SUSTAINABLE AQUATIC RESEARCH
www.saquares.com

Sustainable Aquatic Research (2025) 4(1):41-50
https://doi.org/10.5281/zenodo.15188995
e-ISSN: 2822-4140

RESEARCH PAPER

Marmara Lake (Manisa-Türkiye)'s Final Waters: Assessment of Water Quality Parameters and Trophic Status Before Near-Total Drying

Saniye Türk Çulha[1*], Haşim Sömek[1], Hakkı Dereli[2]

[1*]*Department of Basic Sciences, Fisheries Faculty, Izmir Katip Celebi University, İzmir, Türkiye*
[2]*Department of Fishing, Fisheries Faculty, Izmir Katip Celebi University, İzmir, Türkiye*

Citation

Türk Çulha, S., Sömek, H., Dereli, H. (2025). Marmara Lake (Manisa-Türkiye)'s Final Waters: Assessment of Water Quality Parameters and Trophic Status Before Near-Total Drying. *Sustainable Aquatic Research, 4*(1), 41-50.

Article History

Received: 13 March 2025
Received in revised form:05 April 2025
Accepted: 07 April 2025
Available online: 30 April 2025

Corresponding Author

Saniye Türk Çulha
E-mail: saniye.turk.culha@ikcu.edu.tr
Tel: +90-5359798195

Keywords

Water quality
Trophic level
Eutrophication
Total drying
Marmara Lake

Handling Editor

Sheila Mae Santander-de Leon

Abstract

This study was carried out at 3 different stations in Marmara Lake, in Western Anatolia in Türkiye, and focused on variations in water quality parameters based on months. Water samples collected from the surface of the lake were analyzed monthly in terms of total suspended solids (TSS), volatile suspended solids (VSS), fixed suspended solids (FSS), ammonium nitrogen (NH_4^+-N), nitrite nitrogen (NO_2^--N), nitrate nitrogen (NO_3^--N), phosphate phosphorus (PO_4^{-3}-P), silica (SiO_2) and chlorophyll-*a* (Chl-*a*) parameters. As a result of this study, according to Inland Water Quality Standards defined in Surface Water Quality Management Regulations (SWQMR), Marmara Lake can be considered the Class-I quality by the measured ammonium nitrogen and nitrate nitrogen and the Class-II by the measured nitrite nitrogen and phosphate phosphorus. Moreover, it was evaluated that the lake is in a eutrophic status according to its Carlson's trophic state index (TSI) scores based on the phosphate phosphorus values, and in a hypereutrophic status based on the chlorophyll-*a* values. This study presented the latest scientific research evaluating the surface water quality parameters and trophic levels of Marmara Lake before its complete drying. In this respect, the study has historical importance in documenting the lake's final ecological state and will be able to create a critical reference point for potential restoration efforts.

Introduction

Lakes are valuable wetlands that play an important role in the world hydrological cycle, biodiversity support, regulation of carbon cycling and climate, and also provide various ecosystem services (Zedler et al., 2005; Dudgeon et al., 2006; Tranvik et al., 2009). However, due to global climate change and human activities, lakes or wetlands in many parts of the world face serious threats, including eutrophication, pollution, lowering of water levels, and even complete drying. (Moss et al., 2011; Jeppesen et al., 2014; Tussupova et al., 2020). Of these, the drying not only disrupts the ecological balance but also causes wide-ranging impacts on regional water resource management, biodiversity conservation, and the socioeconomic structure of local human populations (Čížková et al., 2013; Alaniz et al., 2019). According to the Global Wetland Outlook data published by the Ramsar Secretariat in 2018, 87% of the world's wetlands have been lost in the last 300 years due to various problems such as construction, pollution, drying, and overuse. (Gardner & Finlayson, 2018) According to WWF's Living Planet Reports (WWF, 2024), the greatest decrease in vertebrate populations between 1970 and 2012 occurred in wetland species with 81%, and 25% of these are currently at risk of extinction. There are 131 wetlands in Türkiye, including natural lakes. 14 of them are the Ramsar Sites, 59 are Wetlands of National Importance and 58 are Wetlands of Local Importance, apart from these, there are 6 more lakes declared as National Parks, the highest environmental conservation status in Türkiye (DKMP, 2024). Marmara Lake (Manisa-Türkiye) was also included in the wetland category in 2002 and registered as a Wetland of National Importance in 2017. Despite all these protected statuses, the lake, once covering an area of almost 6000 hectares (too variable periodically), is now completely dry due to faulty water basin management choices and drought caused by global climate change (Körbalta, 2019). Before its drying or this ecological catastrophe, the lake was a biodiversity hotspot, hosting 144 bird species—56 of which were breeding there (Gül, 2008); at least 15 fish species (İlhan & Sarı, 2011), emergent or submergent wetland plants (Seçmen & Leblebici, 1982), numerous aquatic macro-microorganisms (Cirik, 1980; Ustaoğlu, 1989) making it an ecosystem of remarkable ecological value. The lake also supported fisheries activities that significantly contributed to the regional economy, providing livelihoods for many local populations in the past.

