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Ecological assessment of Burç Reservoir's surface water (Turkey) using phytoplankton metrics and multivariate approach

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Abstract: The present study aimed to elucidate relationships between phytoplankton species and stressors using multivariate approaches and assess the environmental condition of Burç Reservoir's surface water using phytoplankton metrics from September 2018 to August 2019 according to implementations of the Water Framework Directive. Burç Reservoir had a characteristic of a warm monomictic pattern. Phytoplankton functional groups (E, F, J, L_O, L_M, M_P, P, S_1, T, and W_1) were found in the reservoir. A significant difference was found in total biovolume values changed from 2.28 mm^3/L in November 2018 to 0.51 mm^3/L in February 2019. The first two axes of canonical correspondence analysis explained 99.2% of relationships between stressors and phytoplankton assemblages. Explanatory factors such as electrical conductivity (EC), nitrate (NO_3-N), total nitrogen (TN), water temperature, calcium (Ca^{+2}), precipitation, total organic carbon (TOC), ortho-phosphate (o-PO_4), and total phosphorus (TP) significantly drove the spatiotemporal distribution of phytoplankton. Weighted average regression resulted that phytoplankton species such as *Gymnodinium saginatum, Snowella lacustris, Ceratium hirundinella,* and *Pseudanabaena limnetica* were closely associated with high TP, while *Fragilaria capucina, Navicula trivialis, Cymbella aspera, Ulnaria biceps, Nitzschia palea,* and *Pseudopediastrum boryanum* closely related to the EC. Carlson's trophic state index indicated that Burç Reservoir mainly has a eutrophic characteristic with the assessment of chlorophyll *a*, total phosphorus, and Secchi disk depth, while it had a eu-hypertrophic according to the OECD classification. Results of the modified PTI-phytoplankton trophic index (mean = 2.37), the Med-PTI Mediterranean phytoplankton trophic index (mean = 1.96), and the Q assemblage index (mean = 2.58) indicated a moderate ecological status of Burç Reservoir. The present study confirmed that phytoplankton assemblages are closely integrated with the environmental condition of Burç Reservoir, which could be assessed by using the PTI and Med-PTI.

Key words: Bio-assessment, biomonitoring, canonical correspondence analysis, phytoplankton trophic index, water quality

1. Introduction

Lentic ecosystems are one of the important freshwater resources, play a crucial role in the biogeochemical cycle of the biosphere (Reynolds, 2006). These ecosystems provide potable freshwater to the world's growing population, which is one of the greatest requirements of the century for a sustainable healthy life.

Eutrophication is the most serious environmental problem led by nutrient enrichment and global warming with increasing anthropogenic activities (e.g., urbanization, wastewater disposal, agricultural land-uses, combustion of fossil fuels, and habitat destruction) strongly impacts all freshwaters ecosystems (Bhagowati and Ahamad, 2019). This phenomenon not only affects the physical and chemical characters of ecosystems but also affects the biodiversity and functions of lentic ecosystems with excessive growth of nuisance macrophytes (Bhagowati and Ahamad, 2019), cyanobacterial blooms (Lürling and Mucci, 2020), severe oxygen deficiency (Baxa et al., 2020), excessive animal especially sensitive fish species death (Nobre et al., 2019), loss of submerged macrophytes (Liu et al., 2020), taste and bad odor problems.

The most important environmental legislation is adopted by European Union WFD-Water Framework Directive (European Commisson, 2009) to assess environmental conditions of water resources to achieve the good ecological status using biological quality components (phytoplankton, benthic macroinvertebrates, macrophytes, diatoms, and fishes) supported by abiotic factors (e.g., physicochemical, and hydro-morphology variables). Phytoplankton are effective robust bioindicators especially in lentic ecosystems due to species specific-responses to stressors (Reynolds et al., 2002; Padisák et al., 2009; Kruk et al., 2017). They have adaptive strategies related to their morphologies, occurrences/survival, and physiologies in the different environmental conditions (Reynolds et al., 2002; Padisák et al., 2009). Phytoplankton functional groups (Reynolds et al., 2002; Padisák et al.,

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2009) relating to various environmental stressors are one of the significant tools in limnoecological monitoring to evaluate environmental conditions of lentic ecosystems (Çelekli and Öztürk, 2014; Salmaso et al., 2015; Kruk et al., 2017). Understanding complex phytoplankton-stressors interactions in ecosystems is an important issue to estimate their ecological preferences. Studies dealing with quantifying these interactions are insufficient because it is difficult to evaluate these interactions in nature. Therefore, using multivariate statistical analyses were suggested to make it easier to elucidate such kind of relationships (Kruk et al., 2017; Çelekli and Lekesiz, 2021).

Several phytoplankton metrics such as Q assemblage index (Padisák et al., 2006), TI-trophic index (Ptacnik et al., 2009), PTI-phytoplankton trophic index (Phillips et al., 2013), and Med-PTI-Mediterranean phytoplankton trophic index (Marchetto et al., 2009) have been developed to evaluate ecological status of lentic ecosystems in Europe (e.g., Carvalho et al., 2013; Phillips et al., 2013; Laplace-Treyture and Feret, 2016; Soria et al., 2019). The first attempt in southeast Anatolia was made by Çelekli and Öztürk (2014) to assess spatiotemporal environmental conditions of Alleben Reservoir using phytoplankton metrics. In Anatolia, a few limnoecological studies concerning phytoplankton metrics in two shallow Mediterranean lakes (Sevindik et al., 2017), the Western Mediterranean basin (Toudjani et al., 2018), and Aras basin (Çelekli et al., 2020) have been carried out, but less attention has been paid. The limnoecology of phytoplankton assemblages in Burç Reservoir is the first study to elucidate some distinctive features of phytoplankton assemblages of this ecosystem. Therefore, the main aims of the present study were to (i) compare the ecological status of Burç Reservoir according to the results of different phytoplankton metrics, (ii) elucidate a comprehensive picture of phytoplankton species-stressors relationship using multivariate approaches and their interactions to the environmental conditions of the reservoir, and (iii) determine limnoecological preferences of phytoplankton assemblages using weighted average regression during 12 sampling months according to the requirements of Water Framework Directive. With these aims, the environmental condition in Burç Reservoir was not only assessed by phytoplankton metrics, but also evaluated using biovolume contributions of phytoplankton assemblages, phytoplankton functional groups, and trophic states based on total phosphorous, water transparency, and chlorophyll *a*.

2. Materials and methods

2.1. Study area

Burç Reservoir (37°03'46.64″N; 37°10'10.72″E) is situated at about 835 m asl and about 35 km away from the center of Gaziantep at the southeast Anatolia. This reservoir was built on a wetland area in 1984's for agricultural irrigation, water supply, and recreational territory (Figure 1). Burç Reservoir is an Ogee spillway type that has 21 m of maximum depth, about 10 m mean depth, 54.4 ha surface area, 5.5 hm^3 volume, 121 ha catchment area, and 0.82 years of retention time. About 682 ha agricultural area is irrigated by the waters taken from Burç Reservoir. The information was obtained from the Ministry of Agriculture and Forestry, Gaziantep Directorate of Provincial Agriculture and Forestry. The reservoir is fed by the Burç Creek in a semiarid Mediterranean climate with a rainy winter and spring, followed by a very dry summer.

2.2. Sampling and analysis

Samples of water and phytoplankton were monthly collected from three stations (S1, S2, and S3 in Figure 1) of Burç Reservoir between September 2018 and August 2019 according to the standard method of EN 16698 (European Committee for Standardization, 2015). Sampling stations have different shoreline regions with horizontal spatial heterogeneity. S1 is the indentation in the shoreline of Burç Reservoir. S3 is near the outflow of Burç Reservoir, while S2 is closer to the Burç Creek. The reservoir is surrounded by trees especially planted pines, agricultural lands, and a few villages. Plankton net (Hydrobios net with 55 µm mesh size) was used to obtain dense phytoplankton samples to determine net phytoplankton composition. Phytoplankton samples were fixed with lugol-glycerol solution and collected in 250 mL polyethylene containers according to the standard method of EN 16698 (European Committee for Standardization, 2015). Water samples were directly taken from just beneath the surface water and then they were fixed with the lugol-glycerol solution (2%–3% glycerol), gently mixed, and placed in the containers for the determination of phytoplankton abundance (European Committee for Standardization, 2015).

Physicochemical variables (e.g., pH, EC-electrical conductivity, water temperature, salinity, DO-dissolved oxygen, and TDS-total dissolved solids) of sampling stations were measured in situ, using a multiparameter of YSI professional plus. Secchi disk, a limnological disk with 20 cm diameter, was used to measure the Secchi disk depth. To determine the water mixing regime (thermal stratification and full water circulation) of Burç Reservoir, a 2.5-L Hydrobios bottle was used to determine the temperature of each depth. The precipitation and atmospheric temperature values were obtained from Gaziantep Meteorological Station.

