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Environmental parameters drive the phytoplankton community structure: a case study in Baghdad Tourist Island Lake, Iraq

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Abstract

Phytoplankton community is a model for of monitoring aquatic systems and interpreting the environmental change in aquatic systems. The present study aimed to forecast environmental parameters that drive the change of phytoplankton community structure in the lake. The present study was carried out in Baghdad Tourist Island Lake (BTIL) for the period From October 2021 to May 2022. The study included the quality and quantity of phytoplankton, moreover, the highest and lowest value of the physical and chemical parameters were (Water temperature (13-30 °C), Light penetration (94-275cm), electric conductivity (837-1128 µS/cm), salinity (0.5-0.7 ‰), pH (7-8.2), total alkalinity (126-226 mg CaCO3/L), total Hardness (297-395 mg CaCO3/L), Calcium (62-98 mg/L), Magnesium (59-75mg/L), Sodium (45-77 mg/L), Potassium (4-9 mg/L), dissolved oxygen (6-9 mg/L), total dissolved solids (586-777 mg/L), total phosphorus (0.1-0.7 mg/L), total nitrogen (0.2-3 mg/L). Monthly samples were taken from the subsurface water from three sampling sites in the Lake and the results and presented as dry and wet seasons. A total of 127 algal taxa was identified in the dry and wet seasons with the dominancy of diatoms (*Nitzschia,* Gomphonema, Navicula, *Ulnaria*) and followed by Cyanophyceae (Oscillatoria, Merismopedia) and Chlorophyceae (Cladophora), while Dinophyceae (Ceratium, Gymnodinium), and Euglenophyceae (Euglena) were uncommon. The lowest total cell number of phytoplankton was 221cell*10^4 /L in the first site during the wet season, while the highest total cell number of phytoplankton was recorded at the third site with 323×10^4 cells/L in the dry season. The Canonical Correspondence Analysis (CCA) showed the impact of environmental parameters on phytoplankton community structure. Therefore, the changes in phytoplankton species were noticed in the present study in comparison with previous periods and this finding is a warning of alteration in the environmental condition of the lake.

Keywords: Algae, CCA, Environmental parameters, Phytoplankton, Spatial, Temporal.

1.Introduction

Lakes are a critical part of the hydrological budget, a source of water, and provide valuable habitats for biological species [1]. Aquatic diversity is extremely delicate and influenced by several factors such as light, dissolved oxygen, and nutrients. The organisms in aquatic ecosystems are, however, markers of changes that take place because of numerous anthropogenic activities, such as pollution, climate change, etc. Phytoplankton are unicellular, free-floating members of the algae family. The simplest organism is phytoplankton. The primary producers of food in every aquatic ecosystem, serve as a food source for fish and most other aquatic organisms [2].

The nutrient cycle and the equilibrium between living things and abiotic elements are both significantly influenced by phytoplankton. An essential and crucial organism, phytoplankton serves as the main source of food in all aquatic environments and the primary factor in resolving various environmental issues [3].

In general, algae is considered a suitable organism for biomonitoring of the aquatic system because of their abundance, sensitivity to alteration in water quality, and pollution impact [4]. Phytoplankton is a diverse group of algae, and its species act as a base of the food web, good indicators of water body statutes, and have a different role as a functional group in an aquatic ecosystem [5,6]. Phytoplankton (diatoms) used a model of monitoring aquatic systems, and interpreting the environmental change in aquatic systems [7,6,8]. Van Dam et al., (1998) reported the importance of phytoplankton as potential indicators of aquatic system degradation [9].

Hussian et al. (2015) studied the phytoplankton in Lake Nasser and some physicochemical parameters and revealed that Electric conductivity (EC) and water temperature were driving the phytoplankton community in the study area [10]. Many studies reported the importance of the impact of physicochemical parameters on phytoplankton community structure in different aquatic systems [11, 12,13,14].

Tumas and Hassan (2015) mentioned that Baghdad Tourist Island Lake is suffering from less attention in the environmental management and needs to enhance it. While another study, an enhancement in water quality was mentioned, which means take attention to environment management of the lake [15,13].

The aim of this study is to forecast the impact of environmental changes on phytoplankton community structure and compare the findings of the current study with those of earlier studies that were conducted in the same study area.

2.Material and methods

Study area:

Baghdad Tourist Island Lake is one of the most well-known tourist destinations in Iraq. It is an artificial lake situated in the Al-Fahhama region to the north of Baghdad city (**Figure 1**). The Lake is in the right part of the tourist island. Because the lake is exposed to tourist-related pollution, it is important to monitor water quality. The first site is located at the northern side of the Lake, the second site is located in the tower area in the middle of the Lake, and the third site is on the southern side of the Lake (**Table 1**).

