Biologia (2024) 79:1251–1266
https://doi.org/10.1007/s11756-024-01612-w

ORIGINAL ARTICLE

The effects of salinity on phytoplankton community structure in the 6 lagoons of the Marmara Basin (Türkiye)

Hatice Tunca[1] · Tuğba Ongun Sevi̇ndi̇k[1] · Halim Aytekin Ergül[2] · Mert Kaya[2] · Fatih Ekmekçi̇[3] · Melih Kayal[3] · Barış Güzel[4] · Oltan Canli[4]

Received: 19 January 2023 / Accepted: 15 January 2024 / Published online: 13 February 2024

Abstract

Although the effect of salinity on phytoplankton community structure has been studied in many coastal lagoons at different times, it has not been studied simultaneously in different lagoons that are not on the same delta but are geographically close to each other. In the present study, the effect of temporal and spatial changes in salinity on the phytoplankton biovolume, species richness, diversity, and species composition was investigated seasonally in 2020 and 2021 in 6 coastal lagoons of Marmara Basin (Türkiye). In more saline lagoons, phytoplankton biovolume, species richness, diversity, and the total number of species were lower. In lagoons which salinity values were approximate, the species composition was similar. Although the salinity in the lagoons did not show significant change seasonally, biovolume values were lower in Mert lagoon in the fall of 2020 when the salinity values were higher compared to the spring of 2021. Moreover, the considerable decrease in salinity shifted the dominant species structure from high salinity optima species to low salinity optima species in this lagoon. Other effective parameters in the seasonal distribution of dominant species were detected as temperature, dissolved oxygen, alkalinity, and nitrate nitrogen.

Keywords Biovolume · Diversity · Marmara Basin · Phytoplankton · Salinity

Introduction

Anthropogenic pressures on aquatic systems have been more effective due to increased human population and industrialization, especially in the last century. Human-induced eutrophication and the effects of climate change are two major problems for coastal lagoons (Cloern 2001; Lloret et al. 2008) as in other freshwater lakes (Dugan et al. 2017; Woolway et al. 2020). Increased temperature and decreased precipitation due to climate change cause alterations such as salinity, lake water level, lake water temperature, and biota, especially in lagoons of arid and semi-arid regions

---

✉ Tuğba Ongun Sevi̇ndi̇k
tsevindik@sakarya.edu.tr

Hatice Tunca
htunca@sakarya.edu.tr

Halim Aytekin Ergül
halim.ergul@kocaeli.edu.tr

Mert Kaya
mertkayaa.09@gmail.com

Fatih Ekmekçi̇
fekmekci@dsi.gov.tr

Melih Kayal
melihkayal@dsi.gov.tr

Barış Güzel
guzelbaris08@gmail.com

Oltan Canli
oltan.canli@gmail.com

[1] Faculty of Science, Department of Biology, Sakarya University, Sakarya 54050, Türkiye

[2] Science and Literature Faculty, Department of Biology, Kocaeli University, Kocaeli 41380, Turkey

[3] General Directorate of State Hydraulic Works, Investigating, Planning and Allocations Department, Ankara 06100, Turkey

[4] TUBITAK Marmara Research Centre, Environment and Cleaner Production Institute, Kocaeli 41470, Turkey

(Angus 2017; Shalby et al. 2021). Particularly salinization is becoming a comprehensive environmental problem due to its ecological and economic effects (Rochette et al. 2010; Odountan et al. 2019). Besides climate change, deicing salts usage for safe driving during winter (Corsi et al. 2010), mineral fertilizers used for agricultural productivity (Barzegar et al. 2017), industrialization, and urbanization (Dugan et al. 2017) have increased the salinity level of aquatic systems.

Phytoplankton are effective indicators used in the evaluation of water quality, trophic status, and ecological conditions of coastal ecosystems as well as other ecosystems (e.g. lakes, open sea) due to their rapid response to environmental changes (Lugoli et al. 2012; Garmendia et al. 2013; Allende et al. 2019). Previous studies have shown that the response of phytoplankton to changing salinity is very diverse (Lancelot and Muylaert 2011; Wang et al. 2018). Depending on the interspecific differences in salinity tolerances, the change in salinity affects the phytoplankton diversity (Kirst 1989; Zhong et al. 2016). It has been reported that some species can survive with a wide range of salinity levels (Shikata et al. 2008; Bergesch et al. 2009). On the other hand, most species cannot tolerate increased concentrations or rapid changes in salinity, and consequently both species richness and diversity index decline with increasing salinity (Hammer 1986; Flöder and Burns 2004; Wang et al. 2018). Species number and diversity were detected as low in brackish waters such as lagoons compared with freshwater and marine water systems due to their highly variable salinity concentrations (Flöder and Burns 2004; Flöder et al. 2010). In addition, previous studies have suggested that taxonomic groups of phytoplankton shifted from Cyanobacteria and Chlorophyta to Bacillariophyta (diatoms) and Miozoa (Dinoflagellate) depending on salinity increase (Kies 1997; Muylaert and Sabbe 1999; Li et al. 2021). Although many studies have shown that salinity reduces phytoplankton biomass due to decreased growth rate (Kirst 1989; Evagelopoulos et al. 2007; Redden and Rukminasari 2008; Hernando et al. 2015), some other studies have shown that the high nutrient levels attenuated the inhibitory effect of salinity on phytoplankton biomass (Zhong et al. 2016; Yue et al. 2019).

Since the effect of the salinity gradient is more pronounced in estuarine systems and lagoons, they have been ideal systems for elucidating the effect of salinity on phytoplankton dynamics (Telesh and Khlebovich 2010; Zainol and Akhir 2019). Increased, decreased or absent freshwater inflow, increased evaporation, and seawater entrance by tidal flow during different hydrological periods cause significant spatial and temporal variability in salinity values (Zainol and Akhir 2019; Srichandan et al. 2019; Draredja et al. 2019). Therefore, the temporal and spatial distribution in phytoplankton community structure was observed as a result of changes in environmental parameters, and more dominantly changes in salinity (Haraguchi et al. 2015; Srichandan et al. 2019; Tarafdar et al. 2021). In most temperate and tropical lagoons, it was observed that higher freshwater inflow reduces the salinity concentration and increases the nutrients, and consequently, triggers the biomass increase (Froneman 2004; Gobler et al. 2005; Paerl et al. 2018). On the other hand, other studies have also stated biomass increases due to low or absent flow rates and disconnection with the sea which constitute higher residence time (Ortega-Cisneros et al. 2014).

Lagoons are located mostly in delta regions (Kızılırmak, Yeşilırmak, Büyük Menderes, Küçük Menderes, Gediz, Göksu deltas) in Türkiye. Although there are many lagoons in the Marmara Basin, they are not located on the same delta (Atalay et al. 2015). In recent years, the seasonal distribution of species composition, biodiversity, abundance, and dominant species was investigated for detecting water quality in Küçükçekmece (Yilmaz 2015; Yilmaz et al. 2021a)yükçekmece (Temel 2002; Aktan et al. 2009; Gülecal and Temel 2014; Yilmaz 2019) and Terkos (Yilmaz and Gülecal 2012; Yilmaz et al. 2021b) lagoons, their inlet streams or outlet channels in separate times. Many studies have been conducted on the effects of seasonality, hydrodynamic regime, climate change, and anthropogenic disturbance on the salinity and the phytoplankton community structure of a single coastal lagoon (Jacquet et al. 2006; Nche-Fambo et al. 2015; Caroppo et al. 2018; Derolez et al. 2020). However, there is a lack of studies that collectively evaluate the change in the salinity levels and its effect on phytoplankton of lagoons that are geographically close to each other and have the same trophic condition. The present study is the first study considering the 6 eutrophic lagoons in the Marmara Basin to determine the effect of salinity gradients among lagoons regarding the phytoplankton species richness, diversity, biovolume, the total number of species, taxonomic groups, and dominant species. In the present study: (1) We hypothesize that phytoplankton species richness, diversity, biovolume, the total number of species, and species composition would change in accordance with the salinity gradient among the 6 lagoons. (2) We further hypothesized that besides salinity, other environmental factors would also be effective in the spatial distribution of phytoplankton biovolume and dominant species. (3) Moreover, we hypothesize that as a result of seasonal changes in environmental parameters such as salinity, temperature, and nutrients, seasonal changes would occur in phytoplankton biovolume, species richness, diversity, and dominant species.

Materials and methods

Marmara Basin and studied lakes

The Marmara Basin with a catchment area of 24,100 km^2 covers the precipitation areas of rivers which mostly pour into the Marmara Sea. Its catchment area comprises 3% of the Türkiye. It has boundaries with the Meriç-Ergene, Sakarya, Susurluk, and North Aegean basins. The basin includes the cities such as İstanbul, Kocaeli, and Bursa with the highest population density and industrialization in Türkiye (Özhan 2004). Therefore, domestic, and industrial wastewater have polluted the aquatic environments in the basin (Ergul and Karademir 2020). Due to the large population in İstanbul, the demand for usable water is increasing every year, and consequently, forces the existing water resources (ISKI 2023).

The Marmara Basin has a mild oceanic climate with rainy/snowy days in winter, but a long dry period in summer. The average precipitation is between 586 and 768 mm, and most rainfall occurs in the winter (Serengil et al. 2007). In the basin, during the winter period, the average temperatures were 5–6 °C while in the summer period, temperatures of 23–25 °C were reported (Directorate General of Water Management 2016).

Although there are natural lakes in the basin, many reservoirs were constructed due to the increasing water demand. There are also lagoons in the basin. The 6 eutrophic lagoons of Marmara Basin [Terkos Lagoon (TER), Büyük Çekmece Lagoon (BCK), Dalyan Lagoon (DAL), Hersek Lagoon (HER), Küçükçekmece Lagoon (KCK), and Mert Lagoon (MER)] were studied in the fall and spring of 2020 and 2021 (Fig. 1) (Table 1).

Terkos Lagoon (TER) which is situated 50 km northwest of Istanbul (Yilmaz and Gülecal 2012), was a natural lagoon until 1881. However, with the construction of a barrier between the lagoon and the Black Sea, it gained a freshwater status, and it has been used for the drinking water supply of Istanbul. It is fed by a lot of streams including Istranca, Sivasköy, and Çiftlikköy (Oğuz 1995). Büyük Çekmece Lagoon (BCK) has an important place among the surface waters within the province of Istanbul in terms of its size. It is located on the European side of Istanbul, near Çatalca (Yilmaz 2019). It was a natural lagoon due to its formation and discharges of its waters into the Sea of Marmara. However, due to the construction of a barrier at the connection point with the Sea of Marmara in 1985 to meet the water needs of Istanbul city, it turned into a freshwater lake over time (Özuluğ 1999). It is mainly fed by the Karasu Stream (Özuluğ 1999). Mert Lagoon (MER) is located in İğneada Longoz Forests on the Black Sea coast. This area has been announced as a Natural Site and National Park. There are three lagoons in the area which are fed by groundwaters and streams, and Mert Lagoon is the biggest one. This lagoon

