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Research Article/Araştırma Makalesi

SPATIAL AND TEMPORAL DISTRIBUTION OF PHYTOPLANKTON IN LAKE GALA (Edirne/TURKEY)

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Abstract: This study was performed from March 2004 to February 2005 in 4 stations in Gala Lake, a shallow lake located inside Gala Lake National Park in Meriç Delta. Water samples were taken from the lake in order to determine the phytoplankton present in the lake and to perform physicochemical analysis. A total of 112 taxa from 5 divisio were identified during the study period. Chlorophyta was the most diversed group in the lake with 47 taxa and diatoms were found to have the highest cell counts with a mean value of 670011 cell L^{-1}. The general pattern of seasonal succession in phytoplankton of the lake was represented with Chlorophyta in June and with Cyanophyta in September and Diatoms were the dominant group of the lake in all other months. A spatial heterogeneity was observed in the lake where a slight *Microsystis* spp. increase occurred in early autumn months. Comparison with former phytoplankton data showed distinct differences in terms of the qualitative and quantitative composition of the phytoplankton community of Lake Gala, which indicates lake deterioration.

Key words: Shallow lake, phytoplankton, seasonal distribution, Lake Gala, Edirne.

Gala Gölü (Edirne/Türkiye) Fitoplanktonunun Mevsimsel Dağılımı

Özet: Bu çalışma Meriç deltasında Gala Gölü Milli Parkı içerisinde bulunan ve sığ bir göl olan Gala Gölü'nde belirlenen 4 istayonda Mart 2004-Şubat 2005 tarihleri arasında yapılmıştır. Gölden alınan su örneklerinde fitoplanktonun belirlenmesinin yanı sıra bazı fizikokimyasal analizler de yapılmıştır. Çalışma süresince 5 divizyoya ait toplam 112 taxa gözlemlenmiştir. En fazla tür sayısının 47 tür ile Chlorophyta'ya ait olduğu gölde Diatomlar ortalama 670011 hücre L^{-1} ile en çok hücre sayısına sahip grup olmuştur. Göl fitoplanktonunun mevsimsel süksesyonunda genel yapı Haziran ayında Chlorophyta, Eylül ayında ise Cyanophyta hakimiyeti şeklindedir. Bu ayların dışında tüm örnekleme periyodu boyunca Diatomlar gölün hakim organizmaları konumundadır. Bunun yanısıra sonbahar aylarında hafif bir *Microsystis* spp. çoğalmasının meydana geldiği gölde fitoplanktonun yıl boyunca değiştiği gözlemlenmiştir. Daha önceki veriler ile karşılaştırıldığında Gala Gölü fitoplanktonunda nitel ve nicel olarak farklılıklar tespit edilmiştir.

Anahtar Kelimeler: Sığ göl, fitoplankton, mevsimsel dağılım, Gala Gölü, Edirne.

Introduction

There are more shallow lakes than deep lakes worldwide. Such lakes, used for drinking water, irrigation, fisheries and recreation, are more affected by human activities than deep lakes. The socioeconomic importance of shallow lakes calls for more scientific research on these systems (Padisak & Reynolds 2003). We do not have much information about phytoplankton dynamics of Lake Gala which has a great ecological importance in terms of the Meriç (Maritsa) delta and the immigrant birds. For this reason, this study supplies detailed information on phytoplankton community of Lake Gala to understand the function of the lake.

Phytoplankton research on small lakes has been controversial. While they have been preferred targets for taxonomic and floristic work, the bulk of our knowledge on ecology of phytoplankton originates from middle-sizedor large lakes. The socioeconomic importance of small lakes in itself calls for more detailed scientific knowledge about their limnology and phytoplankton ecology. Moreover, many of them exhibit a large habitat diversity, therefore, they are very important in conservation biology. As a consequence of their small water volume and often unstable hydrological balance small lakes react quickly to human impacts like increased N and P loadings on the watershed, acidification or climatic changes even at small scales. Their common feature is that historical data are largely absent. Interest towards understanding driving forces that govern their spatial and temporal phytoplankton patterns has just started to increase (O'Farrell *et al.* 2003, Stoyneva 2003).

During its annual development, the phytoplankton passes several quite distinct successional stages during which equilibrial compositions develop and pertain for shorter or longer periods. One of the few attempts to quantify criteria for equilibrium phase of phytoplankton communities was provided by Sommer (1983) as: "In natural phytoplankton communities, it is often difficult to determine whether a given 'phase' in a seasonal sequence can be considered to be in an equilibrium state or not, due either to a lack of chemical data, or to insufficient sampling frequency, or to any other cause.

In this paper, we present data from a survey of shallow lakes in Meriç River Delta in European part of Turkey. The present study reports the results of a one year investigation of the phytoplankton community of Lake Gala. The aim of this study was to determine current spatial and temporal variations in phytoplankton composition and abundance in Lake Gala.

Material and Methods

Study area

Lake Gala is located in a region in Edirne province borders where the river Maritsa meets the Aegean Sea. The lake is 2 meters a.s.l and is 10 km far to Enez and Aegean Sea. It is an alluvial set lake lying at 40°46'06.79" N and 26°11'07.63" E and is connected to Maritza river and Saros bay with lake. The depth of the lake varies according to meteorological conditions and to the amount of water used for rice field irrigation. The deepest part of the lake is 2.2 meters during rainy season with increased flood, 1.5 meters during normal conditions and can decrease to 30-40 cm. in dry seasons. During summer, the lake is separated into two sections, Big and Small Gala Lakes, due to drying (DSİ 1986). The bank of the lake is accompanied by macrovegetation consisting of *Phragmites australis* and *Typha* sp. The lake is surrounded with a lot of agricultural areas where rice plantation is carried out mostly (DSİ 1986).

