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RESEARCH PAPER

Investigations on the phytoplankton composition and trophic status of Lake Karagöl (Dikili-İzmir-Türkiye)

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Abstract

The phytoplankton composition, TN:TP ratios as the limiting factor on phytoplankton and the trophic Status of Lake Karagöl, a small volcanic-originated lake, were first investigated in this study. Additionally, the physicochemical parameters of the lake were measured. As a result of the investigations, 21 dominant taxa from four divisions among phytoplanktonic organisms were identified in Karagöl. Three taxa belonged to Cyanobacteria, eleven to Chlorophyta, six to Ochrophyta (only Bacillariophycea), and to one to Myzozoa. The average depth of the lake was calculated as 8.7 m. In line with the atmospheric temperatures brought by the Mediterranean climate prevailing in the region, surface water temperatures of the lake fluctuated between 23.0 °C (summer) and 6.5 °C (winter). Conductivity ranged from 780 to 423 µS and dissolved oxygen ranged from 15.3 to 7.3 mg l^{-1}. The average scores of TSI (SD), TSI (Chl-a), TSI (TN) and TSI (TP) were calculated as 68.0, 55.1, 62.1 and 86.4 respectively. These TSI scores indicated that Lake Karagöl was at eutrophic or hypereutrophic levels. TN:TP ratio of the lake ranged from 9.8 to 7.2 and in this case, the Lake Karagöl food chain is nitrogen-limited because of the low TN:TP ratios. *Dolichospermum flosaquae* (N2-fixing heterocystous Cyanobacteria) was the dominant species in Lake Karagöl phytoplankton during the summer months when the high-water temperature. As a result of this study, based on phytoplankton composition, dominant algae groups (especially Cyanobacteria) and TSI scores, it was evaluated that Lake Karagöl (Dikili) has suitable environmental conditions for many algae species found in mesotrophic and eutrophic lakes and is in a very rapidly progressing hypertrophication process.

Introduction

Small lakes, typically stagnant water bodies with surface areas ranging from a few acres to several hectares, host highly diverse floristic and faunistic communities. These lakes serve as vital habitats for a variety of aquatic organisms such as fish, amphibians and invertebrates, and also contribute to the conservation of local biodiversity by supporting populations of waterfowl and other birds (Schafft et al., 2023; Labat et al., 2022; Biggs et al., 2017). In addition, these lakes, which are recreation areas because they offer opportunities such as fishing, boating, swimming and nature observation, contribute to the physical and mental health of local people, as well as providing numerous ecological, social and economic benefits

(Meyerhoff et al.,2022). Although the protection and management of these valuable aquatic ecosystems have the potential to provide sustainable contributions to the well-being of current and future generations, until recently research on the ecology or hydrobiology of small lakes has lagged that of large lakes (Downing, 2010). Due to their limited morphometry, they exhibit complex ecological dynamics affected by factors such as water depth, nutrient availability and surrounding land use, and are highly sensitive to pressures such as anthropogenic pollution, habitat modification and climate change (Koff et al., 2016; Winslow et al., 2015).

Phytoplankton as communities of microscopic algae, are important primary producers in lake ecosystems and the basis of the aquatic food web because of using sunlight and nutrients for photosynthesis (Reynolds, 2006). Their abundance and diversity serve as crucial indicators of water quality and ecosystem health (Padisák et al., 2006). According to the literature search, curiosity about understanding the driving factors of regulating the spatial and temporal phytoplankton distribution and their functional assemblages of small and shallow lakes started to increase in the early 2000s. (O'Farrell et al., 2003; Ortega-Mayagoitia et al., 2003; Padisák et al., 2003; Stoyneva, 2003). In the following years, studies on the phytoplankton communities, other primary producers, trophic conditions, and ecology of these lakes have also risen in our country (Çelekli et al., 2007; Soylu and Gönülol, 2006; Taş et al., 2010; Altınsaçlı et al., 2014; Taş, 2012). When these studies from the past to present are examined, it is evaluated that the most characteristic problem of these valuable and sensitive aquatic habitats is mostly pollution, and the most common result of this is the eutrophication phenomenon. Global warming and its negative effects on lakes also play a booster role in this dramatic process (Kosten et al., 2012). The Total Nitrogen and Total Phosphorus ratio (TN:TP) is a pivotal factor influencing eutrophication dynamics in water bodies (Smith et al., 1999). This ratio serves as a crucial indicator of nutrient availability, with imbalances often leading to excessive algal growth (especially Cyanobacterial bloom) and subsequent oxygen depletion (Jeppesen et al., 2005; Conley et al., 2009; Frenken, 2023). Such nutrient-driven eutrophication can profoundly impact water quality and ecosystem health (Paerl and Paul, 2012), emphasizing the necessity for effective nutrient management strategies to maintain balanced TN:TP ratios and mitigate eutrophication risks (Elser et al. 2007). Moreover, the Trophic Status Index (TSI) is a critical tool for swiftly evaluating the nutrient levels and ecological health of lakes. Through the analysis of parameters such as nutrient concentrations and chlorophyll levels, TSI provides a concise assessment of a lake's trophic status, facilitating informed management decisions to uphold water quality and ecological equilibrium (Carlson, 1977).