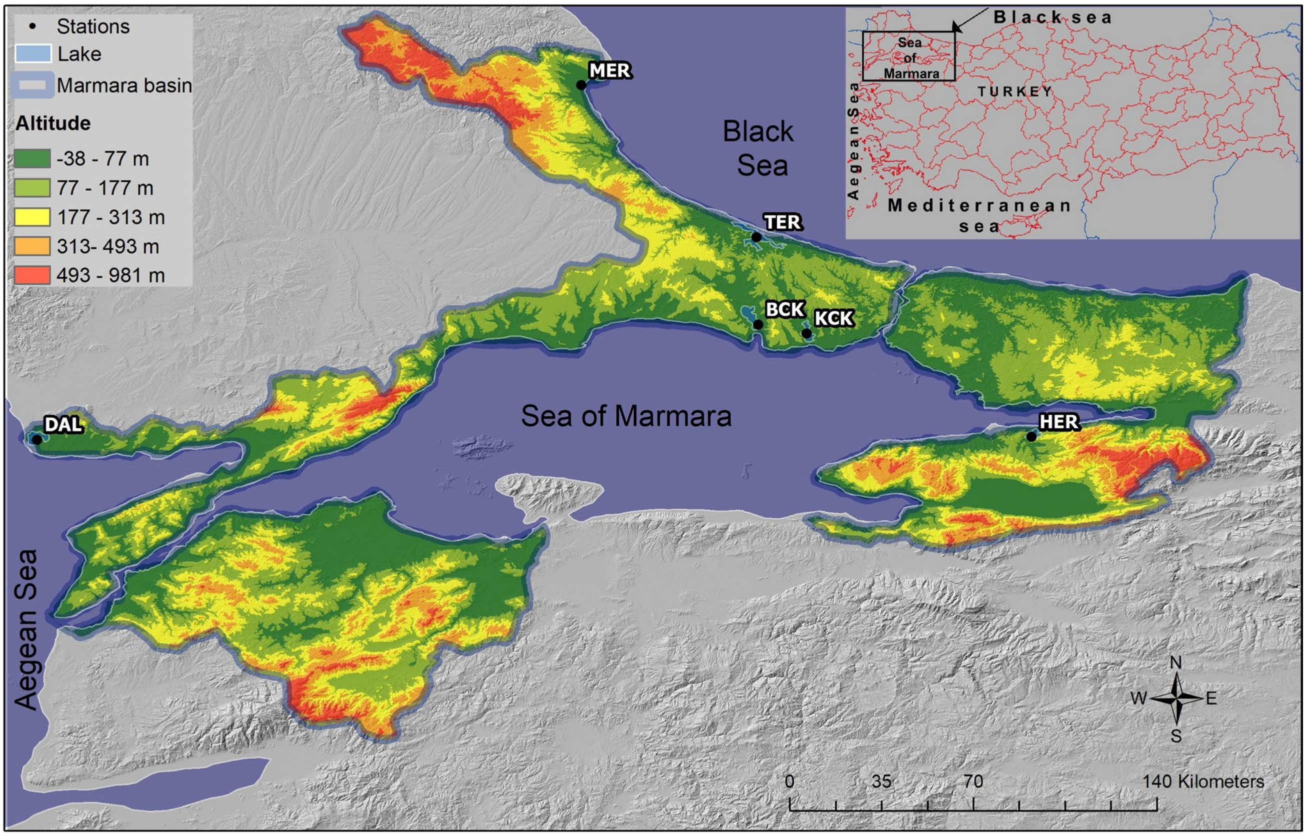


Fig. 1 Location of sampling lagoons in the Marmara Basin (The full names of the lagoons were given in Table 1)

Table 1 The general features of the 6 lagoons in the Marmara Basin (z_{max} denotes the measured minimum and maximum depths at the deepest station of each lake during the studied period)

Lakes	Station code	Number of sampling stations	Surface area (Km^2)	z_{max} (m)	Trophic index	Altitude (m)	Coordinate	
							Latitude	Longitude
Terkos Lagoon	TER	3	39	7–8	52.34 (eutrophic)	2	41°20′30″N	28°34′18″E
Büyükçekmece Lagoon	BCK	3	43	2–7	57.97 (eutrophic)	2	41°02′22″N	28°34′48″E
Mert Lagoon	MER	2	2.22	1-1.5	59.85 (eutrophic)	1	41°51′45″N	27°58′13″E
Küçükçekmece Lagoon	KCK	2	14	12–20	61.80 (eutrophic)	1	41°00′39″N	28°44′34″E
Dalyan Lagoon	DAL	2	3.4	0.3–0.5	55.09 (eutrophic)	1	40°42′58″N	26°04′23″E
Hersek Lagoon	HER	2	1.52	0.3-1	53.75 (eutrophic)	1	40°43′07″N	29°31′05″E

is separated from the Black Sea in the east by sandy dunes. However, with the rising of the waters, it sometimes merges with the sea (Altınsaçlı 2001; Güher 2003; Camur-Elipek et al. 2015). Küçükçekmece Lagoon (KCK) is located 15 km west of Istanbul, and the connection of the lagoon with the Sea of Marmara is provided by the Menekşe Stream, which is 1.5 m deep and 1 km long (Okumuş 2007). Due to the connection channel, lagoon water is saline character. The lagoon is fed by Nakkaşdere, Sazlıdere, and Ispartakule streams (Demirci et al. 2006). Due to the intense urbanization and industrialization around the lagoon, it is affected by different pollutants such as domestic and industrial wastes (Albay et al. 2005). Dalyan Lagoon (DAL) is situated on the Meriç River Delta (Enez district, Edirne) which is one of the nationally important wetlands for Türkiye. It is a natural habitat for many bird species. This lagoon is temporarily connected to the Aegean Sea with two narrow channels, therefore, the salinity of the water varies according to the seasons (Sezgin 2015; Senel et al. 2020). Hersek Lagoon (HER) which is separated from the sea with a sandy ridge, is located near to Gulf of Izmit in the eastern part of the Sea of Marmara (Dalkıran and Baki 2011). This sandy ridge has been reinforced with a concrete dike, but the grooves on the dike allow continuous water exchange. The Sea of Marmara, rainfall, and runoff are the main water resources of the lagoon (Uzun 2014). However, domestic, and industrial pollution due to Izmit Bay affected the water quality of the lagoon (Tolun et al. 2008).

Analysis of environmental variables

Three different depths were determined as surface (10 cm below), middle, and near the bottom for sampling and measuring physical and chemical variables, and the mean values of these three depths were used in the analyses. Hach-Lange HQ 40D water quality instrument was used for measurement in situ of electrical conductivity (EC), salinity (SAL), pH, dissolved oxygen (DO), and water temperature (T). In the laboratory of the Scientific and Technological Research Council of Turkey, Marmara Research Center (TUBİTAK-MAM), it was done measurements of the orthophosphate (PO_4-P), total phosphorus (TP), nitrate-nitrogen (NO_3-N), total nitrogen (TN), chemical oxygen demand (COD) concentrations and alkalinity (ALK) using standard methods. Water transparency was measured using a Secchi disk. Since sampling was conducted in September 2020 and April 2021 when the lagoons were in the mixing period, the mixing layer depth (z_{mix}) was determined as the average depth of the studied lagoons (Naselli-Flores and Barone 2003). The light availability was estimated with the mixed layer to the euphotic zone (z_{mix}/z_{eu}) ratio (Jensen et al. 1994). Chlorophyll-*a* concentrations were measured with methanol extraction (Youngman 1978) to determine the trophic index of lagoons (Carlson and Simpson 1996). At the same time, Secchi disk depth and TP values were used to calculate the trophic index.

Phytoplankton analysis

A total of 28 samples were collected for phytoplankton analysis in September (fall) 2020 and April (spring) 2021. Depending on the surface area of each lagoon, two or three stations were chosen for sampling (Directorate General of Water Management 2015). Attention was taken to ensure that one of the stations was at the deepest point of the lagoon. The euphotic depth (zeu) was calculated as 2.5 times the Secchi depth (Cole 1994). Composite sampling was conducted according to the z_{eu} using an integrated sampling tube. Lugol's and formaldehyde solution was used for the fixation of phytoplankton. Diatoms were identified on permanent slides while other phytoplankton were identified from temporary preparations using an Olympus BX51 microscope (×400, ×600, ×1000) (European Committee for Standardization 2004). Cell counting was performed with an Olympus IX81 inverted microscope using standard methods (Utermöhl 1958). The average of three counting replicates was used to determine the final abundance of each species. Standard identification books and keys such as Trégouboff and Rose (1957), Hendey (1964), Sournia (1986), Round et al. (1990), Delgado and Fortuno (1991), Sims (1996), Throndsen (1997), John et al. (2003), Kramer and Lange-Bertalot (1986, 1991a, b, 1999), Lange-Bertalot (2001), Krammer (2000, 2002, 2003), Lange-Bertalot et al. (2017), Komarek and Anagnostidis (2008), Huber-Pestalozzi (1941, 1950, 1961, 1962, 1969, 1972, 1975, 1982, 1983) were used for the identification of algal species. The validity of species names and their habitat types were checked on the Algaebase website according to Guiry and Guiry (2023). Phytoplankton abundance was calculated from biovolume estimations with the number of cells and cell size measurements using geometric formulas (Sun and Liu 2003). At least 20 individuals were measured for cell size determination of each species in all samples (Brierley et al. 2007).

Data analysis

For the statistical analyses of phytoplankton and environmental variables, a total of 28 samples in 6 coastal lagoons were considered. The diversity index (*H'*) for phytoplankton was calculated according to Shannon and Weaver (1963). Environmental variables were logarithmically transformed except for pH. An analysis of variance (one-way ANOVA) test was applied to data for determining the statistical differences in environmental variables, species richness, diversity, and biovolume among the lagoons and seasons using SPSS 20.0 software. Spearman correlations between the environmental variables and the species richness, diversity, and biovolume were also determined using the SPSS 20.0 software. A linear regression model was also performed in SPSS 20.0 software between the log (salinity) and the log (species richness), log (diversity), and log (biovolume). Species that have a relative abundance of biovolume greater than 20% in one station of the specific lagoon were accepted as dominant species. Optimum levels of phytoplankton dominant species for salinity were calculated using the weighted averaging regression model. Cluster analysis was performed to detect the similarity of phytoplankton species among 6 coastal lagoons by using PAST 4.03 software. Canonical correspondence analysis (CCA) was carried out on the log-normal transformed abundance data using CANOCO software (ter Braak and Smilauer 2002) to reveal the relations between the biovolume (%) of the dominant species, sampling lagoons, and environmental variables since the response data have a gradient 4.56 units long. The statistical significance of the environmental predictor variables was assessed by 999 restricted Monte Carlo permutations. To analyze the relationship between the biovolume (%) of the dominant species and 12 environmental variables (T, pH, DO, SAL, EC, TN, NO_3-N, TP, PO_4-P, z_{mix}/z_{eu}, COD, ALK), we performed a CCA using biovolume (%) values of the 27 dominant species in both of the lagoons. CCA was performed, initially on the whole environmental and dominant species datasets. Forward selection indicated that 6 of the 12 environmental variables made a significant contribution to the variance in the biovolume (%) of the dominant species data.

Results

Environmental parameters

The minimum z_{max} values of the lagoons were measured in the fall of 2020, while maximum z_{max} values were measured in the spring of 2021 (Table 1). In Table 2, it was given the results of physical-chemical variables in 6 coastal lagoons of the Marmara Basin. The mean values of T were higher in fall 2020 ($f = 319.86$, $p < 0.01$). The mean values of DO ($f = 42.10$, $p < 0.01$) and NO_3-N were higher in spring 2021 ($f = 5.65$, $p < 0.01$). However, T, DO, and NO_3-N values were not significantly different among the lagoons. Also, some of the parameters such as pH, COD, TN, and z_{mix}/z_{eu} were not significantly different among the lagoons and the seasons. In DAL and HER lagoons, the mean EC and SAL values were higher ($f = 31.89$, $f = 43.59$, respectively, $p < 0.01$). The mean TP and PO_4-P values were higher in the KCK lagoon ($f = 32.76$, $f = 179.24$, respectively, $p < 0.01$) as well as the mean EC and SAL values. The mean ALK values were different between MER and BCK ($f = 3.51$, $p < 0.05$). On the other hand, EC, SAL, TP, PO_4-P, and ALK were not significantly different among the seasons.

