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Eco-assessment of phytoplankton composition in relation to environmental conditions of saltwater and freshwater lakes in the Konya Closed Basin (Türkiye)

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Abstract: Great importance is given to maintaining lentic ecosystems, threatened by human-induced consequences worldwide. The present study hypothesized to assess differences in species-environment relationships and ecological status of 15 lakes (saline water systems, high-altitude freshwater lakes, and other freshwater lakes) in the Konya Closed River Basin using phytoplankton indices throughout wet and dry periods. Results of canonical correspondence analysis separated saline and freshwater (high-altitude) habitats, which were characterized by different phytoplankton species. Total phosphorus (TP), electrical conductivity (EC), nickel-Ni, and altitude were the most influential environmental factors affecting phytoplankton dispersal in these ecosystems. Saline lakes were under pressure of high EC, TP, and Ni, while high-altitude freshwater ecosystems were associated with the elevation. Lake Uyuz, associated with TP and Ni, is characterized by *Anabaenopsis elenkinii, Cocconeis pediculus, Euglena viridis, Lepocinclis acus, Lepocinclis ovum,* and *Lepocinclis oxyuris*. Several phytoplankton species such as *Dunaliella salina*, *Nitzschia communis, Nitzschia inconspicua, Nitzschia vermicularis*, and *Navicula cincta* were found in saline and saline soda lakes with high EC gradients. Freshwater lakes are characterized by *Tabellaria flocculosa*, *Pinnularia anglica*, *Fragilaria pararumpens*, *Eunotia bilunaris*, and *Pinnularia microstauron*. Results of the phytoassessment displayed a high ecological status for Lake Sülüklü but a bad ecological status for Lake Uyuz. The modified phytoplankton trophic index can be an appropriate phytoplankton metric for determining the environmental conditions of lakes in the Konya Closed system. The Søndergaard metric based on total phytoplankton and cyanobacteria biovolume also supported the ecological statuses of lakes. This work underlined the importance of phytoplankton ecological integration in saline water systems and high-altitude freshwater lakes, as well as the determination of the ecological statuses of various lakes in the semiarid eco-region.

Key words: Eco-assessment, phytoplankton, surface waters, Konya Closed Basin, conductivity

1. Introduction

Freshwater resources, especially lakes, are under increasing pressure from anthropogenic activities such as agricultural land use, urbanization, wastewater discharge, modification (e.g., sand removal, reed cutting, etc.), and climate change (Häder et al., 2020). These forces result in the world's most serious environmental problems, such as eutrophication, acidification, and toxic contamination (Glibert and Burford, 2017; Häder et al., 2020). Nutrient enrichment not only alters abiotic variables in lakes but also shows detrimental effects on the biota (e.g., undesirable algal blooms, excessive growth of nuisance macrophytes, and an increase in fish mortality, particularly in sensitive species), hydromorphology, and functions of lakes (Padedda et al., 2017). Increased degradation of ecosystems and exploitation of freshwater resources (despite global water scarcity) have resulted in a renewed focus on freshwater ecosystems to improve and maintain water resources worldwide (Häder et al., 2020; Çelekli et al., 2021).

The European Water Framework Directive was adopted as the most significant environmental legislation (Directive, 2000). It includes the biological (e.g., phytoplankton, macrophytes, benthic invertebrates, phytobenthos, and fish fauna), chemical (e.g., nutrients, dissolved oxygen, and conductivity), and hydromorphological assessments of water bodies. The distributions of bioindicator taxa based on their ecological preferences are used to develop biotic indices. Phytoplankton species are frequently used in biological assessments of lentic ecosystems to assess environmental conditions and obtain explanatory information about ecosystem health (Mischke et al., 2008; Padisák et al., 2009; Phillips et al., 2013; Poikane et al., 2015). They are robust indicators in aquatic ecosystems because phytoplankton species respond uniquely to environmental

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changes (Reynolds et al., 2002; Kruk et al., 2017). The quantification of species-pollution gradient interactions is used to develop phytoplankton metrics. Among the most well-known metrics are the phytoplankton trophic index (PTI) (Phillips et al., 2013), the Mediterranean phytoplankton trophic index (Med-PTI) (Marchetto et al., 2009), Q assemblage phytoplankton index (Padisák et al., 2006), and the modified phytoplankton trophic index (MPTI) (Çelekli and Lekesiz, 2021). The MPTI was developed to evaluate the ecological status of lakes and reservoirs in Türkiye.

Phytoplankton assemblages in various ecosystems are influenced and driven by a variety of changing environmental conditions. Quantifying phytoplankton assemblages and environment relationships is more difficult. Therefore, multivariate techniques are used to quantify phytoplankton-stressor interactions in complex environmental ecosystems (Kruk et al., 2017; Çelekli and Lekesiz, 2020).

In Anatolia, phytoplankton-environment interactions have been studied (Çelekli and Öztürk, 2014; Sevindik et al., 2017; Çelekli and Özpinar, 2021) but not the bioassessment of lentic ecosystems in the Konya Closed River Basin has been encountered, until now. Hypothesis of the present study was to evaluate differences (i) in the phytoplankton-environment associations in saline water systems, high-altitude freshwater lakes, and other freshwater lakes using multivariate statistical analyses; (ii) in ecological preferences of phytoplankton species in various ecosystems using weighted average regression, and iii) in the bioassessment of different lakes, using the MPTI (Çelekli and Lekesiz, 2021), the Med-PTI (Marchetto et al., 2009) and Søndergaard metric (Søndergaard et al., 2005) during the wet and dry periods.

2. Materials and method

2.1. The research area

The Konya Closed River Basin is surrounded by the Taurus, Geyik, Sultan, and Melendiz mountains in Central Anatolia (Figure 1). Several wetlands, such as Meke Maar and Kızören Sinkhole in this basin have international significance under the Ramsar Convention. Besides, Lake Tuz (Salt) and Ihlara Valley have environmental protection status. This basin has many lakes with different typologies (Table 1).

This basin covers 57% agricultural (92% grain, 5% fruit, and 3% vegetable farming), 33% seminatural, 7.9% wetlands, and 2.1% artificial areas.[1] The Konya Closed River watershed has a continental climate with dry, hot summers and cold, snowy winters with a low annual precipitation (approximately 450 mm). Due to the low temperatures and high altitudes (up to 3404 m a.s.l.), the area around the Taurus Mountains receives abundant precipitation, whereas the plateau regions receive relatively low annual rainfall (340–380 mm on average) and the evaporation rate is high.

Lake Tuz, Lake Küçük, and Meke Maar are saline ecosystems. According to the Ramsar Convention, Meke Maar is a wetland of international importance, and Lake Tuz (Salt) is a designated area for environmental protection. Migratory birds, particularly flamingos, congregate at Tuz and Küçük lakes. With 324 mm of annual precipitation, the region is one of the driest in Türkiye. Meke Maar is a crater lake that forms when a deflated volcano crater fills with water and develops islets in the center due to a volcanic eruption. Narlıgöl and Acıgöl are saline soda lakes formed by volcanic activity. Lake Uyuz, a shallow ecosystem, has a brackish water characteristic, and dense macrophytes are present at the littoral region under pressure of agricultural land use and excessive evaporation in summer.

Lake Gök-Kozanlı is a swamp surrounded by extensive reed-forested wetland meadows and marshes. Tectonically formed Lake Beyşehir is the basin's largest freshwater lake in terms of surface area, covering 65,100 ha. Sülüklü, Dipsiz, Kovalı, and Gavur lakes (>1690 m a.s.l.) are located on Erenler Mountain. Lake Gavur is a tectonic-derived ecosystem at an elevation of 1850 m. These lakes were primarily fed by snow during the spring season.

2.2. Sampling

Water and phytoplankton samples were collected from 26 sampling stations (Figure 1) in 15 different lakes (Table 1), ranging from saline to freshwater lentic ecosystems during wet (May 2017) and dry (August and November 2017) periods. The stations are classified according to their typological criteria such as A-altitude (A1 800 m, A2 800–1600 m, and A3 1600 m), D-depth (D < 5m and D2 > 5m), S-surface area (S1 ≤ 500 ha and S2 > 500 ha), and G-geology (high mineralization-G1 and low mineralization-G2) (see Table 1).

Water samples from beneath the surface were collected and transported to the laboratory for chemical analysis in cooler conditions (+4 °C). The collection of phytoplankton samples was conducted in the sampling stations of lakes below the surface using a motorized Zodiac boat. The collection method followed the standard procedure outlined in EN 16698 (European Committee for Standardization, 2015). We applied composite sampling from the euphotic zone, using the Secchi depth as a criterion, when the ecosystem's depth exceeded 5 m. The obtained subsamples in 250 mL bottles were then preserved

[1] CLC (2018). Corine Land Cover Service. Pan-European Data. Version 2020_20u1, May 2020 [online]. Website https://land.copernicus.eu/en/products/corine-land-cover/clc2018 [accessed 14 January 2021].

Table 1. Hydro-geographical properties of lakes studied in the present study. A-altitude (A1 < 800 m, A2 800–<1600 m and A3 ≥ 1600 m), D-depth (D1 < 5 m and D2 > 5 m), S-surface area (S1 ≤ 500 ha and S2 > 500 ha), and G-geology (G1 high and G2 low mineralization).