Nowadays, the restoration of Marmara Lake is on the agenda through the joint efforts of water-related environmental activists and also the probable contribution of local water management authorities (personal communication). These kinds of restoration efforts will be able to aim not only to save an ecological system that is an important water resource and biodiversity center for the region and a vibrant ecosystem with diverse birds, fishes, and other aquatic species, but also to regain fisheries activities that were once supported by the lake. Water quality parameters are considered important indicators for understanding changes occurring in lake ecosystems (Wetzel, 2001). This study aims to present the latest scientific research evaluating the surface water quality parameters and trophic levels of Marmara Lake before its complete drying. In this respect, it has historical importance in documenting the lake's final ecological state and will be able to create a critical reference point for potential restoration efforts.

Materials and Methods

The research area, Marmara Lake, is an alluvial dam lake at an altitude of 75 m above sea level. Located in the Gediz River basin, the second largest river flowing into the Aegean Sea, the lake covers an area of approximately 70 km^2, 6 km from north to south and 12 km from east to west. Originally a seasonal, slightly salty lake in a closed basin, fed by small streams and groundwater, it was converted into an irrigation reservoir in 1953 (Bulkan, 2009). With the arrangements made, streams such as Kum Stream and Gediz River were added to the sources feeding the lake. The excess water of the lake was released to the Gediz River again through a canal (Arı & Derinöz, 2011).

This study was carried out monthly at 3 different stations in Marmara Lake between January and December 2016 (Figure 1). A Hach Lange DR 6000 brand spectrophotometer was used for measurements. Total suspended solids (TSS), volatile suspended solids (VSS) and fixed suspended solids (FSS) were analyzed with gravimetric methods (Stirling, 1985). Analyses of ammonium nitrogen (NH_4^+-N), nitrite nitrogen (NO_2^--N), nitrate nitrogen (NO_3^--N), phosphate phosphorus (PO_4^{-3}-P), silica (SiO_2) and chlorophyll-*a* (Chl-*a*) have been performed using a spectrophotometer (Strickland & Parsons, 1972; Wood, 1975; Parsons et al., 1984; Egemen & Sunlu, 2003). Alkalinity ($CaCO_3$) was analyzed with the titrimetric method (APHA, AWWA, WPCF, 2005). Water quality of the Marmara Lake has been determined referring to the Inland Water Quality Standards (SWQMR, 2015).

The Carlson's Trophic State Index (TSI) was calculated using chlorophyll-a (Chl-*a*) and total phosphorus (TP/PO_4^{-3}-P) concentrations in µg/L, with the formulas TSI (Chl-*a*) = 9.81 ln(Chl-*a*) + 30.6 for chlorophyll-a and TSI(TP) = 14.42 ln(TP) + 4.15 for total phosphorus, respectively (Carlson & Simpson, 1996). Based on the calculated TSI scores, the trophic state of the lake was evaluated as oligotroph (TSI < 40), mesotroph (40 ≤ TSI < 50), eutroph (50 ≤ TSI < 70), or hypertroph (TSI ≥ 70).

Figure 1. The study area and Marmara Lake's total drying chronology (*: stations)

In the study, the data were classified according to months and stations, checked in terms of their normality and homogeneity and then their average values and standard errors (± se) were calculated. Instead of focusing on stations, the study focused variations in water quality parameters based on months. Statistical analyses were all performed using Past v5.1 software program. Non-parametric several samples variance test (ANOVA followed by Kruskal-Wallis) was used to determine significant differences among months (Hammer et al., 2001).

Results and Discussion

Figure 2 shows the fluctuations in the water quality parameters detected in the monthly study in the surface water of Marmara Lake during a one-year study period. The differences between months were found statistically significant in all parameters ($p < 0.001$). The overall average values of water quality parameters were calculated as 161.5± 10.03 mg/L for alkalinity ($CaCO_3$), 22.53±4.71 mg/L for TSS, 6.52± 1.47 mg/L for VSS, 16.01± 3.81 mg/L for FSS, 3.65±0.602 mg/L for SiO_2, 0.044± 0.008 mg/L for NH_4^+-N, 0.009± 0.001 mg/L for NO_2^--N, 0.011± 0.006 mg/L for NO_3^--N, 0.036± 0.008 mg/L for PO_4^{-3}-P, 26.69± 6.76 µg/L for chlorophyll-*a* . Additionally, a comparison of Marmara Lake with several lakes and reservoirs in Türkiye according to water quality parameters is presented in Table 1.

In most waters, alkalinity ($CaCO_3$) is much more important than total hardness. Waters with total hardness greater than 20 mg/L $CaCO_3$ are considered safe for pond production. Such waters can be useful in protecting fish against the harmful effects of metal ions and pH changes. $CaCO_3$ corresponds to the acid-accepting capacity of water and the concentration of basic compounds in the structure of water. Low-alkalinity waters have low buffering capacity, and as a result, these waters are sensitive to changes in pH. Such changes can directly harm fish populations. Low-alkalinity ponds are less productive than high-alkalinity ponds. Lakes with high alkalinity (< 300 mg/L $CaCO_3$) are unproductive because they contain high levels of CO_2. The ideal range for alkalinity is 20-300 mg/L $CaCO_3$ (Egemen & Sunlu, 2003). The average total alkalinity value determined in the study was determined as 161.5 mg/L± 10.03. This result is among the ideal alkalinity values stated by Egemen & Sunlu (2003). The average alkalinity value determined by Mutlu et al., (2013), Turan & Aldemir (2023) is that value is higher than the alkalinity value we determined.