Phytoplankton

A total of 247 phytoplankton taxa were identified and the numbers of taxa in the TER, BCK, MER, KCK, DAL, and HER lagoons were 82, 63, 95, 31, 39, and 34 respectively. Among them, 199 freshwater, 31 brackish water, and 17 marine taxa were detected. The total percentages (%) of brackish and marine species of KCK, DAL, and HER lagoons were higher than in the other lagoons (Table 3). It was noticed clustering of phytoplankton assemblages of DAL and HER lagoons which are mesohaline, and TER and BCK lagoons which are freshwater characters (Fig. 2). Only species from Cryptophyta were detected in freshwaters, other taxonomic groups were observed in hyposaline and mesohaline lagoons, and their abundance (%) did not show a remarkable change compared to freshwater lagoons (Fig. 3a). However, Charophyta, Chlorophyta and Ochrophyta members did not found in the water greater than 36 ppt salinity concentrations. Relatively high SAL optima were observed for *Chaetoceros* sp., *Chlamydomonas* spp., *Cylindrotheca closterium, Dunaliella obliqua, Gyrosigma* sp., *Gyrosigma wansbeckii, Mougeotia* sp., *Nitzschia acicularis, Prorocentrum micans, Protoperidinium* sp., *Pinnularia* sp., and *Stephanocyclus meneghinianus* (Fig. 3b). Relatively low SAL optima were detected for *Aulacoseira* *granulata, Aulacoseira subarctica, Gymnodinium catenatum, Gymnodinium inversum, Gyrosigma kuetzingii, Hymenomonas* sp., *Pediastrum duplex, Peridinium raciborskii* var. *palustre, Staurosira construens*, and *Trachelomonas manginii* (Fig. 3b). The dominant taxa (> 20%) of the 6 coastal lagoons in fall 2020 and spring 2021 were summarized in Table 4.

The species richness ranged between 4 and 33 during the studied periods in the 6 lagoons. Species richness was the highest in the MER lagoon (f = 12.77, $p < 0.01$) as shown in Fig. 4a. It was also higher in the TER lagoon. Species richness values were not significantly different in the fall of 2020 and spring of 2021 (Fig. 5). Species richness was negatively correlated with EC (r = -0.49, $p < 0.01$), and SAL (r = -0.47, $p < 0.05$). Moreover, it was positively correlated with diversity index ($r = 0.71$, $p < 0.01$) and biovolume ($r = 0.47$, $p < 0.05$). The Shannon diversity index ranged between 0.18 and 3.08 over the two periods. The diversity index was the highest in MER lagoon, while the lowest in KCK lagoon (f = 8.85, $p < 0.01$) (Fig. 4a). It was not significantly different among the seasons (Fig. 5). The minimum phytoplankton biovolume was recorded as 0.11 $mm^3\ L^{-1}$, while the maximum was found as 27.89 $mm^3\ L^{-1}$. Moreover, the mean phytoplankton biovolume was the highest in the KCK lagoon (7.40 $mm^3\ L^{-1}$), while was the lowest in the HER lagoon (0.41 $mm^3\ L^{-1}$). However, biovolume values were not significantly different among the lagoons (Fig. 4a). The biovolume was positively correlated with T ($r = 0.52$, $p < 0.01$), while negatively correlated with NO_3-N (r = -0.41, $p < 0.05$). It was not significantly different among the seasons. However lower biovolume values were detected in spring 2021 of the lagoons except for MER lagoon (Fig. 5). The relationships between log (SAL) and log (Species Richness), log (Shannon Index), and log (Biovolume) were given in Fig. 4b. Regression results showed a higher negative relationship between log (SAL) and log (Species Richness) (r^2= -0.13, $p < 0.05$).

Phytoplankton and environmental parameters

The results of CCA using 6 environmental variables were given in Fig. 6. The dominant species–environmental correlations of CCA axes 1 and 2 are high, and the first two axes account for 94.8% of the variance in the dominant species–environmental relationships. In the positive part of the first axis, generally, DO was correlated with species such as *Gomphonema* sp., *Gymnodinium catenatum, Gymnodinium inversum, Gyrosigma kuetzingii, Hymenomonas sp., Peridinium raciborskii* var. *palustre* and spring period of TER and MER lagoons. NO_3-N was correlated with species such as *Chlamydomonas* spp., *Glenodinium alpestre, Pandorina morum, Protoperidinium* sp., *Stephanocyclus*

Table 2 Mean values and standard deviations of environmental variables measured in 6 lagoons of the Marmara basin

Variable	T (°C)	EC (μScm^{-1})	SAL (ppt)	Salinity classification	pH	DO (mgL^{-1})	z_{mix}/z_{eu}	COD (mgL^{-1})	TN (mgL^{-1})	TP (mgL^{-1})	PO_4-P (mgL^{-1})	NO_3-N (mgL^{-1})	ALK (mgL^{-1})
TER	15.81 ± 8.72	314.75 ± 26.06	0.19 ± 0.03	Freshwater	8.24 ± 0.21	9.57 ± 2.01	2.47 ± 1.84	55.90 ± 42.09	0.99 ± 0.73	0.05 ± 0.03	0.003 ± 0.002	0.29 ± 0.26	140.99 ± 49.70
BCK	19.53 ± 6.60	766.83 ± 84.14	0.43 ± 0.07	Freshwater	8.36 ± 0.20	9.14 ± 1.35	2.98 ± 1.15	49.73 ± 30.60	1.70 ± 1.02	0.02 ± 0.03	0.003 ± 0.001	0.45 ± 0.42	191.75 ± 37.12
MER	18.85 ± 7.48	7449.88 ± 7725.25	4.27 ± 4.36	Hyposaline	8.52 ± 0.65	9.92 ± 1.77	1.17 ± 0.25	39.65 ± 20.27	0.89 ± 0.60	0.07 ± 0.05	0.01 ± 0.004	0.04 ± 0.03	98.46 ± 67.06
KCK	18.98 ± 8.91	24591.58 ± 1679.10	17.23 ± 2.59	Hyposaline	8.06 ± 0.12	7.26 ± 3.14	3.50 ± 3.60	91.83 ± 69.02	1.65 ± 0.61	0.35 ± 0.10	0.08 ± 0.01	0.53 ± 0.56	129.12 ± 18.33
DAL	16.99 ± 4.79	43047.50 ± 17757.70	32.89 ± 12.44	Mesohaline	8.72 ± 0.18	9.56 ± 1.26	0.78 ± 0.27	40.29 ± 21.86	0.63 ± 0.51	0.04 ± 0.02	0.005 ± 0.001	0.01 ± 0.01	184.76 ± 29.88
HER	17.58 ± 8.06	51125.00 ± 11667.44	35.15 ± 4.08	Mesohaline	8.59 ± 0.51	6.53 ± 4.27	1.20 ± 0.31	54.75 ± 64.39	0.57 ± 0.20	0.02 ± 0.01	0.01 ± 0.002	0.04 ± 0.03	129.20 ± 18.57

Abbreviations of lagoons were given in Table 1. *T* Water temperature, *EC* Electrical conductivity, *SAL* Salinity, *DO* Dissolved oxygen, z_{mix}/z_{eu} the ratio of mixing and euphotic layers, *COD* Chemical oxygen demand, *TN* Total nitrogen, *TP* Total phosphorus, *PO_4-P* Orthophosphate, *NO_3-N* Nitrate nitrogen, *ALK* Alkalinity

Fig. 2 A dendrogram of phytoplankton assemblages by cluster analysis in 6 coastal lagoons of Maramara Basin (The full names of the lagoons were given in Table 1)

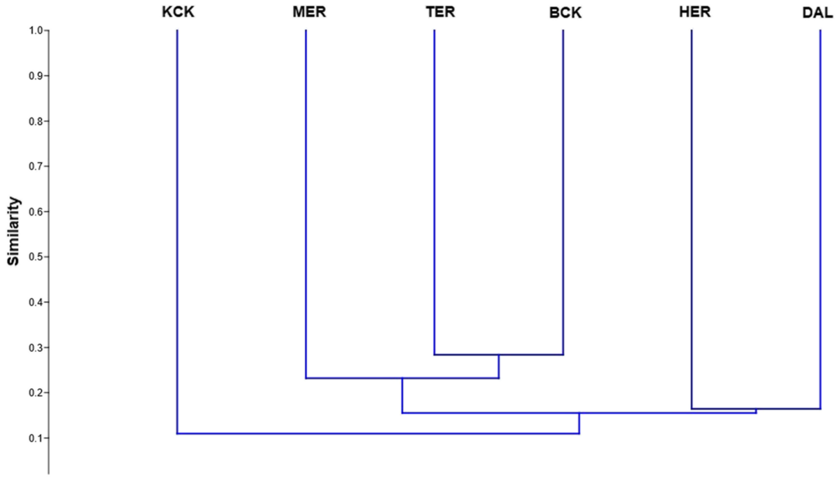
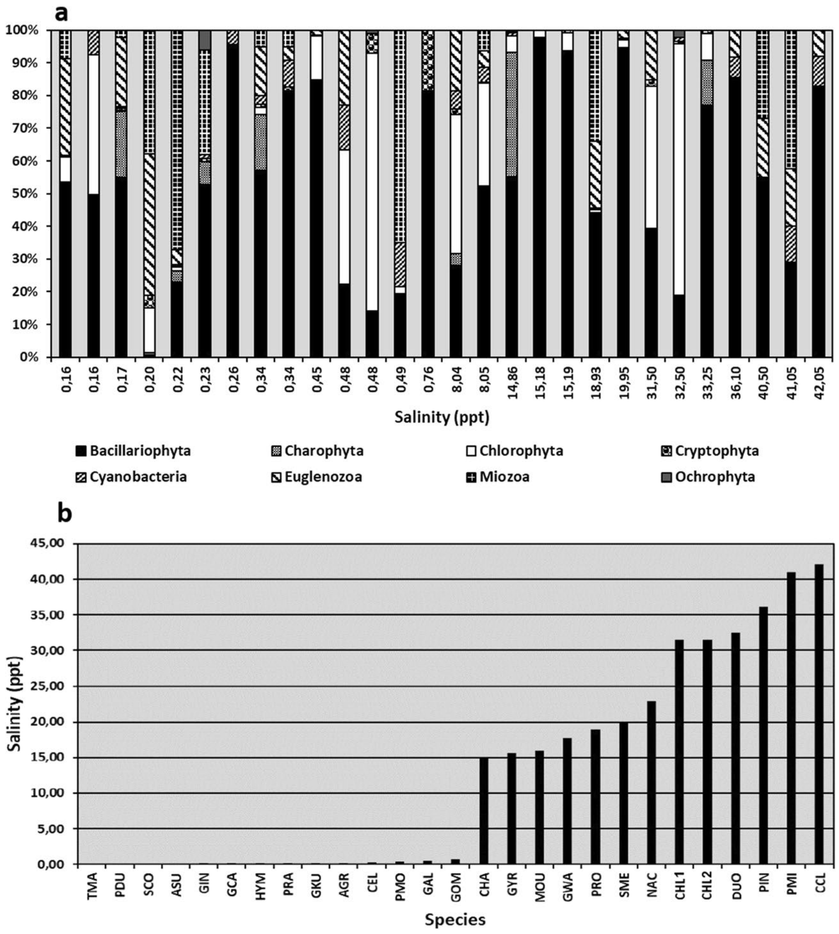


Fig. 3 **a** Relative abundance (%) of phytoplankton taxonomic groups along the salinity gradient (**b**) Result of the weighted average model for salinity in the studied 6 coastal lagoons of Marmara Basin (Abbreviations of the species were given in Table 4)



meneghinianus, and spring periods of the BCK, KCK, and HER lagoons. On the other hand, in the negative part of the first axis, ALK and SAL were correlated with species such as *Cylindrotheca closterium, Gyrosigma wansbeckii, Nitzschia acicularis, Pinnularia* sp., *Prorocentrum micans, Trachelomonas manginii* and fall periods of DAL, HER, and MER lagoons. Moreover, species such as *Aulacoseira granulata, Aulacoseira subarctica, Cymatopleura elliptica, Pediastrum duplex, Staurosira construens* were correlated with T and fall periods of TER and BCK lagoons. The last group which was found in both periods or correlated with both SAL and PO_4-P consisted of species such as *Dunaliella obliqua, Chaetoceros* sp., *Gyrosigma* sp., and *Mougeotia* sp.