Typology	Code	Name	Latitude	Longitude	Altitude (m)	Ecosystem	Origin	Surface (ha)
A2D1S2G2	L01	Lake Uyuz	39.24040	32.92198	1192	Brackish	Tectonic	150
A2D1S1G2	L02	Lake Gök-Kozanlı	39.01952	32.82077	985	Swamp	Tectonic	650
A2D1S2G2	L03	Lake Küçük	39.06240	33.13235	968	Saline	Tectonic	25
A2D1S2G2	L04	Lake Tuz	38.77890	33.18304	906	Saline	Tectonic	166,500
A2D2S2G2	L05	Lake Bakı	38.39716	34.36456	1175	Freshwater	Volcanic	22
A2D2S1G2	L06	Lake Narlıgöl	38.33937	34.45469	1371	Saline soda	Volcanic	96
A2D1S1G2	L07	Meke Maar	37.68979	33.63912	988	Saline	Volcanic	2
A2D2S1G2	L08	Lake Acıgöl	37.71206	33.67342	987	Saline soda	Volcanic	400
A2D1S2G1	L09	Lake Süleymanhacı	37.47076	33.07647	998	Freshwater	Tectonic	95
A3D1S1G1	L10	Lake Sarıot	37.10171	32.11629	1713	Freshwater	Karst	10
A3D1S1G2	L11	Lake Sülüklü	37.56196	32.04894	1742	Freshwater	Volcanic	44
A3D1S1G2	L12	Lake Dipsiz	37.57395	32.03229	1691	Freshwater	Volcanic	29
A3D1S1G2	L13	Lake Kovalı	37.57963	32.03230	1737	Freshwater	Karst	790
A3D1S1G2	L14	Lake Gavur	37.61631	32.07477	1850	Freshwater	Tectonic	2000
A2D2S2G1	L15	Lake Beyşehir	37.67594	31.71379	1123	Freshwater	Tectonic	65,100

using a Lugol (mixture of 100 g KI in 1 L of distilled water and dissolved 50 g iodine (crystalline) in 100 mL glacial acetic acid)-glycerol (2–3% glycerol) solution (European Committee for Standardization, 2015). A Hydrobios plankton net was utilized to collect net plankton, which was then concentrated in a 250-mL polyethylene container and fixed using the Lugol-glycerol solution.

A YSI professional device with multiple probes was used to measure electrical conductivity (EC, µS/cm), dissolved oxygen (DO, mg/L), water temperature (°C), pH, and salinity (ppt) in situ from just beneath the surface in sampling stations.

2.3. Analyses of physical and chemical variables

Water chemicals such as TP–total phosphorus, P-PO_4^{3-} orthophosphate, TN–total nitrogen, N-NO_3^-–nitrate-nitrogen, N-NO_2^-–nitrite-nitrogen, etc., were quantified according to APHA (2012) standard procedures. The metal concentrations (e.g., Ni-nickel, Al-aluminum, Ar-arsenic, Sb-antimony, Cu-copper, B-boron, Fe-iron, Cr-chrome, V-vanadate, Zn-zinc) in lakes were recorded using an ICP-OES-inductively coupled plasma-optical emission spectrometry (Perkin Elmer, Optima 2100 DV).

2.4. Identification of phytoplankton

Net-phytoplankton identification was carried out under an Olympus BX53 model research microscope equipped with a DP73 model digital camera, and a cellSens version 1.6 imaging software, following taxonomic books (Komárek and Fott, 1983; Popovsky and Pfiester, 1990; Komárek and Anagnostidis, 1998; John et al., 2012; Bey and Ector, 2013; Lange-Bertalot et al., 2017). An Olympus CKX41 model inverted microscope was used to count more than 350 settling units of the phytoplankton at magnifications of 400 and 600X (European Committee for Standardization, 2006). Dimensions of phytoplankton cells were measured using the cellSens software, multiplying the taxon's mean cell biovolume to calculate total biovolume (Sun and Liu, 2003).

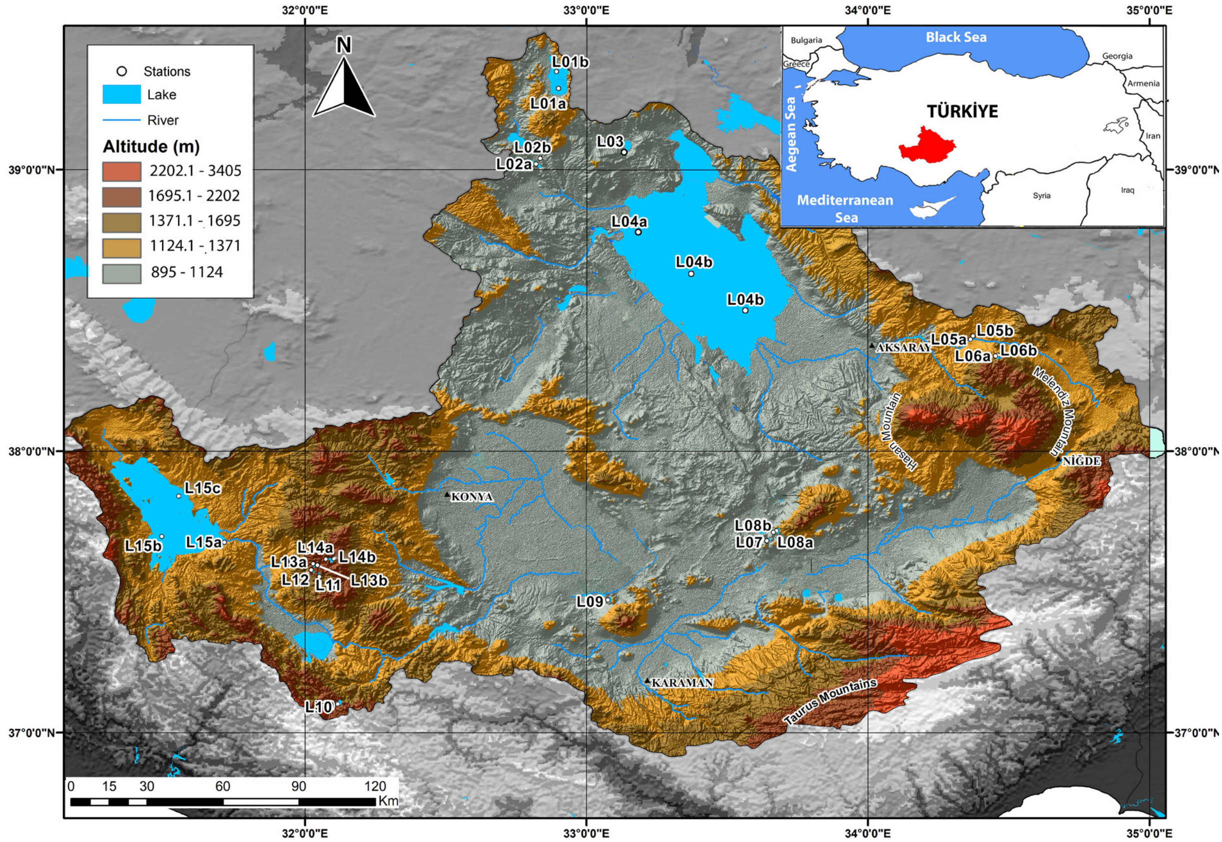

Figure 1. Location of saline and freshwater lakes in the Konya Closed Basin. Symbols of lentic ecosystems with their names are given in Table 1. Lower different letters are used after the codes of the lakes to indicate the different sampling stations. Lake Beyşehir (L15) had three sampling stations coded as L15a, L15b, and L15c.

2.5. Bioassessment of lentic ecosystems

The MPTI (Çelekli and Lekesiz, 2021) and the Med-PTI (Marchetto et al., 2009) were used to assess the ecological conditions of the studied lakes.

Equations 1 and 2 were used to calculate MPTI and Med-PTI values.

$$MPTI = \frac{\sum_{j=1}^{n} a_j \times s_j \times i_j}{\sum_{j=1}^{n} a_j \times i_j}, \quad \text{(Eq. 1)}$$

where a_j is the fractional biovolume, s_j is the optimum for logTP, and i_j is the indicator value for *jth* species. The optimum and indicator values of phytoplankton species were calculated using the Excel tool for each lake. The optimum value was determined based on logTP using the weighted average (WA) regression. Tolerance (t) value was calculated using.

$$t = \sqrt{\left(\sum_{i=1}^{n} (\log \mathrm{TP} - \mathrm{WA})^2 * a_j\right) \Big/ \sum_{i=1}^{n} a_j}$$

According to the results of *t* (tolerance), the indicator value of phytoplankton species varied between 1 and 4.

$$Med-PTI = \frac{\sum_{k=1}^{n} b_k \times v_k \times i_k}{\sum_{k=1}^{n} b_k \times i_k}, \quad \text{(Eq. 2)}$$

In this equation, b_k, v_k, and i_k all refer to the *kth* species and represent its biovolume, trophic value, and indicator value, respectively (Marchetto et al., 2009).

Søndergaard metric (Søndergaard et al., 2005) based on the phytoplankton biovolume was used to estimate the ecological status of lakes.

Carlson's trophic state index values (Carlson, 1977) were used to determine the trophic status of lakes based on Secchi disk depth and total phosphorus values.

2.6. Statistical analysis

Descriptive analysis (SPSS version 15.0, SPSS Inc., Chicago, IL, USA) was used to calculate the means and standard deviations of environmental variables. Duncan's multiple range test (SPSS version 15.0) was used to compare environmental variable means among lentic habitats. Percentile analysis was applied to calculate the data's percentiles (e.g., 25th, 50th, and 75th). The phytoplankton indices-environmental correlations were estimated by the Spearman rank correlation test. An analysis of similarities (ANOSIM) test was used to test the significant differences between saline and freshwater ecosystems' species compositions. An analysis of similarity percentage test (SIMPER) was performed to see the similarity/dissimilarity of the sampling groups along with the individual contribution of phytoplankton species to these similarities/dissimilarities. The ANOSIM and SIMPER analyses were done in Community Analysis Package version 4.1.3 software (Seaby and Henderson, 2007).

Detrended correspondence analysis (DCA) was run to justify the application of unimodal, and the gradient lengths greater than 4.0 indicated the suitability of data for CCA-canonical correspondence analysis (ter Braak J. F. and Šmilauer, 2002). Using the CANOCO 4.5 program, a CCA was performed to analyze phytoplankton-environment associations at the 26 stations sampled over three seasons in the Konya Closed Basin. Environmental variables were log-transformed except pH to alleviate skewness (ter Braak J. F. and Šmilauer, 2002). To determine which environmental factors significantly affected the distribution of phytoplankton species, a Monte Carlo permutation test using forward selection was conducted. We used a weighted averaging (WA) regression (Juggins and ter Braak, 1992) to predict the best possible environmental values for each phytoplankton species. Phytoplankton species found at least twice in sampling sites with more than 1% biovolume were employed in multivariate statistical analyses (Šmilauer and Lepš, 2003).

3. Results

3.1. Environmental variables

Table 2 shows the mean ± standard deviation values of several environmental variables, and others are given in Supplementary 1. Lake Küçük (L03), a shallow saline ecosystem at 968 m a.s.l., had the highest average water temperature of 29.9 °C, while Lake Sarıot (L10) at 1713 m a.s.l. had the lowest (12.0 °C). The mean electrical conductivity (EC) of lakes in the Konya Closed River Basin showed significant distinctness ($p < 0.01$). The EC gradient in the basin ranged from 95 µS/cm in Lake Sülüklü (L11) to 138,800 µS/cm in Lake Tuz (L04).