2.3. Laboratory analysis

Chlorophyll *a* values were determined using a spectrophotometer (UV/VIS Jenway 6300 model) at 665 nm wavelength according to the 90% methanol method (Youngman, 1978). Chemical analyses such as TP–total phosphorus, o-PO_4–orthophosphate, TN–total nitrogen,

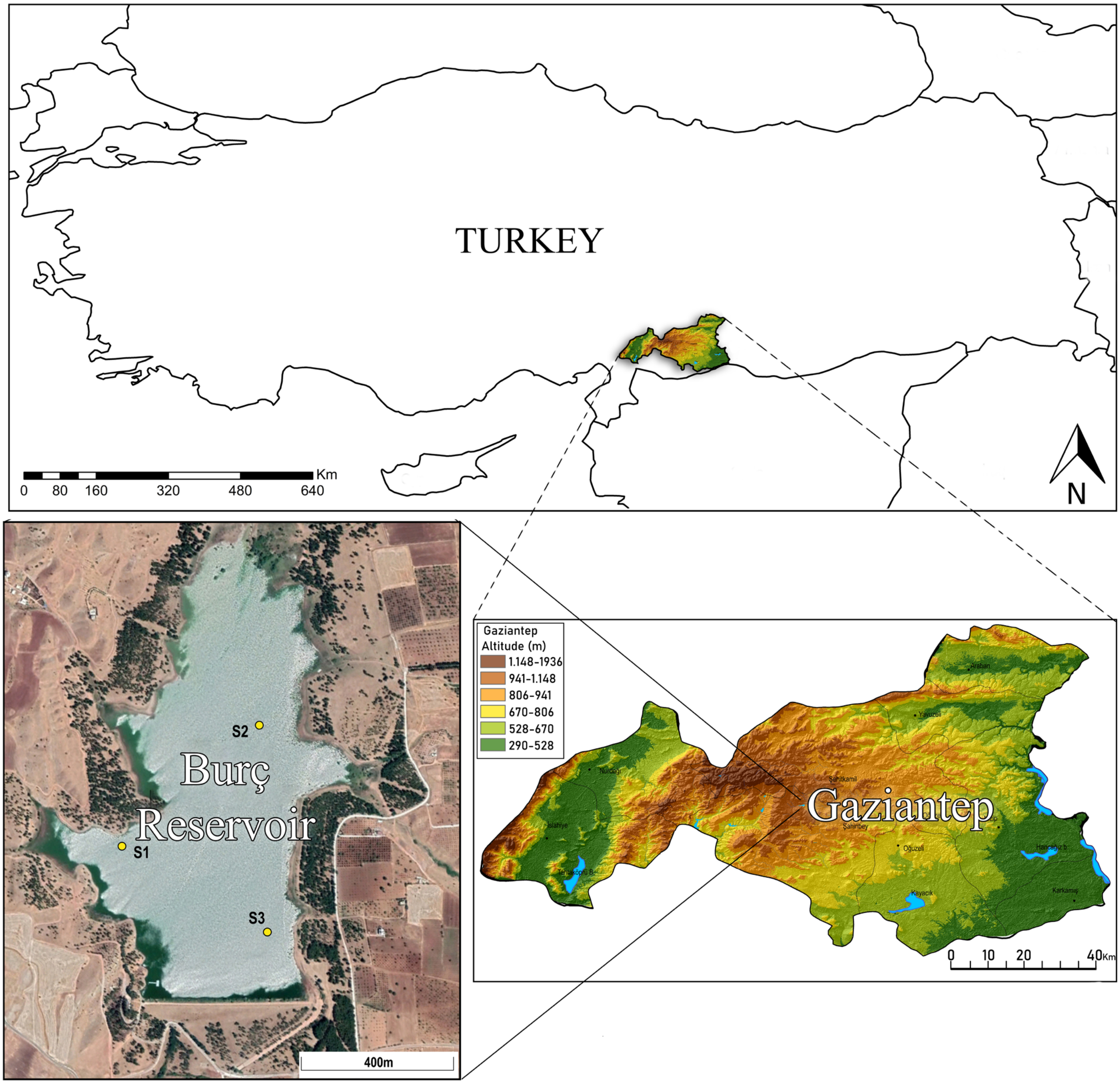

Figure 1. Location of Burç Reservoir and sampling stations.

NO_3-N–nitrate-nitrogen, NO_2-N–nitrite-nitrogen, and NH_4-N–ammonium-nitrogen were carried out by using an Ion Chromatography (Thermo Scientific Dionex ICS-5000). Turbidity of water was measured as nephelometric turbidity unit (NTU). An ICP-OES-inductively coupled plasma-optical emission spectrometry (Perkin Elmer, Optima 2100 DV) was performed to quantify cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), and lead (Pb). Biological oxygen demand (BOD_5), chemical oxygen demand (COD), total organic carbon (TOC), and hardness were determined, following the APHA standard (APHA, 2012).

Phytoplankton samples were examined under a BX53 Olympus light microscope with a DP73 camera and an Olympus CellSens Vers. 1.6 imaging software. Identification of phytoplankton species was done following taxonomic keys provided in Komárek and Fott (1983), Popovský and Pfiester (1990), John et al. (2002); Wehr and Sheath (2003), and Lange-Bertalot et al. (2017). Diatom permanent slides were prepared with the chemical KMnO4 and hot hydrochloric acid and then mounted with the Naphrax. Examination of diatom valves was done under the Olympus BX53 light microscope at 1000× magnification.

The phytoplankton subsamples (25–100 mL) were settled in the counting chamber for 24–48 h and at least 350 settling units (e.g., independent cells, filaments, trichomes, and colonies) of the dominant species were enumerated, using an Olympus CKX41 inverted microscope at 400–600× magnifications according to the standard method of EN 15204 (European Committee for Standardization 2006). Multiplying the mean biovolume of the taxon at the least 25 individuals with the cell density was used to calculate biovolumes of phytoplankton species according to the standard method of EN 16695 (European Committee for Standardization, 2015). Phytoplankton functional groups were assigned according to the criteria of Reynolds et al. (2002) and Padisák et al. (2009). Phytoplankton assemblages having biovolume more than 10% of the total biovolume were assigned as a dominant group.

2.4. Determination of trophic and ecological status

Secchi disk depth (SD), TP, and chlorophyll *a* (Chlo *a*) were evaluated to determine the trophic state of Burç Reservoir, following the criteria of OECD-Organization for Economic Cooperation and Development (Vollenweider and Kerekes, 1982) and results of the TSI-trophic state index (Carlson, 1977).

To assess the ecological condition of Burç Reservoir, the modified PTI (Çelekli, 2016), the Med-PTI (Marchetto et al., 2009), and the Q index (Padisák et al., 2006) were performed based on the phytoplankton biovolume. Equation≠1 (Eq. 1) was used to calculate the modified PTI value.

$$PTI = \frac{\sum_{i=1}^{n} b_i \times s_i \times i_i}{\sum_{i=1}^{n} b_i \times i_i} \quad (1)$$

where b_i, s_i, and i_i are the proportion biovolume, the optima, and the indicator value of *ith* species, respectively.

Equation≠2 (Eq. 2) was used to quantify the Med-PTI score.

$$Med - PTI = \frac{\sum_{i=1}^{n} b_i \times v_i \times i_i}{\sum_{i=1}^{n} b_i \times i_i} \quad (2)$$

where, b_i, v_i, and i_i are the biovolume, trophic value, and the indicator value of *ith* species, respectively.

The Q assemblage index was quantified, using Equation≠3 (Eq. 3).

$$Q = \sum_{j=1}^{n} p_i F \quad (3)$$

where the biovolume value of functional groups is *pi* which equals the biovolume value of *ith* species (n_i) quotient of the total biovolume (N) as $p_i = n_i / N$. Factor F is ranged from 0 to 5 and weight for the phytoplankton functional group in the suggested lake type (Padisák et al., 2006). When calculated scores of Q index, the F values assigned to each functional group Padisák et al. (2006), lake type 1 based on the characteristics of calcareous, average depth 3–15 m. Boundaries of high (4–5), good (3–4), moderate (2–3), poor (1–2), and bad (0–1) conditions demonstrate the Q index classification of ecosystems.

Phytoplankton indices like the modified PTI and the Q assemblage index have positive correlations to TP whereas the Med-PTI has inverse relationship.

2.5. Statistical analysis

Descriptive analysis (SPSS version 15.0, USA) was performed to determine the means and standard deviations (mean ± SD) of environmental data. For the comparison of environmental data among sampling months, a multiple range test of Duncan (SPSS version 15.0, USA) was used (Landau and Everitt, 2004). The percentiles (25th, 50th, and 75th) of data were determined, using the percentile analysis. Spearman's correlation test (SPSS version 15.0, USA) was performed to compute the interactions among the study data (Landau and Everitt, 2004). Results of detrended correspondence analysis had a gradient length larger than 3.0, which is justified the use of canonical correspondence analysis-CCA (Braak and Šmilauer, 2002). The CCA using the CANOCO 4.5 software was performed to elucidate the relationships between response variables (76 phytoplankton species) and 14 physicochemical variables in three sampling stations of Burç Reservoir sampled in 12 months. Logarithmic transformations log (x+1) of the explanatory factors were carried out to reduce the skewness, except pH. The Monte Carlo permutation test with the forward selection was used to determine which explanatory factors significantly affect the phytoplankton distribution during the study. A weighted averaging (WA) regression using the Calibrate program (Juggins and Braak, 1992) was performed to calculate phytoplankton assemblages' optima levels for explanatory variables. Phytoplankton species had biovolume of more than 1% and were observed at least two times in sampling months were used in the multivariate analyses (Lepš and Šmilauer, 2003).

3. Results

3.1. Limnoecological variables

During the study period, no significant difference was found in the environmental variables among sampling stations for each moth. Due to this reason, descriptive results of environmental variables for sampling months are given in Table 1. Water temperature showed a close integration with the air temperature and mean values in the reservoir were changed from 4.0 °C in January 2019 to 25.6 °C in August 2019. The littoral region of the reservoir was partially frozen in late December 2018 and January 2019. Annual precipitation from 1940 to 2019 was recorded as

Table 1. Descriptive results of environmental data in the Burç Reservoir. The data are the mean of three data (3 stations) with their standard deviations for each sampling month. Abbreviation and full names of sampling months are given in Figure 2.

