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Research Article **Araştırma Makalesi**

The Determination of Trophic Level of Küçükçekmece Lagoon Lake (İstanbul, Türkiye) by Using Some Environmental Variables with Indicator Benthic Macroinvertebrates Findings

Küçükçekmece Lagün Gölü'nün (İstanbul, Türkiye) Bazı Çevresel Değişkenler ve İndikatör Bentik Makroomurgasız Bulgularından Yararlanılarak Trofi Düzeyinin Belirlenmesi

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Abstract: In this study, to determine the trophic level of Küçükçekmece Lagoon Lake, water and sediment samplings were performed at five selected stations seasonally during a year between 2014-2015. The water samples were analyzed to determine some environmental variables (water temperature, pH, conductivity, DO (dissolved oxygen), TDS (total dissolved solids), and salinity. NO_3-N, NO_2-N, SO_4^{-2}, PO_4^{-3}, SiO_2, chlorophyll-*a*, TP (total phosphorus), and Secchi disc light permeability) and benthic macroinvertebrates were examined to determine indicator organisms in the sampled sediment material. Bray-Curtis Similarity Index was used to the observed environmental results to determine the similarities of the sampling stations. According to this, station 1 (St. 1) located in the center of the lake, and St. 5 located near the sea were found to be different from other sampling stations while the stations located near the creeks were found to have much more similar to each other. In addition, to determine the trophy level of the lake, Carlson Trophic State Index (CTSI) was used to the obtained some physicochemical results (Secchi disc permeability, total phosphorus, chlorophyll-*a*) and it was found that the lake showed a eutrophic character during all seasons. According to the result of sediment sampling, an average of 350 individuals per m^2 (44.3 % belonging Polychaeta group; 29.5 % belonging Chironomidae group; 19.7 % belonging Oligochaeta group; 6.5 % belonging Bivalvia group) in a total of 6 benthic macroinvertebrate taxa (Bivalvia, Polychaeta, *Tubificoides benedii* (Oligochaeta), *Tubificoides* sp. (immature Oligochaeta), *Limnodrilus hoffmeisteri* (Oligochaeta), and *Chironomus salinarius* (Chironomidae) were determined. Thus, it is observed that the presence of some indicator species supported eutrophic conditions qualitatively. As a result of this study, it was determined that Küçükçekmece Lagoon lake going on to expose the increasing pollution load.

Keywords
- Benthic macroinvertebrates
- Küçükçekmece Lagoon
- Physicochemical variables
- Pollution
- Trophic level

Özet: Bu çalışmada, Küçükçekmece Lagün Gölü'nün trofi düzeyinin belirlenmesi amacıyla 2014-2015 yılları arasında bir yıl boyunca mevsimsel olarak beş istasyonda su ve sediment örneklemesi yapıldı. Su örneklerinde bazı fizikokimyasal analizler (su sıcaklığı, pH, iletkenlik, DO (çözünmüş oksijen), TDS (toplam çözünmüş madde), tuzluluk. NO_3-N, NO_2-N, SO_4^{-2}, PO_4^{-3}, SiO_2, klorofil-*a*, TP (toplam fosfor) ve seki disk ışık geçirgenliği) yapılırken, sediment örnekleri bentik makroomurgasız içerikleri açısından indikatör organizmaları belirlemek için incelendi. Örnekleme istasyonlarının

Anahtar kelimeler
- Bentik makroomurgasızlar
- Küçükçekmece Lagünü
- Fizikokimyasal değişkenler
- Kirlilik
- Trofi düzeyi

çevresel koşullar açısından benzerliklerini belirlemek için Bray-Curtis İndeksi kullanıldı. Buna göre, göl ortasında bulunan istasyon 1 (St. 1) ve denize yakın bulunan St. 5 diğer örnekleme istasyonlarından farklı bulunurken, derelere yakın bulunan istasyonların birbirine çok benzer olduğu görüldü. Ayrıca, elde edilen fizikokimyasal verilere (Secchi disk görünürlüğü, toplam fosfor, klorofil-*a*) trofi düzeyini belirlemek amacıyla Carlson Trophic State Index (CTSI) uygulandı ve göl suyunun yılın her mevsiminde ötrofik karakter gösterdiği belirlendi. Sediment örneklemesine göre, toplam 6 bentik makroomurgasız taksonuna ait (Bivalvia, Polychaeta, *Tubificoides benedii* (Oligochaeta), *Tubificoides* sp. (immature Oligochaeta), *Limnodrilus hoffmeisteri* (Oligochaeta), ve *Chironomus salinarius* (Chironomidae) m^2'de ortalama 350 birey (44,3 % Polychaeta grubu; 29,5 % Chironomidae grubu; 19,7 % Oligochaeta grubu; 6,5 % Bivalvia grubu) tespit edildi. Böylece, bazı indikatör türlerin varlığının kalitatif olarak ötrofik koşulları destekler nitelikte olduğu gözlendi. Çalışmanın sonucunda, Küçükçekmece Lagün Gölü'nün giderek artan kirlilik yükünü ortaya çıkardığı tespit edildi.