Table 3 The percentage (%) of habitat status of the identified species to the total number of species in each lagoon in the 6 coastal lagoons of Marmara Basin (The full names of the lagoons were given in Table 1)

Lagoons	Brackish (%)	Marine (%)	Freshwater (%)
TER	10.97	4.88	84.15
BCK	14.29	4.76	80.95
MER	14.74	6.32	78.94
KCK	25.81	3.23	70.96
DAL	23.07	10.26	66.67
HER	26.47	5.88	67.65

Discussion

Measured environmental parameters such as EC and main nutrients were similar to previous studies in DAL (Altinoluk-Mimiroglu and Camur-Elipek 2018), KCK (Yilmaz 2015), and MER (Altınsaçlı 2001) lagoons compared to our study. However, measured nutrients were slightly higher in previous studies of BCK (Gülecal and Temel 2014; Yilmaz 2019), and TER (Yilmaz and Gülecal 2012) lagoons. This may be related to the climatic factors which determine the water budget and therefore the chemical composition of water, or conservation strategies prepared to protect these drinking water areas in recent years.

In the lagoons, NO_3-N values were generally higher in spring 2021. In this period, the increase in z_{max} values of the lagoons compared to fall 2020 indicated an increase in precipitation. Therefore, allochthonous inputs carried by streams from domestic and agricultural areas cause an increase in NO_3-N values as observed in many coastal lagoons during the flooding period (Serrano et al. 2004; Li et al. 2014). Moreover, DO values were higher in spring 2021 when the precipitation started to increase. The higher DO values in spring 2021 might be related to river influx, and still low T values (Srichandan et al. 2015; Draredja et al. 2019; Akagha et al. 2020), while lower values in fall 2020 could be the reason for increased decomposition of organic matter due to higher phytoplankton biovolume (Domingos et al. 2012; Akagha et al. 2020). EC and SAL values in HER, DAL, and KCK lagoons were measured high due to their connection with the seawater by channels or surmountable dikes. In a lagoon that has a continuous or temporary connection with sea water, salinity values were reported higher than closed ones (Barnes et al. 2008; Navas-Parejo et al. 2020).

Phytoplankton biovolume values were not different significantly among lagoons, however, average values were lowest in HER lagoon where EC and SAL values were highest. Panigrahi et al. (2009) have observed the phytoplankton biomass decrease in seawater exchange areas of Chilika Lagoon (India) due to the increase in salinity values. On the other hand, the highest average biovolume in the KCK lagoon, where SAL values were also high, can be explained by the highest TP and PO_4-P values in this lagoon. High

Table 4 The seasonal distribution, mean abundance (of stations) and their abbreviations of the dominant taxa in 6 coastal lagoons of Marmara Basin (The full names of the lagoons were given in Table 1)

Dominant taxa (2020–2021)		
Lagoons	Fall	Spring
TER	*Aulacoseira granulata* (AGR) (16.12%) *Aulacoseira subarctica* (ASU) (9.25%) *Gyrosigma wansbeckii* (GWA) (9.67%) *Pediastrum duplex* (PDU) (10.65%) *Staurosira construens* (SCO) (8.65%) *Trachelomonas manginii* (TMA) (14.89%)	*Gymnodinium catenatum* (GCA) (8.62%) *Gymnodinium inversum* (GIN) (15.29%) *Hymenomonas* sp. (HYM) (10.07%) *Peridinium raciborskii* var. *palustre* (PRA) (8.93%)
BCK	*Aulacoseira granulata* (AGR) (9.06%) *Gyrosigma* sp. (GYR) (16.80%) *Gyrosigma wansbeckii* (GWA) (11.75%) *Nitzschia acicularis* (NAC) (9.51%) *Cymatopleura elliptica* (CEL) (30.09%)	*Glenodinium alpestre* (GAL) (22.70%) *Pandorina morum* (PMO) (38.62%)
MER	*Gyrosigma wansbeckii* (GWA) (11.12%)	*Gomphonema* sp. (GOM) (12.49%) *Gyrosigma kuetzingii* (GKU) (28.16%)
KCK	*Chaetoceros* sp. (CHA) (75.81%) *Mougeotia* sp. (MOU) (20.02%)	*Protoperidinium* sp. (PRO) (17.48%) *Stephanocyclus meneghinianus* (SME) (46.39%)
DAL	*Cylindrotheca closterium* (CCL) (12.38%) *Nitzschia acicularis* (NAC) (12.01%) *Prorocentrum micans* (PMI) (22.03%)	*Gyrosigma* sp. (GYR) (34.96%) *Mougeotia* sp. (MOU) (22.18%)
HER	*Gyrosigma wansbeckii* (GWA) (24.51%) *Pinnularia* sp. (PIN) (37.29%)	*Dunaliella obliqua* (DUO) (35.69%) *Chlamydomonas* sp.1 (CHL1) (11.65%) *Stephanocyclus meneghinianus* (SME) (19.78%) *Chlamydomonas* sp.2 (CHL2) (11.66%)

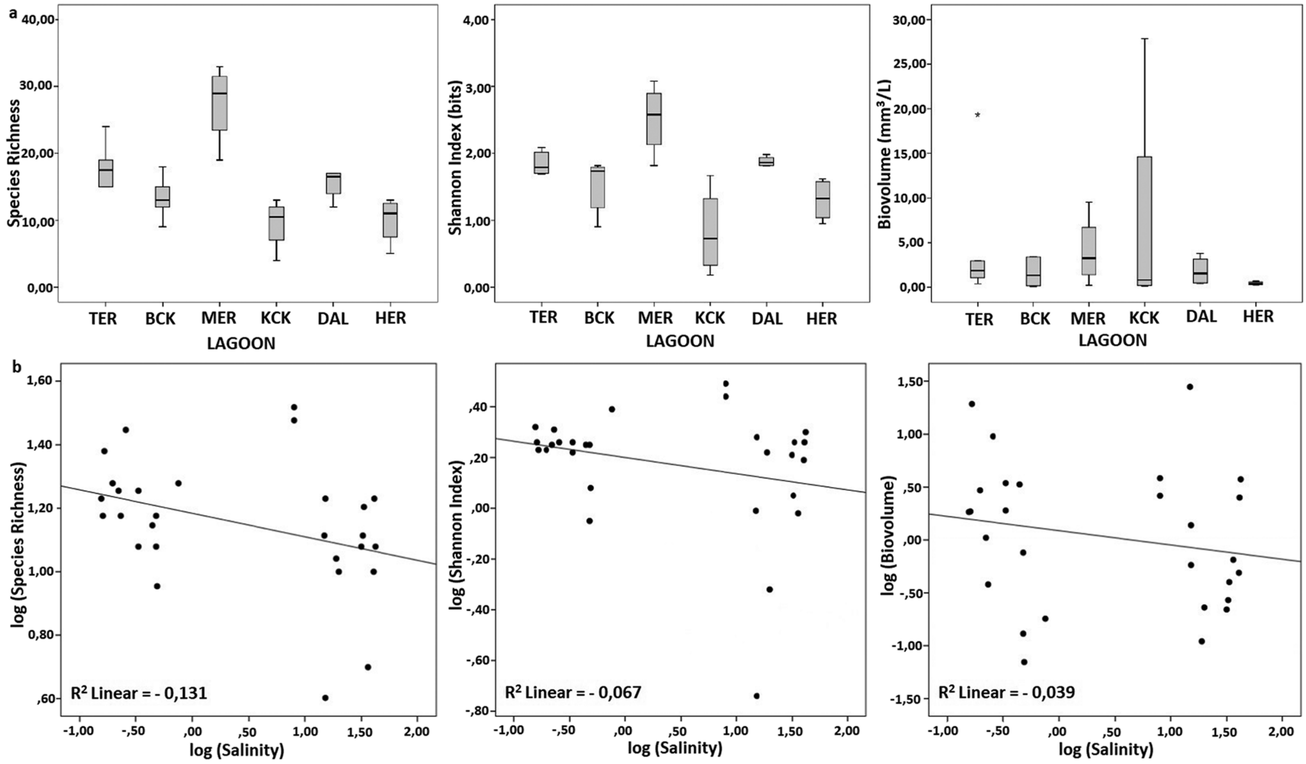


Fig. 4 **a** Distribution of Species Richness, Shannon Index (bits), and Biovolume (mm^3/L) along the 6 coastal lagoons of Marmara Basin (**b**) Relationships between log (Salinity) and log (Species Richness), log (Shannon Index), and log (Biovolume), respectively in the 6 coastal lagoons of Marmara Basin (The full names of the lagoons were given in Table 1)

nutrient values may have reduced the inhibitory effect of SAL on phytoplankton biovolume (Zhong et al. 2016; Yue et al. 2019). Phytoplankton biovolume was slightly higher in the fall of 2020 in most of the studied lagoons. As a result of higher temperature and higher residence time, biomass or biovolume increase was observed during the dry period of several coastal lagoons (Anandraj et al. 2008; Ortega-Cisneros et al. 2014; Srichandan et al. 2015; Tagliarolo and Scharler 2018). Only biovolume was lower in the fall 2020 of MER lagoon compared to the spring of 2021. The very high salinity values in this period compared to spring 2021 (~20 times high) might be effective in the reduction of the phytoplankton biovolume in this lagoon.

Species richness and diversity were detected as low in KCK and HER lagoons compared to other less saline lagoons. Moreover, KCK, DAL, and HER lagoons had the lowest recorded total numbers of species. Besides, a negative correlation was observed between SAL and species richness in the lagoons. These lagoons were affected by the wave movements and exposed to seawater at certain intervals, and consequently, the sudden increase in SAL values during these periods caused osmotic stress on the phytoplankton and triggered the decrease in species number (Kirst 1996). Flöder and Burns (2004) have also stated that intermittent salinity inputs into coastal ecosystems at weekly or monthly periods depending on the seawater inflow, will reduce the species richness compared to under constant freshwater or seawater conditions. Moreover, brackish water and marine species detected in these three lagoons were higher compared to other less saline lagoons. This finding shows that the distribution of both freshwaters, brackish, and marine species in the lagoons was affected by SAL gradients. Another piece of evidence showing the distribution of species affected by SAL was detected in the cluster analysis. According to this analysis, species composition was found as similar in DAL and HER lagoons which are mesohaline characters, while species composition was similar in TER and BCK lagoons which are freshwater characters. Many studies in coastal lagoons have already stated the important effect of SAL on the species composition of phytoplankton (Comin and Valiela 1993; López-Flores et al. 2006; Specchiulli et al. 2008). It has been stated in different studies that each species has a different SAL optima, and SAL affects the phytoplankton growth rate (Braarud 1951; Tyler and Seliger 1981). In our study, 12 of the 27 dominant species were determined to have high SAL optima and were distributed in more saline lagoons. In some previous studies, it has been stated that taxonomic groups of phytoplankton showed variation from Cyanobacteria and Chlorophyta to Bacillariophyta and Miozoa with salinity increase (Kies 1997;

