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Composition and Abundance of Phytoplankton in Boggy Freshwater Lake, Turkey: In Relation to Physical and Chemical Variables

*Hanife Özbay**

Nevşehir Hacı Bektaş Veli University, Faculty of Sciences,
Department of Biology, 50300, Nevşehir, TURKEY
* Corresponding author: hanifeozbay@gmail.com

Abstract. Lake Çalı (41° 12′ N, 43° 13′ E, Kars, Turkey) is a small (171273 m^2, 1 m depth), shallow and macrophyte-dominated semi-arid Mediterranean lake. Although it is called a Lake, in reality it is a small pond. The phytoplankton of Lake Çalı was studied from May to September 2010 at three sampling stations. Eighty-two phytoplankton taxa were determined, consisting of Cyanophyta (15), Chlorophyta (30), Euglenophyta (13), Bacillariophyta (19), Cryptophyta (2), Dinophyta (1) and Chrysophyta (2). Total phytoplankton density increased from May to August. The dominant phytoplankton group was Cyanophyta during the study period, followed by Bacillariophyta and Chlorophyta. Temparature, pH and dissolved oxygen range from 14.6 to 21.6 ^{0}C, 7.62 to 8.08, 5.96 to 7.46 mg/L, respectively. Chlorophyll *a* level ranged from 0.0035 to 0.0059 mg/L. On the other hand both phosphate and nitrogen levels tended to increase from May to July. The maximum and minimum densities of phytoplankton were 14034 org/mL (August) and 11885 org/mL (September), respectively, and this variable correleted significantly with temperature, pH, DO, SRP, TP, Cyanophyta, and Bacillariophyta.

Key words: Lake Çalı, phytoplankton, physico-chemical variable, boggy environment, pond.

Introduction

Throughout the world small, shallow ponds exist in different shapes, depths and sizes. They can occur seasonally, temporarily, or permanently. The environmental conditions that affect their trophic status and biota may also create small ponds (Fairchild *et al.*, 2005; Peteryatko *et al.*, 2007; Soinien *et al.*, 2007). There is a strong interrelation between number of species and habitat diversity. There is also high species diversity in shallow lakes and ponds because they are found in a large number of ecological niches (Reynolds, 1984; Wetzel, 2001; Duelli & Obriit, 2003). Continuous mix in shallow ponds promotes algal growth, allow to algae to remain in suspension and exposing them to light (Messyasz *et al.*, 2005). In shallow ponds, phytoplankton communities generally exhibit a horizontal band close to the surface. The dense phytoplankton growth in this band appears in depths between 5-8cm and 45-50cm. The depth of the band depends on many factors such as water turbidity, nutrient supply and light intensity (Messyasz & Jugonska, 2003).

Although Turkish research on phytoplankton communities has focused predominantly on lakes, no phytoplankton studies have been conducted using data from Lake Çalı. The present study, therefore, is the first attempt to describe the seasonal abundance of phytoplankton in this

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ecological system. The effects of physico-chemical parameters such as temperature, DO, pH, SRP, TP, NH_4-N, NO_3-N and chlorophyll *a* on the phytoplankton community have also been evaluated.

Material and Methods

Lake Çalı (41°12'N, 43°12'E) is a small (171273 m², 1 m depth), shallow and macrophyte-dominated (particularly *Myriophyllum spicatum* L. and *Potamogeton pectinatus* L.) semi-arid Mediterranean lake (Kars, Turkey), adjacent to the road between Kars and Digor that bisects the site (Fig.1). On the south there is a 15 ha permanent lake with reach submersed flora. The macrophytes cover may reach up to 50% in the growing season (summer). The area to the north of the road (approximately 10 ha) is seasonal. Although it is called a Lake, in reality it is a small pond. This small wetland lies in a vast elevated plateau, largely covered by extensively grazed steppe grassland. The site is one of the important bird habitats in Turkey. The lake is fed by seasonal springs. There is one small settlement on the shore and drinking water for Kars is pumped from a well nearby the lake (MAGNIN & YARAR; 1997).

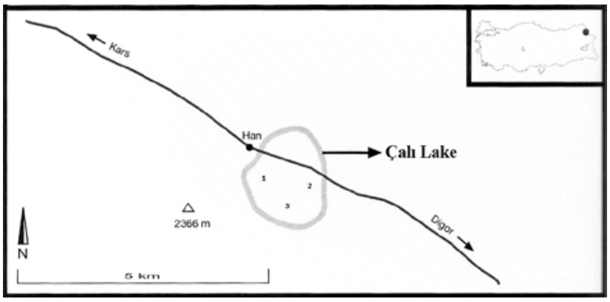

Fig.1. Map of the study area and sampling station.