1. INTRODUCTION

The lagoon ecosystems are dynamic and rich in biodiversity. In addition to the rich biodiversity, these ecosystems are important in terms of fisheries productivity, storm protection, agriculture, tourism, and recreation (Anthony et al., 2009). However, especially with the increasing population and pollution load, industry, etc. they may be the ecosystems most exposed to pollution due to various reasons. Küçükçekmece Lagoon Lake is located in the European part of Türkiye (in Istanbul city which is the most populous city of Türkiye). Although the lake was a drinking water reservoir in the 1980s, at the present it is under a pollution load because of intense urbanization (Demirci et al., 2006; Küçükmehmetoğlu & Geymen, 2006). As a result of intense urbanization, increasing industrialization, population increase, and the discharging of wastewater into the lake accelerate eutrophication by increasing the pollution load in the lake (Akşehirli, 2005; Özçalkap & Temel, 2011). The process of eutrophication affects the community structure of aquatic organisms. The first effects of eutrophication begin with the increase of primary production by phytoplankton, which is the first step of the food chain (Yıldız et al., 2007; Heip, 1995). The increased organic material deposited in sediments is in turn assimilated by bacteria, grazing, and detritus-feeding animals. This situation may after all lead to increases in benthic biomass but also anoxic conditions in sediments and the die-off of benthic organisms (Heip, 1995). Especially the benthic macroinvertebrates are the most affected organisms because of living in sediment and they promote the sustainability of the aquatic ecosystems by doing bioturbation and having an important role in the food chain (Covich et al., 1999). In addition, the presence of some species of these organisms is used as biological indicators that give clues about the structure, biological richness, and water quality of the aquatic ecosystem (Kenney et al., 2009; Rizo-Patrón et al., 2013).

This study aims to evaluate the trophic level of Küçükçekmece Lagoon Lake by using some environmental variables and benthic macroinvertebrates. For this purpose, water and benthic sampling were performed at seasonal intervals in the lake for 1 year. Up to now, although there are studies which were performed about the other aquatic organisms (algae, zooplankton, ostracod, zebra mussels, amphipod) of the Küçükçekmece Lake (Külköylüoğlu et al., 1993; Albay et al., 2005; Çamur-Elipek & Kırgız, 2008; Polge et al., 2010; Özçalkap & Temel, 2011; Berber et al., 2018), there has been no detailed study on evaluating together with environmental factors and indicator benthic macroinvertebrates findings in the lake.

2. MATERIAL AND METHODS

2.1. Study Area

Küçükçekmece Lagoon Lake is located in northwest part of Türkiye in European Region (41º00' N-28º43' E). While the average depth of the lake is approximately 10 m, the deepest part is 20 m. A narrow channel connects it to the Marmara Sea and the 3 stream systems (Nakkaşdere, Sazlıdere, and Eşkinoz) feed the lake (Topçuoğlu et al., 1999) (Figure 1).

2.2. Sediment Sampling and Analyses

A total of five sampling stations were selected from the study area and sampled seasonally during a year between 2014 and 2015 for benthic fauna and physicochemical variables (Fig 1). Spring samplings were made in May 2015, and June 2015; Summer samplings were made in June 2014, July 2014, and August 2014; Autumn samplings were made in September 2014, October 2014, and November 2014; Winter sampling was made in February 2015. Data used in the tables and graphics was calculated by taking the average of obtained values in the sampling dates. The coordinates, sampling depth, and characteristics of sampling stations were presented in Table 1. Sediment samples were taken twice by using Ekman grab from each station (15×15 cm^2) for benthic macroinvertebrates. The sediment was washed through on mesh net series (1.5 mm, 0.7 mm, and 0.3) and the remaining materials were preserved in 70% ethanol. In the laboratory, benthic samples were identified to the lowest possible taxonomic category under a stereo binocular microscope. The individual numbers in m^2 of the determined benthic macroinvertebrates taxa were calculated according to stations and seasons. The following literature was used in benthic macroinvertebrates identification; Brinkhurst, 1971; Casellato, 1994; Milligian, 1997; Seys et al., 1999; Nesemann et al., 2004; Šporka, 2009; Çınar et al., 2014; Orel et al., 2014; Yıldız & Ustaoğlu, 2016.