The aims of this study were to reveal preliminary knowledge of the phytoplankton composition, to determine the limiting factor on phytoplankton by calculating TN:TP ratios, and to evaluate the Trophic Status of this small lake (Lake Karagöl).

Materials and Methods

Study area and sampling

Lake Karagöl (38°57'29"N 26°50'55"E) is located at an altitude of 430 m above sea level and 2.5 km away from the Aegean Sea shores as the crow flies' distance within the borders of the Dikili District of Izmir in Western Anatolia. (Figure 1). Karagöl is a small lake with a surface area of approximately 3.5 ha and it is known that the lake was formed as a result of volcanic activities. Four different eruption phases were distinguished within the volcanic piles on the Kardağ Mountain, where the lake is located, and it was reported that due to the spread of lava flows away from the center of the lake, the origin of the explosion was the lake pit, and this stagnant water structure was a volcanic lake (Karacık et al., 2007). Agricultural and livestock activities were observed near the lake. Biological and water sampling were made seasonally from a single point determined in the lake between 2012 and 2013 years. Phytoplankton sampling was carried out using a Hydrobios plankton net with a 55 µm mesh size and drawing circles for 15 minutes. The collected phytoplankton samples were fixed with formaldehyde to a final concentration of 4%. Prefiltered (60 µm) surface water samples were stored in polyethylene jars (1 L volume) and then taken to the laboratory in freezers to protect them from atmospheric effects. The water samples for chlorophyll *a* analysis were collected into 200-mL amber-glass bottles.

Figure 1. Study location and sampling point

Identification and physicochemical analysis

Monograph-level key books of various researchers were used in the identification of phytoplankton species (Huber-Pestalozzi, 1941, 1942; Philipose, 1967; Sims, 1996; Komárek & Anagnostidis, 1999; John et al., 2003; Komárek & Zapomelova, 2007). The current positions of the identified taxa in the systematic hierarchy were checked on the algaebase.org website (Guiry & Guiry, 2014). All the species identifications were made using an Olympus BX53 upright microscope (Olympus Corporation, Japan).

Measurements of temperature, light penetration (with 30 cm Ø black/white Secchi disk), dissolved oxygen (with WTW Oxi 330) and electrical conductivity (with YSI 30 model SCT meter) from the physicochemical properties of water were carried out in situ. HACH LANGE spectrometric test kits [Total Nitrogen (Koroleff digestion+ 2,6-dimethylphenol method with LCK 138 range: 1-16 mg/L TN), Total Phosphorus (Phosphomolybdenum blue methods with LCK 348 range: 0.5-5.0 mg/L PO_4-P)] were used to analyze the chemical properties of water samples. Analyzes were made with a HACH LANGE DR 2800 model Spectrophotometer and HACH LANGE BRB 200 Thermoreactor (for Total Nitrogen). The fluorometric method (Madden & Day, 1992) was used to determine chlorophyll-*a* concentrations (10 AU Model Turner Designs fluorometer). The Trophic State Index (TSI) method was used to determine the trophic level of the lake. Index results were calculated using the values of Secchi depth, Chlorophyll-*a*, TP and TN concentrations to the formulas given respectively (Kratzer & Brezonik, 1981; Carlson and Simpson, 1996): TSI (SD) = 60-14.41 ln(SD) (SD :Secchi Depth ,m); TSI (Chl-*a*) = 9,81 ln(Chl-*a*) + 30,6 (Chl-*a* : Chlorophyll-*a*, µg l^{-1}); TSI (TP) = 14.42 ln TP+ 4.1 (TP: Total Phosphorus, µg l^{-1}); TSI(TN) = 54.45 + 14.43 ln(TN: Total Nitrogen mg l^{-1}).

Results and Discussion

As a result of the algological examinations, 21 dominant taxa from four divisions among phytoplanktonic organisms were identified in Karagöl. Three taxa belonged to Cyanobacteria, eleven to Chlorophyta, six to Ochrophyta (only Bacillariophycea), and to one to Myzozoa. (Figure 2).