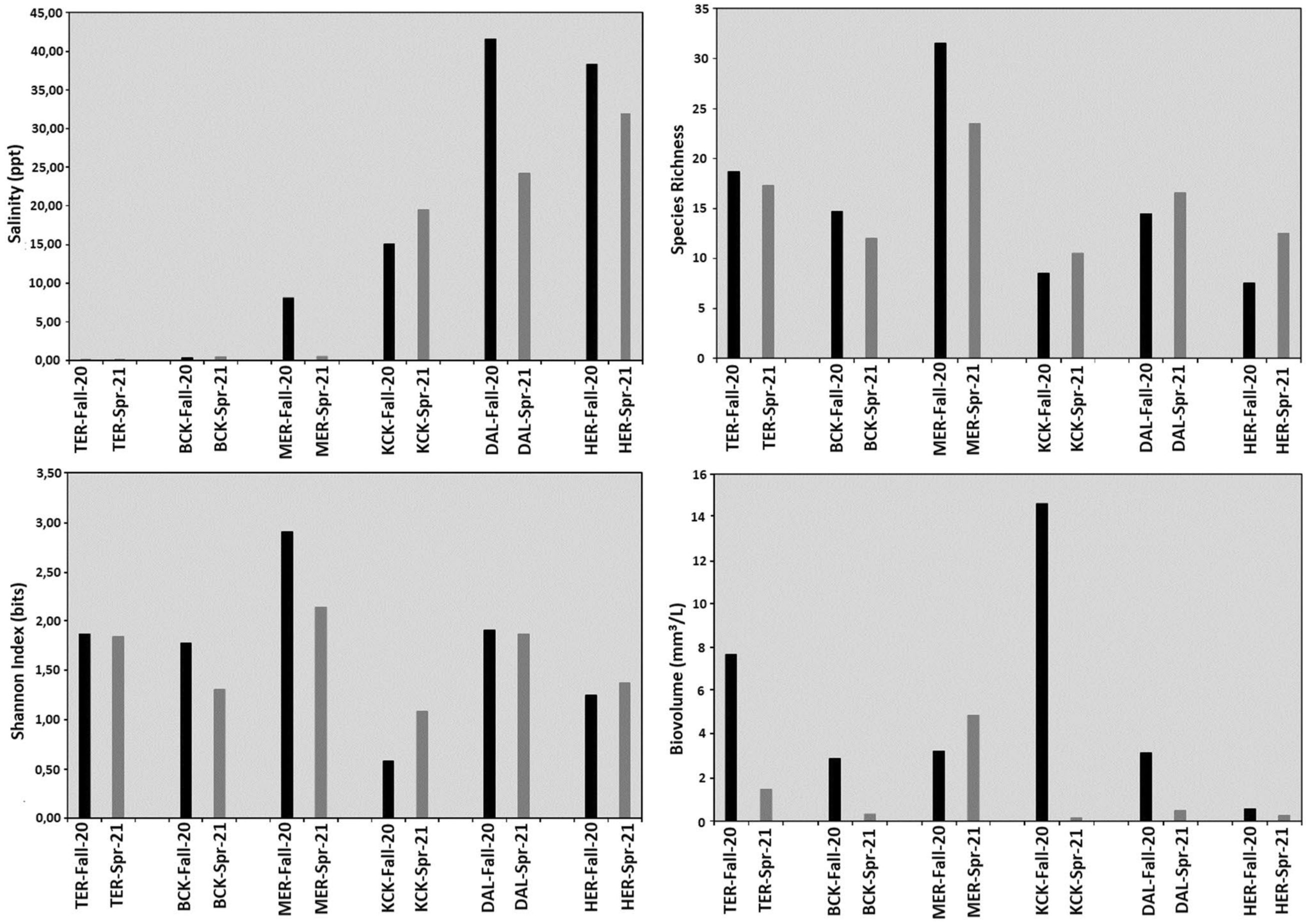


Fig. 5 Seasonal distribution of Salinity, Species Richness, Shannon Index (bits), and Biovolume (mm^3/L) in the 6 coastal lagoons of the Marmara Basin (The full names of the lagoons were given in Table 1) (average values of the stations for each lagoon were used for determining Salinity, Species Richness, Shannon Index (bits), and Biovolume values)

Muylaert and Sabbe 1999; Li et al. 2021). In our study, the individuals of 8 taxonomic groups contributed to the relative abundance of phytoplankton at different rates up to 36 ppt. However, only individuals belonging to the Cyanobacteria, Euglenozoa, Miozoa, and Bacillariophyta were detected over 36 ppt.

In the studied lagoons, the distribution of dominant species was affected by seasonality and was segregated into fall and spring periods. In the CCA diagram, the fall of 2020 period of more saline DAL, HER, and MER lagoons and high SAL optima species such as *Cylindrotheca closterium, Gyrosigma wansbeckii, Nitzschia acicularis, Prorocentrum micans*, and *Pinnularia* sp. were located near to SAL and ALK. It has been stated in different studies that these species have a high tolerance to SAL and were reported in brackish and marine environments (Marshall et al. 1981; Barillé et al. 2003; Van Bergeijk et al. 2003; Fatah et al. 2022; Guiry and Guiry 2023). Since the salinity values in the MER lagoon were much higher in fall 2020 than in spring 2021, the salinity-tolerant *G. wansbeckii* was detected as the dominant species in this environment. Species such as *C. closterium, N. acicularis*, and *P. micans* were reported in highly alkaline environments (Gosselain et al. 1994; El Gammal et al. 2017). The presence of low SAL optima species (*Trachelomonas manginii*) in this group can be explained by the high correlation of this species with ALK. This freshwater euglenophyte was also detected for the first time after the tropical cyclone in the outer channel area in the Chilika lagoon, where SAL values were measured high in previous studies (Srichandan and Rastogi 2020). This lagoon has also high alkalinity values (Srichandan et al. 2015). On the other hand, fall 2020 period of BCK and TER lagoons and low SAL optima species such as *Aulacoseira granulata, A. subarctica, Cymatopleura elliptica, Pediastrum duplex*, and *Staurosira construens* were correlated with T. These species were reported in many freshwater lakes during the early fall periods when the temperature is still high and mixing events increase (Padisák et al. 2009; Sevindik et al. 2017). The presence of benthic pennate diatoms such as

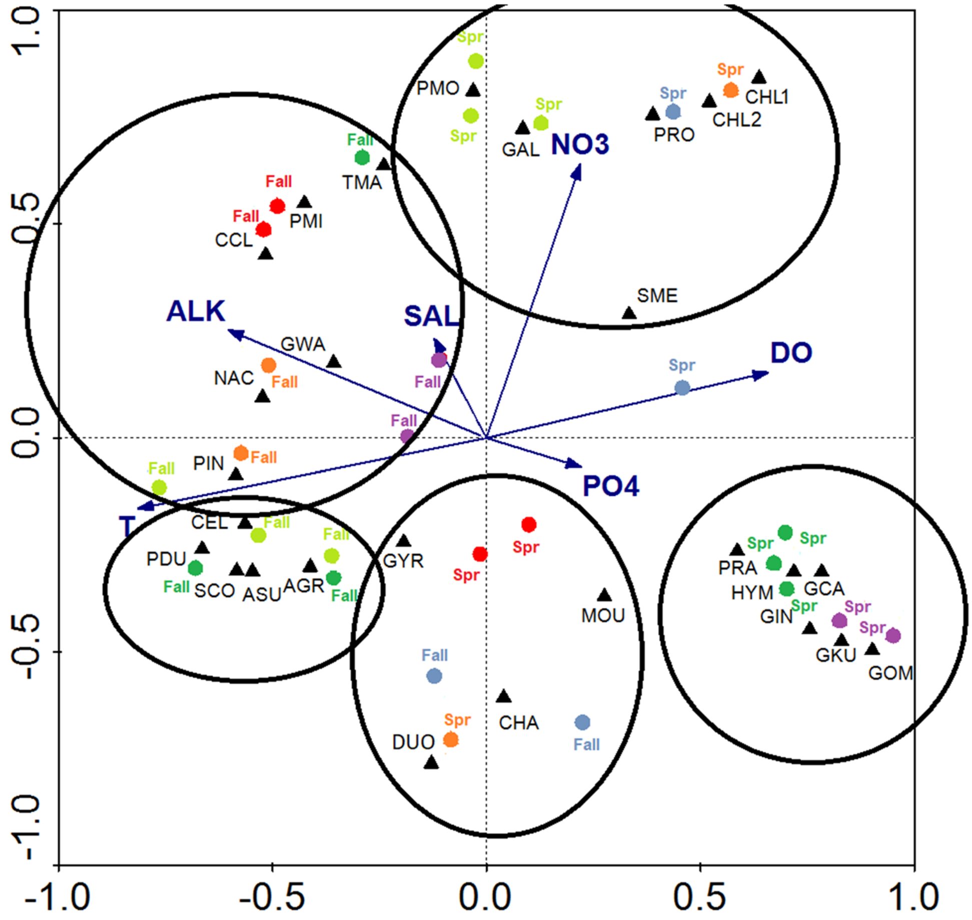


Fig. 6 Ordination of the samples corresponding to the different lagoons, scores of phytoplankton biovolume by dominant species, and environmental variables, along the canonical correspondence analysis axes. **Environmental variables: T**: water temperature, **DO**: dissolved oxygen, **SAL**: salinity, **PO_4**: orthophosphate, **NO_3**: nitrate-nitrogen, **ALK**: alkalinity **(red**: Dalyan Lagoon, **orange**: Hersek Lagoon, **purple**: Mert Lagoon, **blue**: Küçükçekmece Lagoon, **dark green**: Terkos Lagoon, **green**: Büyükçekmece Lagoon)

C. elliptica and *S. construens* in the pelagic environment has also indicated wind-induced sediment resuspension (Padisák et al. 2009; Aubry et al. 2013; Pednekar et al. 2014).

In spring 2021, MER and TER lagoons, and low SAL optima species found in these lagoons (*Gomphonema sp., Gymnodinium catenatum, Gymnodinium inversum*, *Gyrosigma kuetzingii, Hymenomonas sp.*, *Peridinium raciborskii* var. *palustre*) showed high correlation with DO. Due to the SAL decrease in MER lagoon, low SAL tolerant species have become dominant. On the other hand, DO values were much higher in these two lagoons (> 11 mg L^{-1}) compared to other lagoons in the spring period. Ohtake et al. (1982) have attributed the high oxygen concentration detected in the spring to the vigorous photosynthetic activity of *Gymnodinium* spp. in the Nakanoumi lagoon, which was previously artificially freshened similar to TER lagoon to meet the irrigation need. In spring 2021, BCK, KCK, and HER lagoons and species such as *Chlamydomonas* spp., *Glenodinium alpestre, Pandorina morum, Protoperidinium* sp., and *Stephanocyclus meneghinianus* were correlated with NO_3-N. These species have been detected in nitrate-rich eutrophic lakes (Happey-Wood 1976; Carli et al. 1994; Naselli-Flores and Barone 2000; Padisák et al. 2009; Zhang et al. 2013).

High SAL optima species such as *Dunaliella obliqua, Chaetoceros* sp., *Gyrosigma* sp., and *Mougeotia* sp. were separated from other groups in the CCA. In these species, *Chaetoceros* sp. and *Mougeotia* sp. were found in the fall of 2020 or spring of 2021 of KCK and DAL lagoons. They were correlated with PO_4-P. Besides, PO_4-P values in KCK were measured higher than in other lagoons. *Chaetoceros* species were reported in eutrophic coastal environments (Gotsis-Skretas and Friligos 1990; Annabi-Trabelsi et al. 2022), while *Mougeotia* species were detected in the eutrophic saline lake (Reati et al. 1996) with high PO_4-P content. *Dunaliella obliqua*, which was detected in spring 2021 in HER lagoon, was indicated as a marine species (Guiry and Guiry 2023).

Conclusion

1) Although the phytoplankton biovolume did not change significantly due to SAL differences in 6 coastal lagoons, the average biovolume values were minimum in the

most saline HER. Species richness and diversity were detected as low in more saline KCK and HER lagoons. Moreover, the total number of species was recorded as lowest in most saline KCK, DAL, and HER. In these lagoons, higher brackish and marine species were detected. Moreover, only individuals belonging to four taxonomic groups were detected over 36 ppt. In addition, species composition was found as similar in mesohaline lagoons, while species composition was similar in freshwater lagoons. SAL was also effective in the distribution of dominant species and species with higher SAL tolerance were found in most saline lagoons. These results show that the variation in SAL is the most significant factor in shaping the phytoplankton community structure among the lagoons.

2) Considering other environmental variables except for salinity, TP and PO_4-P values affected the average biovolume in the KCK lagoon. Species distributed in a eutrophic environment with high PO_4-P content were dominant in this lagoon. As a result of higher T, phytoplankton biovolume was slightly higher in most lagoons.
3) SAL values were not significantly different among the seasons. However, in the MER lagoon, high SAL values tended to decrease phytoplankton biovolume. The considerable decrease in SAL shifted the dominant species structure from high SAL optima species to low SAL optima species in this lagoon. Moreover, T, ALK, NO_3-N, and DO were the main factors affecting the seasonal distribution of dominant species.