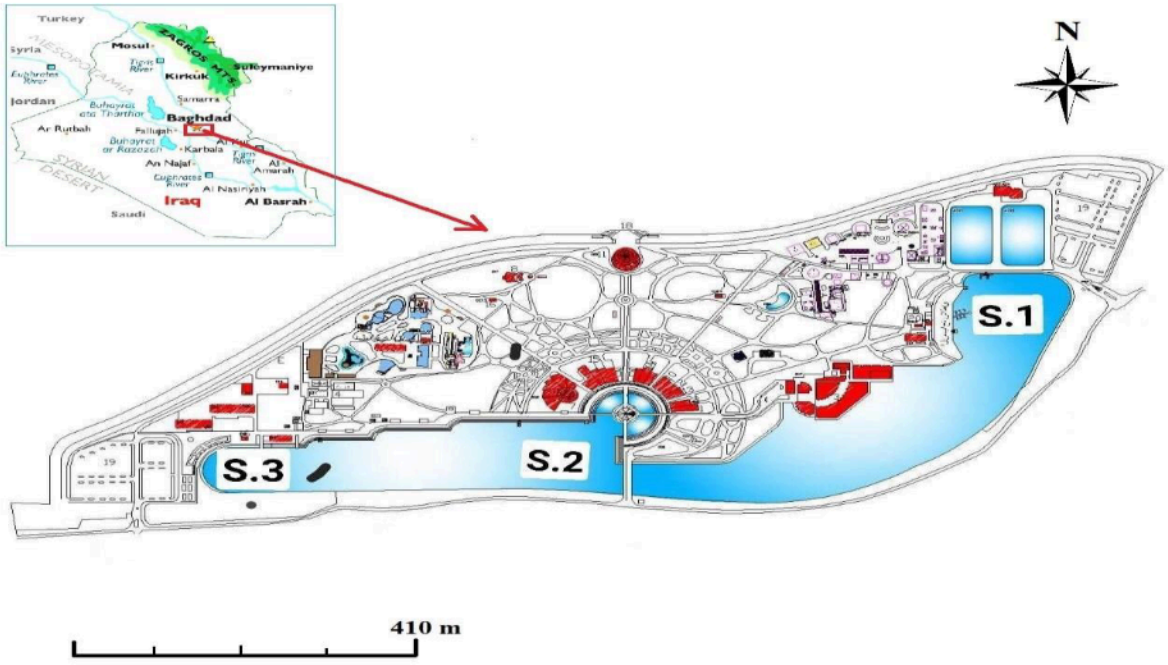

Figure 1. Map of the study area

Table 1. Global Position System (GPS) of the study sites

Site	Longitude (eastwards)	Latitude (northwards)
S1	44° 20'32.4 E	33 °46'39.6 N
S2	44° 09'25.2 E	33 °12'247 N
S3	44 °19'47.4 E	33° 22'366 N

Sample collection:

Physicochemical analysis of tourist Baghdad Island Lake: samples were collected monthly, from three sites in the study area (Table 1) from Oct 2021 to May 2022 and represented as dry and wet seasons. The field measurements are water temperature (C), pH, electric conductivity (µS/cm), salinity(S‰), Total dissolved solids (mg/l), which were measured by the digital portable multimeter (Hach HQ40d -Germany). The dissolved oxygen (mg/l) using Winkler methods after field fixing of oxygen using manganese sulfate and alkali-iodide-azide in Winkler bottles Total Hardness (mg $CaCO_3$/l) EDTA Titrimetric method , Total alkalinity (mg $CaCO_3$/l) hydrochloric acid, Calcium (mg $CaCO_3$/l) EDTA Titrimetric method, magnesium (mg $CaCO_3$/l) Calculation method, sodium (mg/l), and potassium (mg/l) standard methods of examination of water and waste water, Total phosphate (mg/l) Ascorbic acid, Total nitrogen (mg/l) Sulphanilamide, estimated following the methodology of Furet and Benson-Evans [16].

Phytoplankton sample: taken a 1L of each sample and preserved in Lugol's solution (1:100) ml in a cylinder of a 1L then left to settle for (21-27) days and concentrated the sample to 500 ml and then concentrated the sample to 100 ml finally repeated the process to reach (10 ml). The permanent slides were prepared using a concentrated nitric acid, for diatoms clarification, then

classified by utilizing permanent slides. While non-diatom algae were diagnosed by preparing temporary slides and examined by microscope model GX- 140105 at (40x) according to Furet and Benson-Evans method [17]. The taxonomic references [18, 19] were used for the identification

Statistical analysis

The statistical analysis was performed by using R-statistical programming packages [20] and Canonical Correlation Analysis (CAA) was used by performing the CANOCO software to examine the relationship between algal species and environmental parameters [21].

3.Results and discussion

The highest water temperature was 29.93 °C in the dry season, but the lowest was 13.4 °C in the wet season. The pH fell to 7 in the wet season, and it rose to 8.2 in the dry season, the lower Electrical Conductivity was 837.67 µS/cm in the dry season, but the highest was1128.67 µS/cm in the wet season, the lower Salinity was 0.52 S‰ but the highest was 0.7 S‰ in wet season. the increase in electrical conductivity and Salinity in the wet season, was caused by soil erosion which results in the salts being transferred to the water body and an increase in areas affected by agricultural activity [22], Due to the rains and the erosion of the soil in the river. the LP value ranged between 94 cm to 275 cm in dry and wet seasons, respectively. The decline in LP in the dry season caused by increasing in Turbidity values and density of phytoplankton in addition to tourist activity and the dust also greatly affected the LP during the dry season [23,24]. The lowest dissolved oxygen concentration was 6.7 mg/l in the dry season, but the highest was 9.17 mg/l in the wet season. this is because rising temperatures cause dissolved oxygen to become less soluble in water, which increases the activity of microorganisms and their oxygen consumption while also causing existing organisms to use dissolved oxygen for respiration [25]. The lowest value of hardness was 297.2(mg $CaCO_3$/l), whereas the highest hardness in the dry season was 395.27(mg $CaCO_3$/l), Water hardness has risen, according to agriculture, and human activity [26].