The 2.369 ha. area around Gala and Pamuklu Lakes was given Nature Reserve Area status in 1991 and in 1992, the area around Gala Lake was announced as Natural Protected Area. The region where Gala and Pamuklu Lakes are located was announced as the 36th National Park of Turkey in 2005 (Kantarcı 1989, Yarar & Magnin 1997). Gala Lake National Park covers an area of 6.090 ha., of which 3.090 is wetland and 3.000 ha. is forest area. In addition, Gala lake is a part of Maritza Delta listed in class A wetlands and lies along northwest-south axis constituting one of the two main bird migration routes in western Palaearctic region. A total of 163 avian species exist in national park borders of which 46 are native, 27 are winter migrants and 90 are summer migrants. The fish fauna of the region is represented with 16 species among them eel, lucioperca and pike are the prominent taxa of major economic importance (DSİ 1986).

Field work and laboratory analyses

Monthly samplings were performed in 4 stations in Lake Gala, from March 2004 to February 2005, in order to determine whether the dominant algal species in the lake and their abundances showed variations with changing environmental factors (Figure 1). First station is the location that the overloaded lake water is discharged into the sea; 2nd Station is the center of Big Gala; 3rd Station is the location where intense vegetation is the most and 4th Station is the section of Small Gala.

A Ruttner water sampler was used to obtain water samples just below the surface of the water body in order to determine some physico-chemical properties of the lake such as water temperature, dissolved oxygen amount, pH, nitrogen in nitrite and nitrate forms and phosphate values.

Water temperature, pH, dissolved oxygen and conductivity were measured on site during samplings using field type equipments (Lovibond Sensodirenct model portable probes), Water transparency was measured with a Secchi disk. NO_3^-N, NO_2^-N, PO_4, SO_3 and total hardnes were measured in laboratory in accordance with APHA-AWWA-WPCF methods (APHA 1992). Chlorophyll-*a* was determined by spectrophotometric analysis according to Nusch (1980). The quality level of the water was determined according to Turkish Water Pollution Control Regulation (SKKY 2004).

Sampled phytoplankton specimens were identified by investigation of temporary preparations. For this purpose, water samples were filtered from Whatman GF/A paper with the help of a water trompe and dissolved in 10% glycerine. An Uthermol counting chamber was used to calculate the organism number per liter (Uthermohl 1958, Round 1973). Algae species were identified with a Olympus microscope. For the identification of diatoms, frustules were cleaned with concentrated HCl and H_2SO_4. The taxonomic books (Husted 1930, Cleve-Euler 1952, Pestalozzi 1955, 1982, Prescott 1973, Komarek & Fott 1983, Krammer & Lange-Bertalot 1991a, 1991b, 1999) were used for the identification of algal species. All species were checked in algaebase database (Guiry *et al.* 2010).

Statistical analyses

A Bray-Curtis analysis was performed to reveal similarities, if any, among stations based on algal species diversity and abundance (Bray and Curtis, 1957). Abiotic variables were correlated with main phytoplankton attributes using non-parametric Spearman's correlation coefficients. Differences in all variables were tested using a non-parametric Kruskal-Wallis ANOVA median test (KW). Differences at the <0.05 level were accepted as significant. Also, to compare stations, non-parametric statistics (the Mann-Whitney U test) were used. Species richness was considered to be the number of taxa present in each sample. Biological diversity (H´) was calculated by the Shannon and Weaver (1963). The procedures of the analysis were carried out using the XLSTAT-ADA statistical package program (Addinsoft 2015).

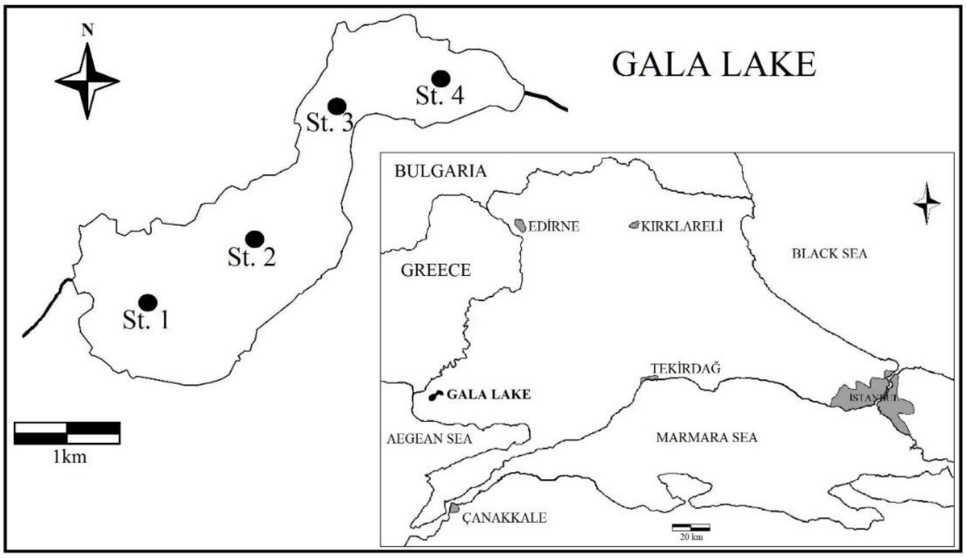

Figure 1. Gala Lake and the sampling stations.

An analysis of variance was carried out on grain yield of the varieties used for different years. The significance of data and interrelations between the traits were tested with ANOVA, PCA and fit analyses using SPSS 19.0 and JMP version 5.0.1a (2002).

