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PROOF RESEARCH PAPER

Influence of Environmental Conditions on the Phytoplankton Community Assemblages in Süloğlu Reservoir (Edirne, Turkey)

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Abstract

Freshwater resources are some of the most important basic needs necessary for usage by people, especially for drinking water. Reservoirs that are built to store freshwater resources and access water on demand, may be prone to get more environmental effects than natural resources. Phytoplankton, which is the first level of in primary production, is specifically affected by environmental changes in different ways. This study investigated the algal flora of Süloğlu Reservoir (Edirne, Turkey) which is utilized as a freshwater reserve, as well as environmental variables influential on its community structure. For this reason a sampling campaign was performed in three stations selected in the reservoir in 3 different depths between January 2013 and November 2013. The study found 111 phytoplanktonic algae taxa belong to the divisions of Chlorophyta, Bacillariphyta, Cyanobacteria, Euglenophyta, Charophyta Miozoa and Ochrophyta. Chlorophyta members were generally dominant, and some environmental factors (i.e. light, pH values, temperature) were significantly effective on the distribution of all algal communities. The Shannon diversity values changed in the range of 1.02-2.75. CCA analysis results showed that there was a noticeable relationship between water quality parameters (chlorophyll-*a*, pH and water temperature) and time-based changes in dominant phytoplankton species. Moreover, recommendations were provided for sustainable usage of the reservoir whose trophic level was determined.

Keywords: Süloğlu Reservoir, phytoplankton, chlorophyll-*a*, trophic status.

Introduction

Although freshwater ecosystems cover a much smaller area in the world in comparison to other ecosystems, they have a crucial place especially in the lives of humans (Wetzel, 2001). The humankind has developed various methods to manage water since the ancient ages. As a result of these efforts, the method of collecting water in dams was adopted in order to be able to use it in a desired time and way (Kimmel, Lind & Paulsen, 1990; Wetzel, 1990; Boztuğ *et al*., 2012). Reservoirs are defined as artificial lakes built for various purposes, and they are distinct from natural lakes with their high flow speeds, presence of suspended solid materials in the input water, and short time of water replacement (Harper, Brierley, Ferguson & Phillips, 1999; Fakıoğlu, Atamanalp & Demir, 2011). Additionally, a set of changes may occur in the organisms living in the aquatic ecosystem as a result of variable environmental factors in dam lakes (Wetzel, 2001; Moss, 2010). Responses of the organisms affected by all these changes will be either elimination from the ecosystem, or increase in population (Wetzel, 1990; Kimmel *et al*., 1990; Harper *et al*., 1999; Wetzel, 2001). Therefore, it is important to scientifically monitor aquatic ecosystems and record their physical, chemical and biological characteristics.

As algae have a very broad area of distribution in aquatic environments, they can be very important source of oxygen in these environments, and they are providing food for all other organisms ranging from benthic invertebrates to fish (Round, 1984). However, overpopulation of algae would take place due to discharge of nutrients into aquatic ecosystems (Akköz & Güler, 2004). Algae overpopulation leads to decrease in water transparency in aquatic ecosystems, and reduction of oxygen production by aquatic plants by creating a pressure on them. Furthermore, with the eutrophication led by algae overpopulation, it will be inevitable that water quality will be worsened, and invertebrate and fish populations will eventually disappear (Bronmark, & Hanssen, 2005; Reynolds, 2006; Solak, Barlas & Pabuçcu, 2007; Jöhnk *et al*., 2008).

In addition to the surface distribution of algae in the water, their vertical distribution in different depths of the water column is also important. Turbidity caused by excessive overpopulation of algae in certain layers of the water body due to various reasons (nutrients, water and air temperature, climate conditions, etc.) will create a pressure on the community structure of species in deeper layers (Reynolds, Huszar, Kruk, Naselli-Flores & Melo, 2002; Akçaalan *et al*., 2006; Akçaalan, Köker, Gürevin & Albay, 2014). Studies on algal flora in inland waters of Turkey started in the 70s and have increased in frequency up to now (Demirhindi, 1972; Tanyolaç & Karabatak, 1972; Aykulu & Obalı, 1981; Ünal, 1984; Gönülol, 1985; Yıldız, 1985). Studies on the effects of environmental variables on distribution on algae started in the 80s (Altuner, 1984; Gönülol & Aykulu, 1984). and a huge amount of data on algal communities of various water resources was published so far (Akçaalan, Köker, Gürevin & Albay, 2014; Ongun-Sevindik, 2010; Çelik & Ongun-Sevindik, 2015; Ongun-Sevindik *et al*., 2017). However, although the subject gained attention of many researchers, the dams in Thrace region was neglected except Kadıköy Reservoir on which a single study was performed so far (Öterler, 2013).

This study was conducted with the aim of determining the phytoplankton structure and the relationship between environmental variables and the lake's phytoplankton in the Süloğlu Reservoir Lake to which provides tap water for the province of Edirne in Turkey. Additionally, it was aimed to contribute to the biodiversity of Turkey and the world with the species to be discovered in the Süloğlu Reservoir, where no algological study has taken place before.

Materials and Methods

Study Area

Süloğlu Reservoir is located on 41º47\'N-41º51\'N ve 26º54\'E-26º57\'E coordinates. Especially it was made to provide tap water to Edirne city centre and it is also used for irrigation. It has 3.68 km^2 area. It has 5 km widht and 30.8 km lenght (Arat, 2014).

Sampling and Analysis

A total of three sampling stations was chosen in the lake. The sampling was made vertically (in subsurface, 1 m, 5 m ve 15 m) between January 2013 and November 2013 at monthly intervals.

Station 1 (St. 1) was the deepest station and 4 samplings were performed here from surface water and from 3 depths of 1, 5 and 15 meters; . Station 2 (St. 2) is selected from the reservoir's western arm and 3 samplings were performed here from surface water and from 2 depths of 1 and 5;, Station 3 (St. 3) is selected from the reservoir's eastern arm and 4 samplings were performed here from surface water and from 3 depths of 1, 5 and 15 meters (Figure 1).