Variables	Unit	S18	O18	N18	D18	J19	F19	M19	A19	Ma19	Ju19	Jl19	Au19
Temp	˚C	23.8 ± 0.7	19.3 ± 0.8	11.1 ± 0.5	8.3 ± 0.3	4.0 ± 0.7	6.8 ± 0.2	10.8 ± 0.5	13.0 ± 0.5	22.6 ± 0.2	24.1 ± 0.6	25.2 ± 0.7	25.6 ± 0.1
EC	µS/cm	432 ±6	411 ± 6	397 ± 1	389 ± 5	460 ± 13	690 ± 62	708 ± 12	686 ± 9	746 ± 4	486 ± 3	425 ± 15	407 ± 1
TDS	mg/L	294 ± 2	304 ± 1	304 ± 1	302 ± 8	325 ± 1	589 ± 85	631 ± 1	578 ± 7	574 ± 4	322 ± 1	290 ± 1	281 ± 1
Salinity	mg/L	0.22 ± 0.00	0.23 ± 0.01	0.23 ± 0.01	0.23 ± 0.01	0.24 ± 0.01	0.45 ± 0.04	0.48 ± 0.01	0.44 ± 0.01	0.44 ± 0.01	0.24 ± 0.01	0.21 ± 0.00	0.21 ± 0.00
pH		8.3 ± 0.1	8.4 ± 0.1	8.6 ± 0.3	8.4 ± 0.1	8.3 ± 0.1	8.6 ± 0.2	8.7 ± 0.1	8.7 ± 0.1	8.6 ± 0.1	8.7 ± 0.1	8.8 ± 0.1	8.9 ± 0.1
DO	mg/L	7.17 ± 0.15	6.18 ± 0.53	7.78 ± 0.31	8.54 ± 0.64	8.14 ± 0.05	10.73 ± 0.19	10.37 ± 0.38	10.16 ± 0.40	6.93 ± 0.26	6.04 ± 0.22	5.40 ± 0.41	6.02 ± 0.76
TSS	mg/L	17 ± 2	23 ± 2	11 ± 1	43 ± 3	11 ± 2	8 ± 1	12 ± 1	19 ± 3	21 ± 3	11 ± 1	11 ± 0	8 ± 0
BOD_5	mg/L	12.3 ± 3.5	3.7 ± 0.6	5.0 ± 1.0	3.0 ± 0.3	2.1 ± 0.1	2.0 ± 0.1	2.2 ± 0.2	3.7 ± 0.6	6.3 ± 0.7	2.7 ± 0.6	4.3 ± 0.6	2.0 ± 0.1
COD	mg/L	50.7 ± 9.2	37.3 ± 1.2	41.2 ± 1.9	37.3 ± 1.2	30.0 ± 0.6	30.0 ± 0.6	34.7 ± 1.5	37.3 ± 1.2	43.3 ± 1.5	35.8 ± 0.3	40.2 ± 1.6	30.0 ± 0.4
TN	mg/L	0.70 ± 0.34	0.63 ± 0.13	2.20 ± 1.34	2.13 ± 0.03	5.85 ± 0.20	5.53 ± 0.53	4.57 ± 1.11	3.97 ± 0.67	3.55 ± 0.77	2.93 ± 0.68	2.50 ± 0.41	1.12 ± 0.42
NH_4-N	mg/L	0.04 ± 0.01	0.06 ± 0.02	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.10 ± 0.02	0.04 ± 0.01	0.04 ± 0.01
NO_2-N	mg/L	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.07 ± 0.01	0.14 ± 0.01	0.10 ± 0.05	0.14 ± 0.01	0.15 ± 0.01	0.20 ± 0.01	0.19 ± 0.01	0.17 ± 0.01	0.10 ± 0.01
NO_3-N	mg/L	0.04 ± 0.01	0.04 ± 0.01	0.09 ± 0.08	4.03 ± 0.26	20.63 ± 2.24	20.18 ± 0.34	15.87 ± 0.22	11.62 ± 0.67	10.71 ± 0.15	8.46 ± 0.07	5.60 ± 0.05	1.90 ± 0.02
TP	mg/L	0.17 ± 0.01	0.26 ± 0.02	0.24 ± 0.02	0.30 ± 0.02	0.35 ± 0.03	0.28 ± 0.02	0.26 ± 0.01	0.16 ± 0.01	0.28 ± 0.02	0.25 ± 0.01	0.21 ± 0.02	0.17 ± 0.05
PO_4	mg/L	0.08 ± 0.04	0.12 ± 0.02	0.12 ± 0.02	0.22 ± 0.01	0.29 ± 0.02	0.12 ± 0.01	0.06 ± 0.03	0.06 ± 0.03	0.19 ± 0.02	0.20 ± 0.02	0.05 ± 0.02	0.04 ± 0.01
Turbidity	NTU	10.8 ± 1.4	12.7 ± 1.5	4.7 ± 0.6	51.2 ± 2.4	11.7 ± 1.2	4.8 ± 0.7	7.3 ± 0.8	4.8 ± 0.5	13.6 ± 1.4	4.9 ± 0.7	5.8 ± 0.6	1.3 ± 0.3
TOC	mg/L	2.6 ± 0.1	2.6 ± 1.6	4.4 ± 0.2	10.1 ± 2.1	3.1 ± 0.1	2.4 ± 0.3	2.4 ± 0.2	5.7 ± 2.2	1.6 ± 0.1	2.3 ± 0.1	3.2 ± 0.1	3.5 ± 0.1
Ca	mg/L	45.7 ± 0.4	44.5 ± 0.5	45.2 ± 0.4	50.3 ± 0.7	76.1 ± 1.1	74.7 ± 0.6	73.7 ± 0.2	75.1 ± 6.7	58.5 ± 1.4	60.4 ± 1.3	46.8 ± 0.4	32.0 ± 13.7
Hardness	mmol/L	2.1 ± 0.1	2.1 ± 0.1	2.1 ± 0.1	2.2 ± 0.1	2.3 ± 0.1	2.7 ± 0.1	2.0 ± 0.1	2.3 ± 0.1	1.6 ± 0.1	2.3 ± 0.1	2.0 ± 0.1	1.8 ± 0.1
Cu	mg/L	0.001	0.001	0.002	0.003	0.003	0.001	0.002	0.003	0.001	0.001	0.001	0.001
Ni	mg/L	0.001	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cd	mg/L	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001
Cr	mg/L	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.002	0.002	0.001	0.001	0.001
Pb	mg/L	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
CN^-	mg/L	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.001
SD	m	2.5 ± 0.3	1.8 ± 0.2	3.0 ± 0.3	0.7 ± 0.1	1.6 ± 0.2	1.2 ± 0.2	0.9 ± 0.1	1.7 ± 0.2	1.23 ± 0.2	1.8 ± 0.2	1.8 ± 0.3	2.0 ± 0.3
Chlo *a*	µg/L	28.1 ± 0.4	48.7 ± 8.8	59.8 ± 9.8	27.2 ± 5.8	31.1 ± 4.0	27.7 ± 1.3	26.5 ± 2.6	22.9 ± 3.7	19.7 ± 3.2	8.0 ± 1.0	19.9 ± 2.9	21.5 ± 5.6
AirTemp	˚C	25.8	18.3	10.8	7.0	3.9	6.00	9.2	12.2	21.8	26.7	28.1	29.3
Precipi	mm	8.4	67.8	38.3	245.5	164.2	116.2	155.4	63.0	6.2	14.2	0.0	0.2

Temp–temperature, EC-electrical conductivity, TDS-total dissolved solid, DO–dissolved oxygen, TSS-total suspended solids, TN–total nitrogen, NH_4-N–ammonium, NO_2- –nitrite, NO_3-N–nitrate, TP–total phosphorus, PO_4–orthophosphate, TOC-total organic carbon, Ca–calcium, Cu-copper, Ni-nickel, Cd-cadmium, Cr-chrome, Pb-lead, CN^-cyanide Ba-barium, SD-Secchi depth, Chlo *a*-chlorophyll *a*, AirTemp-air temperature, Precipi-precipitation.

568 mm from the meteorological data and a high annual precipitation value was detected 879 mm during the study period. Burç Reservoir had slightly alkaline characteristics with a mean pH of 8.57. Electrical conductivity (annual mean of EC = 519.8 µS/cm) significantly varied from 389 µS/cm in December 2018 to 746 µS/cm in May 2019. Total dissolved solids (TDS) and salinity showed a similar trend to the EC gradient in the reservoir.

A significant difference was found in the monitored nutrient concentrations among sampling months. Minimum and maximum TP equal to 0.16 mg/L and 0.35 mg/L were noted in April 2019 and January 2019, respectively. Likely, the highest TN was measured as 5.85 mg/L in January 2019. Low heavy metal concentrations were found in Burç Reservoir during the study period according to the surface water quality management regulation of Turkey. Spearman correlation resulted that water temperature had significantly negative correlations with salinity (r = –0.564, p = 0.01), nutrients (e.g., TP (r = –0.683, p = 0.01), TN (r = –0.554, p = 0.01), and PO_4 (r = –0.492, p = 0.01)) and chlorophyll *a* (r = –0.447, p = 0.01).

The water thermal structure in Burç Reservoir by the depth distribution of isotherms is given in Figure 2. The thermal stratification was formed in the period of September–October of 2018, and it also began again in May 2019 and continued during August 2019. The full water circulation was found in November 2018–April 2019.