Results

Physico-chemical findings

The pH of Lake Gala ranged from 8.04 to 8.62. Conductivity ranged from 141 to 291 µmho cm^{-1}, water temperature ranged from 7.5 to 27 ^{o}C, Dissolved oxygen ranged from 9.69 to18.16 mg L^{-1}, Total hardness from 31.87 to 62.4, NO_3^-N from 0 to 9.4 mg L^{-1}, SO_3 from 0 to 3.89 mg L^{-1} and PO_4 from 0 to 0.08 mg L^{-1}, respectively. The results of analysis of monthly water samples were arranged with respect to seasons (Table 1). The mean depth of the lake was determined as 139 cm and the mean water transparency was measured as 48.7 cm (Figure 2). Gala Lake was classified as eutrophic (OECD 1982).

Algological findings

The phytoplankton species composition of Lake Gala showed the presence of 112 taxa, with Chlorophyta being best represented (47 taxa), followed by Ochrophyta

Table 1. The mean values of some physico-chemical parameters in Gala Lake.

		pH	Cond.	Temp.	DO	TH	NO_3^-N	NO_2^-N	SO_3	PO_4
Spring	**1**st Station	8,53	147	17,33	15,86	32,53	3,36	0,00	2,99	0,00
	2nd Station	8,58	144	17,50	17,01	31,87	9,04	0,00	3,40	0,00
	3rd Station	8,41	141	17,33	13,86	32,27	2,29	0,00	3,21	0,01
	4th Station	8,25	146	17,33	18,16	33,80	2,81	0,00	3,34	0,03
Summer	**1**st Station	8,53	240	26,67	14,42	43,93	1,33	0,00	3,32	0,02
	2nd Station	8,36	229	26,83	13,37	45,00	0,74	0,00	3,12	0,04
	3rd Station	8,21	223	27,00	11,55	46,33	5,32	0,00	3,06	0,04
	4th Station	8,04	219	26,17	10,37	44,27	2,70	0,00	3,02	0,06
Autumn	**1**st Station	8,62	276	17,17	14,87	53,87	0,00	0,32	3,48	0,01
	2nd Station	8,59	272	16,83	16,47	53,13	0,00	0,00	3,89	0,01
	3rd Station	8,50	291	17,17	16,77	59,40	6,72	0,05	3,61	0,03
	4th Station	8,23	284	16,83	10,69	62,40	0,00	0,00	3,37	0,08
Winter	**1**st Station	8,41	162	7,75	9,69	45,95	0,00	0,00	0,10	0,01
	2nd Station	8,60	212	7,50	10,81	56,90	0,00	0,00	0,00	0,00
	3rd Station	8,59	220	8,00	11,60	58,40	0,00	0,00	0,02	0,00
	4th Station	8,42	208	7,50	10,09	36,35	0,00	0,00	0,00	0,01

Cond: Conductivity (µmho/cm); Temp: Water Temperature (ºC); DO: Dissolved Oxygen (mgL^{-1});
TH: Total Hardness (ºFS); Nitrate, Nitrite, Sulphate, and Phosphate (mgL^{-1}).

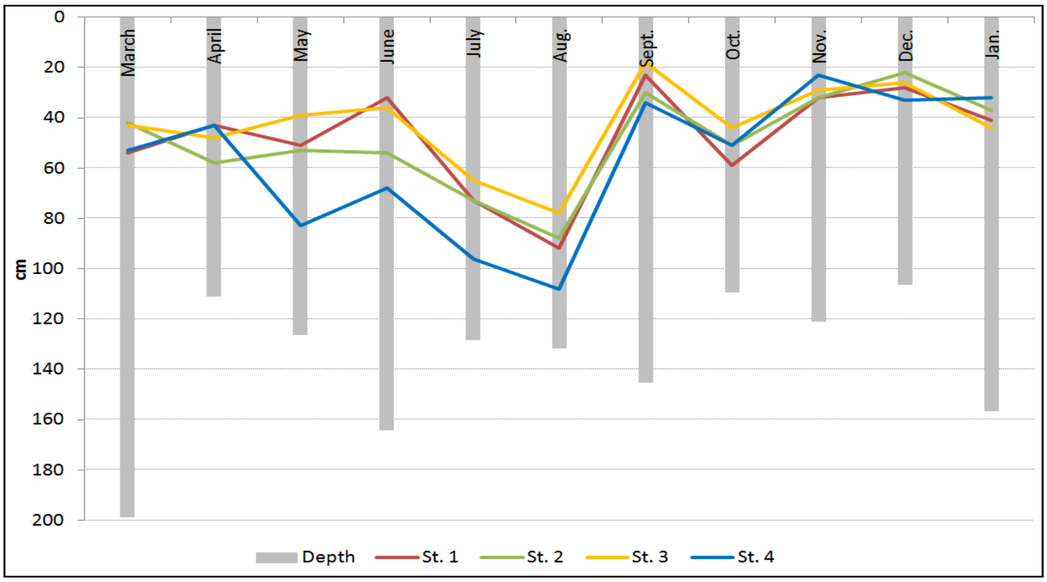

Fig. 2. Seasonal changes in the average depth and secchi disk depth in Gala Lake.

(Diatoms) (43 taxa). Euglenophyta (10 taxa) and Cyanophyta (8 taxa) were moderately represented. Less well represented were Charophyta (4 taxa), as shown in Table 2. First Station was the richest in terms of species diversity with 99 taxa and followed by 2nd statiton with 95 taxa, 3rd station, with 91 taxa and the 4th station was the least diversed station with 90 taxa. On the other hand, diatoms constituted the second dominant group and all stations were similar in terms of their diatom compositions.