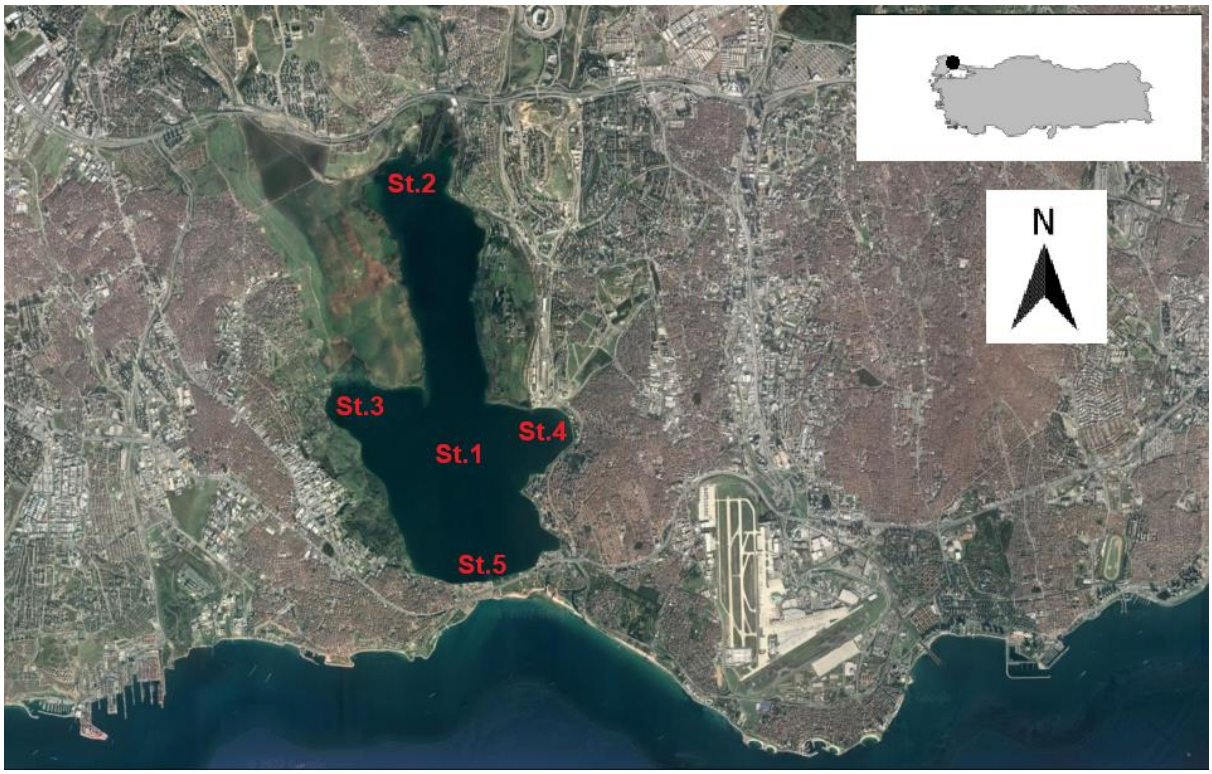

Figure 1. The sampling stations of Küçükçekmece Lagoon Lake

Table 1. The station features, coordinates, and water sampling depth of Küçükçekmece Lagoon Lake

Stations	Coordinates	Stations Features	Water Sampling Depth
St. 1	41°00′18″N, 28°44′47″E	The center of the lake (5-10 m)	5 m
St. 2	41°02′52″N, 28°44′15″E	Near the creek (3-4 m)	1 m
St. 3	41°00′42″N, 28°43′29″E	Near the creek (3-4 m)	1 m
St. 4	41°00′30″N, 28°46′01″E	Near the creek (3-4 m)	1 m
St. 5	40°59′03″N, 28°45′02″E	Near the sea (2-3 m)	1 m

2.3. Water Sampling and Analysis

The water samples were taken by using a Ruttner water sampler from 1-meter depth in each station (except St. 1). During the field studies, A Radiometer Pioneer 65 multi-parameter device was used to measure some environmental variables (temperature, pH, conductivity, dissolved oxygen, TDS (total dissolved solids), salinity) and water transparency was measured by using a Secchi disc in each station. For other analyses (NO_3-N, NO_2-N, SO_4^{-2}, PO_4^{-3}, SiO_2, and TP) the water samples were put into to dark glass bottles (1 lt) and were transported to the laboratory. The analyses were carried out by spectrophotometer (Shimadzu UV 1601) according to APHA-AWWA-WPCF methods (APHA, 1992). Also, chlorophyll-*a* was measured spectrophotometrically according to Nusch (1980). Also, the results of environmental variables findings were evaluated according to the water quality classes included in the water pollution control regulation (WPCR, 2004).

2.4. Statistical Analysis

The seasonal values were calculated by taking the averages of the monthly data. These average values were used in Bray-Curtis Similarity Index to compare similarities between the sampling stations for their environmental variables by the BioDiversity Pro 2.0 program (McAleece et al., 1997). Also, the sampling seasons were compared by using Bray-Curtis Similarity Index. For determining the trophic state of the lake, Carlson's trophic state indices (TSI) (Carlson, 1977) were utilized based on values of chlorophyll-*a* (TSICA), total phosphate (TSITP), and Secchi disk (TSISD). Canonical Correlation Analysis (CCA) was utilized to evaluate the effect of the trophic state and the other physicochemical variables on the dynamic of benthic macroinvertebrates by the Paleontological Statistics Version 3.14 (Hammer et al., 2001). The average number of individuals based on groups of organisms was taken and used in statistical analysis.

3. RESULTS

3.1. Benthic Macroinvertebrates Findings

As a result, It was found that 3 taxa (*Tubificoides benedii* (d'Udekem, 1855) (mature)), *Tubificoides* sp. (immature), *Limnodrilus hoffmeisteri* Claparède, 1862 (mature)) belonging to Oligochaeta come out of 69 individuals/m^2, 1 taxon belonging to Chironomidae (*Chironomus salinarius* Kieffer, 1915) come out of 103 individuals/m^2, 1 taxon belonging to Polychaeta come out of 154 individuals/m^2, and 1 taxon belonging to Bivalvia come out of 22 individuals/m^2 (Table 2). Polychaeta has the highest percentage constituting 44.3 % abundance of the total specimens. It was followed by Chironomidae (with 29.5 %), Oligochaeta (with 19.7 %), and Bivalvia (with 6.5 %), respectively.