TSS is a parameter that, if higher than a certain threshold concentration, usually causes physically negative effects in water column, turbidity, condensation, and toxicity, as well as threats aquatic organisms health by decreasing the water transparency and dissolved oxygen concentration (Uslu & Türkman, 1987). The determined TSS ranged from 2.2 (April) to 45.1 (June), VSS ranged from 17.5 (November) to 1.6 (April) and

Table1. Comparison of water quality parameter values (mg/L) of Marmara Lake with different lakes or reservoirs

Lakes	(NH^{+}_{4}-N)	(NO^{-}_{2}-N)	(NO^{-}_{3}-N)	(PO^{3-}_{4}-P)	(SiO_2)	Chl-*a* (µg/l)	Alkalinity	Ref.
Kalecik	0.23	-	0.27	0.1	-	-	-	1
Çip	0.03	-	1.25	0.05	-	-	-	1
Işıktepe	0.002-0.14	-	0.929	0.06	-	-	98-148	2
Almus	0.29	0.011	0.18	0.03	-	-	-	3
Yamula	0.46	0.083	0.69	0.04	-	-	-	4
Dicle	-	-	-	-	-	-	-	5
Van	0.04-2.62	0.04-17.56	16.79-64.63	7.38-9.13	-	-	7630-7879	6
Derbent	0.18	0.05	0.96	0.05	-	-	163.8	7
Afşar	0.13-1.35	0-0.025	0-1.8	0-1.16	-	0.2-49.5	-	8
Mogan	1.8-2.3			0.1-0.23	-	<50	-	9
Selevir	0.063	0.02	0.006	0.17	-	-	-	10
Uluabat	0.19	0.043	0.99	0.42	-	-	-	11
Karagöl	0.01-0.51	0.00-0.02	0.48-5.96	0.12-0.36	-	-	224.6-304.3	12
Karagöl	0.002-0.64	0.0006-0.154 (Σ)		0.003-0.112	0.80-10.90	0.9-9.3	-	13
Demirköprü	0.08-1.736	0.002-0.074	0-0.154	0.018-0.262	3.29-9.69	1-162	26.8	14
Wadi Al- Arab	-	-	0.7-30.4	0.73-1.02	2.33-1.46	-	-	15
Marmara Lake	0.019-0.121 0.044±0.008	0.004-0.019 0.009±0.001	0-0.06 0.011±0.006	0.003-0.089 0.036±0.008	0.2-6.5 3.65±0.602	2.5-79.2 26.69±6.76	101-197 161.5±10.0	16

Reference: 1. Alpaslan et al., 2015; 2. Küçükyılmaz et al., 2014; 3. Buhan et al., 2010; 4. Çevik & Elibol, 2009; 5. Varol, 2015; 6. Turan & Aldemir, 2023; 7. Taş, 2006; 8. Ayvaz et al., 2011; 9. Ozdemir, et al., 2024; 10. Bulut et al., 2011; 11. Iscen et. al., 2008; 12. Mutlu et al., 2013; 13. Sömek & Balık, 2009; 14. Türk Çulha & Erdoğuş, 2018; 15. Saadoun et al., 2010; 16. This study.

FSS ranged from 40.1 (June) to 0.5 (April) mg/L. According to SWQMR (2015), the required TSS value for the eutrophication limit of lakes is 5 mg/l. The average values of water quality parameters were detected in Marmara Lake as; 22.53±4.71 mg/L for TSS, 6.52± 1.47 mg/L for VSS, 16.01± 3.81 mg/L for FSS (Figure 2). It is evaluated that the TSS and FSS values are high due to the increase of phytoplankton biomass and the terrestrial inputs transferred by rainwater and snowmelt. This result is considerably higher than the Demirköprü Dam Lake (5.41 mg/L) and Dicle Dam Lake (3.15 mg/L) TSS values (Türk Çulha & Erdoğuş, 2018; Varol, 2015). The TSS result in Marmara Lake shows that the lake is in the polluted water category.

The average SiO_2 value determined in Marmara Lake was determined as 3.65±0.602 mg/L. Similar to these values, Sömek & Balık (2009) reported the SiO_2 values from the Karagöl Lake, Saadoun et al., (2010) reported the SiO2 value to be between 2.33-7.60 mg/L in the Wadi Al-Arab Dam in Bulgaria, and Türk Çulha & Erdoğuş (2018) reported it to be 3.29-9.69 mg/L in the Demirköprü Dam Lake. Egemen & Sunlu (1996) assessed that the SiO_2 concentrations were very low in the spring season when the growth of diatoms was rising and high in the winter season when phytoplankton activity was poor. However, in this study, the main source of SiO_2, which is at its maximum level in the autumn months, is thought to be from terrestrial inputs due to precipitation.