Water samples were collected vertically with Nansen water bottles and water temperature, dissolved oxygen, pH, salinity and conductivity were measured on site using portable equipment and probes (Lovibond-SensoDirect) for each sampled depths. Subsurface water samples of all stations were transferred to laboratory in dark-colored glass bottles for total phosphate, soluble reactive phosphorus, nitrite nitrogen and nitrate nitrogen analyses made according to APHA-AWWA-WPCF methods (APHA, 1998). Chlorophyll-*a* of all depths of all stations were measured by using ethanol based on Nusch's method (1980). Moreover, the depth of each station was measured, in addition to the measurement of water transparency using secchi disk.

Phytoplankton samples were condensed by filtering 1 L of water samples through a Whatmann GF/A filter paper, and identification of algae other than diatoms were achieved in temporary preparates using an Olympus brand CX41 model microscope. In identification of diatoms, the samples brought to the laboratory were boiled in 1:1 by volume H_2SO_4+HNO_3 to get rid of organic matter, their pH was neutralized by rinsing in distilled water for a few times, and a drop was taken from this product and dried on a lamella. They were covered with Naphrax, their permanent preparates were prepared, and they were identified under the microscope. In addition, phytoplankton samples were taken from different depths in order to determine phytoplankton counts,

Figure 1. The map of the Süloğlu Reservoir and the sampling stations.

25-50 and 100 mL sub-samples were prepared from the water samples, sedimentation based on the method of Uthermöhl (1958), and their organism counts and calculations were made under an Olympus CK2 inverted microscope. Identifications were carried out at 1000x magnification under immersion oil and identification of taxa was done with the help of related literature of Huber-Pestalozzi, 1982; John, Witton & Brook, 2003; Krammer & Lange-Bertalot, 1986-2004; Round, Crawford & Mann, 1990; Komarek & Anagnostidis, 2005; Hindák, 2008 and Kristiansen & Preisig, 2011. All identified species were checked in algaebase (Guiry & Guiry, 2017). The names of the authors are abbreviated according to Brummitt & Powell (1992).

In order to determine the trophic state of the lake, the method of "Trophic State Index (TSI)" was used. The index results were calculated by using Secchi disk measurements (TSI_{SD}), Chlorophyll-*a* values (TSI_{CA}) and total phosphate (TSI_{TP}) (Carlson & Simpson, 1996). The Carlson's trophic state indices for Süloğlu Reservoir (TSI_{TP}, TSI_{CA} and TSI_{SD}) were calculated (Carlson, 1977) from the mean values of TP, Chl-*a*, and SD using the following equations;

Secchi disk: $TSI_{SD} = 60 - 14.41 \ln(TSI_{SD})$

Chlorophyll-*a*: $TSI_{CA} = 9.81 \ln(TSI_{CA}) + 30.6$

Total phosphorus: $TSI_{TP} = 14.42 \ln(TSI_{TP}) + 4.15$

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 sampling mounths, non-parametric statistics (the Mann-Whitney U test) were used. The existence of temporal and spatial differences of species diversity, richness, and evenness of the phytoplankton was determined by ANOVA (SPSS, 22.0). Multivariate analyses were used to identify environmental parameters that were most strongly associated with each other and to define associations between environmental factors and phytoplankton species. A Canonical Correspondence Analysis (CCA) was performed with XLSTAT-ADA statistical package in order to determine the relative importance of environmental variables, sampling time and phytoplankton species (Addinsoft, 2015).

Results

In the study where a total of 111 taxa were found, while Chlorophyta was found to have the highest number of taxa by 36, it was followed by Bacillariophyta 34, Charophyta by 13, Cyanophyta by 13, Euglenophyta by 10, Miozoa by 4 and Ochrophyta by 1 (Table 1).

In the lake, an average of 58 taxa were identified in St. 1, while this number was 64 for St. 2 and 66 for St. 3. Throughout the study period, high numbers of green and blue-green algae were recorded. The maximum number of species (n = 89) was recorded in July, and the minimum number (n = 29) was recorded in January in the lake (Figure 2). There was also a significant difference in algal diversity, according to the sampling month ($F = 3.59$, $P<0.05$). The species diversity values were 1.02 to 2.75 (Figure 3).

Along the study, it was also aimed to calculate the number of phytoplankton per liter from all stations and selected depths (see Figure 4 for all stations and for all depths). Throughout the study, the highest individual numbers were usually found in samples taken from the surface. However, since the number of *M. aerogunosa* colonies increased by 5 meters, the highest number of individuals was detected in August. Accordingly, the highest number of cells in St. 1 was found in July, while the lowest was found in February. At this station, the highest and lowest numbers at 1 m depth were found in August and February respectively, while in August and December respectively for 5 m and in May and October respectively for 15 m. The highest number of cells in St. 2 was found in July, and the lowest was found in February. At this station, the highest and lowest numbers at 1 m depth were found in July and January respectively, while in August and February for 5 m, respectively. The highest number of cells in St. 3 was found in August on the surface and at 1 m depth, and the lowest was found at 1 m in February. The highest and lowest numbers at 5 m depth were found in September and March, respectively. These months were July and March for 15 m, respectively. Table 2 shows the distribution of mean number of cells and percentages by groups.

The green algae *Chlorella vulgaris*, *Coelastrum astroideum*, *Monoraphidium contortum*, *Pediastrum duplex* and *Scenedesmus quadricauda*, the Charophyta *Closterium pronum* and *Staurastrum paradoxum*, the Cyanobacteria *Microcystis aeruginosa* and *Pseudanabaena limnetica*, and the Miozoa *Peridiniopsis borgei* were determined as the dominant organisms of the Süloğlu Reservoir along the study. While *C. astroideum*, *S. paradoxum* and *P. limnetica* were dominant in winter months, *C. vulgaris*, *S. paradoxum* and *P. borgei* in spring months, *C. astroideum* and *M. aeruginosa* in summer months. The dominant species of fall months were *M. aeruginosa*, *P. duplex* and *C. pronum*. The dominant species and their relative abundance levels are given in Figure 5.