In terms of individuals per m^2 at the average in stations St. 4 was the most with 867 individuals/m^2 and followed by St. 5 with 528 individuals/m^2, St. 2 with 189 individuals/m^2, St. 3 with 156 individuals/m^2, and St. 1 with 11 individuals/m^2 (Table 2). During the study period, the maximum number of individuals was found in summer with 1583 individuals/m^2 and followed by autumn with 351 individuals/m^2, winter with 85 individuals/m^2, and spring with 76 individuals/m^2 (Table 2).

Table 2. The individual numbers in m^2 of benthic macroinvertebrates which are determined from sampling stations of Küçükçekmece Lagoon Lake and seasons (St: Station, Ave: Average, Domin: Dominance)

Stations ⟶	**St. 1**	**St. 2**	**St. 3**	**St. 4**	**St. 5**	**Ave**	**Domin.**
BIVALVIA	0	0	45	11	56	**22**	**6.5**
POLYCHAETA	11	122	89	411	139	**154**	**44.3**
OLIGOCHAETA *T. benedii* (d'Udekem, 1855) *Tubificoides* sp. Lastockin, 1937 *L. hoffmeisteri* Claparede, 1862	0	0	0	17	333	**69**	**19.7**
CHIRONOMIDAE *C. salinarius* Kieffer, 1915	0	67	22	428	0	**103**	**29.5**
Total	**11**	**189**	**156**	**867**	**528**	**350**	

Seasons ⟶	**Spring**	**Summer**	**Autumn**	**Winter**
BIVALVIA	76	13	0	0
POLYCHAETA	0	342	227	49
OLIGOCHAETA *T. benedii* (d'Udekem, 1855) *Tubificoides* sp. Lastockin, 1937 *L. hoffmeisteri* Claparede, 1862	0	218	44	18
CHIRONOMIDAE *C. salinarius* Kieffer, 1915	0	396	18	0
Total	**76**	**1583**	**351**	**85**

3.2. Environmental Variables Findings

The seasonal values and their average and standard deviation of some physicochemical variables measured from the lake were given in Table 3. While the average of pH (8.38), temperature (18.43 ºC), DO (9.75 mg/L), SO_4^{-2} (41.31 mg/L), and NO_3-N (0.53 mg/L) values were determined in the first class water quality, the average of NO_2-N (0.07 mg/L) was the fourth class, PO_4^{-3} (0.4 mg/L) was the third, TDS (14.35 g/L) was the second class water quality according to the water pollution control regulation (WPCR, 2004). The high average conductivity (19.7 mho/cm), TDS (14.35 g/L) and salinity (ppt) values are proof of the input of seawater. According to the water pollution control regulation, in terms of chlorophyll-*a* (34.6 µg/L) and total phosphorus (0.6 mg/L), average values exceed the acceptable values (WPCR, 2004).

Table 3. Physicochemical variables in Küçükçekmece Lagoon Lake during the study period

	Spring	Summer	Autumn	Winter	Average	Water Quality Classes
Temp.	23.1	27.0	15.3	8.3	**18.43± 8.32**	**I**
pH	8.1	8.5	7.9	9.0	**8.38± 0.49**	**I**
Cond.	21.9	23.6	20.2	13.1	**19.7± 4.61**	**-**
DO	8.3	9.8	7.5	13.4	**9.75± 2.61**	**I**
TDS	15.0	14.8	15.1	12.5	**14.35± 1.24**	**II**
Salin.	14.1	13.7	15.2	11.4	**13.6± 1.6**	**-**
NO_3-N	0.6	1.0	0.2	0.5	**0.58± 0.33**	**I**
NO_2-N	0.04	0.02	0.12	0.09	**0.07± 0.05**	**IV**
SO_4^{-2}	32.54	47.48	37.23	48.0	**41.31± 7.67**	**I**
PO_4^{-3}	0.3	0.5	0.5	0.3	**0.40± 0.12**	**III**
SiO_2	1.11	2.06	2.90	5.84	**2.98± 2.04**	**-**
CA	55.6	41.2	10.3	31.3	**34.6± 19.03**	**-**
SD	78	104	166	85	**108.25± 40.04**	**-**
TP	0.6	0.7	0.6	0.5	**0.6± 0.08**	**-**

Cond: Conductivity (mho/cm); Temp: Temperature (ºC); CA: chlorophyll-*a* (µg/L); DO: Dissolved Oxygen (mg/L); Salin: Salinity (ppt); SD: Secchi Disc (cm); TP: Total Phosphorus (mg/L); TDS: Total Dissolved Solids (g/L)

While Bray-Curtis Similarity Index showed that the most similar seasons were found as summer and spring (88.2% similarity), the most similar stations were found as St. 2, St. 3, and St. 4 (98.1% similarity) (Figure 2 a, b).