In this study, The NH_4^+-N ranged from 0.121 (January) to 0.019 (May). It is thought that the reason for the relatively low NH_4^+-N values in the spring season in Marmara Lake is the consumption of increased phytoplankton biomass as food and the conversion of ammonium to ammonia with increasing pH during this period. The average NH_4^+-N value determined in the study was found to be lower than the value determined for the Yamula Dam Lake by Çevik & Elibol (2009) (0.46 mg/L), while it was found to be higher than the data of other lentic water bodies listed in Table 1. The overall average value of NH_4^+-N is in the Class I category according to SWQMR (2015). Sarıyıldız et al. (2008) reported that the NH_4^+-N value in their study conducted with samples taken from the region where the Gediz River enters the same lake fell into the Class IV category according to SWQMR (2015).

NO_2^--N is an unstable nitrogen form that occurs as a result of the oxidation of ammonia or the reduction reaction of ammonia to nitrate and rarely accumulates in the water column (at the anoxia); additionally, it was able to originate from the decomposition of various organic proteins (Boyd & Tucker, 1998). The mean NO_2^--N value in this study is 0.009±0.001 mg/L. Buhan et al., (2010) reported no pollution due to NO_2^--N (0.011 mg/L) values in the Almus Dam Lake. Türk Çulha & Erdoğuş (2018) stated that nitrite in Demirköprü dam lake was higher in summer than in other months. According to the SWQMR (2015) water quality parameters, the values of NO_2^--N are in the Class II water category. In Marmara Lake, the highest nitrite value was determined in the months representing the autumn period. This result was assumed to be due to the high temperature and low oxygen conditions occurring in the summer and autumn months in Lake Marmara, which was quite shallow and under the influence of possible fertilization due to intensive agricultural activities in its surroundings before it dried out completely, causing disruptions in the nitrogen cycle processes in both the water column and the sediment. Previous research has shown that this cycle in lakes can be impacted by environmental factors like temperature, N availability, dissolved oxygen, and microbial diversity and abundance (Yoshinaga et al., 2011; Xu et al., 2012; Wu et al., 2012; Zhu et al., 2015).

The average NO_3^--N value determined in the study is 0.011±0.006 mg/L. These data are considerably lower than the other nitrate values given in Table 1. When the monthly distribution of nitrate is examined, the value is determined only in January and March. When the average NO^{3-}-N values determined in Marmara Lake are compared with the water quality parameter values specified by SWQMR (2015), it is determined that they fall into the Class I category. Again, the NO^{3-}-N values determined in Selevir and Demirköprü dam lakes fall into the Class I category (Bulut et al., 2011; Türk Çulha & Erdoğuş, 2018).

PO_4^{-3}-P is measured in relatively limited concentration in uncontaminated natural waters by the pollutants and determines the productivity of lakes (Tepe & Boyd, 2003). Unlike nitrogen, which has many forms in lake systems, the most obvious inorganic phosphorus forms are ortho-phosphate or phosphate phosphorus, and more than 90% of the phosphorus detected in freshwater is found in the cells of living aquatic organisms as organic phosphate (Wetzel, 1983). The basis of all organic phosphorus compounds are the ortho-phosphate anions (Uslu & Türkman 1987). The average PO_4^{-3}-P value determined in Marmara Lake is 0.036±0.008 mg/L. PO_4^{-3}-P values were determined to be higher in the autumn months. This increase is thought to be due to, during the rainy period, the surface waters coming from terrestrial environments mixing with rainwater due to the slope of the land where the lake is located, nutrients coming from the agricultural areas, and the geological structure of the lake. Similar results were determined in Demirköprü Dam Lake (Türk Çulha & Erdoğuş, 2018). When compared with the study data in Table 1, it has a lower phosphorus value than Afşar, Uzunçayır, Selevir, Hirfanlı, Demirköprü Van, Uluabat and Wadi Al-Arab lakes. When compared with the water quality parameter values specified by SWQMR (2015), the PO_4^{-3}-P values determined in Marmara Lake fall into the Class II category. Chlorophyll-*a* is a dominate photosynthetic pigment in all phytoplanktonic organisms to carried out the primer production of nutrients and these organisms constitute the first link of the food chain in a freshwater ecosystem, with aquatic macrophytes. Therefore, the concentration of chlorophyll-a is the most important indicator to estimate phytoplankton biomass and trophy levels in a lake (Vollenweider & Kerekes, 1982). Chlorophyll-*a* values determined in Marmara Lake having 6 m of the deepest point, were inversely proportional with nutrient elements, reaching high values in autumn months, while lower values were determined in spring season when production is lower. In this study, the average chlorophyll-a amount was measured as 26.69±6.76 µg/L. This value is higher than the values of Borçka and Hirfanlı dam lakes given in Table 1, but lower than the values of other lakes. The average chlorophyll-*a* amount determined in Lake Marmara is in the hypereutrophic level according to SWQMR (2015). Furthermore, the excessive developments of macrophytes in surface water during the study periods is another indicator of eutrophication.