Additionally, among the measured parameters based on depths, dissolved oxygen was the highest in February on the surface and the lowest in September at 15 m depth; water temperature was the highest in August on the surface and the lowest in December on the surface; pH was the highest in July at 1 m depth, and the Chlorophyll-*a* amount was the highest in June on the surface (Table 3). Water transparency was found as the lowest (75 cm) in March, and the highest (209 cm) in January The mean water transparency

Table 1. Monthly distribution of the taxa found in the Süloğlu Reservoir during the study period

	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13	Oct 13	Nov 13
CHLOROPHYTA											
Chlorophyceae											
Coelastrum astroideum De Not.	x	x	x	x	x	x	x	x	x	x	x
Coelastrum microporum Nägeli		x	x	x	x	x	x	x	x		
Coelastrum sphaericum Nägeli						x					
Desmodesmus abundans (Kirch.) E.Hegew.			x	x	x	x	x	x	x	x	x
Haritonia reticulata P.A.Dang.					x	x	x	x			
Kirchneriella sp.					x	x	x	x	x		
Monoraphidium contortum (Thur.) Komárk.-Legn.	x	x	x	x	x	x	x	x	x	x	x
Monactinus simplex (Meyen) Corda				x	x	x	x	x	x	x	x
Monoraphidium minutum (Nägeli) Komárk.-Legn.		x	x	x	x	x	x	x	x	x	x
Pandorina morum (O.F.Müll.) Bory					x	x	x	x	x		
Pediastrum duplex Meyen				x	x	x	x	x	x	x	x
Pediastrum integrum Nägeli		x		x	x	x	x	x			
Pseudopediastrum boryanum (Turp.) E.Hegew.				x	x	x	x	x	x		
Scenedesmus bijugus (Turp.) Lagerh.			x	x	x	x			x		
Scenedesmus ecornis (Ehrenb.) Chodat		x	x	x				x	x	x	
Scenedesmus quadricauda (Turp.) Bréb.	x	x	x	x	x	x	x	x	x	x	x
Stauridium tetras (Ehrenb.) E.Hegew.							x	x	x		
Tetradesmus dimorphus (Turp.) M.J.Wynne			x	x	x	x	x	x	x		
Tetradesmus lagerheimii M.J.Wynne & Guiry	x	x			x	x	x	x			
Tetradesmus obliquus (Turp.) M.J. Wynne			x	x	x	x	x	x	x		
Tetraedriella regularis (Kütz.) Fott		x	x	x	x	x	x	x	x	x	x
Tetraedron caudatum (Corda) Hansg.		x	x	x	x	x	x	x	x	x	x
Tetraedron trigonum (Nägeli) Hansg.		x		x	x		x				
Tetrastrum staurogeniiforme (Schröd.) Lemmerm.		x	x	x	x	x	x	x	x	x	x
Willea rectangularis (A. Braun) John, Wynne & Tsarenko					x	x	x	x	x		
Trebouxiophyceae											
Chlorella sp.	x	x	x	x	x	x	x	x	x	x	
Chlorella vulgaris Beij.		x	x	x	x	x	x	x			
Crucigenia tetrapedia (Kirch.) Kuntze					x	x	x	x	x		
Dictyosphaerium ehrenbergianum Nägeli						x	x	x	x		
Dictyosphaerium sp.				x	x	x	x	x	x		
Lagerhemia sp.			x	x	x	x		x			
Lagerheimia genevensis (Chodat) Chodat		x	x		x	x	x	x			
Mucidosphaerium pulchellum (H.C. Wood) Bock, Preshold & Krienitz					x	x	x				
Oocystis sp.	x	x	x	x	x	x	x	x	x		
Oocystis lacustris Chodat			x	x	x	x	x	x	x	x	
Oocystis parva West & G.S.West	x		x		x	x	x	x			
CHAROPHYTA											
Conjugatophyceae											
Closterium acerosum Ehrenb. Ex Ralfs	x	x			x	x	x		x		
Closterium aciculare T.West			x	x	x	x	x				
Closterium littorale F.Gay				x	x	x	x	x	x		
Closterium lunula Ehrenb. & Hempr.							x	x	x		
Closterium pronum Bréb.		x	x	x	x	x	x	x	x	x	x
Closterium sp.				x	x	x	x	x			
Cosmarium botrytis Menegh. ex Ralfs				x		x					
Cosmarium crenatum Ralfs ex Ralfs							x	x			
Cosmarium laeve Rabenh.				x	x						
Cosmarium sp.				x		x	x	x	x	x	x
Staurastrum chaetoceras (Schröd.) G.M.Sm.			x	x	x	x	x				
Staurastrum paradoxum Meyen ex Ralfs		x	x	x	x	x	x	x	x	x	
Staurastrum punctulatum Bréb.		x	x	x	x	x	x	x	x	x	
BACILLARIOPHYTA											
Bacillariophyceae											
Amphora ovalis (Kütz.) Kütz.				x	x	x	x	x	x		x
Brebissonia lanceolata (C.Agardh) R.K.Mahoney & Reimer			x				x	x	x		
Caloneis bacillum (Grunow) Cleve					x						
Caloneis amphisbaena (Bory) Cleve				x	x	x		x			
Cocconeis placentula Ehren.				x	x	x		x		x	x
Cymatopleura elliptica (Bréb.) W.Sm.	x	x		x	x	x			x	x	
Cymatopleura solea (Bréb.) W.Sm.	x	x	x	x		x	x	x	x		x
Cymbella cymbiformis C.Agardh		x		x		x	x	x			
Cymbella tumida (Bréb.) van Heurck		x		x		x	x		x		x