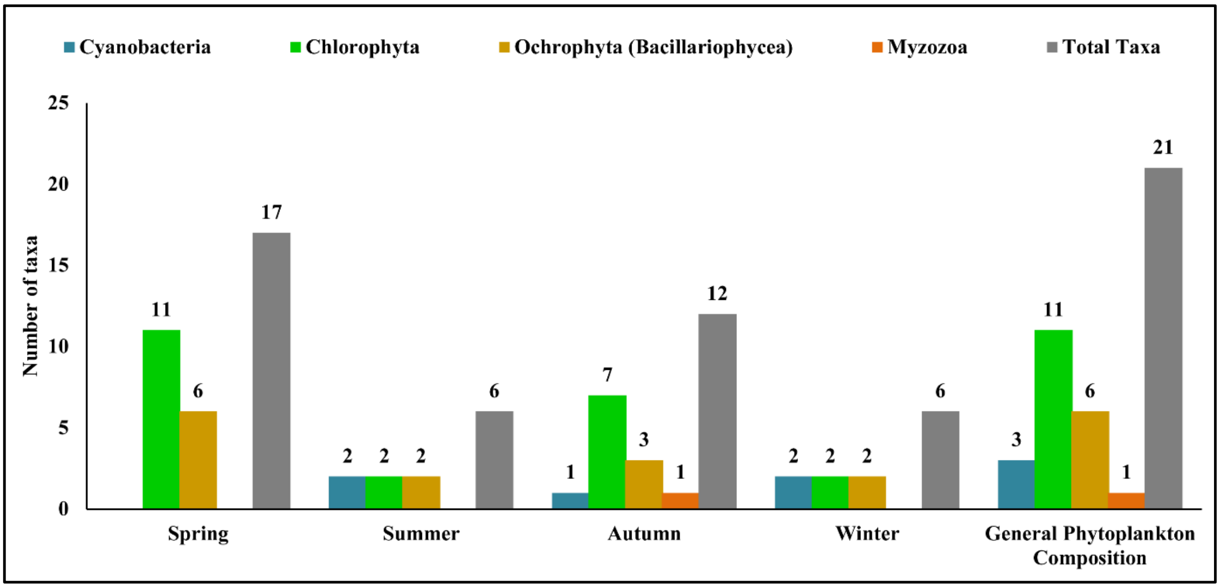

Figure 2. The distribution of phytoplankton divisions and number of taxa by seasons

Dominantly observed phytoplankton species and their seasonal compositions in Lake Karagöl are listed in Table 1. Cyanobacteria (blue-green algae) members were detected more commonly in eutrophic lakes in our country (Cirik-Altındağ, 1982; Gönülol & Çomak, 1992; Albay et al., 2003**;** Sömek & Balık, 2009), and the members of this section were found to be abundant in nutrient-rich and eutrophic lakes in the summer months (Vaitomaa, 2006). During this research, very few taxa from Cyanobacteria were identified, but when their density was evaluated, they were found to be relatively dominant in phytoplankton in summer. In a study conducted on the processes regulating the dominance of planktonic diatoms and cyanobacteria in several eutrophic lakes, it was found that diatoms and, to a lesser extent, Chlorophyta species were dominant in periods when water temperature (<15 °C) and water column stability were low, and in periods when water temperature and water column stability were high. It has been reported that cyanobacteria are dominant (Zhang and Prepas, 1996). When the seasonal change of phytoplankton of Karagöl (Dikili) was examined, an analogous phytoplankton dynamic was observed.

The Chlorophyta (green algae) division was the phytoplankton group represented by the highest number of taxa in our research area. The entire Chlorophyta division consisted of Chlorococcales members. This pattern is like the phytoplankton composition of many mesotrophic and eutrophic lakes in our country. (Gönülol & Obalı, 1998; İşbakan-Taş et al., 2002; Ongun-Sevindik, 2010). The presence of Chlorococcales members was reported as a transition from the oligotrophic level to the eutrophic level (Hutchinson, 1957). It is known that species belonging to the *Monoraphidium* genus are dominant in oligotrophic and mesotrophic lakes (Legnerova, 1965). *Scenedesmus* and *Pediastrum* species, which are other Chlorococcales members frequently found in current study area, were frequently encountered in oligomesotrophic reservoirs and eutrophic lakes in our country (İşbakan-Taş et al., 2002; Kıvrak & Gürbüz, 2005; Ongun-Sevindik, 2010). Desmids, another group of green algae whose species are found in many oligotrophic and mesotrophic lakes in our country (Akgöz & Güler, 2004; Baykal et al., 2004; Karacaoğlu et al., 2004), were not observed in Lake Karagöl (Dikili). Palmer (1980) reported that most Desmidiaceae species can be found in oligotrophic water bodies, and a few in eutrophic water bodies.