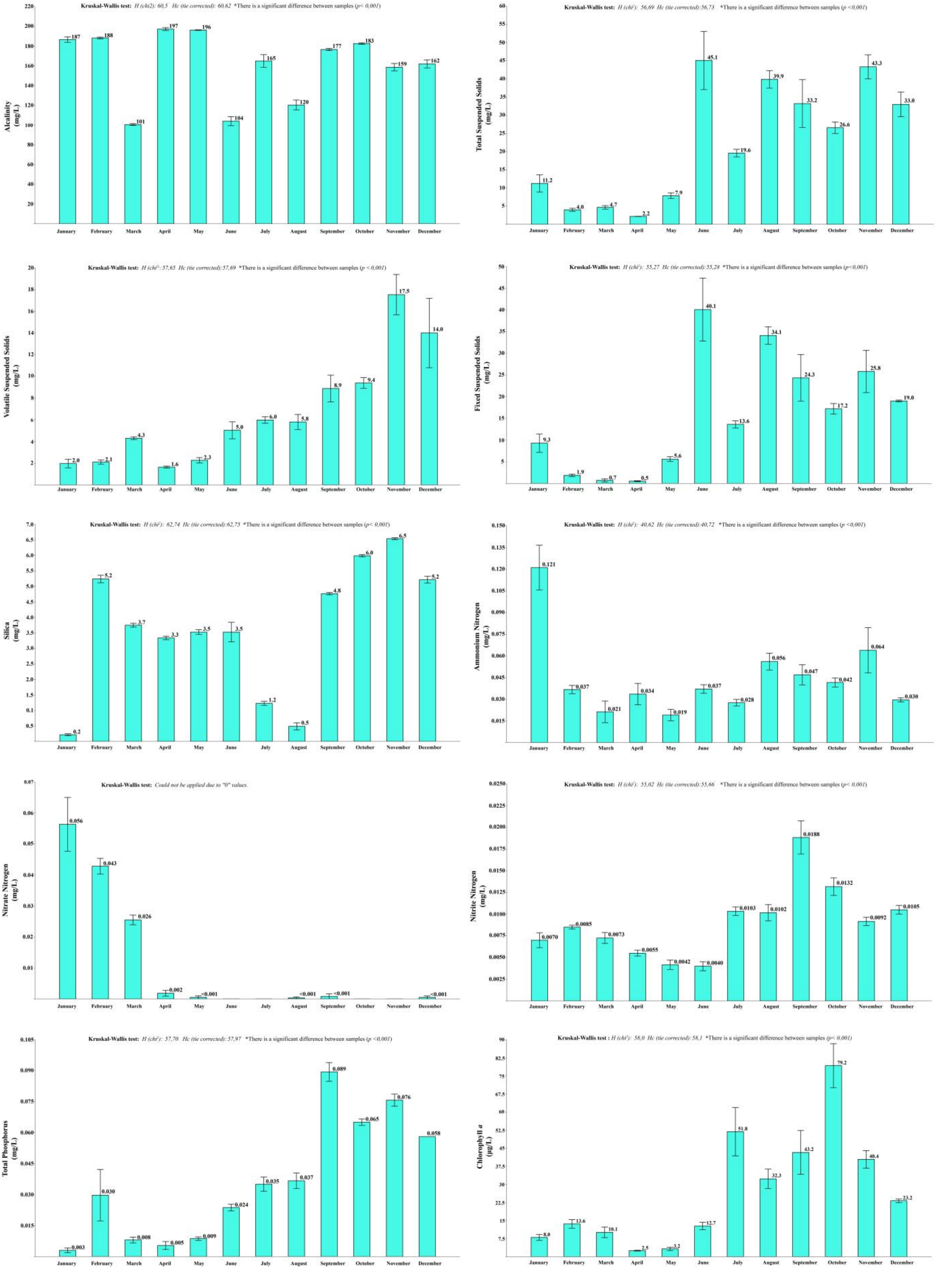

Figure 2. Monthly variations of water quality mean values (with ± se) in the Marmara Lake

The overall average TSI scores were calculated 47.9±5.1 for TSI(TP) and 57.8± for TSI(Chl-*a*). The TSI (TP) scores ranged from 19.7 (April) to 68.6 (September), TSI (Chl-*a*) scores ranged from 39.4 (April) to 73.1 (October). Based on the calculated TSI scores, the trophic state of the lake is classified into one of four categories: oligotrophic (TSI < 40), mesotrophic (40 ≤ TSI < 50), eutrophic (50 ≤ TSI < 70), or hypertrophic (TSI ≥ 70). According to these trophy classification, Marmara Lake was eutrophic by the TSI (TP) and was hypertrophic by TSI (Chl-*a*) in the summer and autumn months (Figure 3).