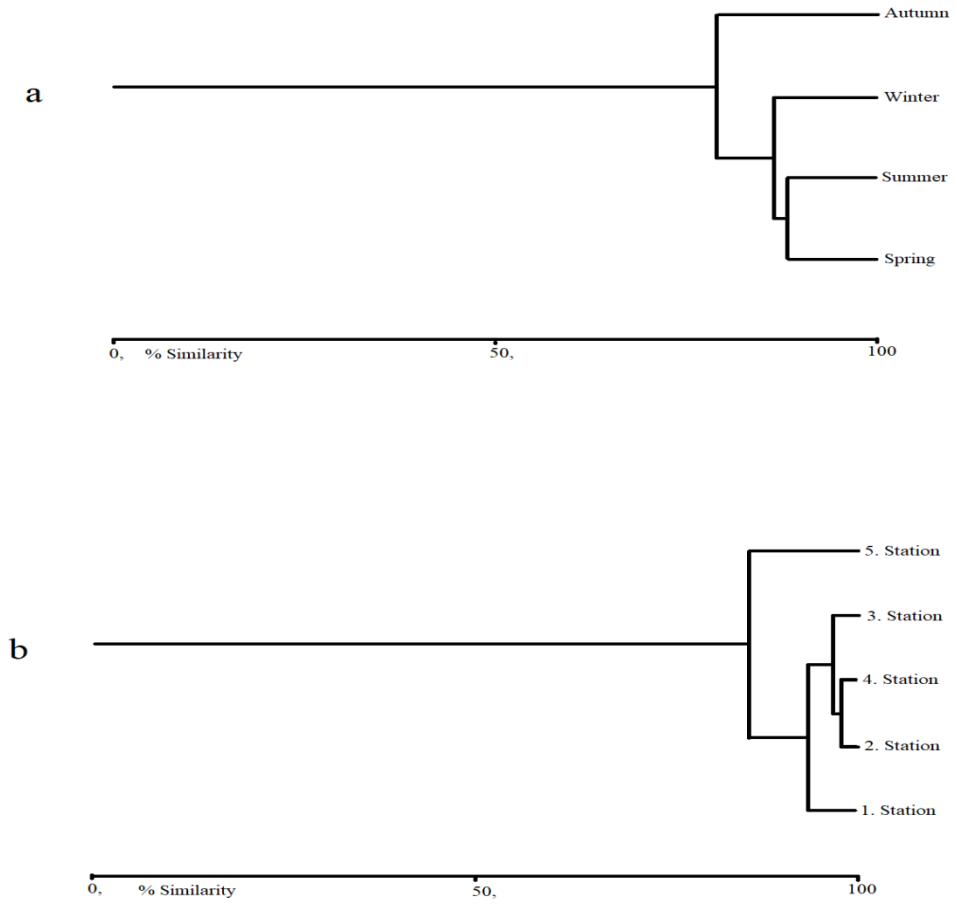

Figure 2. The dendrogram of similarity of seasons (a) and stations (b) in Küçükçekmece Lagoon Lake in relative to the physicochemical variables

Concerning Carlson's trophic state index results which were measured based on TP, CA, and SD; all index values exceed the eutrophication limits during all the sampling seasons (Table 4). In terms of Carlson's trophic state index (CTSI) values, the water of the lake showed a eutrophic character during all seasons of the year and it means the dominance of blue-green algae, algal scums, and dense macrophytic problems (Carlson, 1977).

Table 4. Carlson's trophic state index (CTSI) values according to the sampling seasons of the Küçükçekmece Lagoon Lake.

	Spring	Summer	Autumn	Winter	Average
TSI (CD)	65.3	66.7	51.5	63.5	**62**
TSI (SD)	64.22	60.11	53.50	62.38	**60**
TSI (TP)	97.24	98.22	95.71	94.7	**96**
CTSI	75.58	75.01	66.91	73.54	**73**

In the Canonical Correlation Analysis (CCA), the eigenvalues of the first two axes were calculated as 0.775 and 0.197, respectively. In the analysis, the two axes explain 98,47% of the variance of the species, 78.47% (Axis 1) and 20% (Axis 2). Concerning the CCA, while the distribution of Polychaeta (Poly), *T. benedii*, and *L. hoffmeisteri* (L. hoffm) was affected by NO_2-N, SiO_2, DO, and SD, it was not affected by salinity, CA, TDS, CTSI, conductivity, temperature, TP, and NO_3-N (Figure 3). SO_4^{-2}, PO_4^{-3}, and pH affected the distribution of *C. salinarius* (C. salin) and *Tubificoides* sp. (T. sp.). Also, the analysis results show that environmental variables do not affect the distribution of Bivalvia (Figure 3).