As a result of the examinations, diatoms (Bacillariophyceae) in phytoplankton were the second most dominant group after the members of the Chlorophyta division. It has been reported that the pelagic species, *Ulnaria ulna* (Nitzsch) Compère, which was frequently detected in our research area, is one of the characteristic species of eutrophic lakes (Hustedt, 1930, 1945; Reynolds et al., 2002). Centric diatoms are algal groups that are best adapted to systems that are rich in nutritious mineral substances and have high turbidity (Izaguirre et al., 2001). Species of the *Aulacoseira* and *Cyclotella* species were observed in Lake Karagöl (Dikili) in the autumn phytoplankton, where water column stability was disrupted and mixing increased. Species originating from benthic were also identified among the diatom members in the lake (*Gomphonema olivaceum* (Hornemann) Ehrenberg, *Pinnularia maior* (Kützing) Rabenhorst). It is known that pennate diatoms of benthic origin are transported to the pelagic region due to various water movements in relatively shallow, small-area lakes and ponds (Round, 1973). Similar situations were reported in the lakes of our country (Şen et al., 2001; Akgöz & Güler, 2004). Most of the Bacillariophyceae members identified in this research have a high tolerance to environmental variables and are widely distributed in many lakes and other water bodies at different trophic levels in our country (Aysel, 2005). In our research area, only *Peridiniopsis cunningtonii Lemmermann* species from the Myzozoa (Dinoflagellates) was identified. *P. cunningtonii* is also found in mesotrophic or eutrophic inland water ecosystems in Türkiye (Sömek et al., 2005; Ongun-Sevindik, 2010).

Table 1. Dominant phytoplankton species and seasonal composition of Lake Karagöl

	Spring	Summer	Autumn	Winter
Cyanobacteria				
Dolichospermum flosaquae (Brébisson ex Bornet & Flahault) P.Wacklin, L.Hoffmann & J.Komárek		+	+	
Merismopedia minima G.Beck				+
Limnothrix sp.		+		+
Chlorophyta				
Actinastrum hantzschii Lagerheim	+			
Botryococcus braunii Kützing	+	+	+	
Desmodesmus communis (E.Hegewald) E.Hegewald	+		+	
Desmodesmus opoliensis (P.G.Richter) E.Hegewald	+		+	
Golenkinia radiata Chodat	+			
Micractinium pusillum Fresenius	+			+
Monoraphidium griffithii (Berkeley) Komárková-Legnerová	+			
Monoraphidium irregulare (G.M.Smith) Komárková-Legnerová	+		+	
Pseudopediastrum boryanum (Turpin) E.Hegewald	+	+	+	+
Scenedesmus obliquus (Turpin) Kützing	+		+	
Tetraëdron minimum (A.Braun) Hansgirg	+		+	
Ochrophyta (Bacillariophycea)				
Aulacoseira italica (Ehrenberg) Simonsen	+			
Cyclotella meneghiniana Kützing	+			
Gomphonema olivaceum (Hornemann) Brébisson	+			+
Nitzschia acicularis (Kützing) W.Smith	+	+	+	
Pinnularia maior (Kützing) Cleve	+		+	+
Ulnaria ulna (Nitzsch) P.Compère	+	+	+	
Myzozoa				
Peridiniopsis cunningtonii Lemmermann			+	

Physicochemical parameters measured in Karagöl are given in detail in Table 2. During the study, no dramatic changes were observed in the depth of the lake and the average depth was calculated as 8.7 m. In line with the atmospheric temperatures brought by the Mediterranean climate prevailing in the region, surface water temperatures of the lake fluctuated between 23.0 °C (summer) and 6.5 °C (winter). Conductivity ranged from 780 to 423 µS and dissolved oxygen ranged from 15.3 to 7.3 mg l^{-1}, according to, Turkish Surface Water Quality Regulation (SWQR, 2016), the quality of Lake Karagöl surface water was class II (good) and class I (very good), respectively. Carlson's Trophic

State Index (TSI), developed by Robert G. Carlson, is a method used to evaluate and classify the trophic state of freshwater bodies such as lakes and reservoirs, based on measurements of chlorophyll-a concentration, total phosphorus and Secchi disk transparency (Carlson, 1977). The classification of freshwater bodies according to TSI values ranges from oligotrophic (TSI < 40) to hypereutrophic (TSI > 70), with mesotrophic (TSI 40-50) and eutrophic (TSI 50-70) classifications in between. Secchi depth (SD), Chlorophyll *a* (Chl-a), Total Nitrogen (TN) and Total Phosphorus (TP) values were used to generate the Carlson Trophic State Index scores. The average scores of TSI (SD), TSI (Chl-*a*), TSI (TN) and TSI (TP) were calculated as 68.0, 55.1, 62.1 and 86.4 respectively. These TSI scores indicated that Lake Karagöl was at eutrophic or hypereutrophic levels.