The mean nutrient contents in saltwater and freshwater ecosystems were substantially different ($p < 0.05$). Mean nutrient concentrations were highest in saltwater lakes such as Lake Uyuz (4.49 mg/L TN and 2.05 mg/L TP), Lake Tuz (1.20 mg/L TN and 2.35 mg/L TP), and Meke Maar (1.14 mg/L TN and 1.43 mg/L TP), and then lowest in a freshwater lake such as Lake Sülüklü (0.29 mg/L TN and 0.01 mg/L TP). There were significant differences ($p < 0.05$) in heavy metal contents among the lakes. Metal concentrations were found to be rather high in saline habitats. Lake Tuz had quite high arsenic (67.26 µg/L Ar) and boron (21.54 mg/L B) concentrations. Metal concentrations were relatively high in Lake Uyuz (e.g., 15.45 µg/L Ar, 16.41 µg/L Cu, 21.86 µg/L Zn, and 25.62 µg/L Ni) (see Table 2 and Supplementary 1).

3.2. Phytoplankton composition and environmental relationship

A total of 308 phytoplankton taxa were identified in 15 lakes, and 154 of them (Supplementary 2) were found more than once in sampling stations and had biovolumes greater than 1% of total biovolumes. Phytoplankton species such as *Botryococcus braunii, Chlamydomonas globosa, Cocconeis placentula, Cryptomonas ovata, Pantosekiella ocellata, Cryptomonas ovata, Desmodesmus communis, Fragilaria capucina, Mougeotia boodlei, Peridiniopsis cunningtonii, Peridinium cinctum,* and *Tetraëdron minimum* were found in the majority of the sampling stations during the identification studies. According to the ANOSIM, there was a significant difference in the species compositions between the saline and freshwater environments ($p < 0.05$). The SIMPER indicated a 95.1% dissimilarity between saline and freshwater ecosystems, which was exhibited by *P. cinctum*, *P. cunningtonii*, *M. boodlei*, *C. ovata*, *T. minimum*, *Lepocinclis oxyuris*, *Ulnaria ulna*, and *Peridinium willei*. Within-group similarity in lakes was determined to be 10.4% and 5.9% for the freshwater and saline habitats, respectively. The most contributing phytoplankton species to within-group similarity in freshwater ecosystems were *P. cinctum*, *M. boodlei*, *C. placentula*, *Ceratium hirundinella*, *C. ovata*, and *P. willei*, whereas *C. ovata*, *L. oxyuris*, *C. placentula*, and *P. cinctum* were the most contributing species to within-group similarity in saline waters.

Phytoplankton groups that contributed to total phytoplankton biovolume for saline and freshwater ecosystems are illustrated in Figures 2a and 2b, respectively. Among the saline lakes, Lake Uyuz (L01) had the highest phytoplankton biovolume (1.10 mm^3/L), while Lake Tuz (L04) had the lowest (0.11 mm^3/L). Most of the total phytoplankton biovolume of L01 (0.54 mm^3/L) was formed by Miozoa, while Ochrophyta was unable to contribute. Among the freshwater lakes, Lake Beyşehir (L15) had the highest phytoplankton biovolume (1.12 mm^3/L), while Lake Süleymanhacı (L09) had the lowest biovolume (0.19 mm^3/L). Chlorophyta showed the highest contribution to the total phytoplankton biovolume of L15 (48.24%) and L09 (70.24%). Lake Bakı (L05) had the largest Chlorophyta biovolume (79.53%) among freshwater lakes.

Table 2. Mean ± SD (standard deviation) values of environmental variables in lentic ecosystems. Meanings of the codes of lakes are given in Table 1.

Code	Temp (°C)	EC (µS/cm)	Salinity (ppt)	pH	DO (mg/L)	BOD (mg/L)	TP (mg/L)	TN (mg/L)	NO_3 (mg/L)	Ni (µg/L)
L1	24.7 ± 10.2^{a-c}	2519 ± 902	1.31 ± 0.49^{a}	9.3 ± $0.3^{f,g}$	5.32 ± 3.53^{a}	14.0 ± 21.0^{a}	2.05 ± 2.62^{b}	4.49 ± 4.78^{c}	0.16 ± 0.13^{a}	25.62 ± 18.85^{a}
L2	28.2 ± $4.6^{b,c}$	735 ± 382	0.36 ± 0.19^{a}	9.6 ± 0.2^{g}	10.68 ± 3.37^{a}	8.4 ± 11.2^{a}	0.08 ± 0.06^{a}	0.91 ± 0.74^{a}	0.14 ± 0.09^{a}	11.03 ± 3.46^{a}
L3	29.9 ± 13.5^{c}	60,800 ± 34,082	42.30 ± 26.87^{b}	9.1 ± 0.8^{d-g}	9.51 ± 1.55^{a}	110.4 ± 153.5^{b}	0.06 ± 0.07^{a}	4.12 ± $5.71^{b,c}$	0.08 ± 0.00^{a}	1.90 ± 0.01^{a}
L4	27.4 ± $5.8^{b,c}$	138,800 ± 10,6450	nd	7.4 ± $0.3^{a,b}$	7.03 ± 0.67^{a}	15.9 ± 8.0^{a}	1.02 ± $1.26^{a,b}$	1.2 ± $0.45^{a,b}$	0.43 ± 0.27^{b}	5.63 ± 6.47^{a}
L5	20.3 ± 4.3^{a-c}	600 ± 104	0.30 ± 0.06^{a}	7.5 ± 0.6^{a-c}	10.45 ± 2.31^{a}	5.0 ± 4.3^{a}	0.03 ± 0.02^{a}	1.20 ± $0.69^{a,b}$	0.14 ± 0.09^{a}	6.39 ± 7.78^{a}
L6	22.1 ± 4.4^{a-c}	2706 ± 677	1.46 ± 0.47^{a}	8.2 ± 0.3	8.26 ± 1.56^{a}	5.2 ± 3.5^{a}	0.01 ± 0.00^{a}	0.85 ± 0.73^{a}	0.08 ± 0.00^{a}	3.90 ± 4.48^{a}
L7	30.9 ± 2.7^{c}	186,000 ± 4352	nd	7.1 ± 0.3^{a}	4.87 ± 0.58^{a}	1.9 ± 0.0^{a}	0.06 ± 0.01^{a}	1.14 ± $0.23^{a,b}$	0.11 ± 0.00^{a}	1.9 ± 0.00^{a}
L8	21.4 ± 5.0^{a-c}	70,950 ± 21,747	34.93 ± 1.45^{b}	8.1 ± 0.3^{b-d}	8.32 ± 0.54^{a}	2.1 ± 0.4^{a}	0.02 ± 0.02^{a}	0.69 ± 0.28^{a}	0.14 ± 0.07^{a}	1.90 ± 0.01^{a}
L9	18.4 ± 2.4^{a-c}	407 ± 0	0.20 ± 0.00^{a}	8.7 ± 0.3^{d-g}	7.9 ± 0.54^{a}	1.9 ± 0.0^{a}	0.01 ± 0.01^{a}	1.83 ± 0.00^{a-c}	0.17 ± 0.00^{a}	1.90 ± 0.01^{a}
L10	12.0 ± 1.5^{a}	226 ± 0	0.11 ± 0.00^{a}	8.7 ± 0.3^{d-g}	9.04 ± 0.67^{a}	1.9 ± 0.0^{a}	0.01 ± 0.00^{a}	0.81 ± 0.00^{a}	0.08 ± 0.00^{a}	1.90 ± 0.00^{a}
L11	20.5 ± 7.9^{a-c}	95 ± 36	0.05 ± 0.02^{a}	9.1 ± 0.7^{e-g}	8.89 ± 1.29^{a}	6.0 ± 1.0^{a}	0.01 ± 0.01^{a}	0.29 ± 0.29^{a}	0.09 ± 0.00^{a}	1.90 ± 0.01^{a}
L12	15.8 ± $2.5^{a,b}$	215 ± 79	0.10 ± 0.04^{a}	8.5 ± 0.3^{d-f}	8.12 ± 1.02^{a}	5.0 ± 0.9^{a}	0.44 ± 0.39^{a}	0.82 ± 0.66^{a}	0.08 ± 0.00^{a}	2.39 ± 0.84^{a}
L13	18.7 ± 11.3^{a-c}	206 ± 83	0.10 ± 0.05^{a}	7.5 ± $0.4^{a,b}$	7.09 ± 0.26^{a}	7.4 ± 1.6^{a}	0.06 ± 0.07^{a}	0.64 ± 0.51^{a}	0.08 ± 0.00^{a}	1.90 ± 0.01^{a}
L14	18.1 ± 9.2^{a-c}	351 ± 398	0.04 ± 0.03^{a}	7.6 ± 0.9^{a-c}	12.00 ± 8.56^{a}	6.6 ± 1.8^{a}	0.05 ± 0.06^{a}	0.84 ± 0.18^{a}	0.16 ± 0.11^{a}	1.90 ± 0.00^{a}
L15	20.5 ± 5.1^{a-c}	414 ± 24	0.18 ± 0.03^{a}	8.5 ± 0.2^{c-f}	8.37 ± 0.65^{a}	4.7 ± 4.9^{a}	0.01 ± 0.01^{a}	0.48 ± 0.4^{a}	0.09 ± 0.00^{a}	1.90 ± 0.01^{a}

Temp: temperature, EC: electrical conductivity, DO: dissolved oxygen, BOD: biological oxygen demand, TP: total phosphorus, TN: total nitrogen, NO_3^-: nitrate, Ni: nickel.