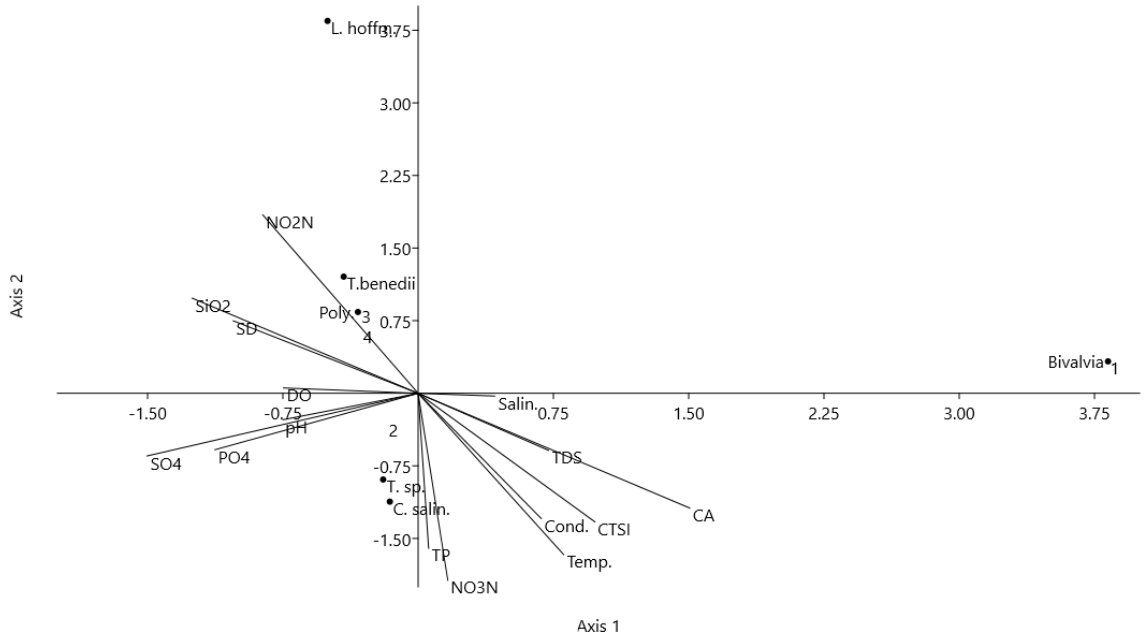

Figure 3. CCA between physicochemical variables and benthic macroinvertebrate taxa

4. DISCUSSION

In the present study, it was determined that the identified species were found to be more tolerant species that adapt to eutrophic conditions. It has been reported that some Polychaeta species and *T. benedii* are dominated by increasing eutrophication conditions and changing climatic conditions

(Giere et al., 1999; Schückel & Kröncke, 2013). In this study, according to the CCA analysis results, it was shown that CTSI value did not affect the distribution of Polychaeta and *T. benedii* species in the lake. (Figure 3). Although *L. hoffmeisteri* is a common freshwater worm, it can be found in lagoons systems and often regarded as an indicator of organic pollution (Lobo & Alves, 2011). In terms of physicochemical variables, the identified species were tolerant. *C. salinarius* determined in this study in summer and autumn, prefers aquatic ecosystems which have a wide salinity spectrum and tolerate variations in salinity (Drake & Arias, 1995; Zinchenko et al., 2019; Michailova et al., 2021). *L. hoffmeisteri* has a tolerance to nitrogen compound and acts as a sink for inorganic nitrogen via bioturbation (Shang et al., 2014).

Three stations (St. 2, St. 3, and St. 4) were found to have the most similar to each other (Figure 2b; about 90%) in terms of the similarity of stations the lake in relative to the physicochemical variables and it can say that this similarity because of being close to the streams (Figure 1). In addition, the season autumn showed a difference from the others (Figure 2 a) and it can be a result of seawater mixing with the lake water in autumn when the water level of the lake decreases and this case can affect the physicochemical variables.

The physicochemical variables of chlorophylla-*a*, total phosphorus, PO_4^{-3}, Secchi disc, NO_2-N, and NO_3-N are important in the evaluation of the trophy state. In this study, while NO_2-N and NO_3-N averages were found to be acceptable limits, the others were found between hypertrophic limits according to the water pollution control regulation (WPCR, 2004). But, the effects of eutrophication are usually more related to phosphorus than to nitrogen compounds and organic matter (Sara 2007).

In the previous studies in the Küçükçekmece Lagoon Lake, it was concluded that the lake had an apparent feature of eutrophication in terms of the phytoplankton, zooplankton compositions and water quality (Özçakalp & Temel, 2011; Demirci et al., 2006; Yılmaz, 2015; Polge et al., 2010; Albay et al., 2005). The present study results showed a eutrophic state in terms of both the benthic macroinvertebrates findings and some physicochemical variables (conductivity, NO_2-N, PO_4^{-3}, chlorophyll-*a*, TP (total phosphorus), and Secchi disc light permeability). For the composition of the benthic macroinvertebrate, diversity and individuals per square meter values were low and the determined taxa were tolerant taxa adapt to eutrophic conditions. According to Heip (1995), increased organic loadings lead to the upward movement of reducing conditions and anoxia in sediments and ultimately in the water column, and this shifts sediments from aerobic to anaerobic pathways that can lead to the disappearance of the benthic macroinvertebrates fauna. For the physicochemical variables, especially the parameters chlorophylla-*a*, total phosphorus, PO_4^{-3}, SiO_2, and Secchi disc that have a great effect on the eutrophication process were determined at high rates.

5. CONCLUSION

According to the results of this study, it can be concluded that there is an intensive pollution load to the Küçükçekmece Lagoon lake because of industrial, agricultural, and domestic waste, and urbanization around the lake. In terms of the protection and sustainability of Küçükçekmece Lagoon Lake, it is recommended to monitor the lake with such biological and chemical studies.

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CONFLICT of INTEREST

The authors declare that they have no financial interests or personal relationships that could affect this work.

AUTHOR CONTRIBUTIONS

All authors contributed equally.

ETHICAL STATEMENT

There are no ethical issues with the publication of this manuscript.

DATA AVAILABILITY STATEMENT

Data used in this study are available from the corresponding author upon reasonable request.

REFERENCES

Akşehirli, İ. (2005). *A landscape analysis of Küçükçekmece lake and its surroundings for ecological planning*. [Master's thesis, İstanbul University].