The wet season recorded the highest water alkalinity was 226.67 (mg $CaCO_3$/l), while the dry season had the lowest level at 126.67 (mg $CaCO_3$/l). Cole (1983) explains that the alkalinity was affected by temperature which leads to an increase in the solubility of CO2 and carbonic acid in water [27]. Smith (2004) reported a decrease in alkalinity because of increases in the density of algae and subsequently leads to the consumption of CO2 [28].

Calcium values were between 62.8-92.9 (mg $CaCO_3$/l) highest in the dry season and lowest in the wet season and return increase in calcium value is due to erosion of soil loaded with these salts [29], as for the decrease in the value of calcium concentration returns to its consumption by algae and aquatic plants and building some structures of living organisms. while magnesium was between 54.03-72.2 (mg $CaCO_3$/l) in wet season The high concentration of magnesium may be the result of soil washing rainwater, while its decrease is due to its consumption by algae, as it enters the structure of the chlorophyll molecule, Increasing the numbers of algae works to consume magnesium and thus drop its percentage in water [30].The lowest value of Na^+, K^+ (45, 4.83 mg/L) was recorded in wet season, while the highest value (77.67, 9.47 mg/L) was recorded in the dry season. The weathering of the rocks is the reason for the addition of Sodium and Potassium in aquatic bodies [31]. Total dissolved solids TDS ranged from 586.37 to 777.23mg/l, highest in dry season and lowest in the wet season, The activity of tourists and agriculture is one of the possible reasons for the increase in TDS [23].

The lowest total phosphorus concentration of 0.1 mg/l, but the highest concentration of 0.69 mg/l in the wet season. Decrease TP due to its consumption by algae and aquatic plants because phosphorous is an important nutrient for living organisms [33]. Its rise is due to the use of

phosphate fertilizers and its erosion in the watercourse due to the washing of agricultural land [34]. The lowest value of Total Nitrogen was 0.25 mg/l in the dry season, but the highest was 3.2 mg/l in the wet season. The high concentration of nitrogen that was recorded is attributed to fertilizers usage and the sweeping of irrigation water from the adjacent land into the river [35].

Some physicochemical parameters were determined in the lake during the two seasons (Table 2). The lake was alkaline, very hard, oligohaline and good aerated. The trophic states were oligotrophic according to TP and TN concentrations.

Table 2. Physicochemical parameters during the study period in Baghdad Tourist Island Lake

Parameters			
	Code	Dry	Wet
		Mean±SD	Mean±SD
Water temp. °C	WT	22.343±4.513	15.08±1.615
light penetration	LP	159.25±41.06	158.583±57.25
Electric Conductivity µS/cm	EC	906.807±40.357	993.499±109.595
Salinity ‰	S‰	0.552±0.023	0.613±0.067
pH	pH	7.759±0.312	7.478±0.199
Total Alkalinity (mg CaCO3/L)	TA	153.61±13.291	172.502±23.317
Total Hardness(mg CaCO3/L)	TH	345.193±31.406	341.368±19.425
Calcium (mg CaCO3/L)	Ca	74.614±10.425	73.719±7.327
Magnesium (mg CaCO3/L)	Mg	64.881±6.995	66.136±5.105
Sodium (mg/L)	Na	59.722±6.189	56.473±7.157
Potassium (mg/L)	K	7.667±0.833	6.735±0.728
Total dissolved solids (mg/L)	TDS	630.293±25.299	704.866±94.305
Dissolved oxygen (mg/L)	DO	7.82±0.808	8.139±0.715
Total Phosphorus (mg/L)	TP	0.486±0.104	0.359±0.178
Total Nitrogen (mg/L)	TN	0.992±0.681	1.262±1.135

A total of 127 taxa were identified in the lake throughout the study period (Table 3). The identified phytoplankton belonged to diatoms (Bacillariophyceae (50.4%), Fragilariophyceae (6.2%) and Coscindiscophyceae (5.4%) which represented 62% in terms of a number of species, followed by Cyanophyceae (18.60%),(11.63%), Euglenophyeae (5.42%) and Dinophyceae (2.33%). Bacillariophyceae was the predominant group at all sites during the study seasons because of their ability to tolerate a wide range of environmental changes and the availability of silica in the Iraqi

water system [36], moreover, Bellinger and Sigee (37) interpret diatom dominancy due to their genetic diversion and high diversity make them enabled to exist in high percentage and present in many different environments [37]. The identified phytoplankton in the present study was less than recorded by previous studies on the same lake [12,13]. Ismail (12) recorded 230 phytoplankton taxa during 1988-1989, and 180 taxa by Kadeem et al. [13] study. The decline of phytoplankton taxa during the three periods (1988-1989, 2019-2020, and the present study, 2021-2022) was an alarm of environmental change in the lake. The change in species abundance and disappearance are sign of climate change which impacts aquatic ecosystems and subsequently community structure [38,39]. Moreover, the alteration in the phytoplankton community depends on different environmental factors and anthropogenic effects [40].