The highest floristic diversity was recorded in July at 4th Station (63 taxa). In general, higher diversity was characteristic for littoral localities (3rd and 4th stations), probably because of the lower water depth and very closeness to macrophytic vegetation (benthic and epiphytic forms-*Navicula*, *Cymbella*, *Gomphonema*, *Epithemia* etc.-resuspended from the lake bed and macrophytes). On the contrary, lower diversity was recorded at the relatively pelagic localities (1st and 2nd stations) where euplanktonic species dominated in the phytoplankton community (*Pediastrum*, *Scenedesmus*, *Oocystis*, *Microcystis*, *Planktothrix*, *Cyclotella*, etc.) (Figure 3). The total phytoplankton abundance in Lake Gala ranged from 319381 cells L^{-1} (January) to 3194170 cells L^{-1} (September). In general, two peaks of abundance were recorded: the first peak in July, due to high density of diatoms and green algae, and the second peak in September as a consequence of the explosion of diatoms, green algae and blue-green algae. The cell counts with respect to stations were given in Table 3 and monthly values of the number of phytoplanktonic algae and Chlorophyll_*a* content were given in Figure 4.

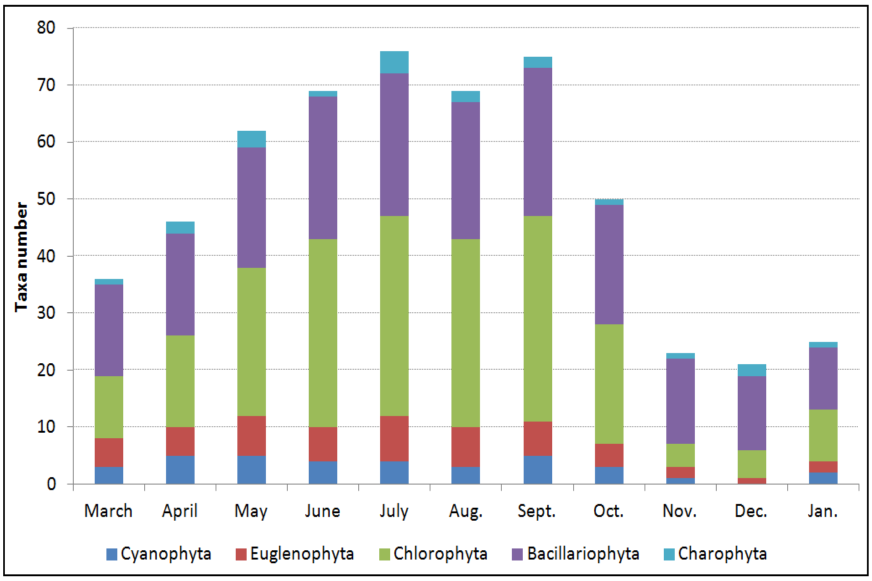

Fig. 3. The spatial distribution of phytoplankton taxa identified in the lake

Table 2. The list of the planktonic algal species observed in Lake Gala during the study period.

	Stations			
	1	**2**	**3**	**4**
Empire Prokaryota				
Kingdom Eubacteria				
Subkingdom Negibacteria				
Phylum Cyanobacteria				
Class Cyanophyceae				
Anabaena sp.	+	+	+	-
Aphanizamenon sp.	+	+	+	+
Merismopedia sp.	+	+	+	+
Microcystis sp.	-	-	+	-
Oscillatoria articulata Gardner	+	-	-	-
O. limosa Agardh	+	+	+	+
Oscillatoria spp.	+	+	+	+
Planktothrix agardhii Anag. & Kom.	-	+	+	+
Empire Eukaryota				
Kingdom Protozoa				
Phylum Euglenophyta				
Class Euglenophyceae				
Euglena acus (Müller) Ehrenberg	+	-	-	-
E. elongata Schewiakoff	-	-	+	+
E. limnophila Lemm.	-	-	-	+
E. polymorpha Dangeard	-	-	+	+
E. tuberculata Swirenko	+	-	-	+
Phacus acuminatus Stokes	+	+	+	+
P. helikoides Pochmann	-	+	-	-
P. longicauda (Ehrenberg) Dujardin	+	+	+	+
P. tortus (Lemm.) Skvortzov	+	-	-	-
Trachelomonas sp.	+	+	+	+
Empire Eukaryota				
Kingdom Chromista				
Phylum Heterokontophyta				
Class Fragilariophyceae				
Asterionella formosa Hassall	+	+	+	+
Diatoma vulgaris Bory de Saint-Vincent	+	+	+	+
Fragilaria crotonensis Kitton	+	+	+	+
D. hyemalis (Roth) Heiberg	+	+	+	-
Ulnaria acus (Kütz.) Cambra & Ector	+	+	+	+
U. ulna (Nitzsch) P. Compère	+	+	+	+
Class Bacillariophyceae				
Amphiprora alata (Ehrenberg) Kützing	+	-	-	-
Amphora ovalis Kütz.	+	+	+	+
Caloneis amphisbaena Cleve	+	+	+	+
Cocconeis placentula Ehrenberg	+	+	+	+
Cymatopleura eliptica Smith	+	+	+	+
C. solea W. Smith	+	+	+	+
Cymbella cistula (Ehren.) Kirchner	+	+	+	+
C. tumida (Bréb.) Van Heurck	+	+	+	+
Epithemia argus (Ehr.) Kützing	+	+	+	+
E. sorex Kützing	-	-	+	+
Gomphonema truncatum Ehren.	+	+	+	+
Gyrosigma acuminatum (Kütz.) Rab.	+	+	+	-
G. attenuatum Kütz. Cleve	+	-	+	-
G. macrum (Smith) Cleve	+	+	+	+
Mastogloia smithii Thwaites	+	+	+	+