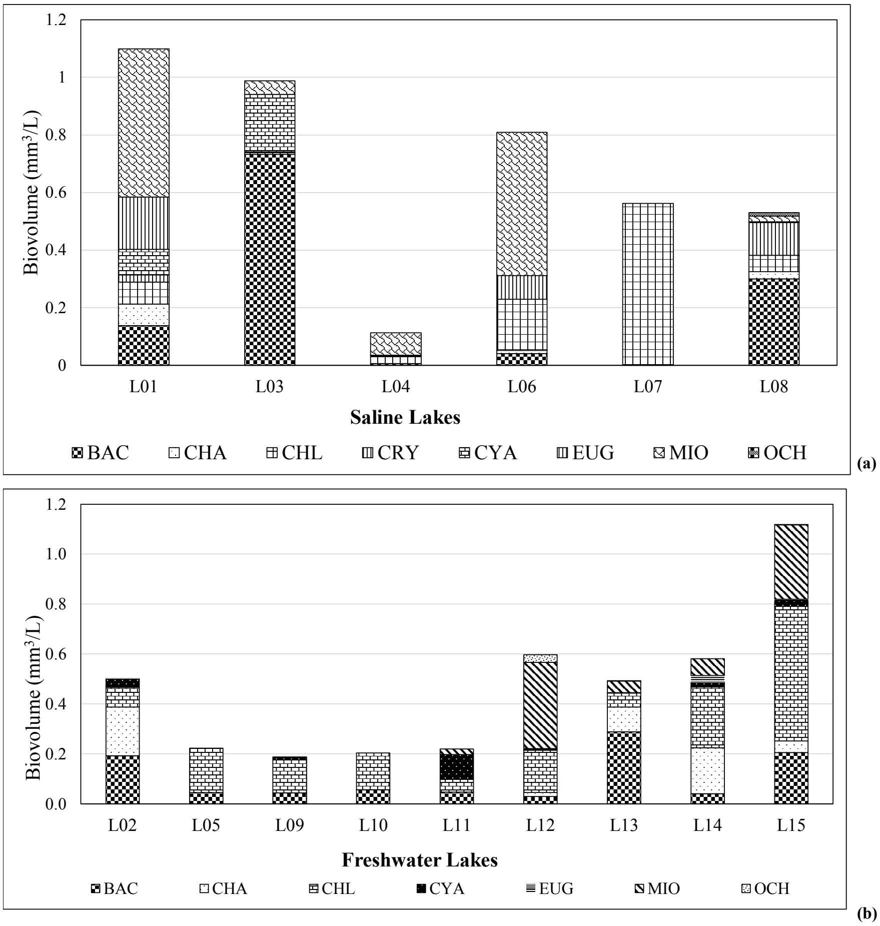

Figure 2. Contribution of phytoplankton groups to total biovolume of (a) saline and (b) freshwater lakes. BAC-Bacillariophyta, CHA-Charophyta, CHL-Chlorophyta, CRY-Cryptophyta, EUG- Euglenozoa, MIO- Miozoa, and OCH-Ochrophyta. Codes of lakes with their full names are given in Table 1. Phytoplankton biovolumes from seasons were pooled together in Figure 2.

The relationship of phytoplankton species with environmental factors differed in saline water systems, high-altitude freshwater lakes, and other freshwater lakes in the Konya Closed River Basin during the study. About 88.7% of species-environment relationships were elucidated by the first two axes of the CCA. The Monte Carlo test indicated that TP, EC, Ni-nickel, and altitude were found in the most significant environmental parameters affecting phytoplankton distribution among lentic habitats (Figure 3a). During the study, EC gradients were higher in the dry period than in the rainy period (Figure 3b).

The CCA grouped the lakes of the Konya Closed River Basin as saline water systems (L1, L3, L4, L6–L8), the high-altitude freshwater lakes (L10L14) and other freshwater systems (L02, L05, L09, and L15) in the diagram (Figure 3). Saline water systems were associated with high TP, EC, and Ni concentrations, whereas the high-altitude freshwater lakes are strongly related to elevation (Figure 3). Saline water systems such as Tuz (L04), Küçük (L03), Narlıgöl (L06), Meke Maar (L07), and Acıgöl (L08) lakes are related to high EC gradients, which were integrated by *Dunaliella salina*, *Nitzschia communis, Nitzschia inconspicua, Nitzschia vermicularis*, *Cyclotella iris*, *Navicula cincta*, *Coelastrum astroideum*, *Navicula cari*, and *Spirulina major* (Figure 3a). Lake Uyuz (L01) is associated with TP and Ni, and it was characterized by *Anabaenopsis elenkinii, Cocconeis pediculus, Euglena viridis, Mougeotia quadrangulata, Lepocinclis acus, Lepocinclis ovum,* and *L. oxyuris.* Additionally, weighted average (WA) regression revealed that these species had greater optima than the 75th percentiles of TP (Figure 4a) and Ni (Figure 4b). These phytoplankton taxa had EC optima higher than the 75th percentile (Figure 4c). High-altitude freshwater

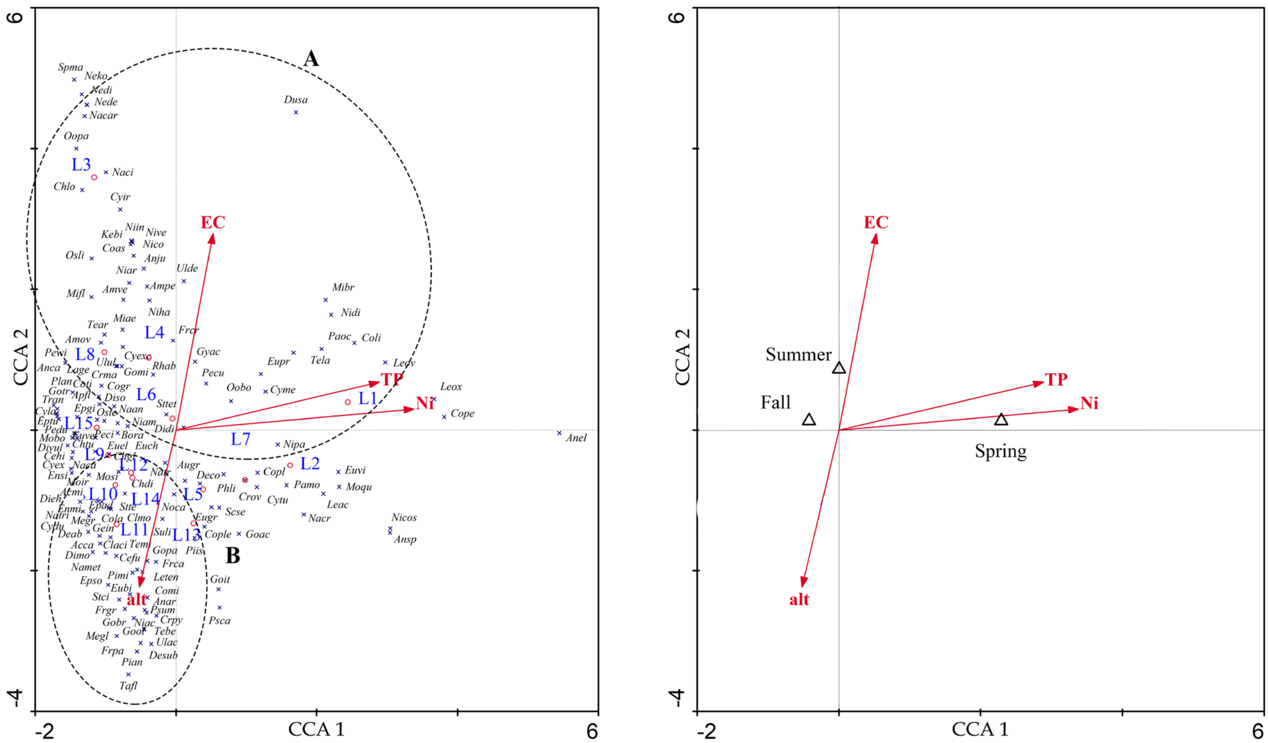

Figure 3. (a) Phytoplankton species (x) – environmental variables (arrows) relationships in sampling stations (circles) and (b) season-environmental factors relationships. Group A is saline water system, B is high-altitude freshwater lakes, and the remaining lakes are freshwater ecosystems. Codes of lakes and species with their full names are given in Tables 1 and Supplementary 2, respectively. EC-electrical conductivity, alt–altitude, TP-total phosphorus, and Ni-nickel.

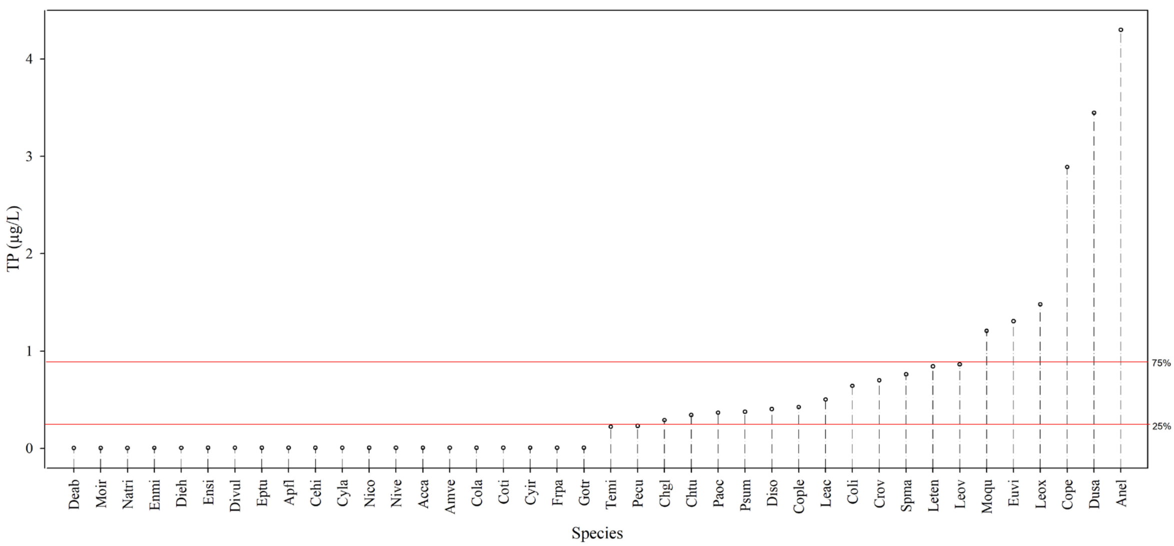

Figure 4. Optimum values of phytoplankton species for (a) TP-total phosphorus, (b) Ni-Nickel, c) EC-electrical conductivity, and (d) Alt-altitude. It was taken exclusively from the bottom twenty species and the top twenty species connected with environmental conditions. Codes of species with their full names are given in Supplementary 2.