Table3. Identifies phytoplankton taxa during the study period in Baghdad Tourist Island Lake (10^4 cell/L)

classes	Dry						Wet					
	S1	%	S2	%	S3	%	S1	%	S2	%	S3	%
Chlorophytyceae	15	5	17	6	17	5	5	2	7	2	5	2
Cyanophyceae	7	3	9	3	8	2	6	3	7	2	9	3
Dinophyceae	3	1	2	1	3	1	1	1	1	0	1	0
Euglenophyceae	1	0	1	0	2	1	1	0	1	0	1	0
Coscinodiscophyceae	16	6	17	5	20	6	7	3	15	5	14	5
Bacillariophyceae	232	83	251	81	247	76	176	79	255	87	245	80
Fragilariophyceae	6	2	12	4	26	8	26	12	8	2	31	10
Total number	280	100	310	100	323	100	221	100	293	100	307	100

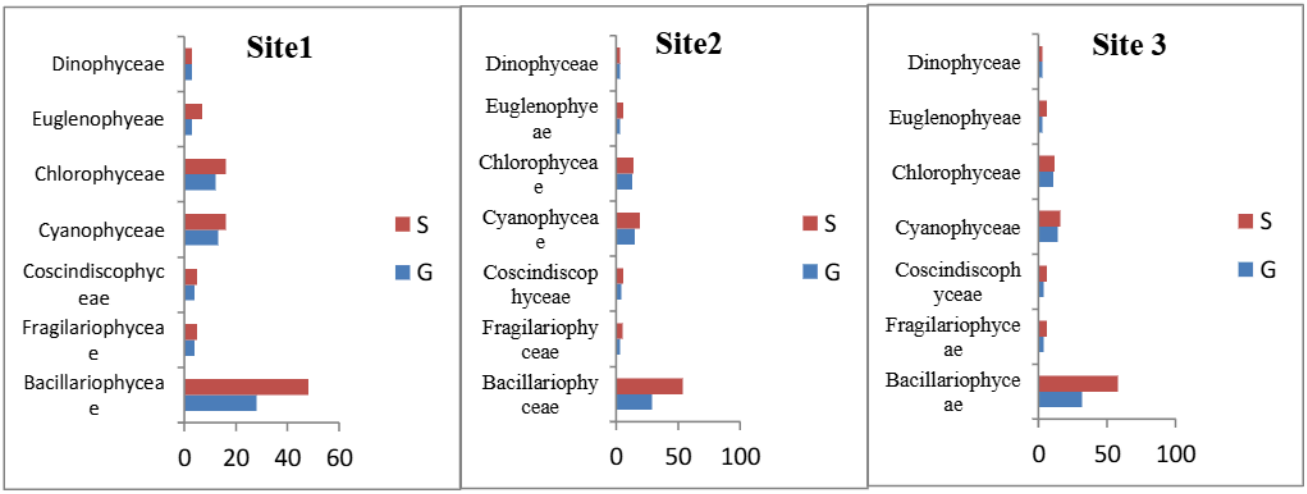

Figure 2. A spatial variation in number of species and genera of phytoplankton during the study period in Baghdad Tourist Island Lake.

Some genera were recorded as a high number of species; *Nitzschia* (10spp.), *Navicula* (7spp.), *Gomphonema* (4 spp.), *Merismopedia* (4spp.), and 3 species for each of *Cymbella*, *Cocconeis*, *Ulnaria*, *Phacus*. According to previous studies on phytoplankton, some genera were reduced in number, and others such as *Oscialltoria* and *Achnanthidium* which they recorded as dominant species in previous studies [12, 13].

The total number of phytoplankton ranged from 280 to 323 Cells*10^4/L at sites 1 and 3, respectively in the dry season and 221 to 307 Cells*10^4/L at sites 1 and 3 in the wet season (**Figures 3 and 4**). Pokhrel et al. [41] noticed a high algal diversity in the dry season than in the wet season and they interpreted it on the basis of the nutrient dilution factor in the wet seasons.