The TN:TP ratio is a key approach frequently used to analyze the dynamics of lake ecosystems (van Wijk et al., 2024). It has been reported that nitrogen is limiting when the TN:TP ratio is <10, phosphorus is limiting when the TN:TP ratio is >17, and freshwater ecosystems are balanced when the TN:TP ratio is between 10-17 (Smith, 1983). TN:TP ratio of the lake ranged from 9.8 to 7.2 and in this case, the Lake Karagöl food chain is nitrogen-limited because of the low TN:TP ratios. It has been observed in the studies that the blooms of N_2-fixing (heterocystous blue-green algae) cyanobacteria can be supported by low TN:TP ratios or N-limited conditions (Moisander et al, 2012; González-Madina et al., 2019). This succession dynamic was confirmed by the presence of *Dolichospermum flosaquae* (Bornet & Flahault) P.Wacklin, L.Hoffmann & Komárek as the dominant species in Lake Karagöl phytoplankton during the summer months when the high-water temperature.

Table 2. Physicochemical parameters and Carlson's TSI values of Lake Karagöl

PARAMETERS	Mean	Maximum	Minimum	TSI_Mean	TSI _Max	TSI _Min
Depth (m)	8.7	10.0	8.1	-	-	-
Temperature (°C)	14.8	23.0	6.5	-	-	-
Conductivity (25°C) µS	497.2	780	423	-	-	-
Dissolved Oxygen (mg l^{-1})	9.6	15.3	7.3	-	-	-
Secchi Depth (m)	0.58	0.70	0.35	** **68.0**	*** **75.1**	** **65.1**
Chlorophyll *a* (µg l^{-1})	12.2	21.2	6.8	** **55.1**	** **60.5**	* **49.4**
TN (µg l^{-1})	2846	4580	1400	** **62.1**	** **66.7**	** **58.2**
TP (µg l^{-1})	300	466	195	*** **86.4**	*** **92.7**	*** **80.2**
TN:TP Ratio	9.5	9.8	7.2	N limitation	N limitation	N limitation

(***mesotrophic, **eutrophic**, *****hypertrophic**)

Conclusions

As a result of the study, it was evaluated that Lake Karagöl (Dikili) is eutrophic or hypereutrophic based on phytoplankton composition, dominant algae groups (especially Cyanobacteria), and TSI scores and so environmental conditions of the lake were suitable for many algae species commonly observed in nutrient-rich inland waters of the world. For this reason, the authors have predicted that Lake Karagöl (Dikili), which is the drainage area of the land it's around, was partially affected by the agricultural and livestock activities nearby.

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Ethical approval

The author declares that this study complies with research and publication ethics.

Informed consent

Not available.

Conflicts of interest

There is no conflict of interests for publishing their study.

Data availability statement

The authors declare that data are available from authors upon reasonable request.

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Author contribution

Haşim Sömek: Writing original draft, Conceptualization, Sampling, Species identification.

Esat Tarık Topkara: Project administration, Investigation, Analysis, Review, Editing.

References

Akgöz, C. & Güler, S. (2004) Topçu Göleti (Yozgat) Alg Florası I: Epilitik ve Epifitik Algler. *S.Ü. Fen Ed. Fak. Fen Derg., 23:* 7-14.

Albay, M., Akcaalan, R., Aykulu, G., Tufekci, H., Beattie. K.A. & Codd, G.A. (2003). Occurrence of toxic cyanobacteria before and after copper sulphate treatment in a water reservoir, Istanbul, Turkey. *Arch Hydrobiol Supp Algol Stud, 109*:67–78.

Altınsaçlı, S., Altınsaçlı, S., & Paçal, F. P. (2014). Species composition and qualitative distribution of the macrophytes in three Turkish lakes (Kandira, Kocaeli, Turkey). *Phytologia Balcanica, 20*(1), 89-98.

Aysel, V.(2005) Check-List of The Freshwater Algae of Turkey. *J. Black Sea/Mediterranean Environment, 11* (1): 5-128.

Baykal. T., Açıkgöz, İ., Yıldız, K. and Bekleyen, A. (2004) A Study on Algae in Devegeçidi Dam Lake. *Turkish Journal of Botany, 28*: 457-472.

Biggs, J., Von Fumetti, S., & Kelly-Quinn, M. (2017). The importance of small waterbodies for biodiversity and ecosystem services: implications for policy makers. *Hydrobiologia*, *793*, 3-39. https://doi.org/10.1007/s10750-016-3007-0

Carlson, R.E. (1977). A trophic state index for lakes. *Limnology and Oceanography. 22*:361-369.

Carlson, R.E. & Simpson, J. (1996). *A Coordinator's Guide to Volunteer Lake Monitoring Methods.* North American Lake Management Society. 96 pp.

Çelekli, A., Albay, M., & Dügel, M. (2007). Phytoplankton (except Bacillariophyceae) flora of lake Gölköy (Bolu). *Turkish Journal of Botany, 31*(1), 49-65.

Cirik-Altındağ, S. (1982). Manisa - Marmara Gölü Fitoplanktonu. I -Cyanophyta, *Doğa Bilim Dergisi, Temel Bilimler, 6* (3) : 67-81.