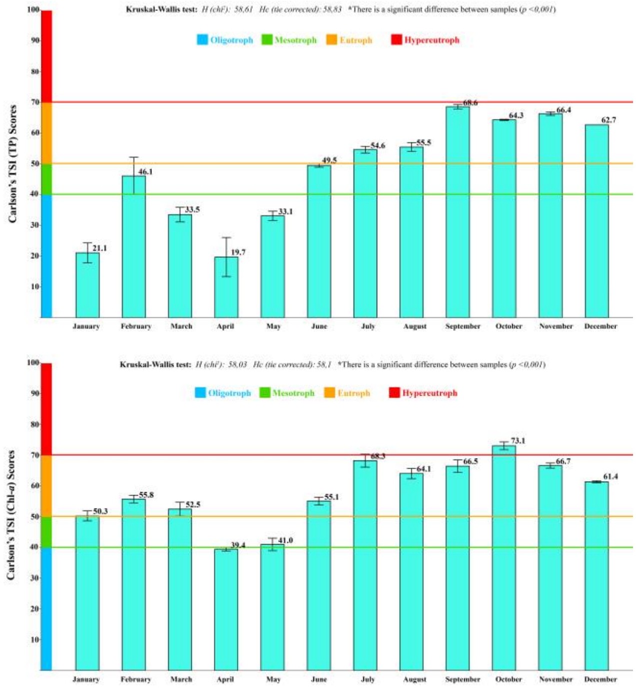

Figure 3. Monthly variations of mean Carlson's TSI scores (with ± se) in the Marmara Lake

A potential wetland restoration will be able to save a regional biodiversity center and a living ecosystem with diverse birds, fishes, and other aquatic species, but also to regain fisheries

Conclusions

According to the data obtained from this study, which was carried out before the Marmara Lake dried up, the lake was determined to fall into the Class I category in terms of ammonium and nitrate nitrogen and the Class II category in terms of nitrite nitrogen and phosphate phosphorus values, according to SWQMR (2015). SMM values were determined to be higher than the SSM value of 5 mg/L required for the control of eutrophication in dam lakes by SWQMR (2015). Moreover, it was evaluated that the lake is in a eutrophic status

activities that were once supported by the lake. Following the restoration project in the future, it can be concluded that the lake area, which is currently used for agriculture, may have high nutritional value as a result of fertilization. The authors recommend that eutrophication control and ecological quality monitoring strategies should be developed, and measures should be taken to prevent fertilizers and other nutrients from agricultural areas from being carried into the lake. Additionally, it is thought that other pollution factors (metal, pesticides, etc.) should also be examined before restoration is carried out.

Acknowledgments

We would also like to thank MSc Mirati Erdoğuş and Dr. Yusuf Şen, who contributed to the field work, and Dr. Fatma Rabia Karaduman, who supported to the laboratory analyses of water samples.

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 of this study

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Funding organizations

No funding available.

according to its trophic state index scores and phosphate phosphorus, and in a hypereutrophic status according to its chlorophyll-a value.

Author contribution

Saniye Türk Çulha: Writing original draft, Conceptualization, Data curation, Formal analysis, Review and editing, Visualization, Supervision. Haşim Sömek: Data entry, Conceptualization, Methodology, Illustrations, Data improvement, Statistical analysis, Writing – Original draft. Hakkı Dereli: Examples, Supervision, Validation, Visualization, Editing, Resources, Review.

References

Alaniz, A. J., Carvajal, M. A., Núñez-Hidalgo, I., & Vergara, P. M. (2019). Chronicle of an environmental disaster: Aculeo Lake, the collapse of the largest natural freshwater ecosystem in central Chile. Environmental Conservation, 46(3), 201-204. https://doi.org/10.1017/S0376892919000122

Alpaslan, K., Karakaya, G., Küçükyılmaz, M., Koçer, M. (2015). Seasonal Variation of Water Quality in Coastal Area of Cip and Kalecik Dam Lakes (Elazığ). Aquaculture Studies, 15(1), 3-10. https://doi.org/10.17693/yunusae.v15i21955.235738

APHA, AWWA, WPCF, 2005. "American Public Health Association American Water Works Association & Water Pollution Control Federation-Standard Methods for the Examination of Water and Wastewater." Washington, DC (USA).

Arı, Y., & Derinöz, B. (2011). How not to manage a wetland? The case of Lake Marmara (Manisa) with a cultural ecological perspective. Journal of Geographical Sciences, 9 (1), 41-60 https://doi.org/10.1501/Cogbil_0000000117

Ayvaz, M., Tenekecioğlu, E. & Koru, E. (2011). Determination of Trophic Status of Afsar (Manisa-Turkey) Dam Lake. Ecology, 20 (81): 37-47. https://doi.org/10.5053/ekoloji.2011.816

Boyd C.E & Tucker C.S. (1998). Pond aquaculture water quality management. Kluwer Academic Publishers. Norwell, Massachusetts, 685 p.

Buhan, E., Koçer, M.A., Polat, F., Doğan, H.M., Dirim, S. & Neary, E.T. (2010). Evaluation of Almus Dam Lake Water Quality for Trout Culture and Estimating of Carrying Capacity. Journal of Agricultural Faculty of Gaziosmanpaşa University, 27(1): 57-65.

Bulkan, Ö. (2009). Geochemical properties of lake Marmara (Manisa) sediments and paleo-ecological evolution of the area in quaternary. (Doctoral dissertation). İstanbul University, Institute of Natural and Applied Sciences, İstanbul.

Bulut, S., Mert, R., Solak, K. & Konuk, M. (2011). Selevir Baraj Gölü'nün Bazı Limnolojik Özellikleri. Ekoloji 20(80): 13-22.