Samples were collected monthly from May to September 2010 at three sampling stations scattered along the lake. In October, the Lake surface was completely covered by floating leaved macrophytes, leaves and debris, and it was not possible to take samples. Sampling was also not carried out during the winter because of the severe weather conditions. At each sampling station, water temperature, dissolved oxygen (DO), and pH were measured *in situ* with commercial meters. Water samples (1 litre) were also collected for analysis of soluble reactive phosphorus (SRP), total phosphate (TP), ammonium-nitrogen (NH_4-N) and nitrate-nitrogen (NO_3-N), following MACKERETH *et al.* (1978). Single subsurface phytoplankton samples were taken with a Van Dorn sampler and preserved with Lugol's solution immediately after sampling. Subsamples were examined and enumerated with an inverted microscope at a magnification of ×400, according to the method described by LUND *et al.* (1958). Standard texts were used for identification of phytoplankton species (LIND & BROOK, 1980; HARIS, 1986; KRAMER & LANGE-BERLATOT, 1991; CANTER-LUND & LUND, 1996). Chl*a* was extracted with acetone, and the concentration was calculated from the absorbance reading at 663 nm (TALLING & DRIVER, 1961). The Shannon-Wiener species diversity index (H') was calculated as follows:

$$H' = -\Sigma P_i (\ln P_i)$$

where P_i represents the proportion of each species in the sample.

The dominance (%) values were calculated for each species as mean density of species divided by mean total density of phytoplankton and multipled by 100. Avarage values were used for all variables in results section. Principal Component Analysis (PCA) was performed using SPSS 22.0 to assess the influence of the physico-chemical variables on the abundance of phytoplankton.

Results

A total of 82 phytoplankton taxa were identified in Lake Çalı. Throughout the study period, the dominant group was Cyanophyta, followed by Chlorophyta and Bacillariophyta. The 11 taxa that made up more than 5% of the total phytoplankton biomass were members of seven functional groups (FGs) (Table 1). Within Cyanophyta, three species exceeded 10% dominance: *Anabaena munitissima*, *Nostoc sp.* and *Lyngbya concorta*. For the Chlorophyta, global dominance > 20% for most of the study period, with only three taxa (*Monoraphidium irregulare, Pediastrum simplex, Scenedesmus communis*) exceeding 5% dominance. Another important group was Bacillariophyta, where only one taxa (*Fragilaria crotonensis*) reached the 10% dominance value. The Shannon-Wiener species diversity index, which is based on the number of individuals, ranged from 3.11 (May) to 3.89 (August) (Table 2).

The physico-chemical variables of Lake Çali ranged from 7.62 (May) to 8.08 (August) for pH, from 14.6 °C (September) to 21.6 °C (June) for temperature, from 5.96 (June) to 7.46 (May) mg/L for DO, from 0.0035 (May) to 0.0059 (June) mg/L for Chl *a*, from 0.145 (September) to 0.442 (June) mg/L for NO_3-N, from 29.18 (May) to 63.76 (June) µg/L for NH_4-N, from 58.2 (September) to 234.3 (July) µg/L for TP, and from 49.1 (September) to 147.1 (July) µg/L for SRP (Fig. 2).

The density of phytoplankton ranged from 11885 (September) to 14034 (August) org/mL (Fig. 3). This variable correlated significantly with temperature ($p<0.05$), pH ($p<0.05$), DO ($p<0.05$), SRP ($p<0.05$), TP ($p<0.005$), Cyanophyta ($p<0.05$), and Bacillariophyta ($p<0.001$); however, the density of phytoplankton did not correlate significantly with the other variables ($p>0.05$ in all cases).

Table 1. Main phytoplankton taxa with the corresponding functional groups in Lake Çalı.

Functional group	Taxon
C	*Cyclotella meneghiniana*
H_1	*Anabaena flos-aquae, Anabaena minutissima*
J	*Pediastrum simplex, Scenedesmus communis*
S_1	*Lyngbya concorta, Planktothrix sp.*
S_2	*Nostoc sp., Spirulina sp.*
P	*Fragilaria crotonensis*
X_1	*Monoraphidium irregulare*

Among the three most abundant groups in the lake, Cyanophyta strongly correlated with temperature, Chlorophyta strongly correlated with pH, and Bacillariophyta strongly correlated with SRP ($p<0.01$ in all cases). Correlation with NH_4-N ($p<0.05$), and TP ($p<0.05$) was also significant for Bacillariophyta. On the other hand, no significant association with NO_3-N was evident for any of the three most abundant groups. Likewise, no significant relation with NH_4-N was found for either Chlorophyta or Cyanophyta (Fig. 4).