Albay, M., Matthiensen, A., & Codd, G. A. (2005). Occurence of toxic blue-green algae in the Kucukcekmece lagoon (Istanbul, Turkey). *Environmental. Toxicology, 20*, 277-284. https://doi.org/10.1002/tox.20118

Anthony, A., Atwood, J., August, P., Byron, C., Cobb, S., Foster, C., Fry, C., Gold, A., Hagos, K., Heffner, L., Kellogg, D. Q., Lellis-Dibble, K., Opaluch, J. J., Oviatt, C., Pfeiffer-Herbert, A., Rohr, N., Smith, L., Smythe, T., Swift, J., & Vinhateiro, N. (2009). Coastal lagoons and climate change: ecological and social ramifications in U.S. Atlantic and Gulf coast ecosystems. *Ecology and Society, 14*(1), 8. https://doi.org/10.5751/ES-02719-140108

APHA-AWWA-WPCF (1992). *Standard methods for the examination of water and waste water*. American Water Works Association and Water Pollution Control Federation, Washington DC.

Berber, S., Ateş, A. S., & Acar, S. (2018). First observation of the zebra mussel (Dreissena polymorpha (Pallas, 1771)) on the narrow-clawed crayfish inhabiting in some water sources of Turkey. *Ege Journal of Fisheries and Aquatic Sciences, 35*(1), 55-61.

Brinkhurst, O. R. (1971). *British Aquatic Oligochaeta*. Univ. Toronto Press, Toronto.

Carlson, R. E. (1977). A trophic state index for lakes. *Limnology and Oceanography, 22*, 361-369. https://doi.org/10.4319/lo.1977.22.2.0361

Casellato, S. (1994). Oligochaete fauna of estuarine areas and lagoons on the northern Adriatic coast (Italy. *Italian Journal of Zoology, 61*(3), 261-269. https://doi.org/10.1080/11250009409355893

Covich, A. P., Palmer, M. A., & Crowl, T. A. (1999). The Role of benthic invertebrate species in freshwater ecosystems. *BioScience, 49*, 119-127. https://doi.org/10.2307/1313537

Çamur-Elipek, B., & Kırgız, T. (2008). Contribution to the knowledge of the distribution of Orchestia cavimana Heller, 1865 (Amphipoda, Talitridae) in Turkey. *Ege University Journal of Fisheries and Aquatic Sciences, 25*(4), 333-335.

Çınar, M. E., Dağlı, E., & Kurt-Şahin, G. (2014). Checklist of Annelida from the coasts of Turkey. *Turkish Journal of Zoology, 38*, 734-764. https://doi.org/10.3906/zoo-1405-72

Demirci, A., McAdams, M. A., Alagha, O., & Karakuyu, M. (2006, Sep 13-16). *The relationship between land use change and water quality in Küçükçekmece Lake Watershed*. 4th GIS Days in Türkiye, İstanbul, Turkey.

Drake, P., & Arias A. M. (1995). Distribution and production of Chironomus salinarius (Diptera: Chironomidae) in a shallow coastal lagoon in the Bay of Cádiz. *Hydrobiologia, 299*(3), 195-206. https://doi.org/10.1007/BF00767326

Giere, O., Preusse, J. H., & Dubilier, N. (1999). Tubificoides benedii (Tubificidae, Oligochaeta) - a pioneer in hypoxic and sulfidic environments. An overview of adaptive pathways. *Hydrobiologia, 406*, 235–241. https://doi.org/10.1023/A:1003711914788

Hammer, Ø., Harper, D. A. T., & Paul, D. R. (2001). Past: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica, 4*(1), 9.

Heip, C. (1995). Eutrophication and Zoobenthos Dynamics. *Ophelia, 41*, 113-136. https://doi.org/10.1080/00785236.1995.10422040

Kenney, M. A., Sutton-Grier, A. E., Smith, R. F., & Gresens, S. E. (2009). Benthic macroinvertebrates as indicators of water quality: The intersection of science and policy. *Terrestrial Arthropod Reviews, 2*, 99-128. https://doi.org/10.1163/187498209X12525675906077

Küçükmehmetoğlu, M., & Geymen, A. (2006, Aug 30 - Sep 3). *The spatial impacts of rapid urbanization on the limited surface water resources in İstanbul.* the 46th Congress of the European Regional Science Association, Volos, Greece.

Külköylüoğlu, O., Altınsaçlı, S., & Kubanç, C., (1993). The Ostracoda (Crustacea) fauna of Küçükçekmece Lake (İstanbul) and seasonal distributions. *Turkish Journal of Zoology, 17*, 19-27.

Lobo, H., & Alves, R. G. (2011). Influence of body weight and substrate granulometry on the reproduction of Limnodrilus hoffmeisteri (Oligochaeta: Naididae: Tubificinae). *Zoologia, 28*(5), 558-564. https://doi.org/10.1590/S1984-46702011000500002

McAleece, N., Gage, J. D. G., Lambshead, P. J. D., & Paterson, G. L. J. (1997). *BioDiversity Professional statistics analysis software*. Jointly developed by the Scottish Association for Marine Science and the Natural History Museum London.