Table 1.Continued

	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13	Oct 13	Nov 13
Diatoma vulgaris Bory	x		x						x	x	x
Fragilaria capucina Desm.			x			x	x				
Fragilaria crotonensis Kitton			x		x	x		x	x		
Gomphonema olivaceum (Hornern.) Bréb.			x	x		x				x	
Gomphonema truncatum Ehrenb.					x	x	x	x	x		
Gyrosigma attenuatum (Kütz.) Rabenh.		x		x	x		x				
Hippodonta capitata (Ehrenb.) Lange-Bert., Metzeltin & Witkowski					x		x		x		x
Navicula cryptocephala Kütz.	x			x		x	x			x	x
Navicula viridula (Kütz.) Ehrenb.			x		x	x	x	x			
Navicula sp.	x	x	x	x	x	x	x	x	x	x	x
Nitzschia acicularis (Kütz.) W.Sm.	x		x	x		x	x	x	x	x	x
Nitzschia amphibia Grunow	x			x						x	x
Nitzschia flexa Schum.						x	x		x		
Nitzschia fonticola (Grunow) Grunow	x					x					
Nitzschia sigmoidea (Nitzsch) W.Sm.						x		x	x	x	
Nitzschia palea W.Sm.	x	x	x	x	x	x	x	x	x		x
Nitzschia sp.	x	x			x		x	x	x	x	x
Tryblionella hungarica (Grunow) Freng.		x		x			x				
Ulnaria ulna (Nitzsch) Compère	x	x	x	x	x	x	x	x	x		x
Coscinodiscophyceae											
Aulacoseira granulata (Ehrenb.) Simonen	x	x	x	x	x	x	x	x			
Aulacoseira italica (Ehrenb.) Simonsen		x		x	x		x	x	x		
Melosira varians C.Agardh				x	x	x	x	x		x	
Mediophyceae											
Cyclotella meneghiniana Kütz.	x	x	x	x	x	x	x	x	x	x	x
Pantocsekiella ocellata (Pant.) Kiss & Ács		x	x								
Stephanodiscus astraea (Kütz.) Grunow	x	x		x	x			x	x		
OCHROPHYTA											
Chrysophyceae											
Dinobryon divergens O.E.Imhof					x	x	x	x			
EUGLENOPHYTA											
Euglenophyceae											
Euglena granulata (G.A.Klebs) F.Schmitz	x	x	x		x	x	x	x	x	x	
Euglena texta (Dujard.) Hübner		x		x	x	x	x	x	x		
Euglena tuberculata Swirenko		x		x	x		x	x	x	x	x
Euglena variabilis G.A.Klebs					x		x	x			
Lepocinclus acus (O.F.Müll.) B.Marin & Melkonian					x	x	x	x	x		
Phacus acuminatus Stokes					x	x	x	x	x	x	x
Phacus longicauda (Ehrenb.) Dujard.				x	x	x	x	x	x	x	x
Trachelomonas armata (Ehrenb.) F.Stein			x		x		x	x	x	x	
Trachelomonas hispida (Perty) F.Stein	x	x	x	x	x	x	x	x	x	x	x
Trachelomonas volvocina (Ehrenb.) Ehrenb.	x	x	x	x	x	x	x	x	x	x	x
CYANOBACTERIA (Cyanophyta)											
Cyanophyceae											
Anabaena oscillarioides Bory ex Bornet & Flahault							x	x	x		
Aphanizomenon sp.							x	x	x	x	x
Chroococcus sp.	x				x	x	x	x	x	x	
Homoeothrix sp.						x	x	x	x	x	
Microcystis aeruginosa (Kütz.) Kütz.					x	x	x	x	x	x	x
Merismopedia punctata Meyen						x	x	x			x
Oscillatoria limosa C.Agardh	x		x		x			x	x	x	
Oscillatoria princeps Vaucher ex Gomont						x			x	x	
Oscillatoria sancta Kütz ex Gomont		x	x		x		x		x		
Pseudanabaena catenata Lauterborn		x						x	x	x	
Pseudanabaena limnetica (Lemmerm.) Komárek	x	x		x	x	x	x	x	x	x	x
Pseudanabaena sp.	x					x			x	x	x
Trichormus variabilis (Kütz. Ex Bornet & Flahault) Komárek & Anagn.						x		x	x	x	
MIOZOA											
Dinophyceae											
Ceratium hirundinella (O.F.Müll.) Dujard.					x	x	x	x	x		
Peridiniopsis borgei Lemmerm.			x	x	x	x	x	x	x	x	
Peridinium cinctum (O.F.Müll.) Ehrenb.		x	x	x	x	x	x	x	x		x
Peridinium sp.					x	x	x	x			

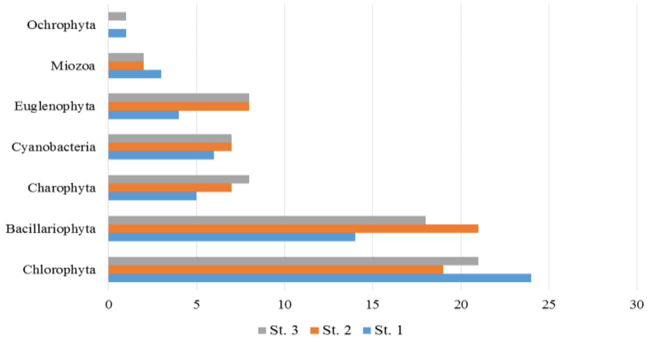

Figure 2. Distribution of the discovered taxa based on stations and groups.

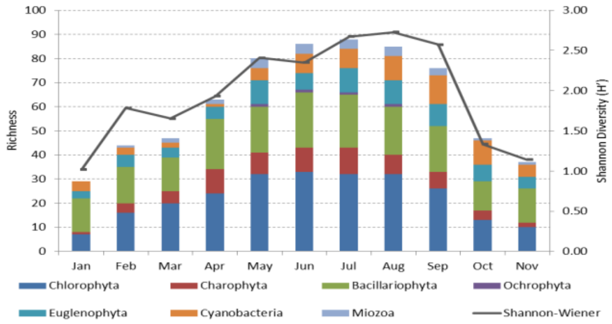

Figure 3. Distribution of the discovered taxa based on months-groups, and their Shannon diversity values.