We can conclude that the changes in abiotic factors, particularly salinity, affect the spatial and temporal algal communities in the lagoons. Also, to better detect the effect of salinity on phytoplankton, these lagoons should be monitored with periodic studies. Therefore, the effects of climate change will be better understood.

Acknowledgements This study was funded by the General Directorate of State Hydraulic Works in the frame of "Water Quality Monitoring of the Marmara Basin" during 2020 and 2022. The authors thank to General Directorate of State Hydraulic Works Investing, Planning and Allocations Department, Environmental Section Managers, Sakarya University Phytoplankton R&D Laboratory, Kocaeli University Hydrobiology R&D Laboratory, and ÇEVSİS R&D for their valuable support during the sampling and analysis procedure.

Author contributions Hatice Tunca conducted the field sampling, identified and counted the phytoplankton, and analyzed the data. Tuğba Ongun Sevi̇ndi̇k designed the experiments, analyzed the data, and wrote the text. Halim Aytekin Ergül participated in project management, designed the experiments, and conducted the field sampling. Mert Kaya prepared the samples for counting, help the qualitative analyses of samples using a light microscope. Melih Kayal and Fatih Ekmekçi̇ conducted the field studies, Oltan Canli and Barış Güzel menaged the field measurements and laboratory analysis of environmental parameters.

Funding None.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Conflicts of interest The authors declare that they have no competing interests.

References

Akagha SC, Nwankwo DI, Yin K (2020) Dynamics of nutrient and phytoplankton in Epe Lagoon, Nigeria: possible causes and consequences of reoccurring cyanobacterial blooms. Appl Water Sci 10:1–16. https://doi.org/10.1007/s13201-020-01190-7

Aktan Y, Gürevin C, Dorak Z (2009) The Effect of Environmental factors on the growth and size structure of two Dominant Phytoplankton species in the Büyükçekmece Reservoir (İstanbul, Turkey). Turk J Biol 33:335–340. https://doi.org/10.3906/biy-0805-28

Albay M, Matthiensen A, Codd GA (2005) Occurrence of toxic blue-green algae in the Kucukcekmece lagoon (Istanbul, Turkey). Environ Toxicol 20:277–284. https://doi.org/10.1002/tox.20118

Allende L, Fontanarrosa MS, Murno A, Sinistro R (2019) Phytoplankton functional group classifications as a tool for biomonitoring shallow lakes: a case study. Knowl Manag Aquat Ecosyst 420:5. https://doi.org/10.1051/kmae/2018044

Altinoluk-Mimiroglu P, Camur-Elipek B (2018) Comparative analysis of chemical and bacterial distribution of coastal lagoons and freshwater lakes in Turkish Thrace. Hidrobiológica 28:61–69

Altınsaçlı S (2001) The Ostracoda (Crustacea) Fauna of Lakes Erikli, Hamam, Mert, Pedina and Saka (İğneada, Kırklareli, Turkey). Turk J Zool 25(4):343–355 (https://journals.tubitak.gov.tr/zoology/vol25/iss4/1)

Anandraj A, Perissinotto R, Nozais C, Stretch D (2008) The recovery of microalgal production and biomass in a South African temporarily open/closed estuary, following mouth breaching. Estuar Coast Shelf Sci 79(4):599–606. https://doi.org/10.1016/j.ecss.2008.05.015

Angus S (2017) Scottish saline lagoons: impacts and challenges of climate change. Estuar Coast Shelf Sci 198:626–635. https://doi.org/10.1016/j.ecss.2016.07.014

Annabi-Trabelsi N, Guermazi W, Leignel V et al (2022) Effects of Eutrophication on Plankton abundance and composition in the Gulf of Gabès (Mediterranean Sea, Tunisia). Water 14(14):2230. https://doi.org/10.3390/w14142230

Atalay I, Ekinci D, Bayrak AGM (2015) Ecological problems based on anthropogenic process of some Coastal Wetlands in Turkey. National Geomorphology Symposium, Samsun

Aubry FB, Acri F, Bianchi F, Pugnetti A (2013) Looking for patterns in the phytoplankton community of the Mediterranean Microtidal Venice Lagoon: evidence from ten years of observations. Sci Mar 77(1):47–60

Barillé L, Haure J, Pales-Espinosa E, Morançais M (2003) Finding new diatoms for intensive rearing of the pacific oyster (Crassostrea gigas): energy budget as a selective tool. Aquaculture 217:501–514. https://doi.org/10.1016/S0044-8486(02)00257-0

Barnes N, Bamber RN, Moncrieff CB, Sheader M, Ferrero TJ (2008) Meiofauna in closed coastal saline lagoons in the United Kingdom: structure and biodiversity of the nematode assemblage. Estuar Coast Shelf Sci 79(2):328–340. https://doi.org/10.1016/j.ecss.2008.03.017

Barzegar R, Moghaddam AA, Soltani S, Fijani E, Tziritis E, Kazemian N (2017) Heavy metal (loid) s in the groundwater of Shabestar area (Nw Iran): source identifcation and health risk assessment. Expos Health 11:251–265. https://doi.org/10.1007/s12403-017-0267-5

Bergesch M, Garcia M, Odebrecht C (2009) Diversity and morphology of Skeletonema species in Southern Brazil, Southwestern Atlantic Ocean 1. J Phycol 45(6):1348–1352. https://doi.org/10.1111/j.1529-8817.2009.00743.x

Braarud T (1951) Salinity as an ecological factor in marine phytoplankton. Physiol Plant 4(1):28–34. https://doi.org/10.1111/j.1399-3054.1951.tb07512.x

Brierley B, Carvalho L, Davies S, Krokowski J (2007) Guidance on the quantitative analysis of phytoplankton in freshwater samples. Report to SNIFFER (Project WFD80), Edinburgh

Camur-Elipek B, Kirgiz T, Oterler B, Tas M (2015) Qualitative and quantitative evaluation of water resources that feed into the National Park Igneada Longoz forests (Turkish Thrace) by using physico-chemical and biological analyses. Hidrobiológica 25(2):231–237

Carli A, Pane L, Romairone V (1994) A study of phytoplankton populations of the Riva Trigoso Bay (Gulf of Genoa) in relation to eutrophication features of the water. Final Reports on Research Projects Dealing with Eutrophication Problems. MAP Technical Reports Series No. 78. UNEP/FAO, Athens

Carlson RE, Simpson J (1996) A coordinator's guide to volunteer lake monitoring methods. N Am Lake Manage Soc 96:305

Caroppo C, Roselli L, Di Leo A (2018) Hydrological conditions and phytoplankton community in the Lesina lagoon (southern Adriatic Sea, Mediterranean). Environ Sci Pollut Res 25(2):1784–1799. https://doi.org/10.1007/s11356-017-0599-5

Cloern JE (2001) Our evolving conceptual model of the coastal eutrophication problem. Mar Ecol-Prog Ser 210:223–253. https://doi.org/10.3354/meps210223

Cole GA (1994) Textbook of Limnology. Waveland Press Inc, Illinois

Comin FA, Valiela I (1993) On the controls of phytoplankton abundance and production in coastal lagoons. J Coastal Res 9:895–906

Corsi SR, Graczyk DJ, Geis SW, Booth NL, Richards KD (2010) A fresh look at road salt: aquatic toxicity and water-quality impacts on local, regional, and national scales. Environ Sci Technol 44(19):7376–7382. https://doi.org/10.1021/es101333u

Dalkıran G, Baki B (2011) Türkiye'nin Tapulu Tek Gölü: Hersek Lagünü. 2. Türkiye Sulak Alanlar Kongresi, Kırşehir, Turkiye (in Turkish)

Delgado M, Fortuno JM (1991) Atlas De Fitoplancton Del Mar Mediterráneo. Sci Mar 55:1–133

Demirci A, Mcadams MA, Alagha O, Karakuyu M (2006) The relationship between land use change and water quality in Küçükçekmece Lake watershed. GIS Days Proceedings Book, pp 27–34

Derolez V, Soudant D, Malet N et al (2020) Two decades of oligotrophication: evidence for a phytoplankton community shift in the coastal lagoon of Thau (Mediterranean Sea, France). Estuar Coast Shelf Sci 241:106810. https://doi.org/10.1016/j.ecss.2020.106810

Directorate General Of Water Management (2015) Yer Üstü Suları, Yer Altı Suları ve Sedimentten Numune Alma ve Biyolojik Örnekleme Tebliği. Resmi Gazete, Sayı, p 29274. (in Turkish)

Directorate General of Water Management (2016) İklim Değişikliğinin Su Kaynaklarina Etkisi Projesi - Marmara Havzası, Proje Nihai Raporu. T.C. Orman ve Su İşleri Bakanlığı

Domingos P, Gômara GA, Sampaio GF, Soares MF, Soares FDFL (2012) Eventos De Mortandade De Peixes Associados A Florações Fitoplanctã Nicas na Lagoa Rodrigo De Freitas: Programa De 10 Anos De Monitoramento. Oecologia Australis 16(3):441–466

Draredja MA, Frihi H, Boualleg C, Gofart A, Abadie E, Laabir M (2019) Seasonal variations of phytoplankton community in relation to environmental factors in a protected meso-oligotrophic southern Mediterranean Marine ecosystem (Mellah lagoon, Algeria) with an emphasis of HAB species. Environ Monit Assess 191(10):1–17. https://doi.org/10.1007/s10661-019-7708-5

Dugan HA, Summers JC, Skaff NK et al (2017) Long-term chloride concentrations in north American and European freshwater lakes. Sci Data 4(1):1–11. https://doi.org/10.1038/sdata.2017.101

El Gammal MAM, Nageeb M, Al-Sabeb S (2017) Phytoplankton abundance in relation to the quality of the coastal water–Arabian Gulf, Saudi Arabia. Egypt J Aquat Res 43(4):275–282. https://doi.org/10.1016/j.ejar.2017.10.004

Ergul HA, Karademir A (2020) A modeling approach on the PCDD/F pollution in surface sediments of the Izmit Bay (the Marmara Sea). Reg Stud Mar Sci 35:101195. https://doi.org/10.1016/j.rsma.2020.101195

European Committee for Standardization (2004) Water quality – Guidance standard for the surveying, sampling and laboratory analyses of phytobenthos in shallow running water. European Standard EN, 15708, Brussels

Evagelopoulos A, Spyrakos E, Koutsoubas D (2007) Thebiological system of the lower salinity ponds in Kalloni Saltworks (NE. Aegean Sea, Greece): phytoplankton and macrobenthic invertebrates. Transit Waters Bullet 1(3):23–25. https://doi.org/10.1285/i1825229Xv1n3p23

Fatah AE, Ali HM, Ibrahim DM (2022) Seasonal dynamics and ecological drivers of Prorocentrum micans Ehrenberg dinoflagellate blooms in Qarun Lake, Egypt. Egypt J Aquat Res 48(4):375–382. https://doi.org/10.1016/j.ejar.2022.07.001

Flöder S, Burns CW (2004) Phytoplankton diversity of shallow tidal lakes: influence of periodic salinity changes on diversity and species number of a natural assemblage. J Phycol 40:54–61. https://doi.org/10.1046/j.1529-8817.2004.03050.x

Flöder S, Jaschinski S, Wells G, Burns CW (2010) Dominance and compensatory growth in phytoplankton communities under salinity stress. J Exp Mar Biol Ecol 395(1–2):223–231. https://doi.org/10.1016/j.jembe.2010.09.006

Froneman P (2004) Food web dynamics in a temperate temporarily open/closed estuary (South Africa). Estuar Coast Shelf Sci 59:87–95. https://doi.org/10.1016/j.ecss.2003.08.003

Garmendia M, Borja A, Franco J, Revilla M (2013) Phytoplankton composition indicators for the assessment of eutrophication in marine waters: present state and challenges within the European directives. Mar Pollut Bull 66:7–16. https://doi.org/10.1016/j.marpolbul.2012.10.005