Table 2. Species composition, dominance values and divesity (H′: Shannon-Wiener diversity index) of phytoplankton in Lake Çalı.

		Dominance (%)				
	Taxa	**May 2010**	**June 2010**	**July 2010**	**Aug. 2010**	**Sept. 2010**
	CYANOPHYTA	56.07	51.31	43.86	43.55	46.12
1	*Anabaena minutissima*	20.58	8.12	3.87	3.27	2.17
2	*Anabaena flos-aquae*	3.71	13.46	6.03	6.00	9.93
3	*Anabaena oscillariodes*	1.52	1.52	1.26	2.69	2.67
4	*Anabaena spiroides*	1.63	2.15	1.67	2.83	2.50
5	*Anabaenopsis elenkinii*	2.71	1.90	1.02	1.56	0.87
6	*Chroococcus minor*	0.85	1.19	2.45	1.60	1.59
7	*Chroococcus turgidus*	0.71	0.49	0.43	0.96	0.94
8	*Gloeocapsa sp.*	1.52	0.62	0.48	1.63	1.57
9	*Lyngbya concorta*	2.49	6.74	6.47	6.94	16.67
10	*Lyngbya sp.*	2.94	1.39	1.44	3.57	3.24
11	*Nostoc sp.*	14.98	6.13	4.56	3.68	1.99
12	*Oscillatoria brevis*	2.41	1.63	1.27	1.24	1.14

13	*Phormidium sp.*	0.60	0.31	0.49	1.41	1.56
14	*Planktothrix sp.*	3.47	1.04	0.91	5.12	2.86
15	*Spirulina sp.*	1.07	2.26	1.49	5.86	1.15
	CHLOROPHYTA	19.80	20.15	26.80	33.75	27.95
16	*Ankistrodesmus falcatus*	0.02	0.07	0.23	0.31	0.40
17	*Ankistrodesmus gracilis*	0.002	0.06	0.25	0.33	0.66
18	*Botryococcus branuii*	0.05	0.006	0.20	0.40	0.74
19	*Chlamydomonas regularis*	0.17	0.34	0.09	0.20	0.57
20	*Chlamydomonas vulgaris*	0.002	0.02	0.05	0.10	0.06
21	*Chlamydomonas sp.*	2.11	0.99	1.04	2.00	1.31
22	*Cladophora sauteri*	0.22	0.27	0.70	1.77	1.31
23	*Closterium calosporum*	0.42	0.15	0.96	1.61	1.19
24	*Closterium ehrenbergii*	0.08	0.24	0.34	0.38	0.56
25	*Closterium sp.*	0.008	0.05	0.06	0.12	0.08
26	*Coelastrum cambricum*	0.05	0.04	0.25	0.55	0.56
27	*Cosmarium subcrenatum*	0.07	0.11	0.11	0.15	0.08
28	*Elakatothrix gelatinosa*	0.005	0.009	0.02	0.02	0.009
29	*Gloeocystis sp.*	0.17	0.04	0.52	0.37	0.69
30	*Lagerheimia sp.*	0.05	0.15	0.32	0.35	0.61
31	*Monoraphidium irregulare*	3.56	3.10	4.50	7.61	6.36
32	*Oocystis elliptica*	0.00	0.05	0.24	0.36	0.58
33	*Oocystis sp.*	0.04	0.28	0.29	0.56	0.47
34	*Pediastrum duplex*	0.05	0.02	0.04	0.07	0.04
35	*Pediastrum simplex*	6.33	4.39	3.61	6.72	3.97
36	*Scenedesmus acuminatus*	0.42	0.31	0.25	0.26	0.13
37	*Scenedesmus arcuatus*	0.69	0.59	0.51	0.61	2.69
38	*Scenedesmus armatus*	0.36	0.36	0.15	0.43	0.47
39	*Scenedesmus communis*	4.39	4.11	3.67	7.94	2.92
40	*Scenedesmus falcatus*	0.45	0.40	0.08	0.21	0.30
41	*Scenedesmus quadricauda*	0.63	0.59	0.51	0.62	1.65
42	*Schroederia setigera*	0.15	0.10	0.11	0.12	0.09
43	*Staurastrum cingulum*	0.00	0.004	0.01	0.03	0.10
44	*Staurastrum denticulatum*	0.02	0.03	0.03	0.06	0.04
45	*Tetrastrum triangulare*	0.93	0.53	0.14	0.33	0.48
	EUGLENOPHYTA	0.11	0.11	0.12	0.19	0.21
46	*Euglena gracilis*	0.05	0.05	0.06	0.06	0.05
47	*Euglena oxyuris*	0.04	0.02	0.03	0.06	0.09
48	*Euglena spirogyra*	0.00	0.00	0.001	0.005	0.003
49	*Euglena tripteris*	0.00	0.002	0.003	0.002	0.00
50	*Euglena sp.*	0.00	0.002	0.001	0.007	0.003
51	*Lepocinclis sp.*	0.00	0.00	0.001	0.005	0.006
52	*Phacus caudata*	0.00	0.002	0.001	0.002	0.006
53	*Phacus granum*	0.00	0.00	0.001	0.07	0.006
54	*Phacus longicauda*	0.00	0.002	0.001	0.01	0.006
55	*Phacus sp.*	0.00	0.00	0.001	0.007	0.006
56	*Trachelomonas armata*	0.01	0.02	0.001	0.01	0.003
587	*Trachelomonas caudata*	0.00	0.002	0.003	0.005	0.01
58	*Trachelomonas sp.*	0.002	0.00	0.001	0.005	0.006
	BACILLARIOPHYTA	22.98	27.35	27.79	21.10	24.94
59	*Amphora ovalis*	0.00	0.00	0.007	0.01	0.01
60	*Asterionella sp.*	0.008	0.01	0.02	0.01	0.01
61	*Cyclotella meneghiniana*	1.00	9.60	4.35	2.31	0.77

