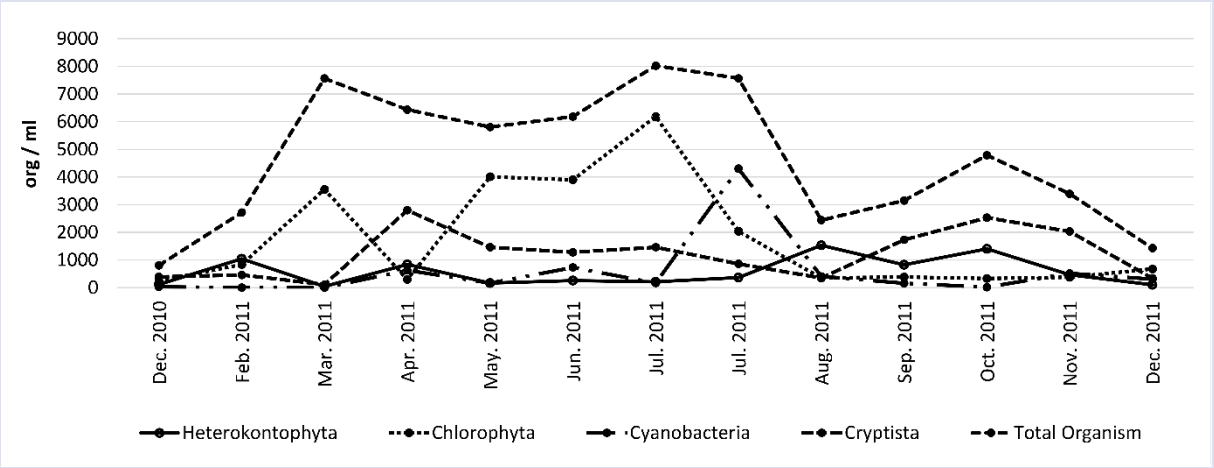

Figure 2. Total organisms and phytoplanktonic status of Ulaş Lake.

Table 2. List of species found in Ulaş Lake

Taxa					
Domain:	Bacteria				
	Kingdom :	Eubacteria			
		Phylum:	Cyanobacteria		
			Class :	Cyanophycea	
				Order :	Chroococcales
					Chroococcus dispersus (Keissler) Lemmermann
					Chroococcus minimus (Keissler) Lemmermann
					Chroococcus minor (Kützing) Nägeli
					Cyanarcus hamiformis Pascher
					Gomphosphaeria aponina Kützing
					Merismopedia glauca (Ehrenberg) Kützing
				Order :	Oscillatoriales
					Oscillatoria nigra Vaucher ex Gomont
					Oscillatoria sp.
				Order :	Spirulinales
					Spirulina subtilissima Kützing ex Gomont
					Spirulina sp.

Domain: Eukaryota
Kingdom : Chromista
Phylum : Heterokontophyta
Class : Mediophyceae
Order : Chaetocerotales
Chaetoceros muelleri Lemmermann
Order : Stephanodiscales
Cyclotella antiqua W.Smith
Cyclotella meneghiniana Kützing
Cyclotella sp.
Pantocsekiella comensis (Grunow) K.T.Kiss & E.Ács
Class: Bacillariophyceae
Order : Achnanthales
Achnanthidium minutissimum (Kützing) Czarnecki
Achnanthes minutissima var. Minutissima
Order : Thalassiophysales
Amphora commutata Grunow
Amphora sp.
Order : Surirellales
Campylodiscus clypeus (Ehrenberg) Ehrenberg ex Kützing
Campylodiscus hibernicus Ehrenberg
Entomoneis paludosa (W.Smith) Reimer
Order : Naviculales
Halamphora holsatica (Hustedt) Levkov
Navicula pygmaea Kützing
Navicula radiosa Kützing
Navicula sp.
Order : Cocconeidales
Cocconeis placentula Ehrenberg
Order : Cymbellales
Cymbella affinis Kützing
Cymbella tumidula Grunow
Encyonema minutum (Hilse) D.G.Mann
Encyonema perpusillum (Cleve-Euler) D.G.Mann
Gomphonema parvulum Ehrenberg
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot
Order : Eunotiales
Eunotia sp.
Order : Fragilariales
Fragilaria capucina Desmazières
Fragilaria tenera (W.Smith) Lange-Bertalot
Order : Rhopalodiales
Rhopalodia gibba (Ehrenberg) O.Müller
Order : Bacillariales
Hantzschia sp.
Nitzschia acicularis (Kützing) W.Smith
Nitzschia littoralis Grunow
Nitzschia palea (Kützing) W.Smith
Nitzschia reversa W.Smith
Class : Chrysophyceae
Order : Synurales
Mallomonas heterospina J.W.G.Lund
Mallomonas producta (Zacharias) Iwanoff
Mallomonas urnaformis Prescott
Mallomonas sp.
Phylum: Cryptista
Class : Cryptophyceae
Order : Cryptomonadales
Cryptomonas acuta Butcher
Cryptomonas erosa Ehrenberg
Cryptomonas ovata Ehrenberg
Cryptomonas marssonii Skuja
Order : Pyrenomonadales
Chroomonas acuta Utermöhl
Rhodomonas lacustris Pascher & Ruttner
Rhodomonas minuta Skuja
Phylum: Dinoflagellata
Class : Dinophyceae
Order : Gymnodiniales
Gymnodinium sp.
Order : Peridiniales
Palatinus pseudolaevis (M.Lefèvre) Craveiro. Calado. Daugbjerg & Moestrup