Gobler C, Cullison L, Koch F, Harder M, Krause J (2005) Influence of freshwater flow, ocean exchange, and seasonal cycles on phytoplankton - nutrient dynamics in a temporarily open estuary. Estuar Coast Shelf Sci 65:275–288. https://doi.org/10.1016/j.ecss.2005.05.016

Gosselain V, Descy JP, Everbecq E (1994) The phytoplankton community of the River Meuse, Belgium: seasonal dynamics (year 1992) and the possible incidence of zooplankton grazing. Hydrobiologia 289(1):179–191. https://doi.org/10.1007/BF00007419

Gotsis-Skretas O, Friligos N (1990) Contribution to eutrophication and phytoplankton ecology in the Thermaikos Gulf. Thalassographica 13(1):1–12

Güher H (2003) Mert, Erikli, Hamam Ve Pedina (İğneada, Kırklareli) Göller'inin Zooplanktonik Organizmaların Kommunite Yapısı. Ege J Fish Aquat Sci 20(1):51–62

Guiry MD, Guiry GM (2023) Algaebase. World-wide electronic publication. National University Of Ireland, Galway. http://www.algaebase.Org Accessed 05.01.2023

Gülecal Y, Temel M (2014) Water quality and phytoplankton diversity in Büyükçekmece Watershed, Turkey. J Water Resour Protect 6:55–61. https://doi.org/10.4236/jwarp.2014.61009

Hammer UT (1986) Saline lake ecosystems of the world. Dr W. Junk Publishers, Kluwer Academic Publisher Group, Dordrecht

Happey-Wood CM (1976) Influence of stratification on the growth of planktonic Chlorophyceae in a small body of water. Brit Phycol J 11(4):371–381. https://doi.org/10.1080/00071617600650421

Haraguchi L, Carstensen J, Abreu PC, Odebrecht C (2015) Long-term changes of the phytoplankton community and biomass in the subtropical shallow Patos Lagoon Estuary, Brazil. Estuar Coast Shelf Sci 162:76–87. https://doi.org/10.1016/j.ecss.2015.03.007

Hendey NI (1964) An introductory account of the smaller Algae of the British Coastal Waters, Part V: Bacillariophyceae (Diatoms). Fishery investigations, ser, vol 4. Her Majesty's Stationery Office, London

Hernando M, Schloss IR, Malanga G, Almandoz GO, Ferreyra GA, Aguiar MB, Puntarulo S (2015) Effects of salinity changes on coastal Antarctic phytoplankton physiology and assemblage composition. J Exp Mar Biol Ecol 466:110–119. https://doi.org/10.1016/j.jembe.2015.02.012

Huber-Pestalozzi G (1972) Das Phytoplankton Des SüßwasSers. Systematik und Biologie: Chlorophyceae (Grünalgen). Ordnung: Tetrasporales. Schweizerbart, Stuttgart

Huber-Pestalozzi G (1941) Das Phytoplankton Des SüßwasSers: Chrysophyceen, Farblose Flagellaten Heterokonten. Schweizerbart, Stuttgart

Huber-Pestalozzi G (1950) Das Phytoplankton Des SüßwasSers: Cryoptophyceen, Chloromonadien, Peridineen. Schweizerbart, Stuttgart

Huber-Pestalozzi G (1961) Das Phytoplankton Des SüßWassers: Chlorophyceae, Ordnung: Volvocales. Schweizerbart, Stuttgart

Huber-Pestalozzi G (1962) Das Phytoplankton Des SüßwasSers. Systematik Und Biologie: Blaualgen. Schweizerbart, Stuttgart

Huber-Pestalozzi G (1969) Das Phytoplankton Des SüßwasSers Systematik Und Biologie: Euglenophyceen. Schweizerbart, Stuttgart

Huber-Pestalozzi G (1975) Das Phytoplankton Des SüßwasSers. Systematik Und Biologie: Diatomeen. Schweizerbart, Stuttgart

Huber-Pestalozzi G (1982) Das Phytoplankton Des SüßwasSers. Systematik Und Biologie: Conjugatophyceae (Desmidiales Und Zygnematales) (Excl. Zygnemataceae). Schweizerbart, Stuttgart

Huber-Pestalozzi G (1983) Das Phytoplankton Des SüßwasSers. Systematik Und Biologie: Chlorophyceae (Grünalgen) Ordnung: Chlorococcales. Schweizerbart, Stuttgart

ISKI (2023) Home page. web site. http://www.iski.gov.tr/web/. Accessed 03.01.2023

Jacquet S, Delesalle B, Torréton JP, Blanchot J (2006) Response of phytoplankton communities to increased anthropogenic influences (southwestern lagoon, New Caledonia). Mar Ecol-Prog Ser 320:65–78. https://doi.org/10.3354/meps320065

Jensen P, Jeppesen E, Olrik K, Kristensen P (1994) ImPact of nutrients and physical factors on the Shift from CyanoBacterial to chlorophyte dominance in shallow Danish lakes. Can J Fish Aquat Sci 51(8):1692–1699. https://doi.org/10.1139/f94-170

John DM, Whitton BA, Brook AJ (2003) The FreshWater Algal Flora of the British Isles: an Identification Guide to Freshwater and Terrestrial Algae. Cambridge University Press, Cambridge

Kies L (1997) Distribution, biomass and production of planktonic and benthic algae in the Elbe Estuary. Oceanograp Lit Rev 11(44):1328

Kirst GO (1989) Salinity tolerance of eukaryotic marine algae. Annu Rev Plant Physiol Plant Mol Biol 40:21–53

Kirst GO (1996) Osmotic adjustment in phytoplankton and macroalgae. In: Kiene PR, Visscher PT, Keller MD, Kirst GO (eds) Biological and environmental chemistry of DMSP and related sulfonium compounds. Springer, Boston, pp 121–129

Komarek J, Anagnostidis K (2008) Cyanoprokaryota: Oscillatoriales, Süßwasserflora Von Mitteleuropa. Spektrum Akademischer Verlag, Heidelberg

Krammer K (2000) Diatoms of Europe. In: Lange-Bertalot H (ed) The Genus Pinnularia, vol 1. A.R.G. Gantner Verlag, Ruggell

Krammer K (2002) Diatoms of the European Inland Waters and comparable habitats, Cymbella, vol 3. A.R.G. Gantner Verlag, Ruggell

Krammer K (2003) Diatoms of Europe. Cymbopleura, Delicata, Navicymbula, Gomphocymbellopsis, Afrocymbella, vol 4. A.R.G. Gantner Verlag, Ruggell

Krammer K, Lange-Bertalot H (1986) Freshwater flora of Central Europe: Bacillariophyceae, I. Naviculaceae. Gustav Fischer Verlag, Stuttgart

Krammer K, Lange-Bertalot H (1991a) Freshwater flora of Central Europe: Bacillariophyceae. III. Centrales, Fragilariaceae, Eunoticeae. Gustav Fischer Verlag, Stuttgart

Krammer K, Lange-Bertalot H (1991b) Freshwater flora of Central Europe: Bacillariophyceae. IV. Achnanthaceae, critical additions to Navicula (Lineolatae) and Gomphonema. Gustav Fischer Verlag, Stuttgart

Krammer K, Lange-Bertalot H (1999) Freshwater flora of Central Europe: Bacillariophyceae. II. Epithemiaceae, Surirellaceae. Gustav Fischer Verlag, Stuttgart

Lancelot C, Muylaert K (2011) 7.02 trends in estuarine phytoplankton ecology. Treatise on estuarine and coastal science. Academic Press, Waltham, pp 5–15

Lange-Bertalot H (2001) Navicula Sensu Stricto 10 genera separated from Navicula Sensu Lato Frustulia. In: Lange-Bertalot H (ed) Diatoms of Europe - Diatoms of the European Inland Waters and comparable habitats. Gantner Verlag, Ruggell

Lange-Bertalot H, Hofmann G, Werum M, Cantonati M, Kelly MG (2017) Freshwater benthic diatoms of Central Europe: over 800 common species used in ecological assessment. Schmitten-Oberreifenberg, Koeltz Botanical Books, Germany

Li Z, Gao Y, Wang S, Lu Y, Sun K, Jia J, Wang Y (2021) Phytoplankton community response to nutrients along lake salinity and altitude gradients on the Qinghai-Tibet Plateau. Ecol Indic 128:107848. https://doi.org/10.1016/j.ecolind.2021.107848

Li RH, Liu SM, Li YW, Zhang GL, Ren JL, Zhang J (2014) Nutrient dynamics in tropical rivers, lagoons, and coastal ecosystems of eastern Hainan Island, South China Sea. Biogeosciences 11(2):481–506. https://doi.org/10.5194/bg-11-481-2014

Lloret J, Marín A, Marín-Guirao L (2008) Is coastal lagoon eutrophication likely to be aggravated by global climate change? Estuar Coast Shelf Sci 78(2):403–412. https://doi.org/10.1016/j.ecss.2008.01.003

López-Flores R, Boix D, Badosa A, Brucet S, Quintana XD (2006) Pigment composition and size distribution of phytoplankton in a confined Mediterranean salt marsh ecosystem. Mar Biol 149(6):1313–1324. https://doi.org/10.1007/s00227-006-0273-9

Lugoli F, Garmendia M, Lehtinen S, Kauppila P, Moncheva S, Revilla M, Roselli L, Slabakova N, Valencia V, Dromph KM, Basset A (2012) Application of a new multi-metric phytoplankton index to the assessment of ecological status in marine and transitional waters. Ecol Indic 23:338–355. https://doi.org/10.1016/j.ecolind.2012.03.030

Marshall HG, Nesius KK, Cibik SJ (1981) Phytoplankton Studies within the Virginia Barrier islands II. Seasonal Study of Phytoplankton within the Barrier Island channels. Castanea, pp 89–99

Muylaert K, Sabbe K (1999) Spring phytoplankton assemblages in and around the maximum turbidity zone of the estuaries of the Elbe (Germany), the Schelde (Belgium/ The Netherlands) and the Gironde (France). J Mar Syst 22:133–149. https://doi.org/10.1016/S0924-7963(99)00037-8

Naselli-Flores L, Barone R (2000) Phytoplankton dynamics and structure: a comparative analysis in natural and man-made water bodies of different trophic state. Hydrobiologia 438(1):65–74. https://doi.org/10.1023/A:1004109912119

Naselli-Flores L, Barone R (2003) Steady-state assemblages in a Mediterranean Hypertrophic Reservoir. The role of Microcystis Ecomorphological variability in maintaining an apparent equilibrium. In: Naselli-Flores L, Padisák J, Dokulil MT (eds) Phytoplankton and Equilibrium Concept. The Ecology Of Steady-State Assemblages Springer, Dordrecht, pp 133–143

Navas-Parejo JCC, Corzo A, Papaspyrou S (2020) Seasonal cycles of phytoplankton biomass and primary production in a tropical temporarily open-closed estuarine lagoon-the effect of an extreme climatic event. Sci Total Environ 723:138014. https://doi.org/10.1016/j.scitotenv.2020.138014

Nche-Fambo FA, Scharler UM, Tirok K (2015) Resilience of estuarine phytoplankton and their temporal variability along salinity gradients during drought and hypersalinity. Estuar Coast Shelf Sci 158:40–52. https://doi.org/10.1016/j.ecss.2015.03.011

Odountan OH, de Bisthoven LJ, Koudenoukpo CZ, Abou Y (2019) Spatio-temporal variation of environmental variables and aquatic macroinvertebrate assemblages in Lake Nokoué, a RAMSAR site of Benin. Afr J Aquat Sci 44(3):219–231. https://doi.org/10.2989/16085914.2019.1629272

Oğuz S (1995) İstabul'Un İçme Suyu Meselesi. İSKİ Haber 1:11–12

Ohtake H, Kondo K, Seike Y (1982) Seasonal and areal features of the lagoonal environment in Lake Nakanoumi, a shallow coastal lagoon in Japan. Hydrobiologia 97(1):15–26. https://doi.org/10.1007/BF00014956