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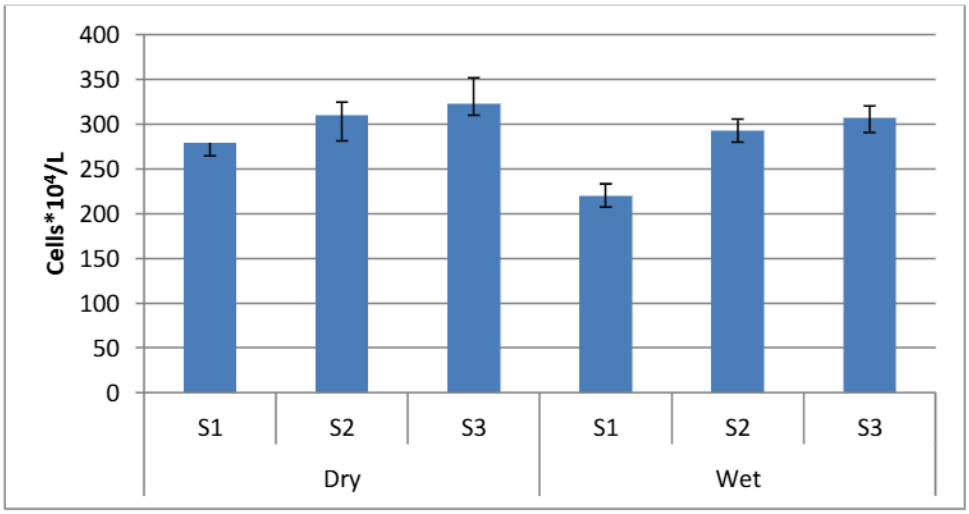
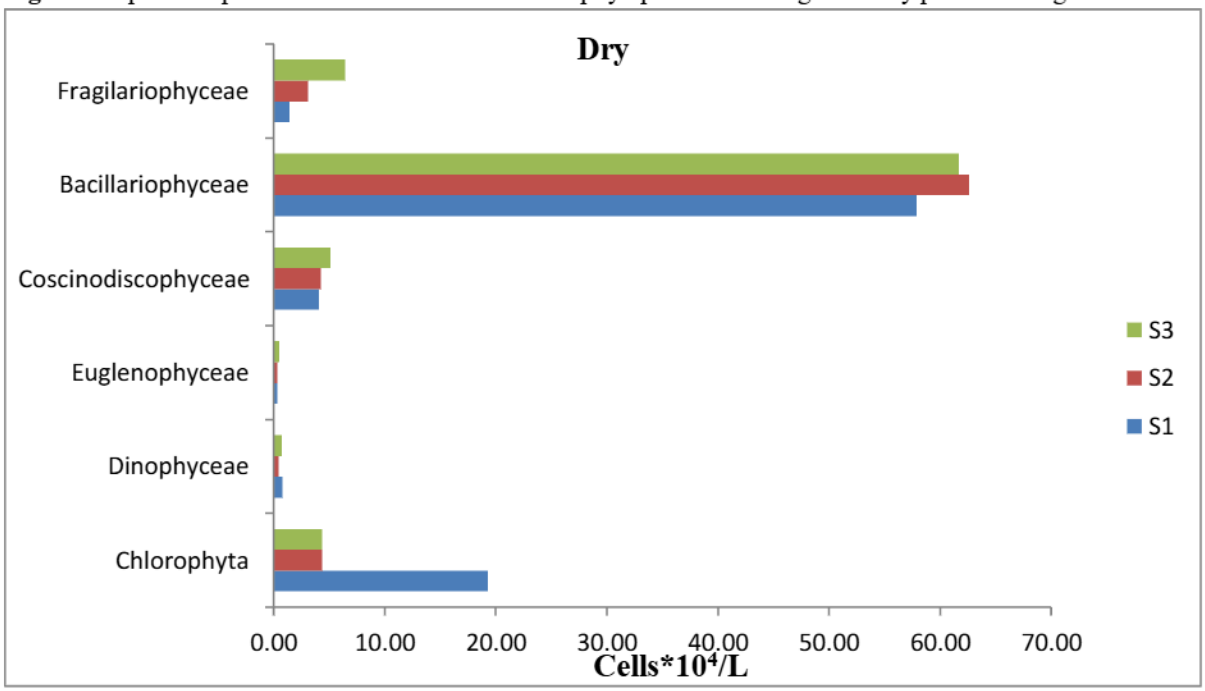


Figure 3. Spatiotemporal variation in total amount of phytoplankton during the study period in Baghdad Tourist Island Lake.



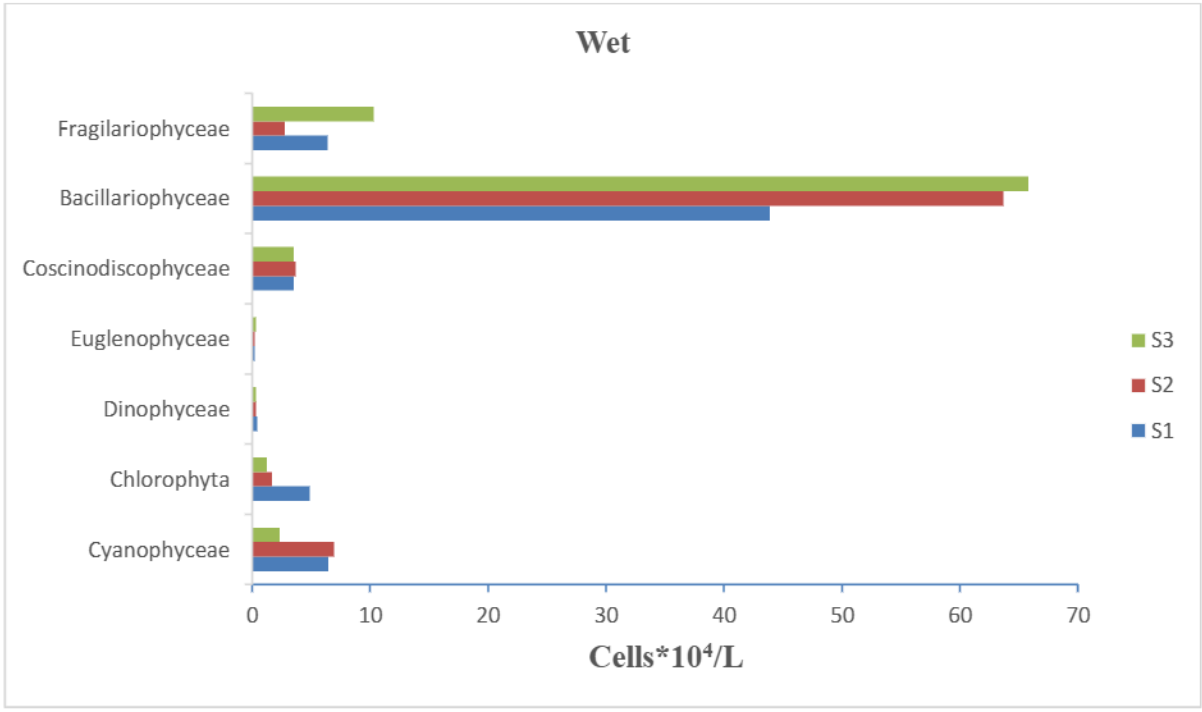


Figure 4. Spatiotemporal variation in percent of phytoplankton groups during the study period in Baghdad Tourist Island Lake.