3.2. Phytoplankton composition

A total of 136 phytoplankton species belonging to 8 phyla were identified in Burç Reservoir. The 76 of them with biovolumes higher than 1% of total biovolume and occurred more than once is listed in Table 2, which were considered for the applications of multivariate approaches to reveal phytoplankton-environment relationships. *Aulacoseira granulata, Ulnaria biceps, Ulnaria ulna, Cryptomonas marssonii, Cryptomonas ovata, Crucigenia tetrapedia, Pediastrum duplex, Scenedesmus brevispina,*

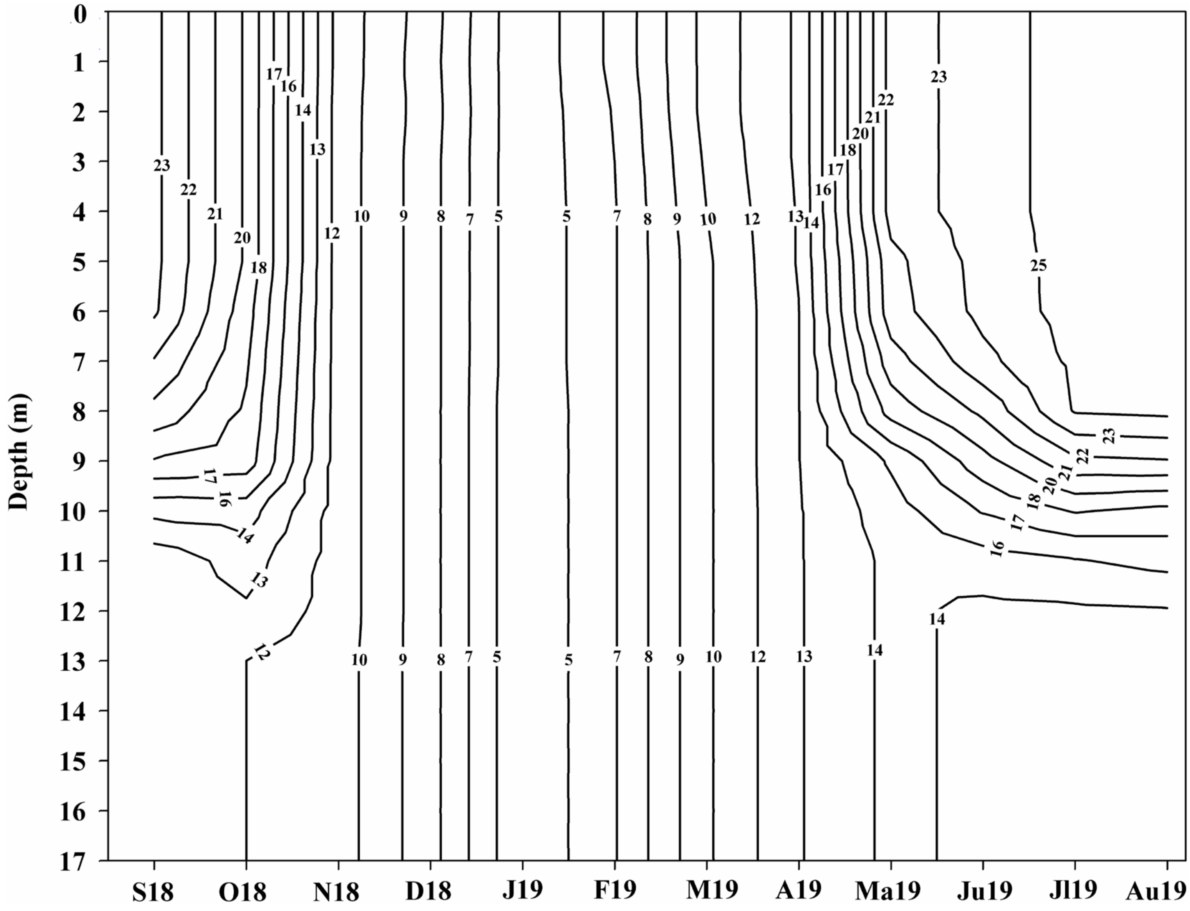

Figure 2. The thermal stratification and water circulation in Burç Reservoir. Abbreviations of sampling months; S18-September 2018, O18-October 2018, N18-November 2018, D18-December 2018, J19-January 2019, F19-February 2019, M19-March 2019, A19-April 2019, Ma19-May 2019, Ju19-June 2019, Jl19-July 2019, and Au19-August 2019.

Table 2. Phytoplankton species having biovolumes larger than 1% of total biovolume and occurred more than once in the Burç Reservoir.

Phylum: Bacillariophyta	
Amov	*Amphora ovalis* (Kützing) Kützing
Augr	*Aulacoseira granulata* (Ehrenberg) Simonsen
Chsp	*Chaetoceros* sp.
Cyme	*Cyclotella meneghiniana* Kützing
Cyaf	*Cymbella affinis* Kützing
Cyas	*Cymbella aspera* (Ehrenberg) Cleve
Cyne	*Cymbella neolanceolata* W.Silva
Frca	*Fragilaria capucina* Desmazières
Frcr	*Fragilaria crotonensis* Kitton
Gysp	*Gyrosigma* sp.
Icca	*Iconella capronii* (Brébisson & Kitton) Ruck & Nakov
Nasp	*Navicula* sp.
Natr	*Navicula trivialis* Lange-Bertalot
Nipa	*Nitzschia palea* (Kützing) W.Smith
Nisi	*Nitzschia sigmoidea* (Nitzsch) W.Smith
Nisp	*Nitzschia* sp.
Suli	*Surirella librile* (Ehrenberg) Ehrenberg
Ulbi	*Ulnaria biceps* (Kützing) Compère
Ulul	*Ulnaria ulna* (Nitzsch) Compère
Phylum: Charophyta	
Claci	*Closterium aciculare* T. West
Clco	*Closterium cornu* Ehrenberg ex Ralfs
Clgr	*Closterium gracile* Brébisson ex Ralfs
Elac	*Elakatothrix acuta* Pascher
Klri	*Klebsormidium rivulare* (Kützing) M.O.Morison & Sheath
Mobo	*Mougeotia boodlei* (West & G.S West) Collins
Moel	*Mougeotia elegantula* Wittrock
Monu	*Mougeotia nummuloides* (Hassall) De Toni
Moqu	*Mougeotia quadrangulata* Hassall
Mosc	*Mougeotia scalaris* Hassall
Splo	*Spirogyra longata* (Vaucher) Kützing
Stch	*Staurastrum chaetoceras* (Schröder) G.M.Smith
Stdi	*Staurastrum dilatatum* Ehrenberg ex Ralfs
Phylum: Chlorophyta	
Bobr	*Botryococcus braunii* Kützing
Clgl	*Cladophora glomerata* (Linnaeus) Kützing
Clac	*Closteriopsis acicularis* (Chodat) J.H.Belcher & Swale
Cllo	*Closteriopsis longissima* (Lemmermann) Lemmermann
Coas	*Coelastrum astroideum* De Notaris
Deco	*Desmodesmus communis* (E.Hegewald) E.Hegewald
Mipu	*Micractinium pusillum* Fresenius

Table 2. (Continued).

Mosi	*Monactinus simplex* (Meyen) Corda
Ooma	*Oocystis marssonii* Lemmermann
Pamo	*Pandorina morum* (O.F.Müller) Bory
Pedu	*Pediastrum duplex* Meyen
Psbo	*Pseudopediastrum boryanum*(Turpin) E.Hegewald
Scbr	*Scenedesmus brevispina* (G.M.Smith) Chodat
Scse	*Schroederia setigera* (Schröder) Lemmermann
Tela	*Tetradesmus lagerheimii* M.J.Wynne & Guiry
Temi	*Tetraëdron minimum* (A.Braun) Hansgirg
Ulae	*Ulothrix aequalis* Kützing
Ulsp	*Ulothrix* sp.
Phylum: Cryptophyta	
Crma	*Cryptomonas marssonii* Skuja
Crov	*Cryptomonas ovata* Ehrenberg
Plna	*Plagioselmis nannoplanctica* (Skuja) G.Novarino, I.A.N.Lucas & Morrall
Phylum: Cyanobacteria	
Anca	*Anabaena catenula* Kützing ex Bornet & Flahault
Miae	*Microcystis aeruginosa* (Kützing) Kützing
Noca	*Nostoc caeruleum* var. *planctonicum* (V.S.Poretsky & V.K.Tschernow) B.A.Whitton
Oste	*Oscillatoria tenuis* C.Agardh ex Gomont
Psli	*Pseudanabaena limnetica* (Lemmermann) Komárek
Pssp	*Pseudanabaena* sp.
Snla	*Snowella lacustris* (Chodat) Komárek & Hindák
Phylum: Euglenozoa	
Euch	*Euglena chlamydophora* Mainx
Euvi	*Euglena viridis* (O.F.Müller) Ehrenberg
Euca	*Euglenaria caudata* (E.F.W.Hübner) Karnowska-Ishikawa, Linton & Kwiatowski
Leac	*Lepocinclis acus* (O.F.Müller) B.Marin & Melkonian
Leox	*Lepocinclis oxyuris* (Schmarda) B.Marin & Melkonian
Phlo	*Phacus longicauda* (Ehrenberg) Dujardin
Phylum: Miozoa	
Bips	*Biecheleria pseudopalustris* (J.Schiller) Moestrup, K.Lindberg & Daugbjerg
Cefu	*Ceratium furcoides* (Levander) Langhans
Cehi	*Ceratium hirundinella* (O.F.Müller) Dujardin
Chlo	*Chimonodinium lomnickii* (Woloszynska) Craveiro, Calado, Daugbjerg, Gert Hansen & Moestrup
Gysa	*Gymnodinium saginatum* T.M.Harris
Gyub	*Gymnodinium uberrimum* (G.J.Allman) Kofoid & Swezy
Pecu	*Peridiniopsis cunningtonii* Lemmermann
Toco	*Tovellia coronata* (Woloszynska) Moestrup, K.Lindberg & Daugbjerg
Phylum: Ochrophyta	
Didi	*Dinobryon divergens* O.E.Imhof
Diso	*Dinobryon sociale* (Ehrenberg) Ehrenberg

Microcystis aueroginosa, and *Dinobryon sociale* were commonly found in the reservoir.