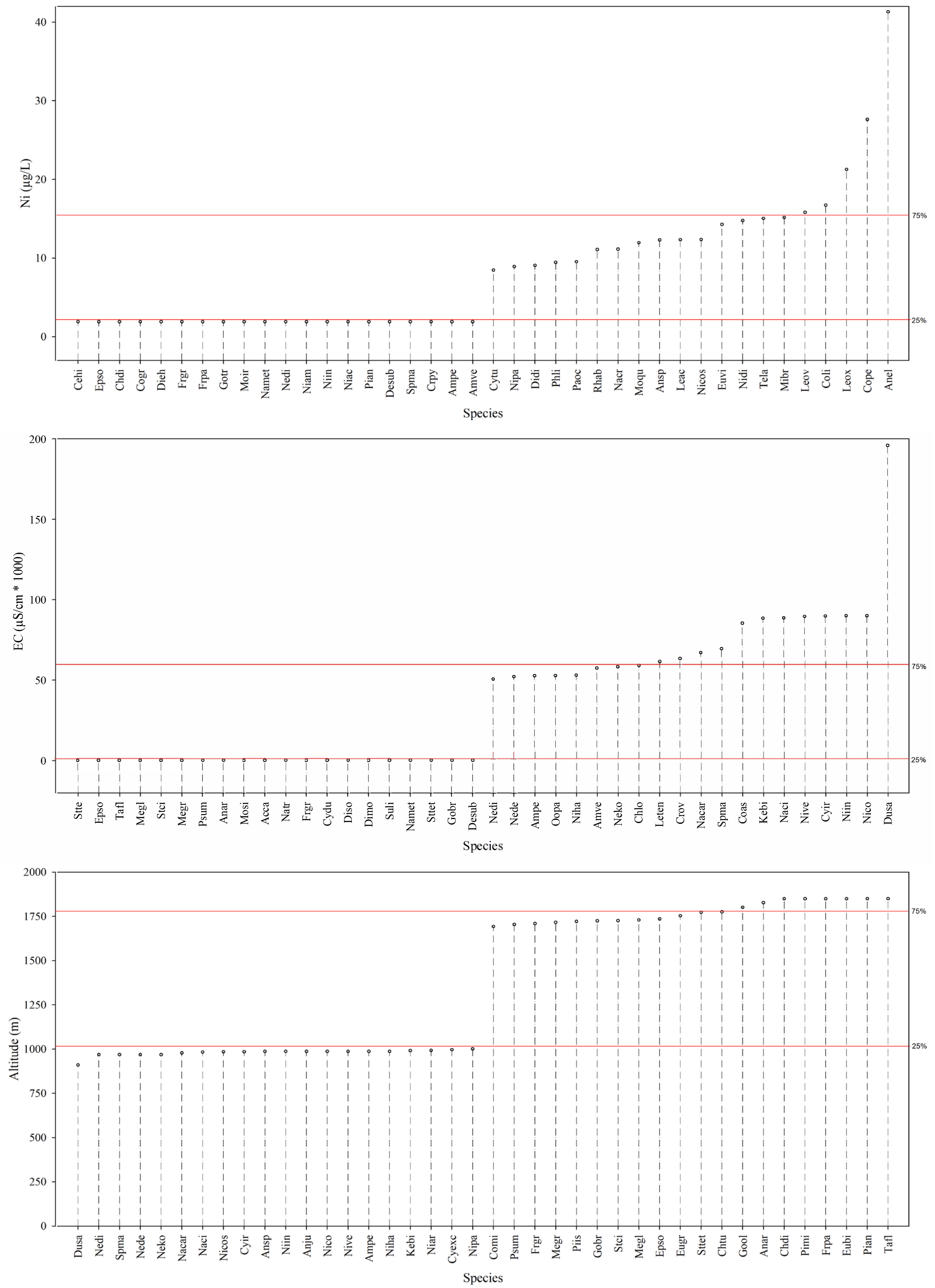

Figure 4. Continued

ecosystems (Sülüklü (L11), Kovalı (L13), Gavur (L14), Sarıot (L10), and Lake Dipsiz (L12) lakes) are subjected to altitude, characterized by *Tabellaria flocculosa*, *Pinnularia anglica*, *Fragilaria pararumpens*, *Eunotia bilunaris*, *Pinnularia microstauron*, and *Chroococcus dispersus* (Figure 3). These species preferred high altitudes (>75% of altitude in Figure 4d).

The remaining freshwater lakes (L02, L05, L09, and L15) are close to the center of the diagram and distributed between saline and high-altitude lakes (Figure 3a). Lake Gök-Kozanlı (L02) was a swamp, Lake Süleymanhacı (L09) was a temporal ecosystem, and Bakı (L05) and Beyşehir (L15) lakes were freshwater systems at a similar altitude.

Eco-assessments of lentic ecosystems using MPTI and Med-PTI are illustrated in Figure 5. MPTI values ranged from 0.84 in Lake Sülüklü to 2.82 in Lake Uyuz, while Med-PTI values ranged between 0.76 in Lake Uyuz and 5.72 in Lake Sülüklü. According to the MPTI and Med-PTI results, Lake Uyuz had a poor ecological status, whereas Lake Sülüklü had a high ecological status. Among saline water systems (L1, L3, L4, L6–L8), only Lake Tuz (L04) had a moderate ecological status, while the others had a good ecological status. With regard to the high-altitude freshwater lakes (L10–L14), a high ecological status was determined in Sarıot (L10) and Sülüklü (L11), Lake Dipsiz (L12) was a moderate, and Kovalı (L13) and Gavur lakes were a good ecological status. In the remaining freshwater group (L02, L05, L09, and L15), Lake Gök-Kozanlı (L02) had a moderate ecological status, and others had a good ecological status. The findings of the regression analysis revealed that the MPTI displayed the highest correlation coefficient value ($R^2 = 0.95$). Moreover, the results of the Søndergaard metric indicated a moderate environmental condition for Lake Uyuz and a good ecological condition for Lake Sülüklü.

The results of Carlson's trophic state index based on TP indicated that Uyuz, Tuz, and Dipsiz lakes are hypertrophic, while Sülüklü, Narlıgöl, Acıgöl, Sarıot, and Beysehir lakes are oligotrophic characteristic. According to the findings of water transparency, a hypertrophic state was found in Uyuz and Tuz lakes, and an oligotrophic state was not determined.

4. Discussion

Twenty-six sampling points in fifteen lentic (salt, brackish, and freshwater) habitats (Figure 1) were monitored during wet and dry seasons for this limno-ecological study. Lentic ecosystems exhibited temporal and spatial variations in environmental variables. Saline water systems had high EC gradients, and the highest mean EC value was determined in Lake Tuz (a protected area), followed by Lake Küçük and Meke Maar. In Central Europe, saline lakes have conductivities ranging from approximately 3000 to approximately 60,000 µS/cm (Stenger-Kovács et al., 2018), which is lower than those of Tuz, Küçük, and Acıgöl lakes (Table 2). The shallow lakes in the present study exhibit a remarkably high salt content, especially during the summer. This phenomenon occurs due to the limited inflow of freshwater and the intense evaporation caused by high temperatures. As a result, the concentration of dissolved

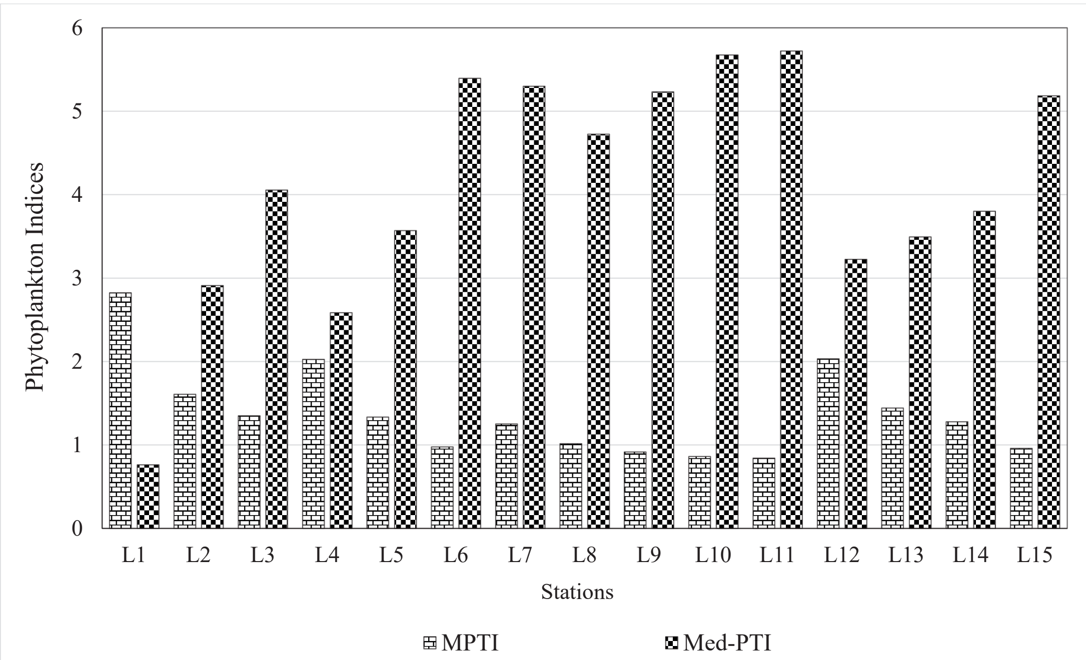

Figure 5. Results of the modified phytoplankton index (MPTI) and Mediterranean phytoplankton index (Med-PTI).

salts in the lakes becomes significantly elevated. Another factor is that the region is one of the driest in Türkiye, with 324 mm of annual precipitation. Besides, Lake Tuz, a hypersaline ecosystem, is impacted by anthropogenic (e.g., wastewater discharge, agricultural land use, salt extraction from the lake, and unregulated groundwater use in this region) and climatic (e.g., low precipitation and excessive annual evaporation of 1372.7 mm) factors (Dengiz and Baskan, 2009). This hypersaline condition caused a decrease in the number of phytoplankton species and the lowest total phytoplankton biovolume in Lake Tuz. Tuz and Küçük lakes are significant accommodation (refugia) ecosystems for migratory birds, particularly flamingos, which use them for resting, breeding, nesting, and feeding on *Artemia salina* (red brine shrimp). Lake Tuz is Türkiye's largest flamingo nesting site, with approximately 6000 nesting nets (OECD, 2010; Atıcı, 2022).