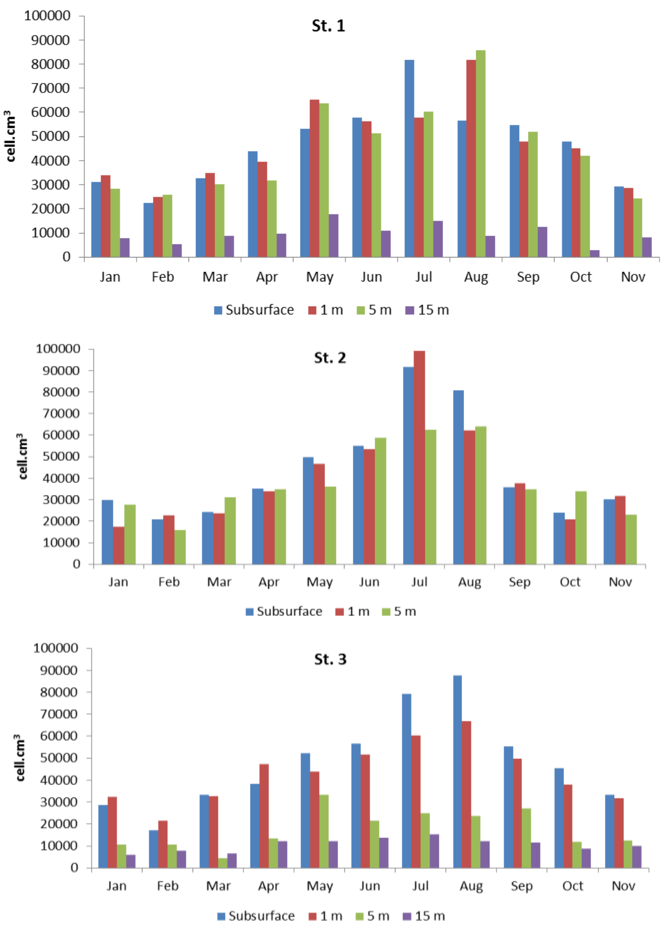

Figure 4. Monthly distribution of numbers of organisms found in Sampling Stations.

Table 2. Numbers of individuals and % distributions of the phytoplankton community in the Süloğlu Reservoir by groups

Phytoplankton Group	Abundance (cells.cm^{-3})		Contribution (%)
	Range	Mean	Mean
Chlorophyta	9334-18647	14379	36.42
Charophyta	1887-7931	4311	10.92
Bacillariophyta)	755-2748	2106	5.33
Ochrophyta	112-696	463	1.17
Cyanobacteria (Cyanophyta)	6417-15168	11748	29.76
Miozoa	3546-6425	5436	13.77
Euglenophyta	873-1145	1035	2.62

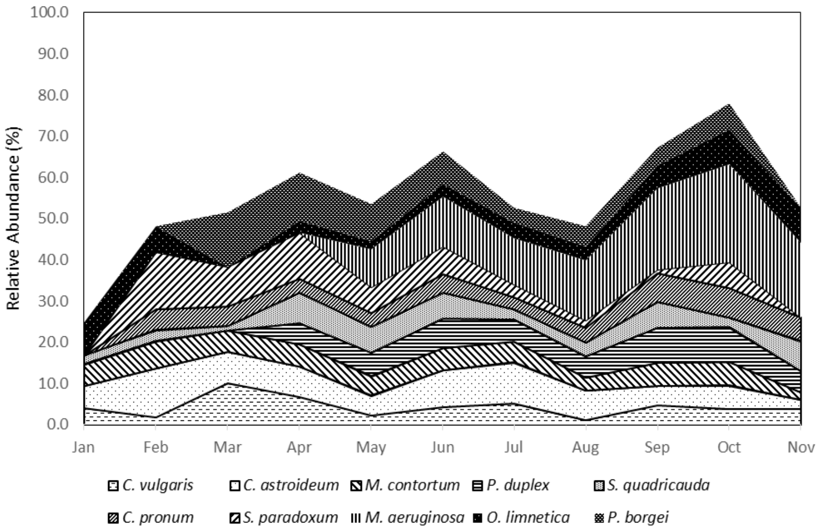

Figure 5. Monthly changes in the relative abundance (% abundance) of dominant species found in the Süloğlu Reservoir phytoplankton.

Table 3. The mean water temperature, pH, dissolved oxygen and chlorophyll-a values measured in the Süloğlu Reservoir based on depths (Surface, 1mt and 5mt mean values of three stations, 15 mt, mean values of St.1 and St.3)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Temp.(°C)	Surface	6,3	8,1	11,6	13,4	18,5	25,8	27,1	23,8	20,3	14,9	5,2
	1mt	6,5	8,1	11,4	12,9	17,6	24,7	26,3	23,7	19,8	14,6	5,3
	5mt	6,5	8,2	11,1	10,1	15,2	22,4	25,1	22,9	17,3	13,5	5,3
	15mt	7,1	9,1	9,4	9,6	11,3	13,5	16,2	16,2	15,7	13,8	6,8
pH	Surface	8,05	7,75	7,35	8,38	8,52	8,48	8,95	8,81	8,78	8,12	7,65
	1mt	8,15	8,35	8,05	8,44	8,45	8,15	9,25	8,88	8,85	8,04	7,75
	5mt	8,17	8,12	7,79	8,33	8,24	7,73	8,25	8,73	8,35	7,94	7,85
	15mt	8,21	7,83	7,65	8,24	8,12	7,56	8,06	8,38	8,07	7,76	7,25
D.O(mg L^{-1})	Surface	10,55	11,35	9,25	10,75	8,75	7,85	8,95	8,15	7,75	7,25	9,85
	1mt	8,55	7,85	9,15	10,25	8,4	8,15	9,15	8,15	7,65	7,65	9,35
	5mt	8,15	8,2	9,3	10,9	8,25	7,55	9,05	8,25	7,05	7,2	9,8
	15mt	9,25	10,35	9,55	10,15	7,85	7,45	8,25	8,15	4,95	5,15	9,65
Chl-*a*(µg L^{-1})	Surface	3,55	3,55	3,55	4,44	17,76	31,96	21,32	21,32	26,64	14,2	5,32
	1mt	1,77	2,55	1,77	3,55	14,28	23,08	26,64	24,86	23,97	13,74	3,55
	5mt	5,32	1,77	3,55	3,55	10,56	28,41	28,41	30,19	15,98	17,31	4,44
	15mt	3,55	2,65	5,32	3,55	7,1	14,2	8,88	17,76	20,42	10,65	3,55

values of the three stations of the reservoir is given in Figure 6. The depth of the lake was measured as 33.4 m on average. The total phosphorus (TP) of Süloğlu Reservoir ranged from 10 to 550 mg/m^3.