Kingdom: Plantae
Phylum: Chlorophyta
Class : Chlorophyceae
Order : Chlamydomonadales
Carteria globosa Korshikov
Carteria wisconsinensis Huber-Pestalozzi
Carteria sp.

Order : Sphaeropleales
Ankistrodesmus falcatus (Corda) Ralfs
Coelastrum microporum Nägeli
Coelastrum sphaericum Nägeli
Coenochloris fottii (Hindák) Tsarenko
Desmodesmus communis (E.Hegewald) E.Hegewald
Gloeocystis gigas (Kützing) Lagerheim
Gloeocystis vesiculosa Nägeli
Kirchneriella contorta (Schmidle) Bohlin
Kirchneriella irregularis (G.M.Smith) Korshikov
Kirchneriella obesa (West) West & G.S.West
Kirchneriella lunaris (Kirchner) Möbius
Monoraphidium contortum (Thuret) Komárková-Legnerová
Monoraphidium griffithii (Berkeley) Komárková-Legnerová
Monoraphidium irregulare (G.M.Smith) Komárková-Legnerová
Monoraphidium komarkovae Nygaard
Monoraphidium longiusculum Hindák
Monoraphidium tortile (West & G.S.West) Komárková-Legnerová
Quadrigula closterioides (Bohlin) Printz
Schroederia robusta Korshikov
Scenedesmus arcuatus (Lemmermann) Lemmermann
Scenedesmus armatus (Chodat) Chodat
Scenedesmus intermedius Chodat
Scenedesmus quadricauda var. armatus (Chodat) Dedusenko
Tetradesmus dimorphus (Turpin) M.J.Wynne
Tetradesmus obliquus (Turpin) M.J.Wynne
Tetraëdron minimum (A.Braun) Hansgirg
Order: Chlorodendrales
Tetraselmis cordiformis (H.J.Carter) F.Stein
Order : Chattonellales
Vacuolaria virescens Cienkowski

Class : Trebouxiophyceae
Order : Trebouxiales
Botryococcus braunii Kützing
Botryococcus calcareus West
Order : Prasioales
Koliella longiseta (Vischer) Hindák
Order : Chlorellales
Chlorella vulgaris Beyerinck (Beijerinck)
Closteriopsis acicularis (Chodat) J.H.Belcher & Swale
Closteriopsis longissima (Lemmermann) Lemmermann
Crucigeniella rectangularis (Nägeli) Komárek
Dictyosphaerium chlorelloides (Nauman) Komárek & Perman
Dictyosphaerium pulchellum H.C.Wood
Dictyosphaerium tetrachotomum Printz
Didymogenes anomala (G.M.Smith) Hindák
Oocystis borgei J.W.Snow
Oocystis gloeocystiformis O.Borge
Oocystis parva West & G.S.West
Oocystis pusilla Hansgirg
Oocystis borgei J.W.Snow
Oocystis gloeocystiformis O.Borge
Oocystis parva West & G.S.West
Oocystis pusilla Hansgirg
Order : Volvocales
Chloromonas sp.
Gonium sociale (Dujardin) Warming
Sphaerocystis schroeteri Chodat

Phylum: Charophyta
Class : Zygnematophyceae
Orders : Desmidiales
Closterium setaceum Ehrenberg ex Ralfs
Cosmarium granatum Brébisson ex Ralfs
Cosmarium sp.