The high concentrations of nutrients, particularly TN and TP, as well as the presence of heavy metal ions, were determined in shallow Lake Uyuz. The degradation of this lake could be a result of both intensive agricultural land use and livestock farming, as well as intense evaporation in this semiarid region, which is consistent with previous limno-ecological studies in Mediterranean semiarid climates (Naselli-Flores and Barone, 2003; Çelekli and Bilgi, 2019). Migratory birds' resting areas may load phosphorus, resulting in persistently high TP values in the saline ecosystems studied in this study and European saline lakes (Stenger-Kovács et al., 2014). Additionally, *Oxyura leucocephala* (white-headed duck), a globally endangered species, is bred in Lake Uyuz with a decreasing trend (Özgencil and Uslu, 2021). Generally, EC values were higher in the dry period than in the rainy period. Climatic variables (e.g., rainfall, weather temperature, and evaporation) of two hydrological periods and geology could affect the differences in physical and chemical variables of ecosystems between dry and wet periods in the present and previous studies (Coelho et al., 2015; Çelekli and Lekesiz, 2021).

Variations in environmental factors such as EC, TP, and altitude in these distinct (saline, saline soda, brackish, and freshwater) ecosystems influenced the distribution of the phytoplankton community in the Konya closed River system (Figure 3). Similar patterns (e.g., phytoplankton species associated with conductivity, salinity, TP, etc.) were also observed in the Armando Ribeiro Gonçalves Reservoir in Brazil (Chellappa et al., 2009), the west Mediterranean lentic ecosystems (Çelekli and Lekesiz, 2020), and two subtropical Brazilian reservoirs (Coelho et al., 2015).

Saline water systems (L01, L03, L04, L06–L08) had high TP, EC, and Ni concentrations (Figure 3), which affected the composition of phytoplankton in these ecosystems. Among saline water systems, saline (Tuz (L04) and Küçük (L03)) lakes and saline soda (Narlıgöl (L06), Meke Maar (L07), and Acıgöl (L08)) lakes with high EC gradients were characterized by *D. salina*, *N. communis, N. inconspicua, N. cincta*, and *C. astroideum*. These species preferred high EC optima (>the 75% percentile). Lake Tuz (L04) is a hypersaline ecosystem that is characterized by *D. salina,* which contributes to the lake's red brick color through its massive accumulation of β-carotene (Çelekli and Dönmez, 2006; Oren, 2005; Atıcı, 2022). Mesocosms were set up in Mono Lake to examine how salinity influences diatom diversity and primary production (Herbst and Blinn, 1998). They found that at intermediate salinity levels, *N. communis* predominated, and its relative abundance increased with increasing salinity. Besides, this diatom was found in saline soda lakes with *Dunaliella viridis* in Russia (Samylina et al., 2014). *Nitzschia inconspicua* has a wide range of habitats and tolerates salinity and organic or nutrient pollution (Hausmann et al., 2016; Çelekli and Lekesiz, 2020). Trobajo et al. (2013) reported that *N. inconspicua* prefers primarily saline or brackish environments. *Nitzschia inconspicua* also had a high EC preference (>8680 S/cm) in the West Mediterranean Basin (Çelekli and Lekesiz, 2020). Moreover, *N. inconspicua* is considered a pollution-tolerant species in a variety of ecoregions, including the USA (Hausmann et al., 2016) and Europe (Rott et al., 1999; Dell'Uomo, 2004; Kelly et al., 2008; Çelekli et al., 2019). *Coelastrum astroideum* was collected in a hypereutrophic Rosedal Lake in Argentina (Rodriguez-Florez et al., 2019) and preferred relatively high BOD_5 values (>30.66 mg/L) in Lake Aktaş of the Aras River catchment (Türkiye) (Çelekli et al., 2020).

A hypereutrophic Lake Uyuz (L1) was characterized by pollution-tolerant species like *A. elenkinii, C. pediculus, E. viridis, L. acus, L. ovum,* and *L. oxyuris,* which are associated with high TP and Ni. Lake Uyuz is under the pressure of agricultural land use and excessive evaporation in a semiarid region. *Anabaenopsis elenkinii* was related to nutrient-rich shallow waters (Padisák et al., 2009) and was also found in shallow eutrophic lakes such as Lithuania's Lake Jieznas (Karosienė et al., 2020) and Bulgaria's Lake Vaya (Teneva et al., 2020). Additionally, a period of bird (*Pelecanus crispus*) mortality was found when a few cyanobacteria, such as *A. elenkinii*, enhanced their biomass containing cyanotoxins in Greece's Karla Reservoir (Papadimitriou et al., 2018). Furthermore, *A. elenkinii,* a haloalkaliphilic cyanobacterium, was found in a Brazilian saline soda lake (Delbaje et al., 2021). *Cocconeis pediculus* was associated with TP in Lake Uyuz, where macrophytes covered the littoral zone (Krammer and Lange-Bertalot, 2004; Power et al., 2009). This diatom seems to be a cosmopolitan species in inland waters with medium to higher electrolyte content and brackish coastal waters (Krammer and Lange-Bertalot, 2004). Euglenophytes like *E. viridis, L. acus, L. ovum,* and *L. oxyuris* were considered the most tolerant species to pollution (Palmer, 1969; Çelekli et al., 2007; Çelekli and Şahin, 2021). These euglenoid species were also associated with organic matter-rich husbandry or sewage (Padisák et al., 2009; Çelekli and Şahin, 2021). The organic and inorganic enrichment in shallow and hypereutrophic Lake Uyuz could support the enhancement of the abundance of euglenoids during the study (Palmer, 1969).

High-altitude freshwater lakes such as Sarıot (L10), Sülüklü (L11), Kovalı (L13), and Gavur (L14), lakes, which have an altitude of more than 1700 m a.s.l. were under low human activity. *Tabellaria flocculosa, P. anglica, F. pararumpens, E. bilunaris*, and *P. microstauron* were integrated with the high-altitude lakes, which had high altitude optima preferences (>75%). Cooccurrence of *Tabellaria, Pinnularia, Fragilaria,* and *Eunotia* species was also found in sediment cores of Lake Panch Pokhari in the Helambu Himalaya (Krstić et al., 2012), Lake Abant (Çelekli and Külköylüoğlu, 2006), and in water bodies in the Subarctic Tundra (Kopyrina et al., 2021). Carballeira and Pontevedra-Pombal (2020) reported these genera as the typical oligotrophic diatom taxa of European peatlands, also observed in Lake Gavur. Blinn and Bailey (2001) pointed out that *T. flocculosa* was strongly associated with upland streams with fast currents, relatively low orthophosphate values, low salinity, and low temperatures in Australia.

The remaining freshwater lakes (L02, L05, L09, and L15) are located at similar altitude levels. Climate factors in dry periods strongly affected Gök-Kozanlı (L02, a swamp) and Lake Süleymanhacı (L09, a temporal system). Lake Gök-Kozanlı is surrounded by extensive reed-forested wetland meadows and marshes and is under the pressure of land use, settlement, farming, and semiarid regional factors. Kırankaya and Ekmekçi (2014) reported that *Cobitis turcica* inhabits Lake Gök-Kozanlı and in the creek from Pınarbaşı Spring into the lake. *Cobitis turcica*, a species unique to Anatolia, is threatened by habitat loss because of its scavenging lifestyle. This species was added to the IUCN Red List as endangered in 2006 due to drought and water pollution. Excessive evaporation led to Lake Süleymanhacı as a temporary ecosystem. Palaeolimnological studies indicated that there is substantial evidence in the diatom record for changes in palaeoconductivity and the lake water fluctuation in Lake Süleymanhacı that match well to inferred changes in evaporative concentration (Reed et al., 1999). The littoral region of Lake Bakı (L05) was covered with dense macrophytes, and it was under the pressure of intensive agricultural activities, residential waste, and semiarid regional factors. Climate change adversely affects many aquatic ecosystems in the world. Lake Beyşehir (L15) lake is the largest freshwater ecosystem in the Konya Closed River Basin, which is under the impact of various land use, excessive irrigation, and climate changes. Effects of these factors on the water quality of Lake Beyşehir were provided to predict its future environmental condition and ecosystem services (Bucak et al., 2018). Prolonged periods of diminished hydraulic loads and excessive evaporation resulted in declines in water levels and subsequent diminishment of the lake's ecological services as an agricultural water source. Besides, extended agricultural land use with fertilizer application could lead to enhanced phosphorus and nitrate load to the lake, which also strongly affected the ecological status of Lake Beyşehir.

The bioassessment of lakes in the Konya Closed Basin using phytoplankton metrics enables a more integrative approach to determining the ecological condition of lentic ecosystems for the purpose of use, conservation, and restoration (Padisák et al., 2006; Marchetto et al., 2009; Phillips et al., 2013; Çelekli et al., 2020). It is the first attempt to characterize the environmental conditions of various lakes in the Konya Closed Basin. The results of the phytoplankton assessment ranged from a bad ecological status in Lake Uyuz (L01) to a high ecological status in Lake Sülüklü (L11). The results of Søndergaard metric (Søndergaard et al., 2005) based on total phytoplankton and cyanobacterial biovolumes likewise corroborated these environmental conditions in Uyuz and Sülüklü lakes.

Among saline water systems, a moderate ecological status was found in Lake Tuz (L04), whereas Lake Küçük (L03), Lake Narlıgöl (L06), Meke Maar (L07), and Lake Acıgöl (L08) had a good ecological status. There is no settlement around L03 and L06–L08 lakes, mainly under pressure of excessive evaporation. Lake Tuz (L04) is a critical refugia habitat for migratory birds, particularly flamingos, which use them for resting, breeding, nesting, and feeding (OECD, 2010; Atıcı, 2022). Lake Tuz is under pressure from agricultural activities, wastewater discharge, salt withdrawal, and excessive evaporation. A moderate ecological status was found in Lake Gök-Kozanlı (L02), a shallow swamp under the pressure of settlement, agricultural land use, and animal husbandry. Natural factors (such as drought, warm weather, and excessive evaporation), human activities, and geology may all contribute to eutrophication, a problem in Lake Uyuz and Lake Gök-Kozanlı because of their high nutrient content. Effects of low precipitation and excessive evaporation on water fluctuation of lakes in the Konya Closed Basin were determined (Demir and Keskin, 2020).