Functional groups of E, F, J, L_O, L_M, M_P, P, S_1, T, and W_1 as descriptors were found in the phytoplankton composition of Burç Reservoir (Table 3). Phytoplankton species *Ceratium hirundinella, D. sociale*, *Dinobryon divergens, U. ulna, Phacus longicauda*, *Pediastrum duplex,* and *U. biceps* had important contributions to the total biovolume. *Ulnaria ulna* and *U. biceps* made up the major fractions of biovolume value during the spring water mixing. The dinoflagellates dominated by *C. hirundinella* strongly developed in December 2018 and January 2019, while the chrysophytes whose main representative is *D. sociale*, had high biovolume peaks in June and July of 2019. The euglenoid *Phacus longicauda* had a remarkable peak in October 2018, while the chlorophytes dominated by *P. duplex* were observed in September 2018 and August 2019.

Temporal variations in the total biovolume with the contributions of phytoplankton classes in Burç Reservoir are plotted in Figure 3. There was a difference in total biovolume values (changed from 2.28 mm^3/L in November 2018 to 0.51 mm^3/L in February 2019) among sampling months. Concerning total phytoplankton biovolume, Bacillariophyta had the highest contribution (24.55%), whereas the lowest contribution part was done by Cyanobacteria (1.95%). The highest biovolume of blue-green algae (0.20 mm^3/L) was determined in September 2018. Euglenozoa (1.33 mm^3/L), Ochrophyta (1.55 mm^3/L), and Miozoa (1.05 mm^3/L) had the highest biovolume in October, November, and December of 2018, respectively.

3.3. Relationship between phytoplankton and environmental factors

The first two axes of CCA using the Monte Carlo test with the application of forward selection explained 99.2% of relationships between stressors and phytoplankton assemblages. Among stressors, EC ($F = 3.529$, $p = 0.002$), NO_3-N ($F = 3.136$, $p = 0.002$), TN ($F = 2.845$, $p = 0.002$),

Table 3. Taxonomic and functional groups of descriptor phytoplankton species (Reynolds, 2002; Padisák et al., 2006, 2009). Factor F is the weights of each functional group in Burç Reservoir.

Functional group	Descriptor species	Taxonomic group	F
E	*Dinobryon divergens*	Ochrophyta	2
E	*Dinobryon sociale*	Ochrophyta	2
F	*Spirogyra longata*	Charophyta	5
J	*Pediastrum duplex*	Chlorophyta	1
J	*Pseudopediastrum boryanum*	Chlorophyta	1
L_M	*Microcystis aeruginosa*	Cyanobacteria	0
L_M	*Ceratium furcoides*	Miozoa	0
L_M	*Ceratium hirundinella*	Miozoa	0
Lo	*Gymnodinium uberrimum*	Miozoa	5
MP	*Cladophora glomerata*	Chlorophyta	5
MP	*Surirella librile*	Bacillariophyta	5
MP	*Ulnaria ulna*	Bacillariophyta	5
MP	*Iconella capronii*	Bacillariophyta	5
MP	*Ulnaria biceps*	Bacillariophyta	5
MP	*Nitzschia sigmoidea*	Bacillariophyta	5
MP	*Ulothrix aequalis*	Chlorophyta	5
MP	*Ulothrix* sp.	Chlorophyta	5
P	*Aulacoseira granulata*	Bacillariophyta	5
P	*Staurastrum chaetoceras*	Charophyta	5
S1	*Pseudanabaena limnetica*	Cyanobacteria	0
T	*Mougeotia scalaris*	Charophyta	5
W1	*Phacus longicauda*	Euglenozoa	0

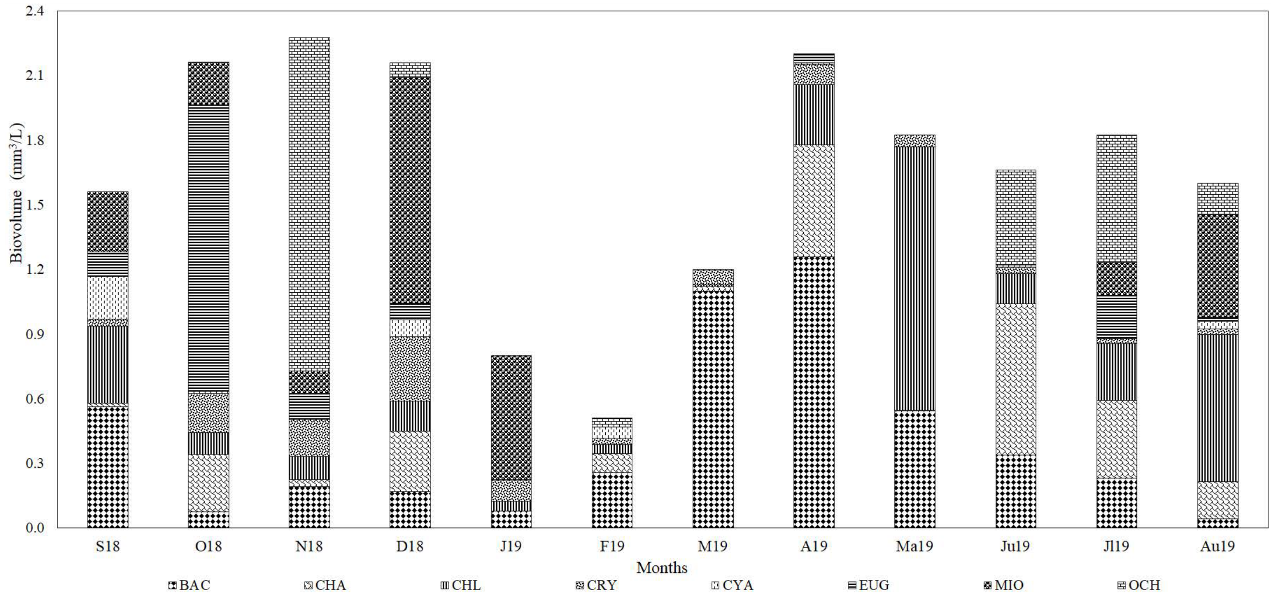

Figure 3. Total biovolume of Burç Reservoir with the contribution of phytoplankton groups. BAC-Bacillariophyta, CHA-Charophyta, CHL-Chlorophyta, CRY-Cryptophyta, EUG-Euglenozoa, MIO-Miozoa, and OCH-Ochrophyta. Abbreviation and full names of sampling months are given in Figure 2.

water temperature ($F = 2.666$, $p = 0.002$), DO ($F = 2.588$, $p = 0.002$), Ca ($F = 2.377$, $p = 0.002$), precipitation ($F = 2.246$, $p = 0.002$), TOC ($F = 2.146$, $p = 0.002$), PO_4 ($F = 1.998$, $p = 0.004$), and TP (with $F = 1.924$, $p = 0.008$) significantly affected the phytoplankton distribution among the sampling months (Figure 4).

The CCA grouped the sampling months into four seasons (Figure 4). September, October, and November of 2018 were collected in the autumn as group A under pressures of BOD_5 and Secchi disk depth, and this group is characterized by phytoplankton species such as *M. aeruginosa, Ceratium furcoides, Lepocinclis oxyuris, Nostoc caeruleum* var. *planctonicum*, *Mougeotia elegantula*, *Euglenaria caudata, Euglena viridis, Lepocinclis acus, P. longicauda, Staurastrum chaetoceras,* and *Cyclotella meneghiniana*.

Group B included sampling months of the winter which are mostly related to TP and TOC and are characterized by phytoplankton assemblages such as *Gymnodinium uberrimum, Plagioselmis nannoplanctica, C. hirundinella, Pseudanabaena* sp., *Gymnodinium saginatum,* and *Botryococcus braunii*. Among the months, February 2019 was related to phytoplankton species associated with TN and NO_3-N (e.g., *Closterium gracile, Closteriopsis acicularis, Elakatothrix acuta,* and *Micractinium pusillum*).

The spring months in group C were associated with EC and NO_2-N and characterized by *U. ulna, U. biceps, Nitzschia palea, Gyrosigma* sp., *Fragilaria capucina,* and *Navicula trivialis*. The summer months categorized in group D are mainly located at the center of CCA ordination and characterized by *D. sociale, Coelastrum astroideum, Oocystis marssonii* and *Amphora ovalis*.

The phytoplankton species optima for TP and EC are given in Figures 5a and 5b, respectively. Phytoplankton species such as *G. saginatum, Snowella lacustris, C. hirundinella, Pseudanabaena* sp., *Pseudanabaena limnetica, S. brevispina, Spirogyra longata, P. nannoplanctica,* and *C. aciculare* had high optimum values for TP (>75% percentile) (Figure 5a). Some species like *F. capucina, Cladophora glomerata, N. trivialis, Cymbella aspera, U. biceps, N. palea,* and *Pseudopediastrum boryanum* displayed optimum values larger than 75% percentile for EC levels (Figure 5b).

3.4. Trophic state and ecological status

A temporal variation in the trophic state of Burç Reservoir was found by the assessment of chlorophyll *a*, TP, and Secchi disk depth that is summarized in Table 4. Carlson's trophic state index indicated that Burç Reservoir mainly has a eutrophic characteristic, while it had a eu-hypertrophic according to the OECD classification.