62	*Cyclotella kützingiana*	0.71	0.45	1.18	2.42	0.97
63	*Cymbella microcephala*	0.13	0.13	0.23	0.37	0.45
64	*Cymbella minuta*	0.25	0.24	0.28	0.54	0.56
65	*Diatoma vulgare*	0.03	0.05	0.05	0.11	0.11
66	*Fragilaria crotonensis*	10.32	2.84	2.79	4.96	14.41
67	*Gomphonema angustatum*	2.95	5.05	5.17	2.47	1.71
68	*Gomphonema truncatum*	3.24	4.00	3.24	2.68	1.83
69	*Navicula lanceolata*	1.07	0.73	0.71	1.69	1.18
70	*Navicula minuscula*	0.52	0.31	0.54	1.19	0.89
71	*Navicula sp. 1*	0.49	0.41	0.38	0.84	0.80
72	*Navicula sp. 2*	0.80	0.47	0.49	0.89	0.53
73	*Nitzschia sp.*	0.40	0.36	0.32	0.45	0.52
74	*Stephanodiscus hantzschii*	0.36	0.48	0.39	0.60	0.81
75	*Surirella sp.*	1.55	0.17	0.28	046	0.53
76	*Synedra capitata*	0.77	0.41	0.47	0.70	0.75
77	*Tabellaria sp.*	0.43	0.32	0.50	0.69	0.61
	CRYPTOPHYTA	0.83	0.71	0.55	0.70	0.35
78	*Chroomonas sp.*	0.58	0.52	0.45	0.61	0.35
79	*Cryptomonas ovata*	0.25	0.18	0.09	0.08	0.00
	CHRYSOPHYTA	0.28	0.28	0.47	0.84	0.49
80	*Dinobryon sp.*	0.19	0.18	0.34	0.70	0.40
81	*Tribonema sp.*	0.08	0.09	0.12	0.13	0.08
	DINOPHYTA	0	0.04	0.02	0.01	0.01
82	*Peridinium sp.*	0.00	0.004	0.02	0.01	0.01
	Diversity index H'	3.11	3.43	3.71	3.89	3.26

Discussion

In the present study, total phytoplankton density increased from May to August in Lake Çalı, then decreased during September (Fig. 2). Throughout the study period, the dominant phytoplankton group in Lake Çalı was Cyanophyta. This disagrees with a number of studies performed in Turkish lakes that have identified diatoms (Bacillariophyta) as a dominant group (AYKULU *et al.*, 1983; OBALI, 1984; ÜNAL, 1984; ALTUNER, 1984; GÖNÜLOL & OBALI, 1986; ELMACI & OBALI, 1992; 1999; TEMEL, 1997; ŞAHIN, 1998; KILINÇ, 1998; AKBULUT & AKBULUT, 2000; ŞAHIN, 2000). On the other hand, results similar to the present study have been reported by ÖZEMSI (1987) and YILDIZ *et al.* (1999) who found Cyanophyta to be a dominant group in Sultan Sazlığı and Hotamış Sazlığı, which are both Turkish wetlands that are as important as Lake Çalı. In both studies, within Cyanophyta, Anabaena, Nostoc, Oscillatoria, Lyngbya and Spirulina species were similar to those of Lake Çalı. Similarly, in Lake Aktaş (ÖZBAY & KILINÇ, 2008) and the River Kars (ÖZBAY, 2011), which are both in the same region as Lake Çalı, Cyanophyta have been found as a dominant phytoplankton.