Fragilariophyceae recorded a high total number in the wet season (>6 Cells*10^4/L at sites 1 and 3) except in site 2 (<3) and greater than 3 Cells*10^4/L in dry season at sites 2 and 3, while it's number of cells at site 1 less than 2. Coscindiscophyceae ranged from 4.09-5.12 Cells*10^4/L at sites 1 and 3 in dry season, respectively while in the wet season its total number was less than 4 Cells*10^4/L. The dominance of diatoms is a very known phenomenon in the Iraqi aquatic ecosystem [42]. This finding is supported by previous studies on the lake [12,13]. On another hand, the dominancy of diatoms in the lake referred to the satiability of the ecosystem [43,44].

Cyanophyceae were <1 -<7 Cells*10^4/L in both seasons. Chlorophyceae was noticed a high total number (19.30 Cells*10^4/L) in the dry season at site 1 and 4.89 Cells*10^4/L in the wet season while its low total number was recorded in the wet season (<2). Li et al. (45) found that the increase in TDS values caused an increase in the total number of diatoms and Cyanocphyceae, while an inhibitory effect was observed on Chlorophyceae, therefore, in the present study both algal groups (diatoms and Cyanocphyceae) were increased in the wet season with a noticeable rise in TDS values [45]. Euglenophyeae and Dinophyceae had a higher number of cells in dry season than in the wet season.

The phytoplankton community structure was becoming altered from the previous studies in terms of richness in genera and species. In the present study, some of the genera of phytoplankton were dominant in terms of the number of taxa and total cell number compared with previous studies on the lake (**Table 4**). Nitzschia spp.; *N. frusbulus*, *N. obtuse N. longissima, N. microcephala, N. fonticola, N. sigma, N. amphibian, N. palea, N. minuta,* and *N. linearis* were recorded a high taxa number and total cell number (**Figure 5**). Lowe (46) mentioned that *Nitzschia* spp., is considered as an indicator for alteration in water quality and its tolerated-pollution species. Moreover, the *Nitzschia* spp., their number increased in the presence of organic nitrogen. In the present study, their total number increased in the wet season with synchronism with an increase in TN concentration.

Table 4. The alteration in dominancy of phytoplankton genera during three periods in Baghdad Tourist Island Lake. (Modified from [12])

	2021-2022 (Present study)	2019-2020 (Kadeem et al., 2021)	1988-1989 (Ismail 1989
↑	*Nitzschia*	*Achnathidium*	*Cyclotella*
	Gomphonema	*Amphora*	*Anomoeoneis*
	Gomphonella	*Cocconeis*	*Meloseira*
	Navicula	*Cyclotella*	*Diplona*
	Achnanthes	*Cymatotopleura*	*Cymbella*
	Bacillaria	*Gomphonema*	*Achnanthes*
	Cocconeis	*Ulnaria*	*Nitzchia*
	Ulnaria	*Melosira*	*Navicula*
	Rhoicosphenia	*Navicula*	*Cymbella*
	Peronia		*Gomphonema*
	Encyonema		*Synedra*

*Navicul*a spp., were recorded a high number at site 2 in dry seasons, these genera included the following species; *N. inflafa*, *N. radiosa, N. oblonga, N. cryptocephala, N. cincta, N. schoretri*, and *N. phyllepta*. Navicula is classified in functional group MP in shallow, turbid, continue mixing lake [47,48].