Plots of logTP versus the modified PTI ($R^2 = 0.86$), Med-PTI ($R^2 = 0.79$), and the Q assemblage index ($R^2 = 0.06$) are given in Figures 6a–6c, respectively. The modified PTI (Figure 6a) and Med-PTI (Figure 6b) showed well-agreements with logTP gradients, but the Q index did not show. The highest correlation coefficient value makes the modified PTI as a suitable metric for evaluating the ecological status of Burç Reservoir. Besides, the modified PTI had significant correlations with water temperature ($r = -0.73$, $p < 0.01$), EC ($r = 0.43$, $p < 0.01$), TN ($r = 0.49$, p

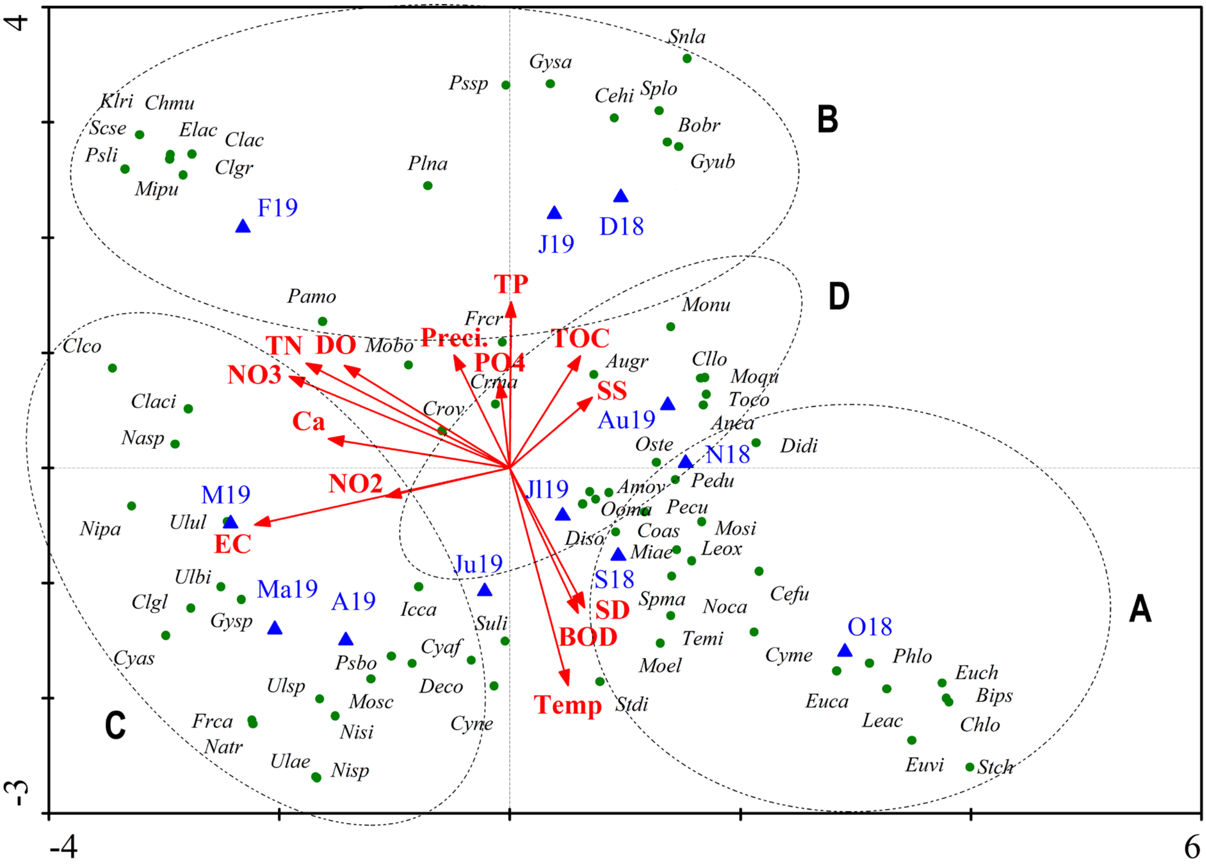

Figure 4. Phytoplankton composition (green circle), environmental (red arrow) relations in Burç Reservoir for 12 months. Abbreviations and full names of phytoplankton species are given on Table 2. Abbreviation and full names of sampling months (up triangle) are given in Figure 2.

< 0.01), NO_3–N (r = 0.48, p < 0.01), TP (r = 0.93, p < 0.01), and PO_4 (r = 0.65, p < 0.01). Results of the modified PTI (mean = 2.37) and Med-PTI (mean = 1.96) indicated that Burç Reservoir has a moderate environmental condition that is also supported by the Q assemblage index (mean = 2.58).

4. Discussion

The dynamic environment was found in Burç Reservoir, which is the main environmental forces on biota composition in lentic systems. Thermal stratification (from the late spring to the middle of autumn) and water circulation (in the period of the late fall-the middle spring) of Burç Reservoir indicated a warm monomictic characteristic. Similar temperature behavior in water depth profile was found in the Mediterranean ecosystems such as Alleben Reservoir (Çelekli and Öztürk, 2014), Sau Reservoir (Becker et al., 2010), and Pareja Reservoir (Molina-Navarro et al., 2014). Lentic systems can undergo the long stratification period of the late spring-earlier autumn in the Mediterranean climate with four seasons (Becker et al. 2010; Çelekli and Öztürk 2014). Reynolds (2006) reported that the mixing regime strongly affects both environmental factors variables (e.g., nutrients and light), and phytoplankton dynamics (e.g., their buoyance, functional type, availability of growth-limiting physical and chemical requisites, etc.). The water mixing period in Burç Reservoir decreased light availability (mean SD = 0.7 m in December 2018) which is a limiting factor for phytoplankton dynamic. On the other hand, the increment of light during the long stratification period in this reservoir could lead to P-limitation in the epilimnion due to consuming available nutrients by phytoplankton. The mixing regime is an important driven factor in the seasonality of phytoplankton communities because of the nutrients and light availability, EC, grazing, sinking, etc. (Reynolds, 2006; Cao et al., 2018). The mixing regime interacting with the availability of the light and nutrients was also observed in Mediterranean lentic ecosystems such as Pareja limno-reservoir (Molina-Navarro et al., 2014), Alleben Reservoir (Çelekli and Öztürk, 2014), Sau Reservoir (Becker et al., 2010), and Batman Reservoir (Varol, 2019). Nutrient enrichment in Burç Reservoir and also mentioned lentic ecosystems at different level is not

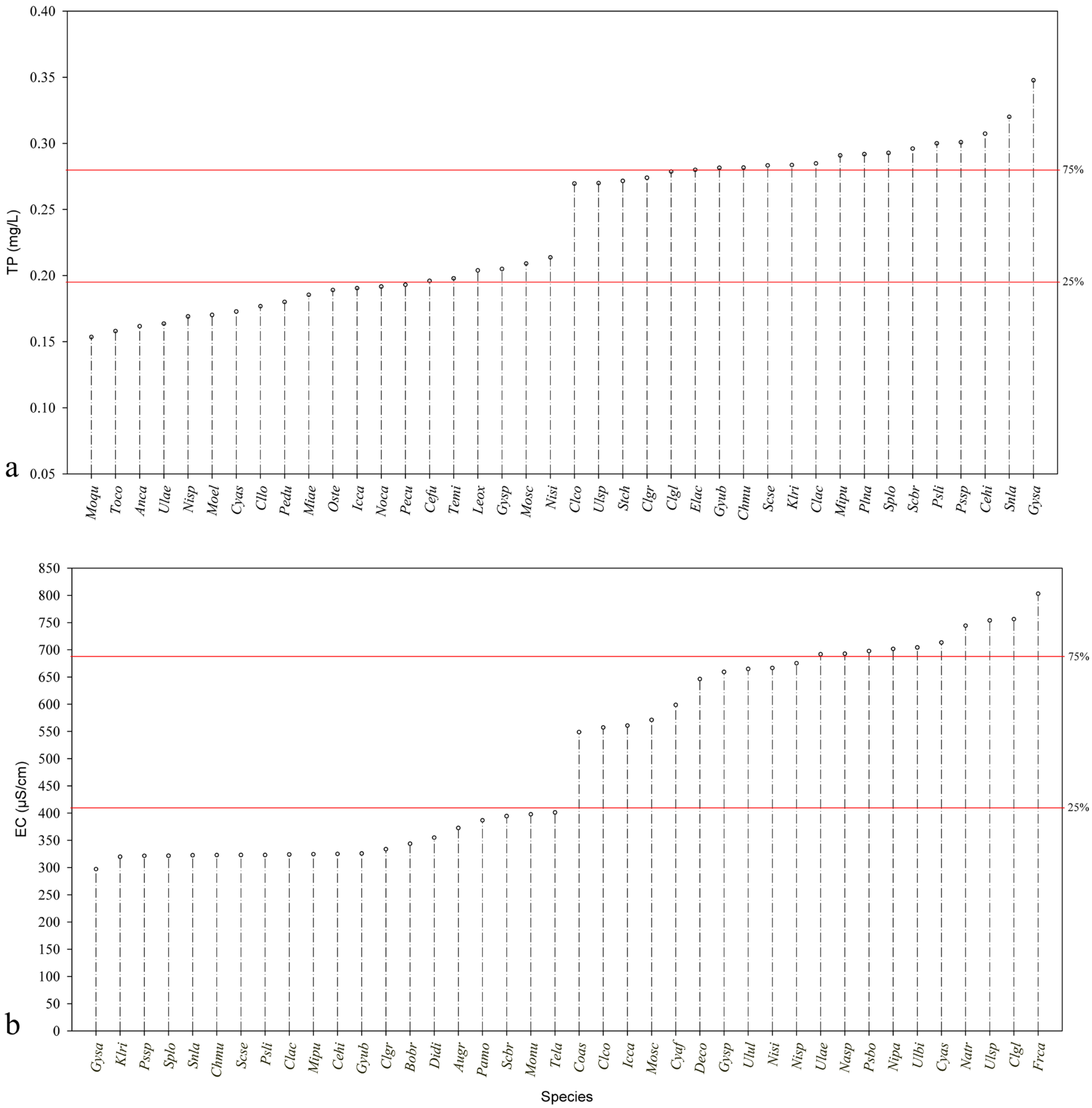

Figure 5. Phytoplankton species optima for TP (a) and EC (b). Red lines on the plots indicate percentile values (25% and 75%).

only increased by the sediment resuspension with the water mixing but also is enhanced by the external inputs nutrients from erosion, agriculture, sewage, etc.