Conley, D. J., Paerl, H. W., Howarth, R. W., Boesch, D. F., Seitzinger, S. P., Havens, K. E., ... & Likens, G. E. (2009). Controlling eutrophication: nitrogen and phosphorus. *Science, 323*(5917), https://doi.org/10.1126/science.1167755

Downing, J. A. (2010). Emerging global role of small lakes and ponds: little things mean a lot. *Limnetica, 29*(1), 0009-24.

Elser, J. J., Bracken, M. E., Cleland, E. E., Gruner, D. S., Harpole, W. S., Hillebrand, H., ... & Smith, J. E. (2007). Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems. *Ecology letters, 10*(12), 1135-1142.

Frenken, T., Brandenburg, K. M., & Van de Waal, D. B. (2023). Long-term nutrient load reductions and increasing lake TN: TP stoichiometry decrease phytoplankton biomass and diversity in a large shallow lake. *Limnology and Oceanography, 68*(10), 2389-2401. https://doi.org/10.1002/lno.12428

Gönülol, A. & Obalı, O. (1998). Seasonal Variations of Phytoplankton Blooms in Suat Uğurlu (Samsun-Turkey). *Turkish Journal of Botany, 22*: 93-97.

Gönülol, A. & Çomak, O., 1992, Bafra Balık Gölleri (Balık Gölü, Uzun Göl) Fitoplanktonu Üzerinde Floristik Araştırmalar. I -Cyanophyta, Doğa Tr. J. of Botany 16 : 223-245

González-Madina, L., Pacheco, J. P., Yema, L., de Tezanos, P., Levrini, P., Clemente, J., ... & Mazzeo, N. (2019). Drivers of cyanobacteria dominance, composition and nitrogen fixing behavior in a shallow lake with alternative regimes in time and space, Laguna del Sauce (Maldonado, Uruguay). *Hydrobiologia, 829*, 61-76.

Guiry, M.D. & Guiry, G.M. (2014) AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 29 April 2014.

Huber-Pestalozzi, G. (1941). *Das Phytoplankton des Süßwassers. (Die Binnengewässer, Band XVI). Teil 2. (i) Chrysophyceen, Farblose Flagellaten Heterokonten.* E. Schweizerbart'sche Verlag-sbuchhandlung, Stuttgart.

Huber-Pestalozzi, G. (1942). *Das Phytoplankton des Süßwassers. (Die Binnengewässer, Band XVI). Teil 2. (ii). Diatomeen. E.* Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Hustedt, F. (1930) *Bacillariophyta Diatome* Heft: 10 A Pascher DieSusswasser Flore Mitteleuropas. Ed. Gustav Fischer Pub., Jena, Germany,466pp.

Hustedt, F. (1945). *Die Diatomeenflore Norddeutscher Seen Mit Besonderer Berücksichtigung Des Holsteinischen Seen-Gebiets*. *Arch. Hydro. 41*:392-414.

Hutchinson, G.E. A. (1957) *Treatise on Limnology* Volum I: Geopraphy, Physics an Chemistry,.John Wiley, Newyork.

İşbakan-Taş, B., Gönülol, A. & Taş, E. (2002) A Study on the Seasonal Variation of the Phytoplankton of Lake Cernek (Samsun-Turkey). *Turkish Journal of Fisheries and Aquatic Sciences*, *2*: 121-128.

Izaguirre, I., O'Farrell, I., & Tell, G. (2001). Variation in phytoplankton composition and limnological features in a water–water ecotone of the Lower Paraná Basin (Argentina). *Freshwater Biology*, *46*(1), 63-74.

Jeppesen, E., Søndergaard, M., Jensen, J. P., Havens, K. E., Anneville, O., Carvalho, L., ... & Winder, M. (2005). Lake responses to reduced nutrient loading–an analysis of contemporary long-term data from 35 case studies. *Freshwater biology*, *50*(10), 1747-1771. https://doi.org/10.1111/j.1365-2427.2005.01415.x

John, D.M., Whitton, B.A. & Brook, A.J. (2003). *The Freshwater Algal Flora of the British Isles: An Identification Guide to Freshwater and Terrestrial Algae*. Cambridge University Press. New York. 701 pages.

Karacaoğlu, D., Şükran D. & Dalkıran, N. (2004) A Taxonomic Study on the Phytoplankton of Lake Uluabat (Bursa). *Turkish Journal of Botany, 28*: 473-485.

Karacık, Z., Yılmaz, Y. & Pearce, J. A. (2007) The Dikili-Çandarl› Volcanics, Western Turkey: Magmatic Interactions as Recorded by Petrographic and Geochemical Features. *Turkish Journal of Earth Sciences, 16*: 493-522.

Kıvrak, E. & Gürbüz, H. (2005) Seasonal variations in phytoplankton composition and physical-chemical features of Demirdöven Dam Reservoir, Erzurum, Turkey, *Biologia, Bratislava, 60*/1: 1-8.