It is well known that phytoplankton density increases due to eutrophication (SEABORN, 1997; PETR *et al.*, 2004). High concentrations of cyanobacteria, chlorophytes, cryptophytes, and diatoms are frequently associated with the eutrophic condition in ponds (OLADIPO & WILLIAMS, 2003; HARSHA & MALAMMANAVAR, 2004; PERETYATKO *et al.*, 2007). In general, Lake Çalı had sufficient nutrients for phytoplankton growth during the study period. Nutrient levels in the lake increased from May to July for TP and SRP and from May to June for NH_4-N and NO_3-N due to the uninterrepted mixing of the lake, which moves the nutrients from the bottom to the surface. After June and July, nutrient levels decreased due to the increasing growth of both macrophytes and phytoplankton. In this study, the total phytoplankton density tended to increase according to rising nutrient levels in the Lake from May to July.

This is in agreement with the majority of studies that indicate that phytoplankton density increases due to seasonal succession (AYKULU & OBALI, 1981; CIRIK-ALTINDAĞ, 1982; GÖNÜLOL & OBALI, 1986; CIRIK *et al.*, 1989; CIRIK & CIRIK, 1989; GÖNÜLOL & ÇOMAK, 1992; ŞEN *et al.*, 1994; YILDIZ *et al.*, 1999; ÖZBAY & KILINÇ, 2008) in Turkish freshwater systems. Similarly, some studies have found low phytoplankton numbers in low-nutrient concentration waters (CHESSMAN, 1985; DIMITROVIC *et al.*, 2007).

LAUREN (2007, USA, pers. comm.) suggested that nitrate was the limiting factor for phytoplankton growth in the Duwamish River, USA. In this study, however, no nutrient limitation has been identified, but it is likely that phosphate was the primary nutrient for phytoplankton growth. This is in line with studies that have suggested that phosphorus rather than nitrogen is the limiting factor in freshwater ecosystems (WHEELER & NEUSHAL, 1981; HECKY & KILHAM, 1988). Similarly, FAIRCHILD *et al.* (2005), in a study of 13 eutrophic ponds, reported that the phytoplankton biomass was directly correlated with the total phosphorus and negatively correlated with the Secchi depth. MCMASTER *et al.* (2005) also associated phytoplankton abundance and composition with total phosphorus, total nitrogen and conductivity in Alpine ponds.

Dissolved oxygen yielded negative scores for all the variables tested in this study. Although Chl *a* levels increased with the increase in nutrients, the lack of correlation that was demonstrated between the chlorophyll *a* level and the biomass of phytoplankton or any of the phytoplankton groups may be explained by other factors.

The structure of phytoplankton communities not only depends on grazing pressure but also on nutrient and light availability (REYNOLDS, 1988). As a result, species belonging to similar functional groups can in turn be classified as having one of three basic adaptive strategies: (1) C (colonist-invasive), (2) S (stress-tolerant) and (3) R (ruderal). The succession of phytoplankton in Lake Çalı began with S-strategist in May, and they remained dominant at the end of the study. Since the lake macrophytes dominated, strong competition should be take place for nutrient and light between phytoplankton and macrophytes during the study period. Therefore, because of the S-strategist (Cyanophyta in this study), as a stress-tolerant group, might be compete with the macrophytes better than others, and became dominant group in the lake from the beginning to the end of the study. This group was followed by R-Strategists (Bacillariophyta). Cyanophyta, Bacillariophyta and Chlorophyta were the most abundant groups of phytoplankton in Lake Çalı. Within these three groups, 11 species exceeded the 5-20% dominance: *Anabaena minutissima*, *Nostoc sp.*, *Lyngbya concorta, Monoraphidium irregulare, Pediastrum simplex, Scenedesmus communis, Fragilaria crotonensis, Anabaena flos-aquae*, *Spirulina sp.*, *Planktothrix sp.*, and *Cyclotella meneghiniana.*

KEMP (2009, USA, pers. comm.) indicated that in the Cyanophyta community, the abundance of non-heterocytic (non N-fixing) species decreases with reduced inorganic N. This is in contrast to heterocytic (N-fixing) species such as *A. munitissima* and *A. elenkinii* in both the Yangebup and Bibra Lakes. In this study, there was also an abundance of *A. munitissima* in May when the inorganic N content was low.