Among the subsurface environmental variables measured through the study period, the highest value of salinity was measured in July, while SRP in March, nitrate nitrogene May, nitrite nitrogene January and conductivity in November. Some parameters measured in the lake are given in Table 4. CCA analysis was used to determine the relationship between the abundance of phytoplankton species and environmental variables. Figure 7 shows the 10 taxa dominant in the reservoir and their relationships with

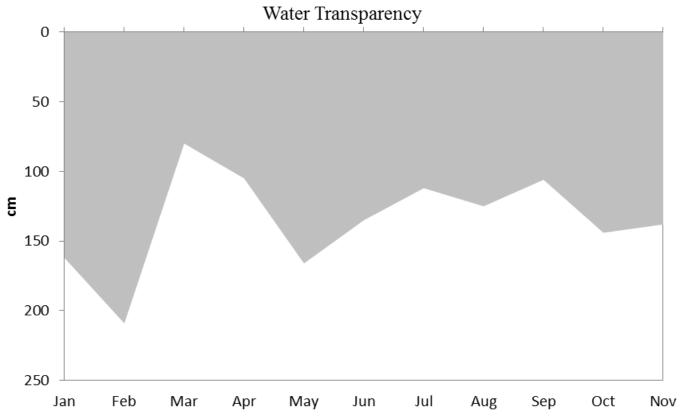

Figure 6. Monthly change in the water transparency values measured at the Süloğlu Reservoir.

Table 4. Mean values of some environmental variables measured at the Süloğlu Reservoir

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Salinity	0.042	0.049	0.046	0.049	0.045	0.049	0.056	0.047	0.045	0.047	0.049
SRP	0.01	0.08	0.55	0.48	0.24	0.12	0.22	0.09	0.01	0.01	0.06
NO_3-N	3.98	4.02	4.18	4.03	4.55	3.46	3.85	3.65	3.85	4.05	4.23
NO_2-N	0.008	0.01	0.01	0.01	0.03	0.03	0.005	0.004	0.004	0.003	0.006
Con.	334	305	225	315	340	325	330	334	337	335	345

*Salinity (g.L^{-1}), (NO_2^- N) Nitrite-Nitrogen (mg.L^{-1}), (NO_3^- N) Nitrate-Nitrogen (mg.L^{-1}), (SRP) soluble reactive phosphorus (mg.L^{-1}), (Con.) (µS.cm^2),

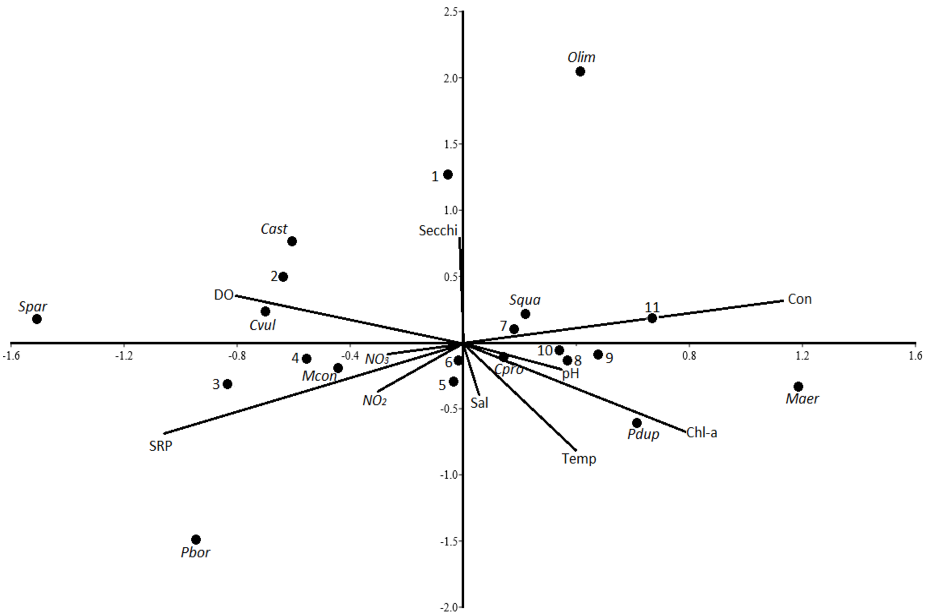

Figure 7. Biplot of first and second CCA axis for phytoplankton in the Süloğlu Reservoir. Dominant algae, *Cvul; C. vulgaris, Cast; C. astroideum, Mcon; M. contortum, Pdup; P. duplex, Squa; S. quadricauda, Cpro; C. pronum, Spar; S. paradoxum, Maer; M. aeruginosa, Olim; O. Limnetica, Pbor; P. borgei.* Environmental variables: Temp; temperature, Secchi; secchi depth, NO_3; nitrate, NO_2; nitrite, Con; conductivity, DO; dissolved oxygen, Chl; chlorophyll-*a*, SRP; soluble reactive phosporus, Sal; salinity. 1 to 11; January to November.

10 different environmental factors. According to the CCA biplot analysis, the eigenvalues of the first two axes were calculated as 0.21 and 0.59, respectively. The first axis of CCA explained 55.34% of the total variance in species, while the second axis explained 24.32% of the total variance. The dominant species *C. vulgaris*, was positively correlated with DO, while *S. quadricauda* with conductivity, *M. contortum* with nutrient.. *C. pronum* was positively correlated with pH and Chlorophyll-*a*, while *P. duplex* with Chlorophyll-*a* in the ordination diagram of CCA (Figure 7).

TSI values of Süloğlu Reservoir was calculated according to Carlson (1977) considering Secchi disc (TSI_{SD}), Chlorophyll-*a* (TSI_{CA}) and total phosphorus (TSI_{TP}) values (Table 5). According to the measurements of Süloğlu Dam's monthly mean Secchi disc, Chlorophyll-*a* and Total Phosphorus values, it was aimed to determine the trophic state of the lake. The mean values were found as, Secchi disc (TSI_{SD}): 55.72, Chlorophyll-*a* (TSI_{CA}): 53.49 and total phosphorus (TSI_{TP}): 68.13. The lake's mean CTSI value was calculated as 59.11 (Figure 8).