Regarding high-altitude freshwater lakes (L10–L14), high ecological status was determined in Sülüklü (L11) and Sarıot (L10) lakes. Lake Sülüklü has a steep coastline between the mountains and clear waters, and Lake Sarıot is located at high altitude. No macrophytes were observed in and in the littoral parts of both lakes. There is no settlement or agricultural activity in the vicinity of Sülüklü and Sarıot lakes. Lake Dipsiz (L12) had a moderate ecological status, and this shallow system is under the pressure of a few highland houses, low agricultural activities, animal husbandry, and excessive water evaporation in summer. Other high-altitude systems are Kovalı and Gavur lakes, with a good ecological status, and there are no settlements and agricultural land use around them.

In terms of performance, the M-PTI and Med-PTI were well-fitted to logTP gradients in various lakes of the Konya Closed Basin. Recently, the use of M-PTI and Med-PTI to estimate water quality has become critical for global water resources management (Marchetto et al., 2009; Phillips et al., 2013; Çelekli and Lekesiz, 2020). When used to evaluate the health of the lakes in this basin, the MPTI yielded the greatest correlation coefficient value. Some examples of bodies of water where the PTI can be used to evaluate ecological health include 1795 lakes in twenty European countries (Phillips et al., 2013), the Pareja limno-reservoir in central Spain (Molina-Navarro et al., 2014), 12 lakes in Türkiye's West Mediterranean Basin (Çelekli and Lekesiz, 2020), 32 lakes in European countries (Thackeray et al., 2013), various lakes in the Aras River catchment (Çelekli et al., 2020), and 313 Swedish lakes (Zhao et al., 2019).

This study conducted in the Konya Closed Basin, which is very important for Türkiye, will be a reference for other basins as well. Similar studies were conducted in the Western Mediterranean Basin (Toudjani et al., 2018; Çelekli and Lekesiz, 2021), Antalya River Basin (Çelekli et al., 2023), and Aras River catchment (Çelekli et al., 2020). The ecological preferences of phytoplankton species in saline and high-altitude freshwater ecosystems vary according to their specific responses to environmental changes under a variety of climatic, human-induced, and geographical factors. Determining the optimum and tolerance levels of individual species to environmental factors is critical for forecasting ecosystem health. Several bioassessment approaches based on phytoplankton are present for evaluating lentic ecosystems, but more studies are needed to develop them worldwide.

5. Conclusion

This study contributes to a better understanding of the environmental conditions in saline and freshwater lakes by using phytoplankton species. Explanatory variables such as EC, TP, and Ni were closely associated with saline water systems, whereas freshwater ecosystems were influenced by altitude. The results of WA regression revealed that the environmental preferences of phytoplankton species in saline and freshwater ecosystems vary according to their responses to environmental changes. According to MPTI and Med-PTI, lentic ecosystems in the Konya Closed Basin had varying ecological conditions based on phytoplankton biovolumes. The results of the phytoassessment indicated that Lake Sülüklü had a high environmental condition, whereas Lake Uyuz had a bad ecological status. The results of total phytoplankton and cyanobacteria biovolume in lakes support the environmental conditions of the lakes using the Søndergaard metric. The ecological associations of phytoplankton assemblages varied throughout the study in the Konya Closed Basin. The MPTI could be a suitable phytoplankton metric for assessing the ecological status of lakes. Consequently, the results of this bioassessment study indicate that the responses of phytoplankton species in saline and freshwater systems to environmental variables provide crucial ecological information about their ecology and help in the estimation of the ecological status of lentic ecosystems.

Contribution of authors

Abuzer Çelekli applied the sampling methodology, collected samples, analyzed physical and chemical variables, identified phytoplankton species, applied statistical analyses, wrote, reviewed, and edited the article. Ömer Lekesiz collected samples, analyzed physical and chemical variables, identified phytoplankton species, and drew the map of the studied region. Tolga Çetin applied the sampling methodology. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

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Supplementary 1. Mean ± SD (standard deviation) values of environmental variables in lentic ecosystems. Meanings of codes of sampling sites were given in Table 1.

	TSS (mg/L)	TOC (mg/L)	NH4 (mg/L)	Al (mg/L)	Sb (µg/L)	Ar (µg/L)	Cu (µg/L)	B (mg/L)	Zn (µg/L)	Fe (mg/L)	Cr (mg/L)	V (µg/L)	Sn (µg/L)
L01	56.3 ± 41.1	20.7 ± 34.5	0.76 ± 0.66	1.12 ± 1.77	0.33 ± 0.33	15.45 ± 18.58	16.41 ± 25.72	1.62 ± 0.52	21.86 ± 33.59	1.96 ± 3.02	8.49 ± 13.26	19.41 ± 17.03	25.17 ± 42.85
L02	101.2 ± 159.2	6.9 ± 8.3	0.08 ± 0.07	0.87 ± 0.69	40.09 ± 69.20	25.39 ± 25.92	5.16 ± 4.91	2.66 ± 0.28	19.37 ± 25.00	0.69 ± 0.40	14.26 ± 21.96	24.20 ± 17.16	23.97 ± 40.78
L03	467.8 ± 600.6	127.1 ± 178.6	0.67 ± 0.88	nd	58.57 ± 82.63	65.72 ± 92.33	0.83 ± 0.00	1.04 ± 0.84	103.42 ± 145.08	0.04 ± 0.0	34.72 ± 47.92	3.19 ± 3.90	34.93 ± 48.78
L04	12.8 ± 6.0	30.3 ± 12.5	0.11 ± 0.11	0.02 ± 0.01	17.63 ± 28.99	67.26 ± 84.20	6.82 ± 5.71	21.54 ± 34.64	26.63 ± 37.63	0.04 ± 0.04	0.83 ± 0.00	14.70 ± 14.51	25.58 ± 43.56
L05	9.3 ± 0.0	17.2 ± 18.8	0.10 ± 0.09	0.01 ± 0.01	0.14 ± 0.01	7.60 ± 6.00	0.96 ± 0.23	6.27 ± 8.01	35.71 ± 45.74	0.01 ± 0.01	0.83 ± 0.00	13.91 ± 11.91	44.86 ± 45.66
L06	9.3 ± 0.0	20.0 ± 9.0	0.09 ± 0.07	0.01 ± 0.01	0.14 ± 0.00	0.6 ± 0.12	0.9 ± 0.16	17.22 ± 2.10	18.27 ± 20.14	0.01 ± 0.01	0.83 ± 0.00	0.43 ± 0.01	42.91 ± 34.48
L07	1924 ± 0.0	0.8 ± 0.0	0.04 ± 0.00	0.06 ± 0.00	8.26 ± 0.00	1805 ± 0.00	0.83 ± 0.00	28.86 ± 0	21.5 ± 0.00	151 ± 0.0	1.24 ± 0.00	68.4 ± 0.00	40.3 ± 0.00
L08	9.3 ± 0.0	19.2 ± 8.4	0.04 ± 0.00	0.02 ± 0.05	0.14 ± 0.01	10.84 ± 2.97	0.83 ± 0.00	38.52 ± 11.95	1.97 ± 2.28	0.42 ± 0.48	0.83 ± 0.00	8.61 ± 3.83	58.35 ± 25.87
L09	9.3 ± 0.0	0.8 ± 0.0	0.04 ± 0.00	0.39 ± 0.00	0.14 ± 0.01	4.35 ± 0.00	0.83 ± 0.00	0.26 ± 0	0.83 ± 0.00	0.18 ± 0	0.83 ± 0.00	4.38 ± 0.00	0.43 ± 0.00
L10	9.3 ± 0.0	3.3 ± 0.0	0.04 ± 0.00	0.08 ± 0.00	1.80 ± 0.01	0.43 ± 0.00	6.82 ± 0.00	0.016 ± 0	28.17 ± 0.00	0.07 ± 0	0.83 ± 0.00	0.43 ± 0.00	0.43 ± 0.00
L11	17.0 ± 10.9	18.4 ± 4.6	0.04 ± 0.00	0.08 ± 0.00	0.18 ± 0.01	0.59 ± 0.77	0.90 ± 0.00	0.30 ± 0.08	5.21 ± 6.09	0.04 ± 0.0	0.83 ± 0.00	0.99 ± 0.78	2.57 ± 3.00
L12	19.8 ± 18.2	13.0 ± 4.8	0.03 ± 0.02	0.02 ± 0.01	0.14 ± 0.01	1.07 ± 1.11	0.83 ± 0.00	0.06 ± 0.05	44.65 ± 26.93	0.18 ± 0.11	0.83 ± 0.00	0.74 ± 0.54	0.43 ± 0.00
L13	9.3 ± 0.0	20.5 ± 3.8	0.04 ± 0.00	0.01 ± 0.01	1.75 ± 2.28	0.43 ± 0.00	3.46 ± 3.72	0.15 ± 0.13	18.62 ± 25.15	0.88 ± 1.15	0.83 ± 0.00	0.43 ± 0.00	2.62 ± 3.1
L14	12.3 ± 6.8	14.6 ± 8.8	0.04 ± 0.00	0.03 ± 0.03	0.99 ± 1.26	0.75 ± 0.26	1.68 ± 1.89	0.09 ± 0.10	17.98 ± 18.36	4.52 ± 2.32	0.83 ± 0.00	0.49 ± 0.08	2.16 ± 2.44
L15	9.3 ± 0.0	11.4 ± 18.1	0.04 ± 0.00	0.09 ± 0.16	0.14 ± 0.01	2.61 ± 0.65	2.05 ± 3.22	0.12 ± 0.11	9.97 ± 20.8	0.09 ± 0.16	0.83 ± 0.00	2.21 ± 0.87	2.87 ± 3.54

TSS: total suspended solids, TOC: total organic carbon, NH_4: ammonium, Al: aluminum, Ar: arsenic, Sb: Antimon, Cu: copper, B: boron, Fe: iron, Cr: chrome, V: vanadate, Zn: zinc.

Supplementary 2. List of phytoplankton species to Konya Closed Basin Lakes.