Koff, T., Vandel, E., Marzecová, A., Avi, E., & Mikomägi, A. (2016). Assessment of the effect of anthropogenic pollution on the ecology of small shallow lakes using the palaeolimnological approach. *Estonian Journal of Earth Sciences*, *65*(4), 221–233. https://doi.org/10.3176/earth.2016.19

Komárek J. & Anagnostidis K. (1999). *Cyanoprokaryota. Chroococcales*. In: E. Ettl, G. Gärtnerand D. Mollenhauer (eds) Süsswasserflora von Mitteleuropa. Bd. 19/1. Gustav Fischer JenaStuttgart, Lübeck Ulm: 548 pp.

Komárek, J. & Zapomelova E. (2007). Planktic morphospecies of the cyanobacterial genus Anabaena_subg. Dolichosperumum—1. part: coiled types. *Fottea 7*: 1–31.

Kosten, S., Huszar, V. L., Bécares, E., Costa, L. S., van Donk, E., Hansson, L. A., ... & Scheffer, M. (2012). Warmer climates boost cyanobacterial dominance in shallow lakes. *Global Change Biology*, *18*(1), 118-126. https://doi.org/10.1111/j.1365-2486.2011.02488.x

Kratzer, C.R. and Brezonik, P.L. (1981) A Carlson-Type Trophic State Index for Nitrogen in Florida Lakes. *Water Resources Bulletin*, *17*, 713-

715. https://doi.org/10.1111/j.1752-1688.1981.tb01282.x

Labat, F., Piscart, C., & Thiebaut, G. (2022). Invertebrates in small shallow lakes and ponds: a new sampling method to study the influence of environmental factors on their communities. *Aquatic Ecology*, *56*(3), 585-603. https://doi.org/10.1007/s10452-021-09939-1

Legnerova, J. (1965) The Genera *Ankistrodesmus* Corda and *Raphidium* Kützing and their Position In the Family Ankistrodesmusmaceae, *Preslia 37*: 1-8.

Madden, C.J. & Day, Jr. J.W. (1992).An instrument system for the high-speed mapping of chlorophyll-a and physicochemical variables in surface waters. *Eustaries.*, *15*(3): 421-427

Meyerhoff, J., Klefoth, T., & Arlinghaus, R. (2022). Ecosystem service trade-offs at small lakes: Preferences of the public and anglers. *Aquatic Ecosystem Health & Management*, *25*(3), 1-11. https://doi.org/10.14321/aehm.025.03.01

Moisander, P. H., Cheshire, L. A., Braddy, J., Calandrino, E. S., Hoffman, M., Piehler, M. F., & Paerl, H. W. (2012). Facultative diazotrophy increases *Cylindrospermopsis raciborskii* competitiveness under fluctuating nitrogen availability. *FEMS Microbiology Ecology*, *79*(3), 800-811. https://doi.org/10.1111/j.1574-6941.2011.01264.x

O'Farrell, I., Sinistro, R., Izaguirre, I., & Unrein, F. (2003). Do steady state assemblages occur in shallow lentic environments from wetlands?. In *Phytoplankton and Equilibrium Concept: The Ecology of Steady-State Assemblages:* Proceedings of the 13th Workshop of the International Association of Phytoplankton Taxonomy and Ecology (IAP), held in Castelbuono, Italy, 1–8 September 2002 (pp. 197-209). Springer Netherlands.

Ortega-Mayagoitia, E., Rojo, C., & Rodrigo, M. A. (2003). Controlling factors of phytoplankton assemblages in wetlands: an experimental approach. In *Phytoplankton and Equilibrium Concept:* The Ecology of Steady-State Assemblages: Proceedings of the 13th Workshop of the International Association of Phytoplankton Taxonomy and Ecology (IAP), held in Castelbuono, Italy, 1–8 September 2002 (pp. 177-186). Springer Netherlands.

Ongun-Sevindik, T. (2010) Phytoplankton Composition of Çaygören Reservoir, Balikesir-Turkey. *Turkish Journal of Fisheries and Aquatic Sciences 10*: 295-304.

Padisák, J., Borics, G., Fehér, G., Grigorszky, I., Oldal, I., Schmidt, A., & Zámbóné-Doma, Z. (2003). Dominant species, functional assemblages and frequency of equilibrium phases in late summer phytoplankton assemblages in Hungarian small shallow lakes. *Hydrobiologia*, *502*, 157-168. https://doi.org/10.1023/B:HYDR.0000004278.10887.40

Padisák, J., Borics, G., Grigorszky, I., & Soróczki-Pintér, É. (2006). Use of phytoplankton assemblages for monitoring ecological status of lakes within the Water Framework Directive: the assemblage index. *Hydrobiologia*, *553*, 1-14. https://doi.org/10.1007/s10750-005-1393-9

Palmer, C.M. (1980). *Algae and Water Pollution*, Castle House Pub., London.