Discussion

Water level changes that occur in reservoirs are much higher than those in natural lakes. The reason for this is that, in addition to evaporation and precipitation events that also occur in natural lakes, the water in reservoirs is used for various purposes (Wetzel, 2001; Dodds, 2002). These very significant changes in water levels that are under control of humans affect the life in the aquatic environment directly (Wetzel, 2001; Dodds, 2002). As a result of the year-long study which was conducted in the Süloğlu Reservoir, we found changes caused by evaporation, as well as withdrawal of water for various needs such as drinking water and irrigation. Nitrate nitrogen values were found low during the study period, and dissolved oxygen values were measured in the range of 2.6-11.6 mg L^{-1}. The Chlorophyll-*a* values varied in the range of 3.32-17.76 µg L^{-1}, while the highest values were found in

Table 5. Carlson's trophic state index values and classification of lakes

TSI values	TrophicStatus	Attributes
< 30	Oligotrophic	Clear water, oxygen throughout the year in the hypolimnion
30-40	Oligotrophic	A lake will still exhibit oligotrophy, but some shallower lakes will become anoxic during the summer
40- 50	Mesotrophic	Water moderately clear, but increasing probability of anoxia during the summer
50-60	Eutrophic	Lower boundary of classical eutrophy: Decreased transparency, warm-water fisheries only
60-70	Eutrophic	Dominance of blue-green algae, algal scum probable, extensive macrophyte problems
70-80	Eutrophic	Heavy algal blooms possible throughout the summer, often hypereutrophic
>80	Eutrophic	Algal scum, summer fish kills, few macrophytes

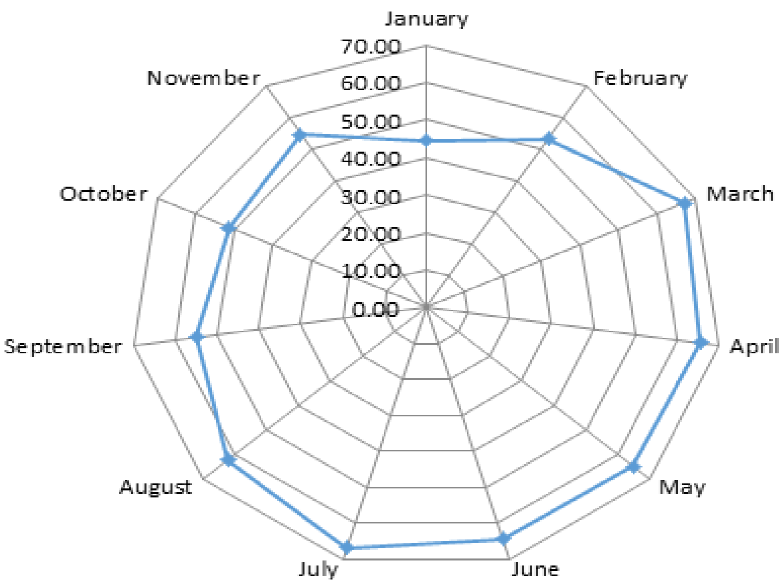

Figure 8. Carlson Trophic State Index, Süloğlu Reservoir 2013.

summer months in which phytoplankton abundance increased; the values decreased starting with September, and reached the lowest numbers in February. The phytoplankton abundance of the Süloğlu Reservoir reached its maximum in summer months. While this agreed with the results on the Kadıköy Dam constructed in Thrace, in contrast to the case here, high phytoplankton abundance was found in fall months in the Hasan Uğurlu (Samsun) and Kemer dam lakes which are mesotrophic (Gönülol & Obalı a, b, 1998; Özyalın & Ustaoğlu, 2008; Öterler, 2013).

While the air and water temperatures measured during the study period were seasonally normal. The water temperature measurements taken from right below the surface and at depths of 1, 5, 15 and 25 were analyzed using YSKYY and found to not exceed 1st Class water quality values (YSKYY, 2015). The measured pH values showed that the water in the lake was slightly alkaline (Table 3). It is reported that the pH value should be between 6.5 and 8.5 in order to provide a suitable environment for aquatic organisms and prevent endangering the lives of those organisms (Wetzel, 2001; Dodds, 2002). It is emphasized that especially high pH values lead to increases in the harmful effects of ammonia and nitrogen compounds in the water, and pH changes are highly important for achieving chemical balance in aquatic environments and therefore continuation of aquatic life (Küçükyılmaz *et al*., 2010; Boztuğ *et al*., 2012). In our study, the pH of the water changed between 7.25 (November) and 9.25 (July). When measurements of pH in the lake water was considered in terms of YSKYY, it appeared that pH values of the lake did not exceed 1st and 2nd Class quality values. While dissolved oxygen concentration is a parameter directly related to photosynthesis, respiration and decomposition, it is also related to light intensity and temperature (Cunha-Santino, Bitar & Bianchini, 2013). Our study found dissolved oxygen values as 1st Class based on YSKYY criteria (YSKYY, 2015).

In freshwater ecosystems, a conductivity value in the range of 250-500 $\mu S.cm^{-1}$ is acceptable (Dodds, 2002). The conductivity values measured in our study showed suitable characteristics for freshwater ecosystems and organisms living there. Salinity is also important for being able to utilize the reservoir in question as a source of drinking water. The salinity values we obtained showed that the Süloğlu Reservoir is suitable as a freshwater reservoir (Dodds, 2002; Tanyolaç, 2011). The nitrate nitrogen values were found between 3.46 and 4.55 mg/L, and according to the YSKYY criteria, they were in the 2nd Class water quality range. According to the nitrite nitrogen values, the lake's water fall into the 2nd and 3rd Classes. The lake moved between 1st and 3rd Class water quality levels.

Generally, it may be stated in terms of monthly mean values that the Süloğlu reservoir has 1st and 2nd class characteristics of water quality according to YSKYY inland water resource directive. However, occasional fluctuations in the nitrogenous compounds may affect the quality of the lake's water negatively (YSKYY, 2015).