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

Çevik, H. & Elibol, M.İ. (2009). Limnology of Yamula Reservoir, DSİ General Directorate, Ankara, 186 p.

Cirik, S. (1980). An Investigation on Manisa-Marmara Lake Phytoplankton (Doctoral dissertation). Ege University, Faculty of Science, Chair of Systematic Botany, İzmir.

Čížková, H., Květ, J., Comín, F. A., Laiho, R., Pokorný, J., & Pithart, D. (2013). Actual state of European wetlands and their possible future in the context of global climate change. Aquatic Sciences, 75, 3-26. https://doi.org/10.1007/s00027-011-0233-4

DKMP (2024). Directorate of Nature Conservation and National Parks, Retrived from https://www.tarimorman.gov.tr/.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.H., Soto, D. & Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. Biological reviews, 81(2): 163-182. https://doi.org/10.1017/S1464793105006950

Egemen, Ö. & Sunlu, U. (2003). Water Quality Textbook, Ege University, Faculty of Fisheries, Publication No: 14, Ege University, Printing House, Bornova, İzmir, 148 p.

Gardner, R. C. & Finlayson, C. (2018). Global wetland outlook: state of the world's wetlands and their services to people. In Ramsar convention secretariat, Stetson University College of Law Research Paper No. 2020-5, Available at SSRN: https://ssrn.com/abstract=3261606

Gül, O. (2008). Researches on the determination of ornithofauna of and environmental factors affecting Marmara lake (Manisa, Turkey). Unpublished M.Sc. Thesis. Ege University, Institute of Science, İzmir.

Hammer, Ø., Harper, D.A.T. & Ryan, P.D. (2001) PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm

İlhan, A., & Sarı, H. M. (2013). Fish fauna and fisheries activities in Lake Marmara. Ege Journal of Fisheries and Aquatic Sciences, 30(4): 187-191. https://doi.org/10.12714/egejfas.2013.30.04.08

Iscen, C. F., Emiroğlu, Ö., Ilhan, S., Arslan, N., Yilmaz, V. & Ahiska, S., (2008). Application of multivariate statistical techniques in the assessment of surface water quality in Uluabat Lake, Turkey. Environ Monit Assess. 144:269–276. https://doi.org/10.1007/s10661-007-9989-3

Jeppesen, E., Meerhoff, M., Davidson, T., Trolle, D., Sondergaard, M., Lauridsen, T. L., Bekliğolu, M., Brucet, S., Volta, P., Gonzalez-Bergonzoni, I. & Nielsen, A. (2014). Climate change impacts on lakes: an integrated ecological perspective based on a multi-faceted approach, with special focus on shallow lakes. Journal of Limnology, 73(s1): 88-111. https://doi.org/10.4081/jlimnol.2014.844

Körbalta, H. (2019). Why Is The Marmara Lake Drying? Kent Akademisi, 12 (3): 441-459. https://doi.org/10.35674/kent.595207

Küçükyılmaz, M., Örnekçi, G.N., Uslu, A.A., Özbay, N., Şeker, T., Birici, N., Yıldız, N. & Koçer M.A.T. (2014). Water Quality of Isıktepe Dam Lake (Maden, Elazığ). Aquaculture Studies, 2: 55-63. https://doi.org/10.17693/yunusae.vi.235397

Moss, B., Kosten, S., Meerhoff, M., Battarbee, R. W., Jeppesen, E., Mazzeo, N., Havens, K., Lacerot, G., Liu, Z., De Meester, L., Paerl, H. & Scheffer, M. (2011). Allied attack: climate change and eutrophication. Inland Waters 1 (2): 101–105. https://doi.org/10.5268/IW-1.2.359

Mutlu, E., Yanık, T. & Demir, T. (2013). Investigation the Water Quality of Karagöl (Hafik-Sivas). Alinteri Journal of Agriculture Science, 24(1):35-45.

Ozdemir, K., Ciner, M.N., Ozcan, H.K. & Aydın, S. (2024). Evaluation of Water and Sediment Quality in Lake Mogan, Türkiye. Water, 16, 1546. https://doi.org/10.3390/w16111546

Parsons, T.R., Matia, Y. &Lalli, C.M. (1984). A manual of chemical and biological methods for seawater analysis, New York: Pergamon Press, 173 p.

Saadoun, İ., Batayneh, E., Alhandal A. & Hindieh, M. (2010). Physicochemical features of Wadi Al-Arab Dam (reservoir), Jordan. Oceanological and Hydrobiological Studies, 39(4), 189-203. https://doi.org/10.2478/v10009-010-0057-x

Sarıyıldız, A., Harmancıoğlu, N., Sılay, A. & Çetin, H.C. (2008). Trend Analysis of Gediz River Water Quality Parameters, Ministry of Environment and Forestry, General Directorate of State Hydraulic Works, World Water Form Regional Preparation Process Turkey Regional Water Meeting, Watershed Pollution Conference, 603-611.

Seçmen, Ö., & Leblebici, E. (1982). Flora and Vegetation of Lakes and Swamps in the Aegean Region, Central Anatolia West and Mediterranean Region West. TUBİTAK Project Report, No.: TBAG-407, 130 pp.