Field studies indicate that large colonies of *A. flos-aquae* are associated with an increase in water transparency (HOLM *et al.*, 1983). In Lake Çalı, *A. flos-aquae* reached a high density in June and September because the high submersed macrophyte density served to increase water transparency in both months. Although there was no Secchi depth measurement in this study, AKPINAR (2011, Turkey, pers. comm.) reported the Secchi depth as 74 cm for June and 63 cm for September in Lake Çalı, both values are high enough to reach the light to the bottom of the lake.

The non N_2 fixing blue green algae, especially those that belong to the Oscillatoriaceae family, are usually a nuisance in shallow eutrophic waters (SCHIFFER, 2004). Members of Oscillatoriaceae

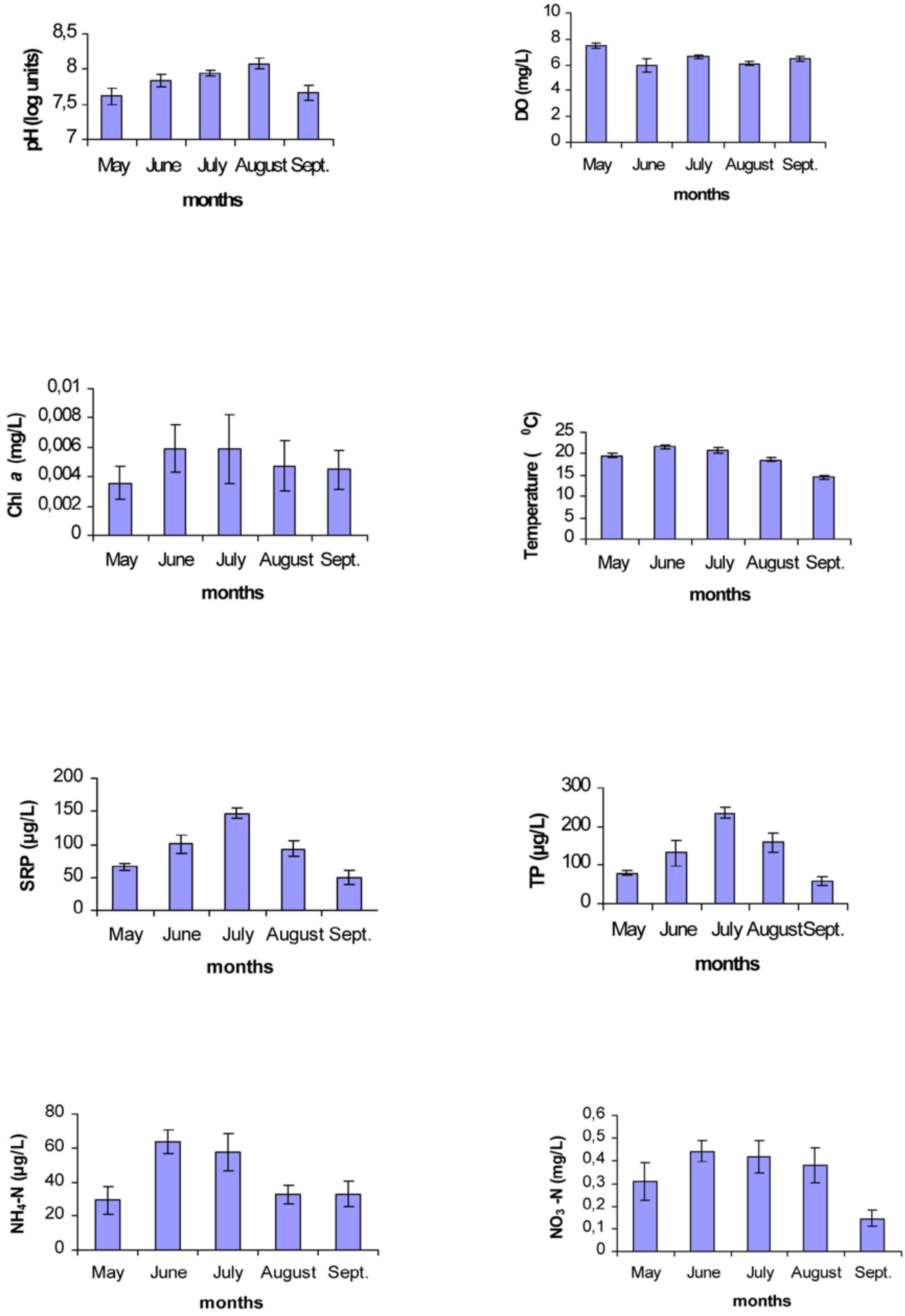

Fig. 2. Avarage values ±SD of physico-chemical variables and chl *a* concentration in lake water during the study. See text for abbreviations.