The evaluation of one year data showed that the highest abundance was in July by 88 taxa. The Chlorophyta was found as the dominant group followed by Cyanophyta, Miozoa and Charophyta, respectively (see Table 2). Diatoms were represented through the year with low numbers, while Euglenoids increased their numbers in spring, summer and early fall in depths below 5 m. *Microcystis aeruginosa* is a dominant algal species in surface of eutrophic lakes. The dominancy of the species here is achieved by its positive bouyancy ability which helps it to survive and increase in number, in contrast to other species which cannot resist surviving in mixing water body with insufficient light whose size is determined by the mixing depth and euphotic depth (Naselli-Flores & Barone, 2003). *M. aeruginosa* increased colony numbers and especially colony diameter (due to increase in the number of cells in a colony) starting with June, and was included among the dominant organisms among the phytoplankton till September. This situation agrees with results of Ömerli Dam (Albay & Akçalan, 2003). Additionally, Teneva, Belkinova, Dimitrova-Dylgerova, Vlaknova & Mladenov, 2010a; Teneva, Mladenov, Belkinova, Dimitrova-Dylgerova & Dzhambazov, 2010b and Dimitrova, Nenova, Uzunov, Shishinova & Stoyneva, 2014 showed that in Bulgaria (Borovitsa Vacha and Vaya reservoirs), a neighboring country with similar climatic conditions, and cyanoprokariotic blooms in September were always dominated by the genus *Microcystis*. *M. aeruginosa* was also found in several studied reservoirs in Turkey such as Hasan Uğurlu, Kemer, Çamlıdere, Derbent, Hirfanlı, Ömerli and Kadıköy Reservoirs (Fakıoğlu *et al*., 2011). This species was also found in the lake and stream studies conducted in Thrace (Öterler, 2013; Öterler, Kırgız & Albay, 2014; Öterler, Albay, Çamur-Elipek, Güher & Kırgız, 2015). Members of the Cyanophyta group except *M. aeruginosa* did not become dominant in the lake.

Chlorophyta was the group of phytoplankton represented with the most taxa and number of organisms in our study area. The Chlorophyta group consisted of Trebouxiophyceae and Chlorophyceae. This situation was similar to the phytoplankton compositions of various mesotrophic and eutrophic lakes in Turkey (Gönülol & Obalı, 1998b; İşbakan-Taş, Gönülol & Taş, 2002; Ongun-Sevindik, 2010). Presence of Chlorococcales members is accepted as transition from the oligotrophic stage to the eutrophic stage (Hutchinson, 1957). Among these *Monoraphidium* species were frequently observed through the study period. It is known that *Monoraphidium* species are dominant in oligotrophic and mesotrophic lakes (Legnerova, 1965). Among other Chlorococcales members frequently found in our study area, *Scenedesmus* and *Pediastrum* were abundantly encountered in oligomesotrophic reservoirs and eutrophic lakes in Turkey (Aykulu & Obalı, 1981; Aykulu, Obalı & Gönülol, 1983; Obalı, 1984; Gönülol & Obalı, 1998a, b; İşbakan-Taş *et al*., 2002; Albay *et al*., 2003; Baykal, Açıkgöz, Yıldız & Bekleyen, 2004; Kıvrak & Gürbüz, 2005; Özyalın & Ustaoğlu, 2008; Ongun-Sevindik, 2010; Çelekli & Öztürk, 2014). The *Oocystis* and *Lagerhemia* taxa, reported to be highly adaptive for oligotrophic and mesotrophic lakes, were encountered in abundance through our study in many months (Hutchinson, 1967; Trifonova, 1998; Reynolds *et al*., 2002).

6 taxa were found in the Charophyta division, and most of these consisted of species in the genus *Staurastrum,* which is reported as a characteristic of oligotrophic lakes (Rawson, 1956; Hutchinson, 1967; Wetzel, 2001; Palmer, 1980). Additionally, species in the genera of *Cosmarium* and *Closterium* (especially *Closterium littoral* and *C. pronum*) also increased in numbers in spring and summer months. Species belonging to these genera are encountered in various oligotrophic and mesotrophic lakes in Turkey (Akköz & Güler, 2004; Baykal *et al*., 2004; Karacaoğlu, Dere & Dalkıran, 2004; Şahin & Akar, 2007; Ustaoğlu Balık, Gezerler-Şipal, Özdemir & Aygen, 2010; Ongun-Sevindik, 2010). However, while the Charophyta group in the Süloğlu Reservoir increased in numbers in some months, it never became dominant in any sampling period during the course of the study.

Ceratium hirundinella, which was the third-degree dominant organism group in the lake after Chlorophyta and reported by Rawson (1956) as an indicator of mesotrophic waters, was found in low numbers in summer months; again, the *Peridinium cinctum*, *Peridiniopsis borgei* species, which are reported to be abundant in oligotrophic and mesotrophic waters, were found in high numbers (Rawson, 1956; Eloranta, 1995; Reynolds *et al*., 2002).

Ochrophyta (Chrysophyceae class) species *Dinobryon divergens* that are reported to be found in phosphorus-poor waters were occasionally found in the lake (Hutchinson, 1944; Lee, 1980; Sandgren, 1988).

The CCA analysis showed a noticeable relationship between water quality parameters and temporal changes in dominant phytoplankton species. In the Süloğlu Reservoir, according to the CCA results, nutrients were effective on the phytoplankton in spring months, while pH and water temperature were effective in summer months. Albay & Akçaalan (2003) indicated that filamentous cyanophytes have a broad range of tolerance to physical disturbance including water level fluctuation, large amounts of suspended solids, and low Secchi disk transparency. Although similar results were reached by Tunca, Ongun-Sevindik, Bal & Arabacı (2014), the relationship between filamentous blue-green algae species and secchi in our study was not significant.

According to the Carlson (1977) trophic status index we used to determine the trophic level of the Süloğlu Reservoir. The TSI values of the Süloğlu Reservoir changed in the range of 44.46-67.29. According to this index, while this lake was found to be mesotrophic in winter months, it generally had a eutrophic conditions.

In lakes, the appearance of cyanoprokaryotic blooms is one of the major consequences of eutrophication (Conley et al., 2009). Phytoplankton diversity and biomass are related to light, pH values, temperature, mixing and water-level fluctuation, but most significantly to the concentration of nutrients as total nitrogen and total phosphorus (Albay *et al*., 2003; Dimitrova *et al*., 2014). The strong temperature-depth gradient within the reservoir might facilitate intense vertical water mixing, which can induce changes in the nutrient concentrations in the surface layer (Yamamoto & Nakahara, 2006). Additionally, phytoplankton growth is influenced by the abundance of sunlight and some nutrient in the water. Moreover, a surplus of these nutrients in suitable conditions may lead to excessive blooming of algae (Marshall, 2009). In conclusion, Süloğlu Reservoir has a mesotrophic character considering the phytoplankton species found in the lake. However, a bloom formation due to the increase in *M. aeruginosa* was recorded in the lake in summer months. This shows that the lake is in the eutrophication process and in a sensitive situation. Therefore, the lake has to be monitored and necessary measures should to be taken.

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