Table 2 continued

	Stations			
	1	**2**	**3**	**4**
Navicula clausa Marsson	+	+	+	+
N. cuspidata Kütz.	+	+	+	+
N. virudula Kütz.	+	+	+	+
Navicula sp.	+	+	+	+
Neidium affine (Ehren.) Pfizer	-	+	-	-
Nitzchia acicularis (Kütz.) Smith	+	+	+	+
N. amphibia Grun.	+	+	+	+
N. elongata Hassal	-	-	+	+
N. hungarica Grun.	+	+	+	+
N. lorenziana Grun.	+	+	-	-
N. palea (Kütz.) W. Smith	+	+	+	+
N. sigmoideae W. Smith	+	+	+	+
Nitzchia sp.	+	+	+	+
Pinnularia acuminata Smith	+	+	+	+
P. viridis Ehr.	+	+	+	+
Rhoicosphenia curvata (Kütz.) Grun.	+	+	+	+
Surirella robusta Ehr.	+	+	-	-
S. ovalis Breb.	+	+	+	+
Class Coscinodiscophyceae				
Aulacoseira italica (Ehren.) Simonsen	+	+	+	+
Cyclotella meneghiniana Kütz.	+	+	+	+
C. radiosa (Grun.) Lemm.	+	+	+	+
Melosira varians Agardh	+	+	+	+
Empire Eukaryota				
Kingdom Plantae				
Phylum Chlorophyta				
Class Chlorophyceae				
Pandorina morum (Müller) Bory	-	-	-	+
Class Trebouxiophyceae				
Actinastrum hantzchii Lagerheim	+	+	+	+
Chlorella elipsoidea Gerneck	+	+	+	+
C. emersonii Shih. & Krauss	-	-	+	+
C. luteo-viridis Chod.	+	+	+	+
C. vulgaris Beyerinck	+	+	+	+
Closteriopsis longissima Lemm.	+	+	+	+
Coelastrum astroideum De Notaris	+	+	+	+
C. microporum Nag.	+	+	-	+
Crucigeniella saugeii Komárek	+	-	-	+
C. rectangularis (Nägeli) Komárek	+	+	+	+
Crucigenia tetrapedia Kuntze	+	+	-	-
Dictyosphaerium sp.	+	+	+	+
Golenkiniopsis longisipina Korshikov	+	+	+	+
Lagerheimia genevensis Chod.	+	+	-	+
L. wratislaviensis Schröder	+	+	+	+
Korshikoviella gracileps Silva	+	+	-	-
Kirchneriella aperta Teiling	+	+	-	-
Monoraphidium arcuatum (Korsh.) Hindák	+	+	+	+
M. contortum Kom-Legn	+	+	+	+
M. griffithii Kom-Legn	+	+	+	+
M. minitum Kom-Leg	+	+	+	+
Oocystis apiculata West	+	+	+	+
O. parva West	+	+	+	+
Pediastrum boryanum Meneghini	+	+	+	+

Table 2 continued

	Stations			
	1	**2**	**3**	**4**
P. duplex Meyen	+	+	+	+
P. simplex Meyen	+	+	+	-
P. tetras (Ehrenberg) Ralfs	+	+	+	+
Scenedesmus acuminatus (Lager.) Chod.	+	+	+	+
S. acutus Meyen	+	+	+	+
S. bicaudatus Dedusenko	+	+	+	+
S. disciformis Fott & Komárek	+	+	+	+
S. ecornis Chod.	-	-	+	-
S. obtusus Meyen	+	+	+	+
S. quadricauda (Turpin) Brébisson	+	+	+	+
Schroederia robusta Korshikov	+	-	-	-
Tetrachlorella incerta Hindák	+	+	-	-
Tetrastrum komarekii Hindák	+	+	+	+
T. staugeniforme (Sch.) Lemm	+	+	+	+
T. triangulare (Chodat) Komárek	+	+	+	+
Tetraedron caudatum Hansgirg	+	+	+	+
T. minimum Hansgirg	+	+	+	+
T. regulare Kützing	+	+	-	-
T. triangulare Korshikov	+	+	+	+
T. trigonum Hansgirg	+	+	+	+
Tetradesmus maior (Fischer) Fott & Kom.	-	+	-	-
T. wisconsinensis Smith	+	+	+	+
Phylum Charophyta				
Class Conjugatophyceae				
Closterium aciculare T. West	+	+	+	+
C. acutum Brébisson	+	+	+	+
C. lunula Ehren. & Hemp.	+	+	+	+
Cosmarium undulatum Corda	+	+	+	+

Diatoms were the dominant group, except June (Chlorophyta) and October (Cyanophyta), in the lake where the phytoplankton showed a uniform distribution in winter months most probably due to high wind conditions. *Cyclotella* was the dominant organism in the lake during all year, whereas *Cocconeis*, *Fragilaria* and *Cymbella* dominated in spring and *Navicula*, *Nitzschia* and *Fragilaria* dominated the flora in summer months. In terms of cell counts, *Aulacoseira* and *Epithemia* became the dominant taxa in August and *Nitzschia*, *Melosira* and *Navicula* species in autumn months but small naviculoid forms and *Rhoicosphenia* were sampled in high numbers with winter.