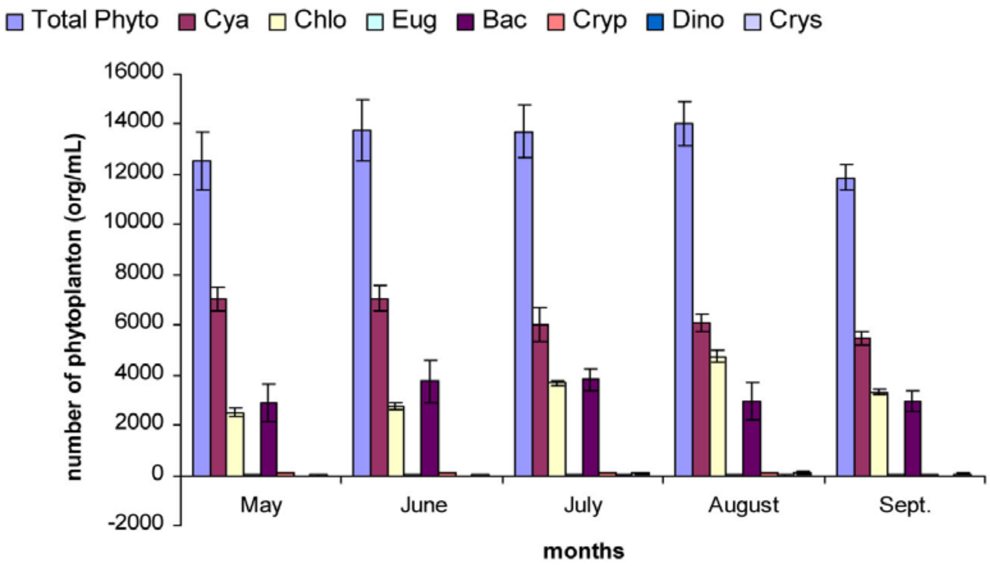

Fig. 3. Average density of phytoplankton groups (org/mL) in Lake Çalı during the study.

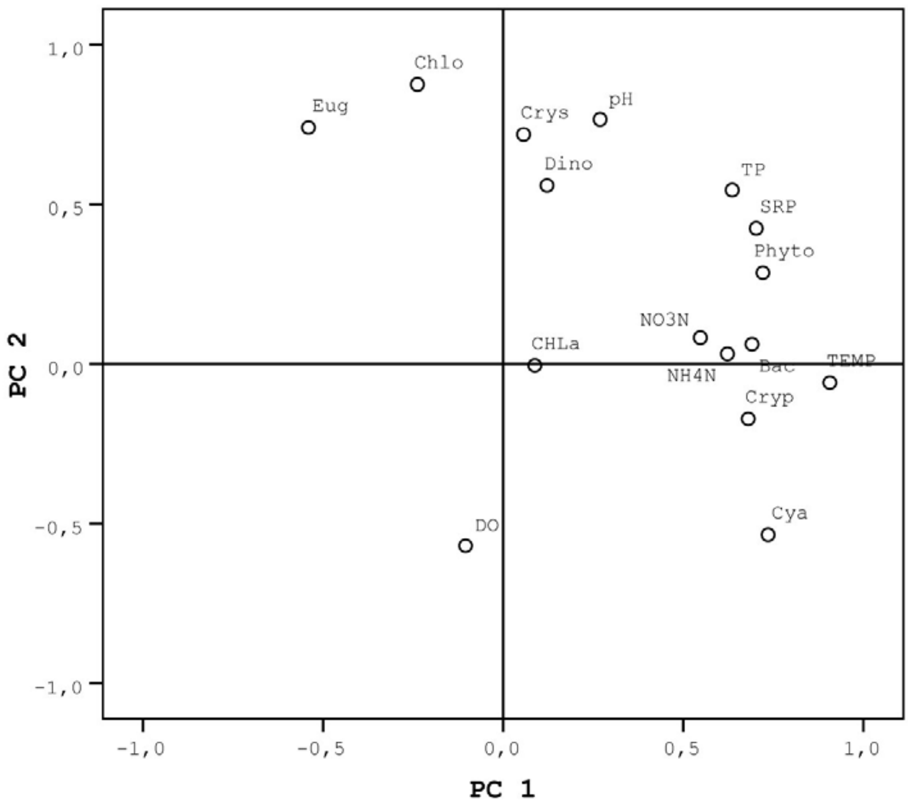

Fig. 4. Principal component analysis (PCA) of physico-chemical variables and main phytoplankton groups. *Abbreviations*: CHL a, chlorophyll *a*; DO, dissolved oxygen; NH_4-N, ammonia nitrogen;NO_3-N, nitrate nitrogen; TP, total phosphate; SRP, soluble reactive phosphorus; TEMP, temperature; Cya, Cyanophyta; Chlo, Chlorophyta; Eug, Euglenophyta; Bac, Bacillariophyta; Cryp, Cryptophyta; Dino, Dinophyta; Cry, Chrysophyta; Phto, total phytoplankton.