Successions of phytoplankton assemblages are associated with availabilities of nutrients, light, and EC, which are driven by these two physical patterns (the stratification and the water full mixing) in the present study. Consequently, various functional groups (FGs) of E, F, J, L_O, L_M, M_P, P, S_1, T, and W_1 as descriptors were found in the phytoplankton composition of Burç Reservoir, which were used as an indicator of the trophic state of this reservoir. Most of them were observed in Mediterranean lentic ecosystems (Becker et al. 2010; Molina-Navarro et al. 2014). Several FGs such as E, J, L_O, L_M, M_P, and P in Burç Reservoir was also found in Alleben Reservoir in the same region (Çelekli and Öztürk, 2014). However, a few FGs of F, S_1, T, and W_1 were only found in the present study. Differences in FGs of ecosystems could be due to differences in time of climate and pressures of the ecoregion.

Table 4. The trophic state of Burç Reservoir based on values of TP-total phosphorous, SD-Secchi disk depth, and Chlo *a*- chlorophyll *a* according to criteria of OECD (Vollenweider and Kerekes, 1982) and the scores of trophic state index (Carlson, 1977). TSI-trophic state index, H-hypertrophic, Eu-eutrophic, M/Eu-mesoeutrophic.

	Carlson's trophic state index			OECD		
Months	TSI_{SD}	TSI_{TP}	$TSI_{Chlo\ a}$	SD	TP	Chlo *a*
S18	Eu	Eu	Eu	Eu	H	H
O18	Ee	Eu	Eu	Eu	H	H
N18	M/Eu	Eu	Eu	Eu	H	H
D18	Eu	Eu	Eu	H	H	H
J19	Eu	Eu	Eu	H	H	H
F19	Eu	Eu	Eu	H	H	H
M19	M	Eu	Eu	H	H	H
A19	Eu	Eu	Eu	Eu	H	Eu
Ma19	Eu	Eu	Eu	H	H	Eu
Ju19	Eu	Eu	M	Eu	H	Eu
Jl19	Eu	Eu	Eu	Eu	H	Eu
Au19	M/Eu	Eu	Eu	Eu	H	Eu

The fall season was under the pressures of BOD_5 and Secchi disk depth and it is characterized by phytoplankton species such as *Microcystis aeruginosa, C. furcoides, Lepocinclis oxyuris, Nostoc caeruleum* var. *planctonicum*, *Euglenaria caudata, Euglena viridis, Lepocinclis acus, Phacus longicauda, Staurastrum chaetoceras,* and *Cyclotella meneghiniana*. *Microcystis aeruginosa* and *C. furcoides* can be attributed to the survival strategies of the L_M FG, whose habitat template is small- to medium-sized eutrophic lakes (Padisák et al., 2009), which corresponds to the properties of Burç Reservoir. The succession of *M. aeruginosa* is associated with eutrophic ecosystems in Mediterranean ecoregion such as artificial lakes (Vadrucci et al., 2017), Lake Cedrino (Padedda et al., 2017), and Karaoun Reservoir (Fadel et al., 2015). Cooccurrence of these phytoplankton species during the fall season was indicated by the CCA in the present study (Figure 4) and was also found in previous limnological studies (e.g., de Almeida et al., 2016; Kruk et al., 2017), which recognize the association with L_M. *Phacus longicauda* preferred warm (19.2 °C) and stratified waters and it is attributed to the FG of W1 and the species is associated with the summer epilimnia in mesotrophic lakes (Reynolds et al., 2002; Padisák et al., 2009). *Staurastrum chaetoceras* is related to the FG of P which is a typical eutrophic epilimnia (Reynolds et al., 2002; Padisák et al., 2009). These correspond with the characteristics of Burç Reservoir. Cooccurrence of *P. longicauda* and *S. chaetoceras* was associated to October 2018 (Figure 4) and they were encountered in four kettle holes near Rostock of Germany (Alkhalaf et al., 2009).

The winter months especially December 2018 and January 2019 mostly related to TP and TOC, which were characterized by phytoplankton assemblages such as *G. uberrimum, C. hirundinella, Spirogyra longata, G. saginatum,* and *Botryococcus braunii* species. The late winter (February 2019) was represented by *C. gracile, C. acicularis, Elakatothrix acuta* and *M. pusillum*, which are associated with TN and NO_3-N. The dinoflagellates like *G. uberrimum* and *C. hirundinella* had important biovolume peaks in the earlier winter with cool water, relatively high TOC and TP in Burç Reservoir is attributed to the FG of Lo, whose habitat is eutrophic lakes (Padisák et al., 2009). *Gymnodium uberrimum* had optima of 0.281 mg/L TP, 8.71 mg/L TOC, and a pH value equal to 8.46 during the study period. Unlike the present study, *G. uberrimum* cooccurred with *Peridinium willei* predominantly at relatively low TP (<25 µg/L) concentrations with pH < 7 in German reservoirs with a high transparency (>3 m) (Niesel et al., 2007). Similar to the present study, *G. uberrimum* was found in Sos Canales Lake (a Mediterranean artificial lake) with the mixing condition during the colder winter months from December to March (Fadda et al., 2016). *Ceratium hirundinella* preferred 0.307 mg/L, TP, 5.51 mg/L TOC, and 8.5 °C water temperature in Burç Reservoir. Likely, *C. hirundinella* dominantly occurred in Karaoun Reservoir, Lebanon during the water mixed conditions

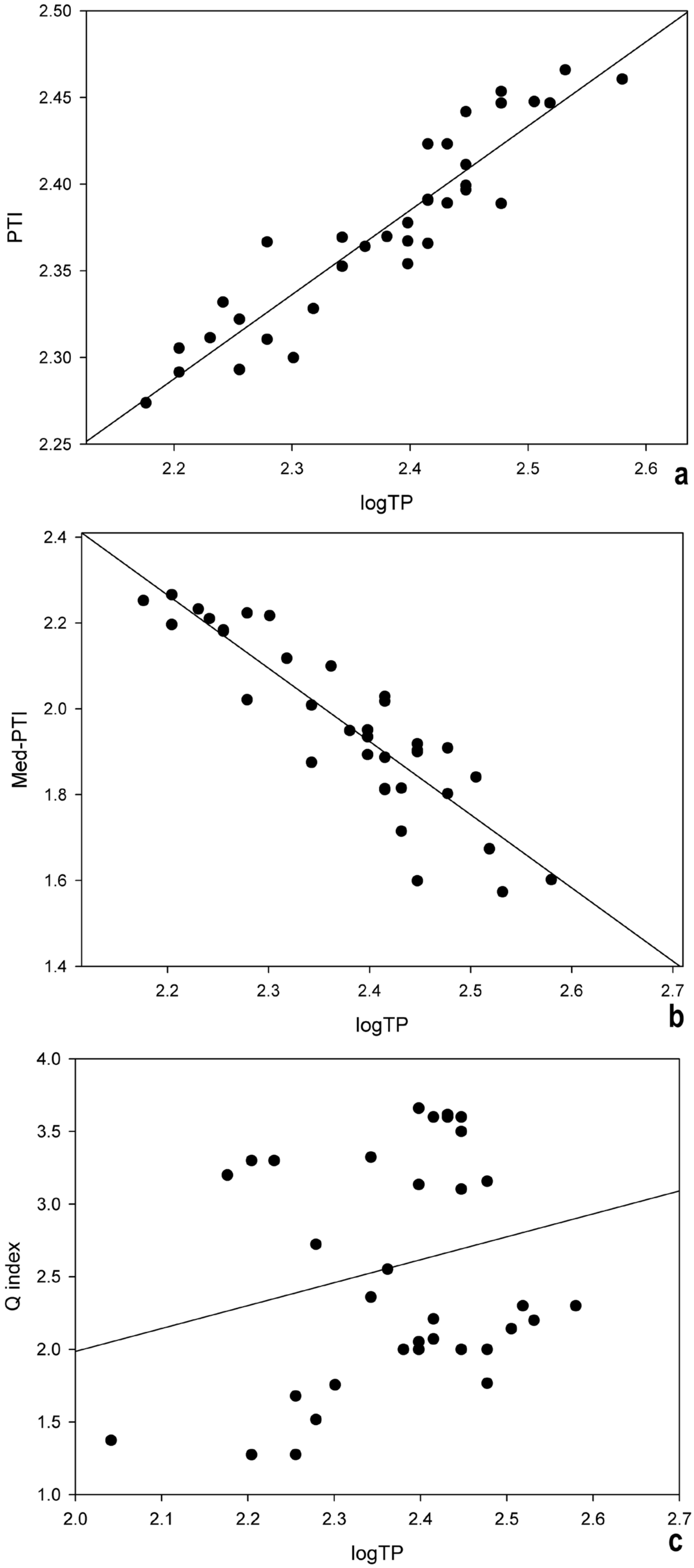

Figure 6. Plots of logTP vs. (a) PTI, (b) Med-PTI, and (c) Q index.

and at low light intensity in the late autumn (Fadel et al., 2015). This dinoflagellate has a wide distribution in different biogeographical regions (Reynolds, 2006; Ersanlı and Mustak, 2017; Çelekli and Lekesiz, 2021). Besides, *C. hirundinella* co-occurred with *P. cinctum* in the Lake Aygır located at high altitude, Turkey (Çelekli et al., 2020) and Batman Reservoir (Varol, 2019).