Kingdom: Protozoa
Phylum: Euglenophyta
Class : Euglenophyceae
Order: Euglenales
Euglena viridis (O.F.Müller) Ehrenberg
Euglena sp.
Lepocinclis steinii (Lemmermann) Lemmermann
Phacus nordstedtii Lemmermann
Phacus orbicularis K.Hübner
Phacus pyrum (Ehrenberg) W.Archer
Phacus sp.
Trachelomonas cylindrica Ehrenberg

Discussion

Due to the lake's shallow depth, averaging around 1 meter in most areas, wind activity causes solid particles from surrounding land, as well as sediment and benthic algae from the lake bottom, to mix into the water, leading to increased suspended solids (SSM) and turbidity. The annual average SSM value of 16 mg/L slightly exceeds the eutrophication control limit (15 mg/L) [23]. Turbidity, which is generally caused by inorganic suspended particles and affects the visual properties of water [24], averaged 16.5 NTU in the lake but was not intense enough to prevent light penetration through the water column. Secchi disk measurements confirmed that light reached the lake bottom throughout the sampling period.

Located just northeast of Ulaş district with no industrial facilities nearby, the lake had an average chemical oxygen demand (COD) of 47 mgO_2/L, which exceeds the eutrophication control limit of 8 mg/L. This high COD is likely due to the transport of organic and inorganic matter into the lake via precipitation [25, 26]. Additionally, wind-induced mixing of bottom sediment into the water contributes to the increase in COD.

The highest water temperature was recorded in July at 24°C, the highest temperature measured in the lake. Increased water temperature leads to oxygen depletion, decomposition of organic matter, and proliferation of microorganisms [27]. The consistently high dissolved oxygen concentration (average 7.5 mgO_2/L) decreased during the summer months, reaching 4.4 mgO_2/L in July 2011, when the water temperature was highest.

Electrical conductivity (EC) was highest during the autumn period (September/October) at 4.15 mS/cm. Increased evaporation due to higher temperatures in the summer months significantly reduces water levels, leading to increased ion concentrations [28]. The presence of gypsum, a mineral that dissolves at a rate of over 2 grams per litter [29], in the geological formation contributes significantly to the increase in electrical conductivity. Additionally, the presence of chloride (up to 389 mg/L) contributes to high mineral content and, consequently, increased EC [30, 31].

The lake water exhibited high annual average values for calcium (786 mg/L), sulphate (101 mg/L), and hardness (207 $mgCaCO_3/L$). The primary sources of sulphate in water are sulphate-rich minerals like gypsum ($CaSO_4$) and soda-rich rocks [32]. Lakes in such regions are classified as hard-water lakes [33]. Hardness is commonly used to assess water quality, with values above 180 $mgCaCO_3/L$ classified as very hard water [34]. With a hardness of 207 $mgCaCO_3/L$, Ulaş Lake falls into the very hard water category.

Ulaş Lake exhibits high alkalinity, with a pH of 8.6 and total alkalinity (TA) of 140 $mgCaCO_3/L$. This alkalinity is attributed to carbonate and hydroxide sources, as these compounds are present in environments with high pH [22]. The high carbonate levels are due to the excessive use of CO_2 in photosynthesis by macrophytes in coastal areas and phytoplanktonic/epiphytic organisms in open areas, removing it from the water [35].

Silica, which is moderately abundant and relatively unreactive, can significantly affect algal production and succession in many lakes [36]. It is particularly used in large quantities during the formation of diatom frustules. In Ulaş Lake, the highest silica concentration (6 mg/L) was recorded in December 2010, when diatom abundance was at its lowest. The annual average silica concentration of 1.6 mg/L is lower than the typical range for natural waters (2–20 mg/L) [37], with a global average of 13 mg/L [38]. The primary source of silica in lakes is surface water, though in some lakes, groundwater is the main source [39]. In Ulaş Lake, which is not fed by groundwater, surface water inputs are the primary source of silica.

Chlorophyll-a, the primary pigment of all oxygen-producing photosynthetic organisms [36], is used as a criterion for assessing a lake's productivity (trophic status) [33]. The annual average chlorophyll-a value in Ulaş Lake was 11 µg/L, which corresponds to the upper limit of the mesotrophic range (3–11 µg/L) [40].

Phosphorus, a nutrient and cellular building block, is present in relatively low amounts compared to other nutrients in nature and is rarely a limiting factor in freshwater systems. Unpolluted natural waters are typically phosphorus-poor, with concentrations ranging from 10–50 µg/L depending on geological formations. In many unpolluted natural waters, phosphorus concentrations are less than 1 µg/L [36]. In Ulaş Lake, the annual average total phosphorus was 55.4 µg/L, and total dissolved phosphorus was 32.1 µg/L. These values indicate a mesotrophic character when compared to Vollenweider (1979) [40]. Additionally, based on total phosphorus concentrations, the lake falls within eutrophication threshold values and is classified as Class I water in terms of water quality [23].