The development of Chlorophyta mainly occurred from late spring to early autumn and their abundance peak occurred in summer (mostly in June). The most abundant green algae were Chlorococcales (*Tetraedron, Crucigeniella, Chlorella, Oocystis* and *Scenedesmus*). The maximal abundance of Cyanobacteria was recorded during early autumn and a peak occurred in September in all stations. A slight bloom of *Microcystis aerogunosa* were recorded in September and October in 1st and 2nd stations. *Microcystis aerogunosa* dominated the community of blue-greens also in these two stations. In addition, *Planktothrix* showed an increase in number in October and November and *Oscillatoria* species became the dominant organisms of the lake in spring months.

Statistical findings

When floristic compositions of all 4 stations were used to obtain a similarity index through the cluster analysis, 1st and 2nd stations, months June and July are similar to each other the most similar (92 % and 78 % similarities, respectively) while the 1st and 4th station and month August and January are the most different (28 % and 17 % similarities, respectively) for the dynamics (distribution both in terms of species and the number of individuals) of phytoplankton in Lake Gala (Figure 5). Bray-Curtis similarity index compares the stations or months according to both species findings and frequency of the specimens.

A statistically significant increase was observed in phytoplankton abundance and this increase was positively correlated with Chl-*a* and temperature ($r = 0.87$ and $r = 0.92$, respectively and $P < 0.01$). The estimates of algal biomass did not show any correlation with nutrients. Some water quality parameters were found to show a significant relationship with the dominant taxa. For example, DO concentration was correlated with the mean total number of *Cyclotella* and *Scenedesmus* ($r = 0.67$ and $r = 0.64$, respectively, and $P < 0.05$). In addition, nitrate and phosphate were found to be negatively correlated with abundance of phytoplankton ($r = -0.58$ and $r = -0.51$, respectively and $P < 0.05$).

According to Shannon-Weaner diversity index, species diversity for algae of the lake was found as 1.21 at average. While the widest diversity were observed in the 2nd station and in July (H' = 1.28 and H' = 1.26, respectively), the 1st station and the month January had the poorest algal diversity (H' = 1.04 and H' = 0.81, respectively).

Discussion

According to SKKY the values of pH and water temperature were found at first quality level in the course of the present study. The lake water was generally found as supersaturated for dissolved oxygen. These supersaturated findings were also reported by Kırgız (1989). The total hardness of the water was found at very hard water quality level. When the water quality was evaluated for nutrients, the values of NO_3^-N and NO_2^-N were found at second quality level while the values of SO_3 and PO_4 were found at first quality level, generally.

Tokatlı *et al*. (2014) classified Gala Lake in third quality level in terms of NO_2^-N and first quality level in terms of NO_3^-N. The lake was found to be a first quality level lake considering SO_3 values obtained in the present study and in study of Tokatlı *et al*. (2014). The results of these author showed that dissolved oxygen values in the lake decreased but PO_4 values increased during the time from our present study and pH and conductivity values showed no significant change.

It is a known fact that oxygen is consumed during decomposition of organic materials in waters and that regain of the consumed oxygen in surface waters is rather

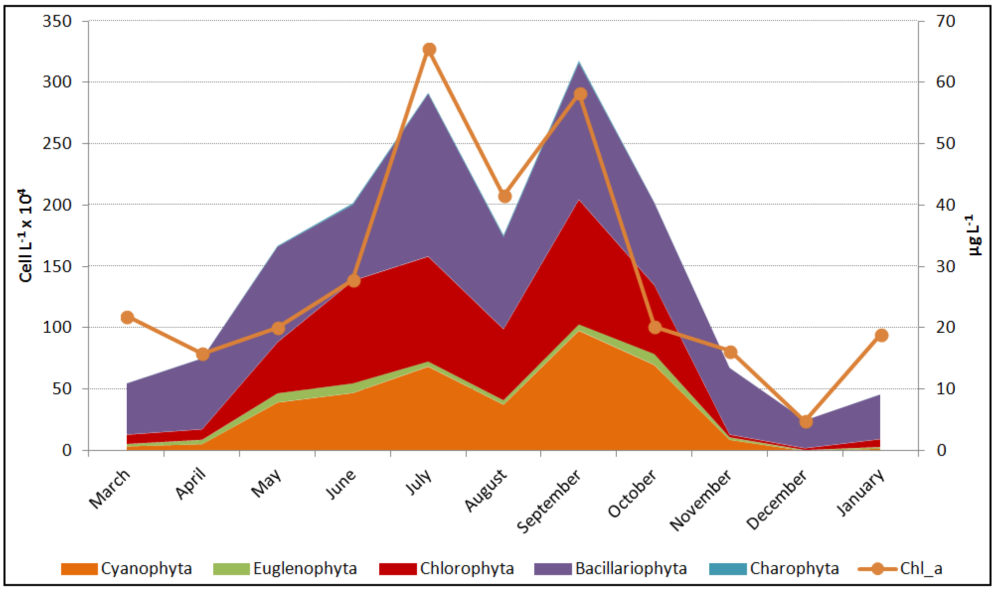

Fig. 4. The number of planktonic algal counts and Chlorophyll_*a* concentration with respect to stations.

slow (Tan 2006). The findings of Kırgız (1989) reporting that the water of the lake is supersaturated for dissolved oxygen was later confirmed by Çamur-Elipek *et al*. (2010). The supersaturated conditions (over 100 %) maybe regarded as good but they can indicate some problems, such as excessive plant growth. The oxygen production by algae or rooted aquatic plants in eutrophic lakes can lead them to become supersaturated since oxygen production is quicker than it can escape into the atmosphere. For instance, DO concentration in some cases can even build up to greater than 200 percent saturation but 110 percent saturation is the critical level since certain fish can be harmfully affected following an excess of DO concentration over this level. For instance, fish suffer from "gas bubble disease" occurring as a result of an excess DO concentration where the oxygen bubbles or emboli can block the flow of blood through blood vessels (Nestle *et al*. 2003). On the other hand, high DO levels seen in lakes during day-time are often countered with low night-time levels due to respiration and the cessation of photosynthesis but wide fluctuations in daily values of DO can also stress fish and other aquatic animals.