Phytoplankton species *C. gracile, C. acicularis, Klebsormidium rivulare Chaetoceros* sp. *Pseudanabaena limnetica, Elakatothrix acuta,* and *M. pusillum* are associated with TN and NO_3-N in February 2019 (Figure 4). *Pseudanabaena limnetica* preferred relatively high TN (4.96 mg/L) in the present study and so it shows the survival strategies of MP whose habitat template is the typical of turbid mixed environments (Reynolds et al., 2002; Padisák et al., 2009). Mentioned cyanobacterium developed and increased its biomass in southern Lake Mangueira, Brazil when nutrients and temperature increased in the winter (da Rosa Wieliczko et al., 2020) and in the Lake Karla, Greece (Latinopoulos et al., 2020).

The spring months are associated with EC and NO_2-N and characterized by *U. ulna, U. biceps, N. palea, Gyrosigma* sp., *Navicula trivialis, F. capucina, Nitzschia sigmoidea, Iconella capronii, P. boryanum, Cladophora glomerata*, *Ulothrix aequalis*, and *Mougeotia scalaris* (Figure 4), which was also supported by results of WA. *Fragilaria capucina, C. glomerata, N. trivialis, U. biceps, N. palea,* and *P. boryanum* preferred EC and NO_2-N higher than that of 75% percentiles. The mixing regime in the reservoir led to the overturning and upwelling of the hypolimnetic biogenic elements and decreasing Secchi depth, which could support the enhancement of diatom biovolume. The survival strategies of phytoplankton FG of MP (*U. ulna*, *U. biceps*, *I. capronii, N. sigmoidea, Ulothrix aequalis,* and *Cladophora glomerata*), J with *Pseudopediastrum boryanum,* and T with *M. scalaris* were found (Reynolds et al., 2002; Padisák et al., 2009). *Ulnaria biceps* and *U. ulna* had main biovolume peaks in March 2019 with relative high preferences for EC and NO_2-N (>75% percentiles), whose habitat template is typical of inorganically turbid stirred environments and these diatom species sensitive to the flushing (Reynolds et al., 2002; Bovo-Scomparin and Train, 2008; Padisák et al., 2009). Diatom assemblages in the present study have relatively high trophic weight values in Austria (Rott et al., 1999) and Turkey (Çelekli et al., 2019). Among the chlorophytes, *P. boryanum* is attributed to the FG of J (Reynolds et al., 2002; Padisák et al., 2009) and had main biovolume peaks in May 2019, after decreasing of diatoms biovolume. The habitat template is mixed and highly enriched systems (Padisák et al., 2009; Kruk et al., 2017), which mainly corresponds with the characteristics of Burç Reservoir except the beginning of the thermal stratification. This phytoplankton species was found in Lake Aktaş (which is hypereutrophic and has a moderate environmental condition) located at a relatively high altitude where phytoplankton species showed the association with nutrients and BOD_5 (Çelekli et al., 2020). Besides, *P. boryanum* has a wide distribution on different ecoregions including English lakes and reservoirs (John et al., 2002), lentic ecosystems in the western Mediterranean basin of Turkey (Çelekli and Lekesiz, 2021), a new reconstructed shallow lentic system of Greece (Latinopoulos et al., 2020), and lakes of France (Laplace-Treyture and Feret, 2016). *Mougeotia scalaris* had main biovolume peaks in May and June 2019, when the stratification in Burç Reservoir begun and it is ascribed to functional group T whose habitat is well-mixed epilimnia and it shows sensitivity to nutrient deficiency (Reynolds et al., 2002; Padisák et al., 2009).

The summer months are characterized by *D. sociale, C. astroideum, Oocystis marssonii, Pediastrum duplex,* and *Amphora* ovalis (Figure 4) during the thermal stratification. The chrysophytes, dominated by *D. sociale* developed in June and July of 2019, while the chlorophytes, *P. duplex* had remarkable peaks in August 2019. *Pediastrum duplex* developed in warm water (25 ^{o}C) with 438 µS/cm EC, 0.180 mg l^{-1} TP and 2.1 m SD, is ascribed to the FG of P, whose habitat is typical of eutrophic epilimnia and organism sensitive to the stratification (Reynolds et al., 2002; Padisák et al., 2009). *Dinobryon sociale* developed in warm water (19.5 °C) with 418 µS/cm EC, 0.241 mg L^{-1} TP and 2.0 m SD, is corresponded to the FG of E, whose habitat is typical of heterotrophic ponds (e.g., Reynolds et al., 2002; Padisák et al., 2009). Thermal stratification condition could support this chrysophyte in the present study and also in Lake Saanajärvi with the oligotrophic state, Finland (Forsström et al., 2005) and the oligotrophic Laghetto Inferiore, Switzerland (Simona et al., 1999). Besides, *D. sociale* was also abundantly found in the calcareous ecosystems such as Lake Balaton (Reynolds et al., 1993) and the karstic Akkaya spring (Çelekli and Külköylüoğlu, 2007). As an additional nutritive source to phototrophy, *Dinobryon* taxa ingest bacteria (Isaksson et al., 1999), which can be important for the ecological interpretation. The reputation of *Dinobryon* is being of it as an indicator of oligotrophic conditions but intolerance of competitors exhausting the carbon. Well-buffered lentic ecosystems by bicarbonate make it difficult for *Dinobryon* to satisfy its carbon requirement. *Dinobryon* is restricted to soft-water lakes ought to be inviolable, but its seasonal abundance in Burç Reservoir is far from being an isolated instance.

Burç Reservoir mainly showed a eutrophic state according to criteria of OECD (Vollenweider and Krekes, 1982) and the scores of trophic state index (Carlson, 1977) concerning the Secchi depth, TP, and chlorophyll *a*.

Similar trophic state was found in Lake Cedrina, a deep system, Italy (Padedda et al., 2017). The assessment of total phytoplankton biovolume (Figure 3) also confirmed that Burç Reservoir is the characteristic of mesoeutrophic according to the classification systems of the annual mean of phytoplankton biovolume (Rott, 1984). However, Cyanobacteria had the lowest contribution to total phytoplankton biovolume in Burç Reservoir which supported good environmental conditions based on Cyanophytes' biovolume <0.09 $mm^3 L^{-1}$ for deep ecosystems (Søndergaard et al., 2005). This is because the percent contribution biovolume of cyanobacteria as a metric is used to evaluate the water quality of lentic ecosystems (Søndergaard et al., 2005). Besides, Euglenozoa had a remarkable contribution (9.6%) to total phytoplankton biovolume, which indicated organic pollution in Burç Reservoir with its highest value in October 2018 that is also supported by its score (*Euglena* pollution index = 5) of Palmer index (Palmer, 1969).

The use of phytoplankton metrics in the biological-assessment of the lentic ecosystems has a great importance to determine the ecological status of water resources and manage them throughout worldwide (Padisák et al., 2006; Marchetto et al., 2009; Phillips et al., 2013; Çelekli et al., 2020). The significant correlation between the index and TP gradient suggested that the modified PTI and Med-PTI (Figures 6a and 6b) could be appropriate metrics to evaluate the ecological status of Burç Reservoir. Conformities of phytoplankton metrics to evaluate the ecological status of lentic systems have also been demonstrated in 1795 lakes of Europe (Phillips et al., 2013), Mediterranean reservoirs (Marchetto et al., 2009), Pareja Reservoir (Molina-Navarro et al., 2014), and the west Mediterranean basin of Anatolia (Çelekli and Lekesiz, 2021). Besides, the modified PTI had significant positive correlations with environmental factors (e.g., EC, TN, NO_3-N, TP, and PO_4). The modified PTI and Med-PTI indicated that Burç Reservoir has a moderate environmental condition and this environmental condition was also found in some lakes of Europe (Phillips et al., 2013), Alleben Reservoir (Çelekli and Öztürk, 2014), and Lake Aktaş in the Aras basin of Turkey (Çelekli et al., 2020). Besides, total phytoplankton biovolume as the Søndergaard metric was used to evaluate the ecological status of lentic ecosystems. The result of the Søndergaard metric indicated that Burç Reservoir showed a good ecological status during the study period. The biovolume contribution of phytoplankton assemblages in lentic ecosystems can be used as an indicator of water quality (Carvalho et al., 2013; Phillips et al., 2013). Functional groups of phytoplankton assemblages (explained above), trophic states-based TP, SD, chlorophyll *a*, and total biovolume and phyto-assessments indicated a deteriorated environmental condition in Burç Reservoir.

5. Conclusion

Phytoplankton assemblages-stressors interactions and the limnoecological status of Burç Reservoir were firstly elucidated by the application of multivariate approaches and phytoplankton metrics according to the WFD requirements. Phytoplankton temporal dynamics in Burç Reservoir are integrated to environmental changes, which could be driven by the water mixing regime, seasonal change, catchment land uses, water level fluctuation, etc. Phytoplankton FGs of E, F, J, L_O, L_M, M_P, P, S_1, T, and W_1 as descriptors were found in the reservoir. The CCA indicated that EC, NO_3-N, TN, water temperature, Ca^{+2}, precipitation, TOC, PO_4, and TP are the most important stressors which significantly drove the temporal distribution of phytoplankton. Carlson's trophic state index indicated that Burç reservoir has mostly a eutrophic characteristic based on the assessment of chlorophyll *a*, TP, and Secchi disk depth. Søndergaard metric indicated that relatively low cyanobacterial biovolume contribution (<2%) and total phytoplankton biovolume in the reservoir resulted in a good environmental condition. The WFD requires to assess ecological status of water resources to achieve the good ecological status using biological quality components supported by abiotic factors. Results of the modified PTI (mean = 2.37) and Med-PTI (mean = 1.96) as appropriate phytoplankton metrics indicated the overall moderate ecological status of Burç Reservoir that is supported by the Q assemblage index (mean = 2.58). The present study revealed that the importance of evaluating ecological integrity based on phytoplankton metrics and chemical characteristics of a lentic ecosystem, which can be used to improve biomonitoring studies of lentic ecosystems in the future.

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