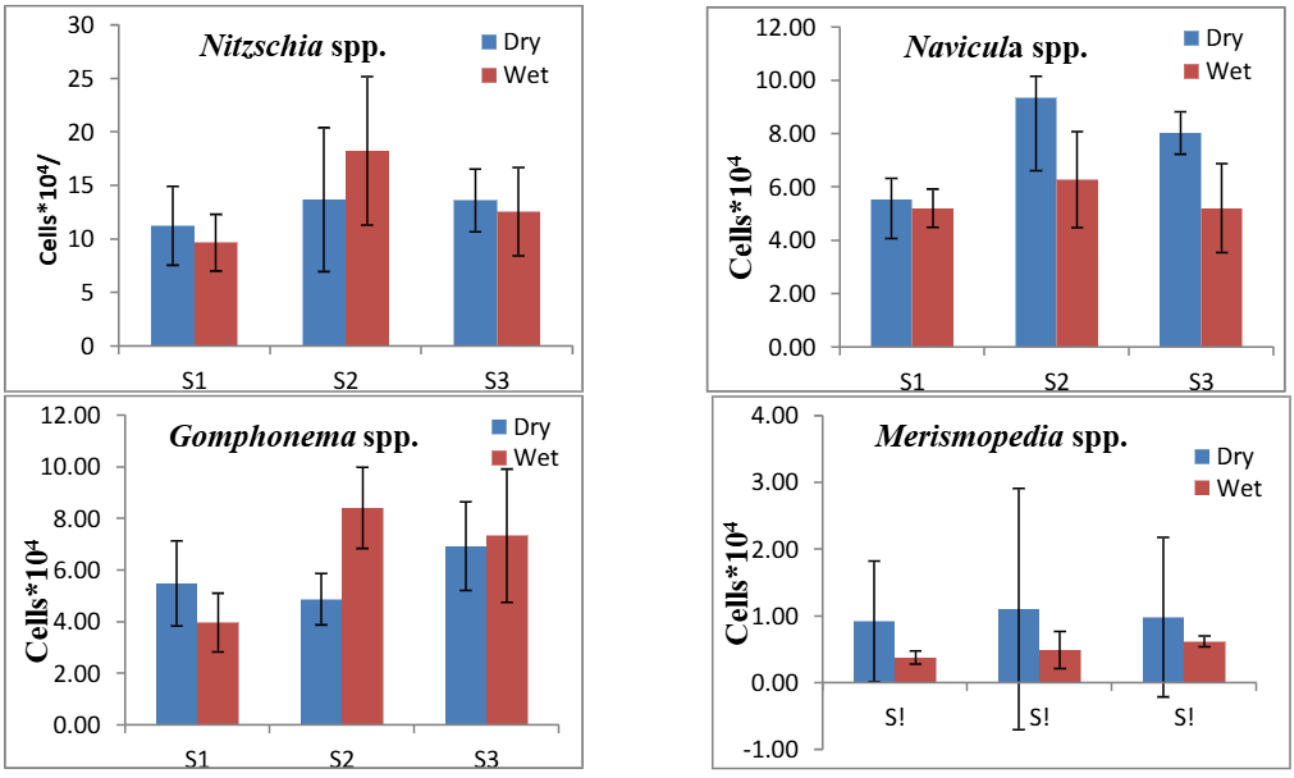


Figure 5. Spatiotemporal variation in dominant phytoplankton species during the study period in Baghdad Tourist Island Lake.

A high number of *Gomphonema* were noticed in wet season at site 2, and its species were; *G. olivacea*, *G. parvlum, G. gracile*, *G. aceumutum*, *G. intrcticm*, and Gomphonema sp. According to Palmer index the *Nitzschia*, *Navicula* and *Gomphonema* are considered as organic pollution indictors [49,50]. Shcherbak et al. (2018) mentioned the presence of centric diatoms (Coscinodiscophyceae) in urban water body referred to the adaptation to organic pollution [51].

Merismopedia spp, were noticed a high total number of cells in dry season at site 2 in contrast with wet season, and its species were *M. glance, M. convoluta*, *M. elgans, and M tenmuissima.* Reynolds (47) put the *Merismopedia* in group L◦, which found in Mesotrophic Lake and its tolerance to segregated nutrient. Canonical Correspondence Analysis.

The Canonical Correspondence Analysis (CCA) showed the relationship between the phytoplankton species and some physiochemical parameters in the present study. Figure 5 illustrate the *Bacillaria paxillifera* (Bpa) and *Achnanthes microcephala* (Ami) have a positive correlation with Water temperature, light penetration (LP), Hardness, total alkalinity, pH, dissolved oxygen (DO), Ca^{++}, K^{+}, and total phosphorus in dry seasons. While *Nitzschia microcephala* (Nmi) showed a negative correlation with physicochemical parameters. *Cocconeis placentula* (Cpl), *Encyonema ventricosum* (Eve), *Nitzschia amphibian* (Nam), *Navicula radiosa* (Nra), and *Tryblionella apiculata* (Tap) were not recorded a correlation with parameters. While *Navicula inflafa* (Min), *Cocconeis pediculus* (Cpe), *Ulnaria ulna* (Uul), *Gomphonella olivacea* (Gol), *Nitzschia frusbulus* (Nfr), and *Navicula cincta* (Nci) have correlated with Total nitrogen (TN) and total nitrogen: total phosphorus (TN:TP).