Water transparency was relatively low in the lake during the study period and the minimum Secchi depth measured coincided with a surface cyanobacterial bloom occurred in September. Light regime in the lake was influenced by wind mixing, causing suspension of silt and detritus in the water. Benthic algae were determined to be suspended in the water column in phytoplankton. The shortage of light as a result of turbidity and wind-promoted turbulence in Lake Gala could be an important species-selection factor. Strong wind is a frequent summer occurrence in the lake and these irregularly occurring mixing events are the predominant disturbance to the succession of phytoplankton, disabling stratification and consequently steady-state formation. A pattern found in shallow lakes is a constant wind action promoting the resuspension of sediment particles. Sediment resuspension can be a factor affecting not only the underwater light climate but also the nutrient concentrations and phytoplankton density. Wind is also an indirect factor influencing other physical and chemical factors in the system to act more directly on the phytoplankton community. As expected, plankton responds to wind-generated hydrodynamics with changes in the community structure, a case reported in many studies in shallow lakes (Wiedner *et al*. 2002, Chen *et al*. 2003, Markensten & Pierson 2007, Blukacz *et al*. 2009).

In the past, zoobenthic and zooplanktonik studies were performed in Lake Gala by Kırgız (1989), Elipek *et al*. (2010) and Güher *et al*. (2011). However there exists only one study in the performed in order to determine the flora of the lake and this previous study has no clear information about the phytoplankton abundance in the lake. A total of 55 phytoplanktonic taxa were identified, mostly at genus level, in this study and diatoms were determined to be the dominant group (DSİ 1986). In our present study, 112 taxa, most of which can be found in mesotrophic or eutrophic lakes, were determined.

Although pennat diatoms were rich in terms of species diversity, *Cyclotella* species of centric diatoms were found to have the highest cell counts in all stations, particularly in spring, summer and autumn months. Spring and summer months, in particular, were characterized by centric species of diatoms, mostly *Cyclotella meneghiniana* and *Cyclotella radiosa*. Although centric diatoms were poor in number of species, they were much more abundant as individuals than the pennate forms and other algae in Lake Gala. Centric diatoms are one of the algal groups best-adapted to turbulent and turbid systems (Reynolds 2006), whereas pennate diatoms are regarded as benthic forms. *C. meneghiniana*, an indicator of mesotrophic waters, polluted water adapted organisms and *Rhoicosphenia curvata* and *Cocconeis placentula*, preferring eutrophic water bodies were also found. Chlorophyta appeared to be