Okumuş E (2007) Küçükçekmece Gölü Sedimentinde Ağır Metal (Zn^{2+}, Fe^{2+}, Cu^{2+}) Adsorpsiyonu. Dissertation, Yıldız Technical University (in Turkish)

Ortega-Cisneros K, Scharler UM, Whitfield AK (2014) Inlet mouth phase influences density, variability and standing stocks of plankton assemblages in temporarily open/closed estuaries. Estuar Coast Shelf Sci 136:139–148. https://doi.org/10.1016/j.ecss.2013.11.021

Özhan S (2004) Watershed management. Publication no. 481. IU Faculty of Forestry Publications, Istanbul

Özuluğ M (1999) A taxonomic study on the fish in the basin of Büyükçekmece Dam Lake. Turk J Zool 23(4):439–452

Padisák J, Crossetti LO, Naselli-Flores L (2009) Use and misuse in the application of the phytoplankton functional classification: a critical review with updates. Hydrobiologia 621(1):1–19. https://doi.org/10.1007/s10750-008-9645-0

Paerl HW, Otten TG, Kudela R (2018) Mitigating the expansion of harmful algal blooms across the freshwater-to-marine continuum. Environ Sci Technol 52:5519–5529. https://doi.org/10.1021/acs.est.7b05950

Panigrahi S, Wikner J, Panigrahy RJ, Satapathy KK, Acharya BC (2009) Variability of nutrients and phytoplankton biomass in a shallow brackish water ecosystem (Chilika Lagoon, India). Limnology 10:73–85. https://doi.org/10.1007/s10201-009-0262-z

Pednekar SM, Kerkar V, Matondkar SGP (2014) Spatiotemporal distribution in phytoplankton community with distinct salinity regimes along the Mandovi estuary, Goa, India. Turk J Bot 38(4):800–818. https://doi.org/10.3906/bot-1309-29

Reati GJ, Florín M, Fernández GJ, Montes C (1996) The Laguna De Mar Chiquita (Córdoba, Argentina): a little known, secularly fluctuating, saline lake. Int J Salt Lake Res 5(3):187–219. https://doi.org/10.1007/BF01997137

Redden AM, Rukminasari N (2008) Effects of increases in salinity on phytoplankton in the Broadwater of the Myall Lakes, NSW, Australia. Hydrobiologia 608(1):87–97. https://doi.org/10.1007/s10750-008-9376-2

Rochette S, Rivot E, Morin J, Mackinson S, Riou P, Le Pape O (2010) Effect of nursery habitat degradation on flatfish population: application to Solea solea in the Eastern Channel (Western Europe). J Sea Res 64:34–44. https://doi.org/10.1016/j.seares.2009.08.003

Round FE, Crawford RM, Mann DG (1990) The diatoms: morphology and Biology of the Genera. Cambridge University Press, Cambridge

Senel G, Dogru AO, Goksel C (2020) Exploring the potential of Landsat-8 OLI and Sentinel-2 MSI data for mapping and monitoring Enez Dalyan Lagoon. Desalin Water Treat 177:330–337. https://doi.org/10.5004/dwt.2020.24802

Serengil Y, Gökbulak F, Özhan S, Hizal A, Sengönül K (2007) Alteration of stream nutrient discharge with increased sedimentation due to thinning of a deciduous forest in Istanbul. For Ecol Manag 246:264–272. https://doi.org/10.1016/j.foreco.2007.04.008

Serrano L, Reina M, Arechederra A, Casco MA, Toja J (2004) Limnological description of the Tarelo lagoon (SW Spain). Limnetica 23:1–10

Sevindik TO, Çelik K, Naselli-Flores L (2017) Spatial heterogeneity and seasonal succession of phytoplankton functional groups along the vertical gradient in a mesotrophic reservoir. Ann Limnol-Int J Lim 53:129–141. https://doi.org/10.1051/limn/2016040

Sezgin E (2015) Trakya'daki Lagüner Göllerin Gastropod (Gastropoda: Mollusca) Faunası. Dissertation, Trakya Üniversitesi Fen Bilimleri Enstitüsü, Edirne (in Turkish)

Shalby A, Elshemy M, Zeidan BA (2021) Modeling of climate change impacts on Lake Burullus, coastal lagoon (Egypt). Int J Sediment Res 36(6):756–769. https://doi.org/10.1016/j.ijsrc.2019.12.006

Shannon CE, Weaver W (1963) The mathematical theory of communication. University of Illinois Press, Urbana

Shikata T, Nagasoe S, Oh SJ et al (2008) Effects of down-and up-shocks from rapid changes of salinity on survival and growth of estuarine phytoplankters. J Fac Agric Kyushu Univ 53:81–87. https://doi.org/10.5109/10075

Sims PA (1996) An Atlas of Britih Diatoms. BioPress Ltd, London

Sournia A (1986) Atlas Du Phytoplankton Marine. Volume I: introduction, Cyanophycées, Dictyochophycées, Dinophycées et Raphidophycées. Centre National de la Recherche Scientifique, Paris

Specchiulli A, Focardi S, Renzi M, Scirocco T, Cilenti L, Breber P, Bastianoni S (2008) Environmental heterogeneity patterns and assessment of trophic levels in two Mediterranean lagoons: Orbetello and Varano, Italy. Sci Total Environ 402:285–298. https://doi.org/10.1016/j.scitotenv.2008.04.052

Srichandan S, Baliarsingh SK, Prakash S, Lotliker AA, Parida C, Sahu KC (2019) Seasonal dynamics of phytoplankton in response to environmental variables in contrasting coastal ecosystems. Environ Sci Pollut Res 26(12):12025–12041. https://doi.org/10.1007/s11356-019-04569-5

Srichandan S, Kim JY, Bhadury P, Barik SK, Muduli PR, Samal RN, Pattnaik AK, Rastogi G (2015) Spatiotemporal distribution and composition of phytoplankton assemblages in a coastal tropical lagoon: Chilika, India. Environ Monit Assess 187(2):1–17. https://doi.org/10.1007/s10661-014-4212-9

Srichandan S, Rastogi G (2020) Spatiotemporal assessment of phytoplankton communities in the Chilika lagoon. In: Finlayson C, Rastogi G, Mishra D, Pattnaik A (eds) Ecology, Conservation, and restoration of Chilika Lagoon, India. Wetlands: Ecology, Conservation and Management, vol 6. Springer, Cham, pp 251–294

Sun J, Liu D (2003) Geometric models for calculating cell Biovolume and Surface Area for Phytoplankton. J Plankton Res 25(11):1331–1346. https://doi.org/10.1093/plankt/fbg096

Tagliarolo M, Scharler UM (2018) Spatial and temporal variability of carbon budgets of shallow South African subtropical estuaries. Sci Total Environ 626:915–926. https://doi.org/10.1016/j.scitotenv.2018.01.166

Tarafdar L, Kim JY, Srichandan S et al (2021) Responses of phytoplankton community structure and association to variability in environmental drivers in a tropical coastal lagoon. Sci Total Environ 783:146873. https://doi.org/10.1016/j.scitotenv.2021.146873

Telesh IV, Khlebovich VV (2010) Principal processes within the estuarine salinity gradient: a review. Mar Pollut Bullet 61:149–155. https://doi.org/10.1016/j.marpolbul.2010.02.008

Temel M (2002) The phytoplankton of lake Buyukcekmece, Istanbul, Turkey. Pak J Bot 34(1):81–92

Ter Braak CJF, Smilauer P (2002) CANOCO reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5). Microcomputer Power, Ithaca

Throndsen J (1997) The planktonic marine flagellates. In: Tomas CR (ed) Identifying Marine Phytoplankton. Academic Press, San Diego, pp 591–729

Tolun L, Telli-Karakoc F, Henkelmann B, Schramm KW, Okay OS (2008) Pcb pollution of Izmit bay (Marmara Sea) mussels after the earthquake. In: Mehmetli E, Koumanova B (eds) The Fate of Persistent Organic pollutants in the Environment. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-6642-9_10

Trégouboff G, Rose M (1957) Manuel De Planctonologie Méditerranéenne, I, II. Centre National de la Recherche Scientifique, Paris

Tyler MA, Seliger HH (1981) Selection for a red tide organism: physiological responses to the physical environment. Limnol Oceanogr 26(2):310–324. https://doi.org/10.4319/lo.1981.26.2.0310

Utermöhl H (1958) Zur Vervollkommnung Der Quantitativen Phytoplankton-Methodik. Mitt Int Ver Limnol 5:567–596

Uzun M (2014) Hersek Deltasında (Yalova) Kıyı Çizgisi-Kıyı Alanı Değişimleri ve Etkileri. Doğu Coğrafya Dergisi 19(32):27–48 (in Turkish)

Van Bergeijk SA, Van der Zee C, Stal LJ (2003) Uptake and excretion of dimethylsulphoniopropionate is driven by salinity changes in the marine benthic diatom Cylindrotheca closterium. Eur J Phycol 38(4):341–349. https://doi.org/10.1080/0967026031000612600

Wang N, Xiong J, Wang X et al (2018) Relationship between phytoplankton community and environmental factors in landscape water with high salinity in a coastal city of China. Environ Sci Pollut Res 25:28460–28470. https://doi.org/10.1007/s11356-018-2886-1

Woolway RI, Kraemer BM, Lenters JD, Merchant CJ, O'Reilly CM, Sharma S (2020) Global lake responses to climate change. Nat Rev Earth Environ 1(8):388–403. https://doi.org/10.1038/s43017-020-0067-5

Yilmaz N (2015) Diversity of phytoplankton in Kucukcekmece Lagoon channel, Turkey. Maejo Int J Sci Technol 9(1):32–42

Yilmaz N (2019) Water quality assessment based on the phytoplankton composition of Buyukcekmece Dam Lake and its influent streams (Istanbul), Turkey. Desalin Water Treat 159:3–12. https://doi.org/10.5004/dwt.2019.23994

Yilmaz N, Gülecal Y (2012) Phytoplankton community of Terkos Lake and its influent streams, Istanbul, Turkey. Pak J Bot 44(3):1135–1140

Yilmaz N, Özyiğit İİ, Dogan I, Demir G, Yalcin I (2021a) A case study performed in Kucukcekmece Lagoon channel/Istanbul, Turkey: how the heavy metal contamination and the seasonal variations on phytoplankton composition influence water quality. Desalin Water Treat 239:126–136. https://doi.org/10.5004/dwt.2021.27817

Yilmaz N, Ozyigit II, Demir HH, Yalcin IE (2021b) Assessment on phytoplankton composition and heavy metal pollution in a drinking water resource: Lake Terkos (Istanbul, Turkey). Desalin Water Treat 225:265–274. https://doi.org/10.5004/dwt.2021.27221

Youngman RE (1978) The measurement of Chlorophyll. Water Research Centre, U.K, Medmenham

Yue L, Kong W, Ji M, Liu J, Morgan-Kiss RM (2019) Community response of microbial primary producers to salinity is primarily driven by nutrients in lakes. Sci Total Environ 696:134001. https://doi.org/10.1016/j.scitotenv.2019.134001

Zainol Z, Akhir MF (2019) Temporal variability of phytoplankton biomass in relation to salinity and nutrients in a shallow coastal lagoon. Malaysian J Anal Sci 23:1090–1106. https://doi.org/10.17576/mjas-2019-2306-16

Zhang JY, Ni WM, Zhu YM, Pan YD (2013) Effects of different nitrogen species on sensitivity and photosynthetic stress of three common freshwater diatoms. Aquat Ecol 47(1):25–35. https://doi.org/10.1007/s10452-012-9422-z

Zhong ZP, Liu Y, Miao LL, Wang F, Chu LM, Wang JL, Liu ZP (2016) Prokaryotic community structure driven by salinity and ionic concentrations in plateau lakes of the Tibetan Plateau. Appl Environ Microb 82(6):1846–1858. https://doi.org/10.1128/AEM.03332-15