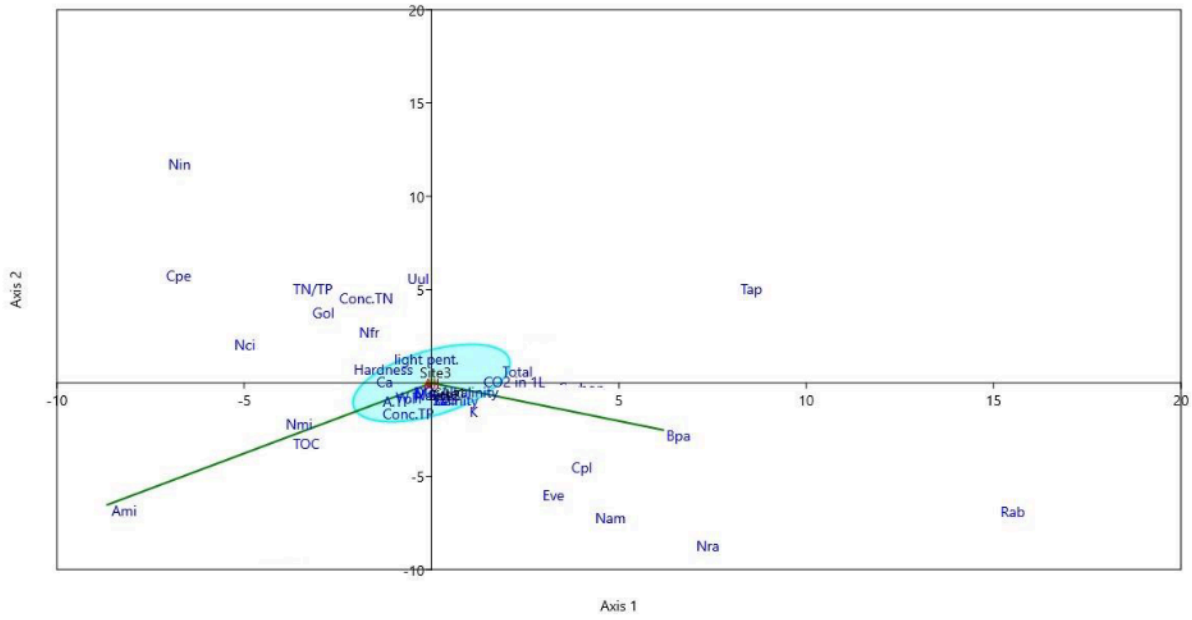


Figure 6.CCA analysis describe the relationships between phytoplankton species and physicochemical parameters in Baghdad Tourist Island Lake in dry season

In wet season (**Figure 7**), *Achnanthes microcephala* (Ami), *Cyclotella meneghiniana* (Cma), *Hantzsch amphioxus* (Ham), Nitzschia minuta (Nmi), Ulnaria ulna (Uul), Staurosira construens (Scu) and *Gomphonema parvlum* (Gpa) were positively correlated with all parameters except TN,TP, and TN:TP. Gomphonella olivacea (Gol) and Rhoicosphenia abbreviate (Rab) were correlated with TP. Peronia fibula (Pfi)and Nitzschia amphibian (Nam) correlated with TN and

TN:TP, while Nitzschia palea (Npa), Bacillaria paxillet (Bpa), and Navicula radiosa (Nra) were correlated with TN: TP. Nitzschia frusbulus (Nfr) was not correlated with physicochemical parameters. Phytoplankton species have different ability to response to the physicochemical parameters [10,52]. Kadeem et al. (13) found different results by CCA with results of the present study such as; *Nitzschia microcephala* (Nmi) showed a positive correlation with physicochemical parameters (13), while it's a negative correlation in the present study which reflected the alteration in phytoplankton community structure [12].

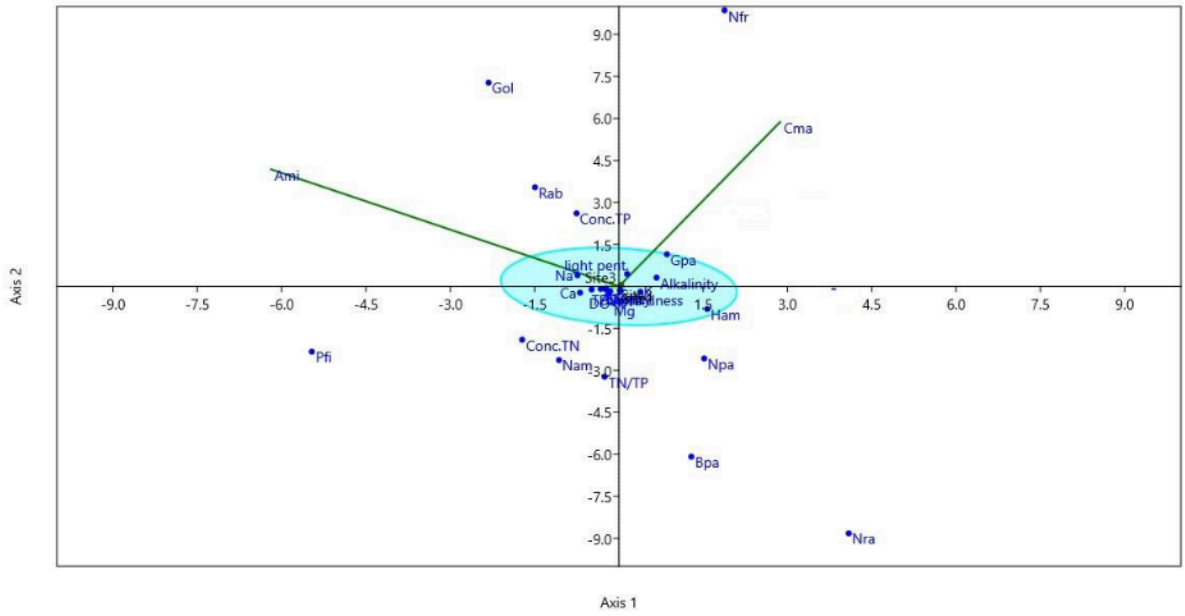


Figure 7.CCA analysis describe the relationships between phytoplankton species and physicochemical parameters in Baghdad Tourist Island Lake in wet season.

4.Conclusion

The environmental parameters revealed that the lake was alkaline, very hard, oligohaline, and good aerated. The trophic states were oligotrophic according to TP and TN concentrations. The community of phytoplankton undergoing a change in dominancy is a term of species not in the main phytoplankton groups. The phytoplankton community has undergone a spatial variation; therefore, the environmental factors drive their community structure.

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