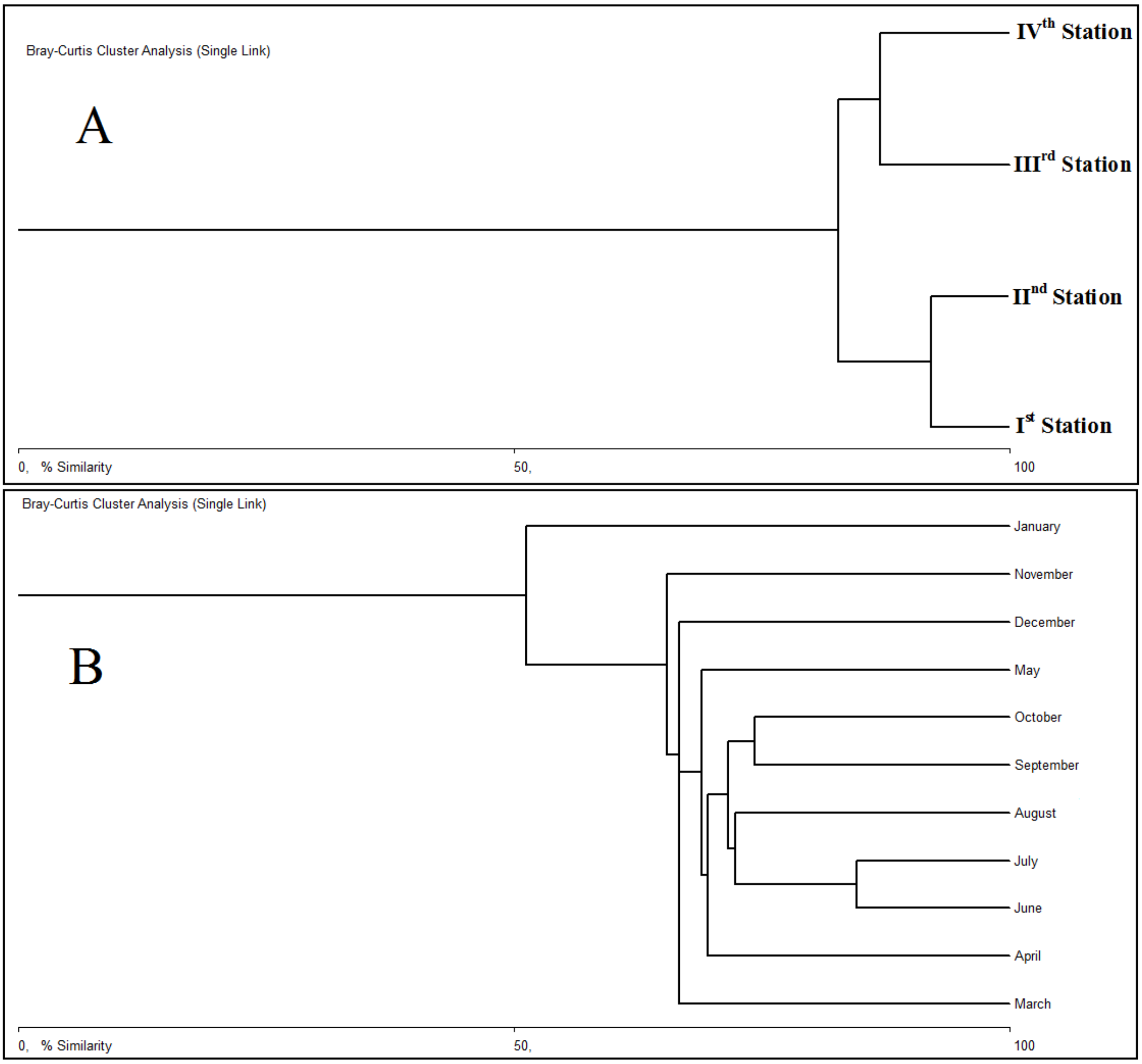

Fig. 5. Results of clustering analyses. A: based on differences in the floristic composition of phytoplankton of Lake Gala (Bray-Curtis distance). B: based on differences in portions of main distinguished algal groups (Bray-Curtis distance).

the group with the highest species diversity. Being almost entirely deprived of self-motility, Chlorococcales are almost deprived of self motility and are completely dependent on water turbulence to keep suspended in the water column. This is why their greatest population net growth rates and abundance can be seen in turbulent waters (Reynolds 2006), like the Gala Lake. Diatoms appeared to be the dominant group in the lake in terms of cell counts followed by green algae as the second dominant group. Among diatoms, *Cyclotella* and *Navicula* species, in particular, were obtained with high cell number in all stations by the beginning of spring season. Other algal groups were recorded with low abundance values except station 1 where Cyanophyta members reached high cell numbers in the study period. The members of Cyanophyta, represented with 7 taxa in the lake, and particularly *Microcystis*, *Planktothrix* and *Oscillatoria* species showed an increase in May, September and October and their remarkable increasing colony numbers led to a change in lake water to green and a notable decrease in transparency values.

When the findings obtained in the present study in Lake Gala are compared to other studies in different inland water resources in Turkey, it appeared that they were in accordance with the results reported in these studies. For instance, genus or genera recorded around Gala Lake were also found in Lake Manyas (Balıkesir) (Şipal *et al*. 1994, Çelik & Ongun 2008), Lake Uluabat (Bursa) (Karacaoğlu *et al*. 2004), Lake Marmara (Manisa) (Cirik 1982, 1983, 1984), Lake İkizgöl (Şipal *et al*. 1996), Lake Kazangöl, (İzmir) (Aysel *et al*. 1998), Ömerli Reservoir (İstanbul) (Albay & Akçaalan 2003), all located along the similar bird migrations paths with lake Gala.

The phytoplankton community in Lake Gala showed a noticeable variation in seasonal-abundance, its peaks associated with the water temperature, water transparency, wind and nutrient concentrations values. Water temperature has two effects, a direct effect through metabolism and reproduction intensity and an indirect effect through nutrients and the grazing of zooplankton. Other similar studies have also detected strong relationships between temperature and phytoplankton composition (Komarkova *et al*. 2003, Rakocevic 2012).

In shallow lakes, the effect of warm weather is especially strong when it occurs with low water level, and the deterioration of water quality usually takes place during the warm period (Pettersson *et al.* 2003)İşaretli kaynak referanslar bölümünde yok. Noges *et al.* (2003) and Padisak & Koncsos (2002) stressed the increase of internal nutrient loading during low water levels. Similarly, long-term investigations of Lake Peipsi and Lake Skadar showed a link between high phytoplankton density with periods of low water level, which can be explained by the increase in bacterial activity, causing a higher uptake of oxygen and an intensive release of phosphate and ammonium from sediment to water (Laugaste *et al*. 2001). In general, the seasonal succession of phytoplankton in Lake Gala was complex, as often happens in many shallow lakes, especially those with a high surface area (Wetzel 2001). In general, the highest phytoplankton abundance characterized the stations 3 and 4.

In shallow lakes, where suspended particles influence the amount of light penetrating underwater, algal species with gas vesicles, such as *Microcystis*, can either float up when underwater light conditions are poor or move down to avoid the high light intensity at the surface (Brookes & Ganf 2001). A summer peak of blue-greens in the phytoplankton community has also been recorded in many former studies (Fabbro & Duivenvoorden 2000, Huszar *et al*. 2003, Albay & Akcaalan 2003). Naselli-Flores *et al*. (2007), in Sicilian reservoir, and Akçaalan *et al*. (2014) reported *Planktothrix* blooms in their studies in winter months. Bonilla *et al*. (2011) provided evidence that *Planktothrix* occurred in a wide temperature range in temperate and subtropical lakes. In Lake Gala, this species was to be the second dominant taxa, following diatoms, as the only member of Cyanophyta, at a temperature of 10 ^{o}C in November and January (Only one species of blue-green members) but never showed a growth that could be considered as a bloom.

In conclusion, in addition to the effect of the real planktonic species on phytoplankton composition of the shallow Lake Gala, the intense effect of epiphytic and epipelic benthic algae is not ignorable. Besides nutrients, physical conditions such as water temperature and wind also effect temporal and spatial changes in algal flora. Moreoever, the slight blue-green algae bloom in the lake surrounded in most parts with rice fields is thought to have increased effects on the lake in near future.

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