may reach a high biomass in eutrophic water, but they cannot be densely abundant on the water surface. This is attributed to their ability to maintain high growth rates at low light conditions (LOEB & RUETER, 1981). Therefore, it is possible that they become dominant phytoplankton in spring and fall when there is wind-drive mixing in shallow waters. This might be the cause in Lake Çalı, because *L. concorta, Planktothrix sp.*, and *Spirulina sp.*, all species belonging to the Oscillatoriaceae family, reached maximum densities in August and September. Research on Lake Shira (Siberia) suggested that the photoheterotrophic capability of *L. concorta* might help to explain its development in deeper waters, where light availability is near the light compensation point (QUESADA *et al.*, 2002). The photoheterotrophic communities are able to assimilate organic compounds, thus supplementing their carbon and energy requirements. A negative relationship has been found between the uptake of organic compounds and light intensity in Lake Shira (DEGERMENDZY & GULATI, 2002). In Lake Çalı, *L. concorta* reached the maximum in September (16.67%), likely due to the increase in organic compounds (e.g., macrophyte decay). Although there is no data for COD (Chemical Oxygen Demand) and BOD (Biochemical Oxygen Demand) in this study, AKPINAR (2011, Turkey, pers. comm.) measured highest conductivity, 126 μScm^{-2}, in September for Lake Çalı, probably because of the increasing decomposition process.

Dominance % of *Cyclotella meneghiniana* was found to be high in June (9.60%), when both the NH_4-N and NO_3-N levels were high in Lake Çalı. Correlation with NH_4-N ($p < 0.05$) was also found significant for Bacillariophyta in Lake Çalı. The Cyclotella species have been commonly found in some other eutrophic lakes in Turkey (AKBAY *et al.*, 1999; KIVRAK & GÜRBÜZ, 2010; FAKIOĞLU & DEMIR, 2011).

Fragilaria crotonensis was found to be dominant in August (7.61%) in Lake Çalı. Species of Fragilaria are tolerant of carbon dioxide depletion and tend to be present more often in eutrophic waters (REYNOLDS *et al.*, 2002). High nutrient levels in Lake Çalı in July might be the reason for finding dominant *Fragilaria crotonensis* in August.

Non-gelatinous, non-motile Chlorococcales is predominant in shallow highly enriched systems represented by *Scenodesmus*, *Pediastrum* and *Coelastrum* (REYNOLDS *et al.*, 2002). In Lake Çalı, both *Pediastrum simplex* and *Scenedesmus communis* became dominant in August following high nutrient levels in July. *Monoraphidium* species also associate with eutrophic water, and in Lake Çalı *Monoraphidium irregulare* was found dominant in August, like the *Pediastrum simplex* and *Scenedesmus communis* species. The initial addition of nutrients shifted the algal composition toward rapid-growing algae from functional groups X_1, J and Y, all presenting characteristic of shallow enriched freshwaters, and as Lo described for stratified water (REYNOLDS *et al.*, 2002). According to ROMO & VILLENA (2005), small, rapidly growing species belonging to the functional grous X_1, Y, J and Lo showed direct increment with higher biomass related to higher nutrient levels in a shallow Mediterranean lake (Spain). This result agrees with the present studies. According to REYNOLDS *et al.* (2002), X_1, Y, and J are potentially more highly grazed by zooplankton, but not all species showed the same response. According to ROMO & VILLENA (2005), the *Scenedesmus* species (J group) was significantly more abundant in mesocosms with presence of larger zooplankton, although the small *S. ecornis* is better developed with microzooplankton. Unfortunately, there is no opportunity to adopt this idea into the present study because of the lack of studies on zooplankton and fish species in Lake Çalı.

In conclusion, Cyanophyta was the dominant group in the phytoplankton of Lake Çalı; however, in contrast, of most of the studies have that found Bacillariophyta was the dominant group in phytoplankton in Turkish lakes. On the other hand, Lake Çalı is a boggy environment and there is limited information about phytoplankton diversity in such environments in Turkey. Thus, more studies are needed to understand and compare the structure and ecology of the phytoplankton in boggy systems within Turkey.

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