Code	Species
Acca	*Achnanthidium catenatum* (Bily & Marvan) Lange-Bertalot
Acmi	*Achnanthidium minutissimum* (Kützing) Czarnecki
Amov	*Amphora ovalis* (Kützing) Kützing
Ampe	*Amphora pediculus* (Kützing) Grunow in A.W.F.Schmidt
Amve	*Amphora vetula* Levkov
Anar	*Ankistrodesmus arcuatus* Korshikov
Anca	*Anabaena catenula* Kützing ex Bornet & Flahault
Anel	*Anabaenopsis elenkinii* V.V.Miller
Anju	*Ankyra judayi* (G.M.Smith) Fott
Ansp	*Anomoeoneis sphaerophora* Pfitzer
Apfl	*Aphanizomenon flosaquae* Ralfs ex Bornet & Flahault
Augr	*Aulacoseira granulata* (Ehrenberg) Simonsen
Bora	*Botryococcus braunii* Kützing
Cefu	*Ceratium furcoides* (Levander) Langhans
Cehi	*Ceratium hirundinella* (O.F.Müller) Dujardin
Chdi	*Chroococcus dispersus* (Keissler) Lemmermann
Chgl	*Chlamydomonas globosa* J.W.Snow
Chlo	*Chimonodinium lomnickii* (Woloszynska) Craveiro, Calado, Daugbjerg, Gert Hansen
Chtu	*Chroococcus turgidus* (Kützing) Nägeli
Claci	*Closterium aciculare* T.West
Clmo	*Closterium moniliferum* Ehrenberg ex Ralfs
Coas	*Coelastrum astroideum* De Notaris
Cogr	*Cosmarium granatum* Brébisson ex Ralfs
Cola	*Cosmarium laeve* Rabenhorst
Coli	*Cocconeis lineata* Ehrenberg
Comi	*Coelastrum microporum* Nägeli
Cope	*Cocconeis pediculus* Ehrenberg
Copl	*Cocconeis placentula* Ehrenberg
Cople	*Cocconeis placentula* var. *euglypta* (Ehrenberg) Grunow
Coti	*Cosmarium tinctum* Ralfs

Supplementary 2. (Continued)

Code	Species
Crma	*Cryptomonas marssonii* Skuja
Crov	*Cryptomonas ovata* Ehrenberg
Crpy	*Cryptomonas pyrenoidifera* Geitler
Crpy	*Cryptomonas pyrenoidifera* Geitler
Cydu	*Cyclostephanos dubius* (Hustedt) Round
Cyex	*Cymbella excisa* Kützing
Cyexc	*Cymbella excisiformis* Krammer
Cyir	*Cyclotella iris* Brun & Héribaud
Cyla	*Cymbella lange-bertalotii* Krammer
Cyme	*Cyclotella meneghiniana* Kützing
Cytu	*Cymbella tumida* (Brébisson) Van Heurck
Deab	*Desmodesmus abundans* (Kirchner) E.H.Hegewald
Deco	*Desmodesmus communis* (E.Hegewald) E.Hegewald
Desub	*Desmodesmus subspicatus* (Chodat) E.Hegewald & A.W.F.Schmidt
Didi	*Dinobryon divergens* O.E.Imhof
Dieh	*Diatoma ehrenbergii* Kützing
Dimo	*Diatoma moniliformis* (Kützing) D.M.Williams
Diso	*Dinobryon sociale* (Ehrenberg) Ehrenberg
Divul	*Diatoma vulgaris* var. linearis Grunow
Dusa	*Dunaliella salina* (Dunal) Teodoresco
Enmi	*Encyonopsis minuta* Krammer & E.Reichardt
Ensi	*Encyonema silesiacum* (Bleisch) D.G.Mann
Epad	*Epithemia adnata* (Kützing) Brébisson
Epgi	*Epithemia gibba* (Ehrenberg) Kützing
Epso	*Epithemia sorex* Kützing
Eptu	*Epithemia turgida* (Ehrenberg) Kützing
Eubi	*Eunotia bilunaris* (Ehrenberg) Schaarschmidt
Euch	*Euglena chlamydophora* Mainx
Euel	*Eudorina elegans* Ehrenberg
Eugr	*Euglena granulata* (G.A.Klebs) F.Schmitz

Supplementary 2. (Continued)

Code	Species
Eupr	*Euglenaformis proxima* (P.A.Dangeard) M.S.Bennett & Triemer
Euve	*Euglena velata* G.A.Klebs
Euvi	*Euglena viridis* (O.F.Müller) Ehrenberg
Frca	*Fragilaria capucina* Desmazières
Frcr	*Fragilaria crotonensis* Kitton
Frgr	*Fragilaria gracilis* Østrup
Frpa	*Fragilaria pararumpens* Lange-Bertalot, G.Hofmann & Werum
Gein	*Geminella interrupta* Turpin
Goac	*Gomphonema acidoclinatum* Lange-Bertalot & Reichardt
Gobr	*Gomphonema brebissonii* Kützing
Goit	*Gomphonema italicum* Kützing
Gomi	*Gomphonema minutum* (C.Agardh) C.Agardh
Gool	*Gomphonella olivacea* (Hornemann) Rabenhorst
Gopa	*Gomphonema parvulum* (Kützing) Kützing
Gotr	*Gomphonema truncatum* Ehrenberg
Gyac	*Gyrosigma acuminatum* (Kützing) Rabenhorst
Kebi	*Keratococcus bicaudatus* (A.Braun ex Rabenhorst) J.B.Petersen
Lage	*Lagerheimia genevensis* (Chodat) Chodat
Leac	*Lepocinclis acus* (O.F.Müller) B.Marin & Melkonian
Leov	*Lepocinclis ovum* (Ehrenberg) Lemmermann
Leox	*Lepocinclis oxyuris* (Schmarda) B.Marin & Melkonian
Leten	*Leptolyngbya tenuis* (Gomont) Anagnostidis & Komárek
Megl	*Merismopedia glauca* (Ehrenberg) Kützing
Megr	*Messastrum gracile* (Reinsch) T.S.Garcia
Miae	*Microcystis aeruginosa* (Kützing) Kützing
Mibr	*Microglena braunii* (Goroschankin) Demchenko, Mikhailyuk & Proschold
Mifl	*Microcystis flosaquae* (Wittrock) Kirchner
Mobo	*Mougeotia boodlei* (West & G.S West) Collins
Moir	*Monoraphidium irregulare* (G.M.Smith) Komárková-Legnerová
Moqu	*Mougeotia quadrangulata* Hassall
Mosi	*Monactinus simplex* (Meyen) Corda

Supplementary 1. (Continued)

Code	Species
Naan	*Navicula angusta* Grunow
Naca	*Navicula capitatoradiata* H.Germain ex Gasse
Nacar	*Navicula cari* Ehrenberg
Naci	*Navicula cincta* (Ehrenberg) Ralfs
Nacr	*Navicula cryptocephala* Kützing
Namet	*Navicula metareichardtiana* Lange-Bertalot & Kusber
Natr	*Navicula tripunctata* (O.F.Müller) Bory
Natri	*Navicula trivialis* Lange-Bertalot
Nede	*Neidium densestriatum* (Østrup) Krammer
Nedi	*Neidium distinctepunctatum* Hustedt
Neko	*Neidium kozlowii* Mereschkovsky
Niac	*Nitzschia acicularis* (Kützing) W.Smith
Niam	*Nitzschia amphibia* Grunow
Niar	*Nitzschia archibaldii* Lange-Bertalot
Nico	*Nitzschia communis* Rabenhorst
Nicos	*Nitzschia costei* Tudesque, Rimet & Ector
Nidi	*Nitzschia dissipata* (Kützing) Rabenhorst
Niha	*Nitzschia hantzschiana* Rabenhorst
Niin	*Nitzschia inconspicua* Grunow
Nipa	*Nitzschia palea* (Kützing) W.Smith
Nive	*Nitzschia vermicularis* (Kützing) Hantzsch
Noca	*Nostoc caeruleum* Lyngbye ex Bornet & Flahault
Oobo	*Oocystis borgei* J.W.Snow
Oopa	*Oocystis parva* West & G.S.West
Osli	*Oscillatoria limosa* C.Agardh ex Gomont
Oste	*Oscillatoria tenuis* C.Agardh ex Gomont
Pamo	*Pandorina morum* (O.F.Müller) Bory
Paoc	*Pantocsekiella ocellata* (Pantocsek) K.T.Kiss & Ács
Peci	*Peridinium cinctum* (O.F.Müller) Ehrenberg
Pecu	*Peridiniopsis cunningtonii* Lemmermann

Supplementary 2. (Continued)

Code	Species
Pedu	*Pediastrum duplex* Meyen
Pewi	*Peridinium willei* Huitfeldt-Kaas
Phli	*Phacus limnophilus* (Lemmermann) E.W.Linton & Karnkowska
Pian	*Pinnularia anglica* Krammer
Piis	*Pinnularia isselana* Krammer
Pimi	*Pinnularia microstauron* (Ehrenberg)
Plan	*Placoneis anglophila* (Lange-Bertalot) Lange-Bertalot
Psca	*Pseudanabaena catenata* Lauterborn
Psum	*Pseudopediastrum boryanum* (Turpin) E.Hegewald
Rhab	*Rhoicosphenia abbreviata* (C.Agardh) Lange-Bertalot
Scse	*Schroederia setigera* (Schröder) Lemmermann
Spma	*Spirulina major* Kützing ex Gomont
Stci	*Staurastrum cingulum* (West & G.S.West) G.M.Smith
Stte	*Staurastrum tetracerum* Ralfs ex Ralfs
Sttet	*Stauridium tetras* (Ehrenberg) E.Hegewald
Suli	*Surirella librile* (Ehrenberg) Ehrenberg
Tafl	*Tabellaria flocculosa* (Roth) Kützing
Tear	*Tetraselmis arnoldii* (Proshkina-Lavrenko) R.E Norris, Hori & Chihara
Tebe	*Tetradesmus bernardii* (G.M.Smith) M.J.Wynne
Tela	*Tetradesmus lagerheimii* M.J.Wynne & Guiry
Temi	*Tetraëdron minimum* (A.Braun) Hansgirg
Tran	*Tryblionella angustatula* (Lange-Bertalot) Cantonati & Lange-Bertalot
Ulac	*Ulnaria acus* (Kützing) Aboal
Ulde	*Ulnaria delicatissima* (W.Smith) Aboal & P.C.Silva
Ulul	*Ulnaria ulna* (Nitzsch) Compère