Paerl, H. W., & Paul, V. J. (2012). Climate change: links to global expansion of harmful cyanobacteria. *Water research*, *46*(5), 1349-1363. https://doi.org/10.1016/j.watres.2011.08.002

Philipose, M. T. (1967) *Chlorococcales*. I. C. A. R., New Delhi, 365 p.

Reynolds, C. S., Huszar, V., Kruk, C., Naselli-Flores, L., & Melo, S. (2002). Towards a functional classification of the freshwater phytoplankton. *Journal of plankton research*, *24*(5), 417-428.

Reynolds, C. S. (2006). *The ecology of phytoplankton*. Cambridge University Press. Cambridge, UK, 535 pp.

Round, F. E. (1973) The Biology of The Algae, Edward Arnold, London,

Schafft, M., Nikolaus, R., Matern, S., Radinger, J., Maday, A., Klefoth, T., ... & Arlinghaus, R. (2023). Impact of water-based recreation on aquatic and riparian biodiversity of small lakes. *Journal for Nature Conservation*, 126545. https://doi.org/10.1016/j.jnc.2023.126545

Şen, B., Çağlar, M. ve Toprak Pala, G. (2001). Tadım Göleti (Elazığ) Diyatomeleri ve Yıl İçindeki Dağılımları. *F.Ü. Fen ve Müh. Bilimleri Dergisi 13*, 2, 255-261.

Sims, P.A. (1996). *An Atlas of British Diatoms*. Illustrated by Horace G. Barber, & John R. Carter, arranged by Bernard Hartley. Biopress Ltd., Bristol, United Kingdom. 601 pp.

Smith, V. H. (1983). Low nitrogen to phosphorus ratios favor dominance by blue-green algae in lake phytoplankton. *Science*, *221*(4611), 669-671.

Smith, V. H., Tilman, G. D., & Nekola, J. C. (1999). Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environmental pollution*, *100*(1-3), 179-196. https://doi.org/10.1016/S0269-7491(99)00091-3

Sömek, H. & Balık, S. (2009). Karagöl'ün (Dağ Gölü, İzmir-Türkiye) Alg Florası ve Çevresel Koşullarının Mevsimsel Değişimi. *E.Ü. Su Ürünleri Dergisi, 26* (2) : 121-128.

Sömek,H., Balık, S. & Ustaoğlu M.R., 2005, Topçam Baraj Gölü (Çine-Aydın) Fitoplanktonu ve Mevsimsel Değişimleri. *S.D.Ü.Eğirdir Su Ürünleri Fakültesi Dergisi, 1*(1): 26-32.

Soylu, E. N., & Gonulol, A. (2006). Seasonal variation in the diversity, species richness and composition of the phytoplankton assemblages in a shallow lake. *Cryptogamie-Algologie*, *27*(1), 85-102.

Stoyneva, M. P. (2003). Steady-state phytoplankton assemblages in shallow Bulgarian wetlands. *Hydrobiologia*, *502*, 169-176.

SWQR (2016). Regulation on amending the surface water quality regulation; [Access Date 2017 July 03]. Access Address http://www.resmigazete.gov.tr/eskiler/2015/04/2015 0415-18.htm (in Turkish)

Taş, B., Candan, A. Y., Can, Ö., & Topkara, S. (2010). Ulugöl (Ordu)'ün bazı fiziko-kimyasal özellikleri. *Journal of FisheriesSciences. com*, *4*(3), 254-263. https://doi.org/10.3153/jfscom.2010027

Tas, B. (2012). Diversity of phytoplankton and trophic status in the Gaga Lake, Turkey. *EES Technology Part A: Energy Sci Res*, *30*(1), 33-44.

Vaitomaa, J. (2006) *The effects of environmental factors on biomass and microcystin production by the freshwater cyanobacterial genera Microcystis and Anabaena*. Edita , Helsinki, Finland, 56 p.

van Wijk, D., Janse, J. H., Wang, M., Kroeze, C., Mooij, W. M., & Janssen, A. B. (2024). How nutrient retention and TN: TP ratios depend on ecosystem state in thousands of Chinese lakes. *Science of The Total Environment*, 170690. https://doi.org/10.1016/j.scitotenv.2024.170690

Winslow, L. A., Read, J. S., Hansen, G. J., & Hanson, P. C. (2015). Small lakes show muted climate change signal in deepwater temperatures. *Geophysical Research Letters*, *42*(2), 355-361. https://doi.org/10.1002/2014GL062325

Zhang, Y., & Prepas, E. E. (1996). Regulation of the dominance of planktonic diatoms and cyanobacteria in four eutrophic hardwater lakes by nutrients, water column stability, and temperature. *Canadian Journal of Fisheries and Aquatic Sciences*, *53*(3), 621-633.