Nitrogen, which originates from various sources, exists in water in multiple forms, including ammonium (NH_4-N), nitrate (NO_3-N), and nitrite (NO_2-N) [36]. Although nitrogen is abundant globally, only a small fraction is bioavailable to organisms [41]. Nitrogen is vital for plants and is primarily taken up as ammonium (NH_4-N) and nitrate (NO_3-N). Ammonium, produced through the biological breakdown of nitrate, is the primary nitrogen source rapidly consumed by algae in the trophogenic zone [42]. In Ulaş Lake, the annual average concentrations were 35 µg/L for ammonium, 47 µg/L for nitrate, and 9 µg/L for nitrite. In well-oxygenated, oxygen-rich waters, ammonium is typically lower than nitrate [43], which is consistent with Ulaş Lake, where ammonium levels are lower than nitrate due to consistently high dissolved oxygen levels. Nitrite is either absent or present in trace amounts in unpolluted clean waters [44], with natural waters typically ranging from 0–10 µg/L [36]. The annual average nitrite value in Ulaş Lake (9 µg/L) falls within this range for unpolluted natural waters.

A total of 115 species were identified in the lake, with 49 belonging to Chlorophyta, 36 to Heterokontophyta, 10 to Cyanobacteria, 8 to Euglenophyta, 7 to Cryptista, 3 to

Charophyta, and 2 to Dinoflagellata. Chlorophyta was the dominant group, accounting for 42.6% of the total species, followed by Heterokontophyta (31.3%), Cyanobacteria (8.7%), Euglenophyta (7%), Cryptista (6.1%), Charophyta (2.6%), and Dinoflagellata (1.7%). In temperate regions, increased light and temperature in spring typically lead to diatom proliferation, followed by increases in Chlorophyta and Cyanophyta in summer [45]. In Ulaş Lake, Chlorophyta members showed numerical abundance in May, June, and July, when water temperature and light increased, with *Monoraphidium tortile*, *Monoraphidium contortum*, *Monoraphidium griffithii*, and *Coenochloris fottii* being the dominant species. The Heterokontophyta group, the second most diverse, was primarily represented by benthic species due to the lake's shallow depth and exposure to wind [46, 47], with significant numerical abundance in August. *Chaetoceros muelleri*, *Cocconeis placentula*, and *Fragilaria capucina* were the dominant species in this group. *Fragilaria* species are known to thrive in slightly saline lakes with high nitrogen and phosphorus levels [48], while *Chaetoceros muelleri* is a common colonial planktonic species in saline environments, peaking in mid-summer [49]. In shallow temperate lakes, Cyanobacteria typically increase in spring [50] and warm seasons [51, 52], and in Ulaş Lake, they formed a significant portion of the phytoplankton in the second July sampling, with *Chroococcus dispersus* and *Chroococcus minor* being dominant. Euglenophyta members, which thrive in polluted waters with high organic matter [53], were rare in Ulaş Lake, which is free of domestic waste, and were most abundant in October but not numerically significant. Cryptista members prefer nutrient-rich waters [6] and are typically present in temperate lakes during winter, mid-summer, and late autumn [54]. In Ulaş Lake, Cryptista members were numerically significant in spring (March and April) and late autumn (September, October, and November), accounting for nearly half of the total organisms, with *Cryptomonas marssonii* and *Rhodomonas minuta* being dominant. The Dinoflagellata and Charophyta groups were present throughout the sampling period but did not reach significant numerical levels.

Conclusions

Ulaş Lake, located in the southwest, was evaluated in terms of water quality according to SKKY [23]. The lake was classified as Class I for pH, water temperature, and NO_3–N (nitrate nitrogen), and as Class II for dissolved oxygen, NO_2–N (nitrite nitrogen), TP (total phosphorus), SSM (suspended solids), and COD (chemical oxygen demand). This hard-water lake exhibits a mesotrophic–eutrophic character based on Chl-a (chlorophyll-a), TP, and TN (total nitrogen) according to the criteria of Vollenweider [40]. With respect to phytoplankton species composition, members of the Chlorophyta group are predominant, and the phytoplankton community is largely composed of species typically found in mesotrophic–eutrophic systems.

The study conducted on the Ulaş Lake, which is susceptible to eutrophication, is significant in terms of elucidating the lake's biological and physicochemical characteristics as well as its trophic status. The findings also provide valuable baseline data for future monitoring efforts. Moreover, the results are expected to contribute to the conservation of the lake's biological diversity. To protect the Ulaş Lake ecosystem, activities that may negatively impact the lake—such as uncontrolled reed cutting, illegal fishing, establishment of picnic areas, canal widening, and water extraction for irrigation—should be strictly avoided in the surrounding area.

Conflicts of interest

There are no conflicts of interest in this work.

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