Michailova, P., Szarek-Gwiazda, E., & Kownacki, A. (2021). Physicochemical characteristics of the Dombrovska pit lake (Ukraine) formed in an opencast potassium salt mine and the genomeresponse of Chironomus salinarius Kieffer (Chironomidae, Diptera) to these conditions. *Environmental Science and Pollution Research, 28*, 446-458. https://doi.org/10.1007/s11356-020-10465-0

Milligian, M. R. (1997). *Identification manual for the aquatic Oligochaeta of Florida. Volume I. Freshwater oligochaetes.* State of Florida Department of Environmental Protection Tallahassee, Florida.

Nesemann, H., Sharma, G., & Sinha, R. K. (2004). Aquatic Annelida (Polychaeta, Oligochaeta, Hirudinea) of the Ganga River and adjacent water bodies in Patna (India: Bihar), with description of a new leech species (Family Salifidae). *Annalen des Naturhistorischen Museums in Wien, 105B*, 139-187.

Nusch, E. (1980). Comparison of different methods for chlorophyll and phaeopigment determination. *Archiv für Hydrobiologie–Beiheft Ergebnisse der Limnologie, 14*, 14-36.

Orel (Zorina), O. V., Istomina, A. G., Kiknadze, I. I., Zinchenko, T. D., & Golovatyuk, L. V. (2014). Redescription of larva, pupa and imago male of Chironomus (Chironomus) salinarius Kieffer from the saline rivers of the Lake Elton basin (Russia), its karyotype and ecology. *Zootaxa, 3841*(4), 528-550. https://doi.org/10.11646/zootaxa.3841.4.4

Özçalkap, S., & Temel, M. (2011). Seasonal changes in zooplankton community structure in Lake Küçükçekmece, İstanbul, Turkey. *Turkish Journal of Zoology, 35*(5), 689-700. https://doi.org/10.3906/sag-1205-78

Polge, N., Sukatar, A., Soylu, E. N., & Gonulol, A. (2010). Epipelic algal flora in the Küçükçekmece Lagoon. *Turkish Journal of Fisheries and Aquatic Sciences, 10*, 39-45. https://doi.org/10.4194/trjfas.2010.0106

Rizo-Patrón, V. F., Kumar, A., McCoy Coltonc, M. B., Springerd, M., & Trama, A. (2013). Macroinvertebrate communities as bioindicators of water quality in conventional and organic irrigated rice fields in Guanacaste, Costa Rica. *Ecological Indicators, 29,* 68-78. https://doi.org/10.1016/j.ecolind.2012.12.013

Sara, G. (2007). A meta-analysis on the ecological effects of aquaculture on the water column: dissolved nutrients. *Marine and Environmental Research, 63,* 390-408. https://doi.org/10.1016/j.marenvres.2006.10.008

Schückel, U., & Kröncke, I. (2013). Temporal changes in intertidal macrofauna communities over eight decades: A result of eutrophication and climate change. *Estuarine, Coastal and Shelf Science, 117,* 210-218. https://doi.org/10.1016/j.ecss.2012.11.008

Seys, J., Vincx, M., & Meire, P. (1999). Spatial distribution of oligochaetes (Clitellata) in the tidal freshwater and brackish parts of the Schelde estuary (Belgium). *Hydrobiologia, 406,* 119-132. https://doi.org/10.1023/A:1003751512971

Shang, J., Liao, Q., Zhang, L., & Fan, C. (2014). The influence of different benthic fauna on inorganic nitrogen flux and denitrification in a large shallow hyper-eutrophic lake. *Fundamental Applied Limnology, 184*(2), 101-108. https://doi.org/10.1127/1863-9135/2014/0431

Šporka, F. (2009). First record of the neozoan species Branchiodrilus hortensis (Stephenson, 1910) (Oligochaeta, Naididae) from Slovakia. *Lauterbornia, 67,* 145-149.

Topçuoğlu, S., Güngör, N., & Kırbaşoğlu, Ç. (1999). Physical and chemical parameters of brackish water lagoon, Küçükçekmece Lake, in Northwestern Turkey. *Toxicological and Environmental Chemistry, 69,* 101–108. https://doi.org/10.1080/02772249909358691

WPCR, (2004). *Water Pollution Control Regulation,* Official Gazette Dated December 31, 2004. Number: 25687, http://suyonetimiormansu.gov.tr.

Yıldız, S., & Ustaoğlu, M. R. (2016). Two New Records For The Brackish water Oligochaeta (Annelida: Naididae: Tubificinae) From The Aegean Coastal Ecosystem (Turkey). *Turkish Journal of Fisheries and Aquatic Sciences 16,* 395-399. https://doi.org/10.4194/1303-2712-v16_2_19

Yıldız, Ş., Altındağ, A., & Borga Ergönül, M. (2007). Seasonal fluctuations in the zooplankton composition of a eutrophic lake: Lake Marmara (Manisa, Turkey). *Turkish Journal of Zoology, 31*, 121-126.

Yılmaz, N. (2015). Diversity of phytoplankton in Kucukcekmece Lagoon channel, Turkey. *Maejo International Journal of Science and Technology, 9*(1), 32-42. https://doi.org/10.14456/mijst.2015.4

Zinchenko, T. D., Golovatyuk, L. V., & Abrosimova, E. V. (2019) Non-bitingmidges (Diptera, Chironomidae) in the benthic communities of saline rivers in the Lake Elton Basin: diversity, salinity tolerance, and distribution. *Entomological Review, 99*(6), 820-835. https://doi.org/10.1134/S0013873819060095