Sömek, H., & Balık, S. (2009). Seasonal variation of Algal flora and Environmental conditions of Karagöl (A Mountain Lake, İzmir). Ege Journal of Fisheries and Aquatic Sciences, 26(2): 121-128.

Stirling, H.P. (1985). Chemical and Biological Methods of Water Analysis for Aquaculturalists. Institute of Aquaculture, University of Stirling, 119.

Strickland, J.D.H. & Parsons, T.R. (1972). A Practical Handbook of Seawater Analysis, 2nd ed. Bulletin, vol 167 Ottowa: Fisheries Research Board of Canada, 310 p.

SWQMR (2015). Surface Water Quality Management Regulation, 15.04.2015 Date and Nr. 29327 TR Official Newspaper, , Ankara.

Taş, B. (2006). Investigation of Water Quality of Derbent Dam Lake (Samsun). Ekoloji, 15(61): 6-15.

Tepe, Y. & Boyd, C.E., (2003). A reassessment of nitrogen fertilization for sunfish ponds, Journal of World Aquaculture Society, 34 (4): 505-511. https://doi.org/10.1111/j.17497345.2003.tb00089.x

Tranvik, L. J., Downing, J. A., Cotner, J. B., Loiselle, S. A., Striegl, R. G., Ballatore, T. J., ... & Weyhenmeyer, G. A. (2009). Lakes and reservoirs as regulators of carbon cycling and climate. Limnology and oceanography, 54(6part2), 2298-2314. https://doi.org/10.4319/lo.2009.54.6_part_2.2298

Turan, A. & Aldemir, A., (2023). Statistical assessment of seasonal variations in water quality for different regions in Lake Van (Türkiye), Environ Monit Assess, 195:237. https://doi.org/10.1007/s10661-022-10820-3

Türk Çulha, S. & Erdoğuş, M. (2018). Investigations on Some Physicochemical Parameters of Demirköprü Dam Lake (Manisa, Turkey), Turkish Journal of Agriculture - Food Science and Technology, 6(9): 1267-1273. https://doi.org/10.24925/turjaf.v6i9.1267-1273.2032

Tussupova, K., Hjorth, P., & Moravej, M. (2020). Drying lakes: A review on the applied restoration strategies and health conditions in contiguous areas. Water, 12(3), 749. https://doi.org/10.3390/w12030749

Uslu, O. & Türkman, A. (1987). Water Pollution and Control, T.R. Prime Ministry General Directorate of Environment Publications Education Directory, 1 Ankara 364 p.

Ustaoğlu, M. R. (1989). Investigations on Zooplankton of Lake Marmara (Salihli). (Doctoral dissertation), Ege University, Institute of Natural and Applied Sciences, Department of Biology, İzmir.

Varol, M. (2015). Assessment of Water Quality of Dicle Dam Lake According to Turkish Water Pollution Control Regulation, Turkish Journal of Agriculture and Natural Sciences, 2(1): 85–91.

Vollenweider, R. A., & Kerekes, J. (1982). Eutrophication of waters. Monitoring, assessment and control. Organization for Economic Co-Operation and Development (OECD), Paris, 156.

Wetzel, R. G., (2001). Limnology: lake and river ecosystems. gulf professional publishing, Academic Press, San Diego, 1006p.

Wood, R.D. (1975). Hydrobotanical metods, University pf Paris Press, London, 173 p.

Wu, Y., Xiang, Y., Wang, J., & Wu, Q. L. (2012). Molecular detection of novel anammox bacterial clusters in the sediments of the shallow freshwater Lake Taihu. Geomicrobiology Journal, 29(9), 852-859. https://doi.org/10.1080/01490451.2011.635760

WWF (2024). World Wrestling Federation Living Planet Reports. Retrived from, https://www.wwf.org.uk/our-reports.

Xu, L., Li, H., Liang, X., Yao, Y., Zhou, L., & Cui, X. (2012). Water quality parameters response to temperature change in small shallow lakes. Physics and Chemistry of the Earth, Parts A/B/C, 47, 128-134. https://doi.org/10.1016/j.pce.2010.11.005

Yoshinaga, I., Amano, T., Yamagishi, T., Okada, K., Ueda, S., Sako, Y., & Suwa, Y. (2011). Distribution and diversity of anaerobic ammonium oxidation (anammox) bacteria in the sediment of a eutrophic freshwater lake, Lake Kitaura, Japan. Microbes and environments, 26(3), 189-197. https://doi.org/10.1264/jsme2.ME10184

Zedler, J. B., & Kercher, S. (2005). Wetland resources: status, trends, ecosystem services, and restorability. Annu. Rev. Environ. Resour., 30(1), 39-74. https://doi.org/10.1146/annurev.energy.30.050504.144248

Zhu, G., Xia, C., Shanyun, W., Zhou, L., Liu, L., & Zhao, S. (2015). Occurrence, activity and contribution of anammox in some freshwater extreme environments. Environmental microbiology reports, 7(6), 961-969. https://doi.org/10.1111/1758-2229.12341