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Effect of Pollution Type on the Phytoplankton Community Structure in Lake Mariut, Egypt

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THE EFFECT of water quality on the phytoplankton community was investigated in Mariut wetland, Egypt. Water samples were collected from the lake through five stations representing the four basins of the lake (northeast, northwest, southeast and southwest), in addition to Nubaria canal. Eighty-nine phytoplankton species, dominated with bacillariophytes and cyanophytes, were recorded. The northwest basin had the highest number of phytoplankton followed by the northeast basin, Nubaria canal, and the southeast and southwest basins. Holoplanktons dominated over tycoplanktons, meroplanktonic, and epiphetic algae. The dendrograms resulting from the agglomerative clustering technique based on water characteristics and phytoplankton composition had more or less the same trend. Moreover, the application of principal component analysis indicated that water pH, P, Cd, Zn and HCO_3 were the most effective variables affecting the distribution of phytoplanktons. Cyanophytes were highly affected by K and salinity, while bacillariophytes were affected by water pH and Pb, euglenophytes by Ca and Mg and chlorophytes by P, Cu and Fe. The predominance of bacillariophytes in the lake indicates the tolerance of this group to the different pollution types, while cyanophytes prefer fresh water and dominates the least polluted wetlands.

Keywords: Algae, Bioindicators, Community, Diatoms, Pollution.

Introduction

Phytoplankton is one of the highly diverse groups of microorganisms, which serves as one of the paradigm systems for maintaining species diversity (Stomp et al., 2007). Many factors such as productivity, nutrient supply and under-water light intensity, are known to affect phytoplankton species coexistence and distribution at a local scale (Khairy et al., 2015). The influence of various factors on the appearance of phytoplankton differs significantly, with physical factors such as temperature and light intensity being the most important; while chemical factors such as dissolved oxygen, pH, salinity, total hardness and nutrient level being of relatively less importance (Reynolds, 1984).

The distributions, abundance and species diversity and composition of phytoplankton are used to assess the biological integrity of the water body (Townsend et al., 2000). Phytoplankton is the main component of the aquatic ecosystem, where their diversity and productivity are strongly related to water quality (Moss, 1988). They reflect the nutrient status of the environment (Levich & Bulgakov, 1992). Over the last decades, numerous shallow lakes have been reported to have become eutrophic due to the excessive continuous inflow of nitrogen and phosphorus as a result of human activities (Los, 1991). Eutrophication of shallow lakes is often associated with abundant phytoplankton biomass, increasing water turbidity, and rapid decline of submerged macrophytes (Asaeda et al., 2001).

Water pollution is considered one of the most hazards affecting both developing and developed countries (Chakravarty et al., 2010). Lake Mariut is situated along the Mediterranean coast of Egypt at latitude 31° 2′-31° 12′ N and longitude 29° 51′-29° 59′ E. It is divided by artificial embankments into four basins (Fig. 1) northeast or main basin with an area of about 27.3km^2, southeast (fish farm) of about 4.2km^2, and southwest and northwest basins with a total area of 31.5km^2. The water depth varies between 0.5m and 1.2m with a mean of 0.80m. The fact that Lake Mariut is the only coastal lake in Egypt with no natural connection to the Mediterranean Sea increased

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the accumulation of pollutants in the lake. In the last decades, Mariut wetland was subjected to exponential anthropogenic impacts resulting from agricultural, human and industrial activities, which collectively pollute the water body of the lake (Galal et al., 2012). Erroneous polices for the disposal of sewage, industrial and agricultural wastes of Alexandria and Beheira Governorates seem to have no regard for environmental considerations, and led to severe deterioration of Lake Mariut (Galal, 2005).

The studies on the microphytes (i. e., phytoplankton) cover the species diversity and standing crop biomass of the major algal groups such as diatoms (El-Sherif, 1989 and El-Sheekh & Zalat, 1999), cyanophytes and chlorophytes (Kobbia, 1982 and El-Sherif, 1993). Some other studies were carried out on the epiphytes attached on the most dominant submerged hydrophyte *Potamogeton pectinatus*. The effect of pollution upon the liminological characteristics (Abdel-Moneim et al., 1987) and the aquatic organisms (Khalil & Awady, 1990) of Lake Mariut was studied. Several ecological studies demonstrated human impacts on the aquatic habitats (Raven et al., 1995).

The spatial and temporal differences in the extreme environmental conditions can affect the occurrence, relative abundances of phytoplankton, and specifically influence the community composition (Rauch et al., 2006). The role of phytoplankton as a main source of fish nutrition is well known, and in order to develop the fish economy it is necessary to study well the phytoplankton communities and the factors affecting their distribution (El-Sherif, 1993). Moreover, many studies were carried out on the impact of water pollution on macrophytes (Galal et al., 2008; Galal & Shehata, 2014 and Galal & Farahat, 2015), while little were carried out on phytoplankton. Therefore, the present study aims at investigating the effect of water quality and pollution type on the phytoplankton community structure and distribution in Mariut wetland, Egypt.

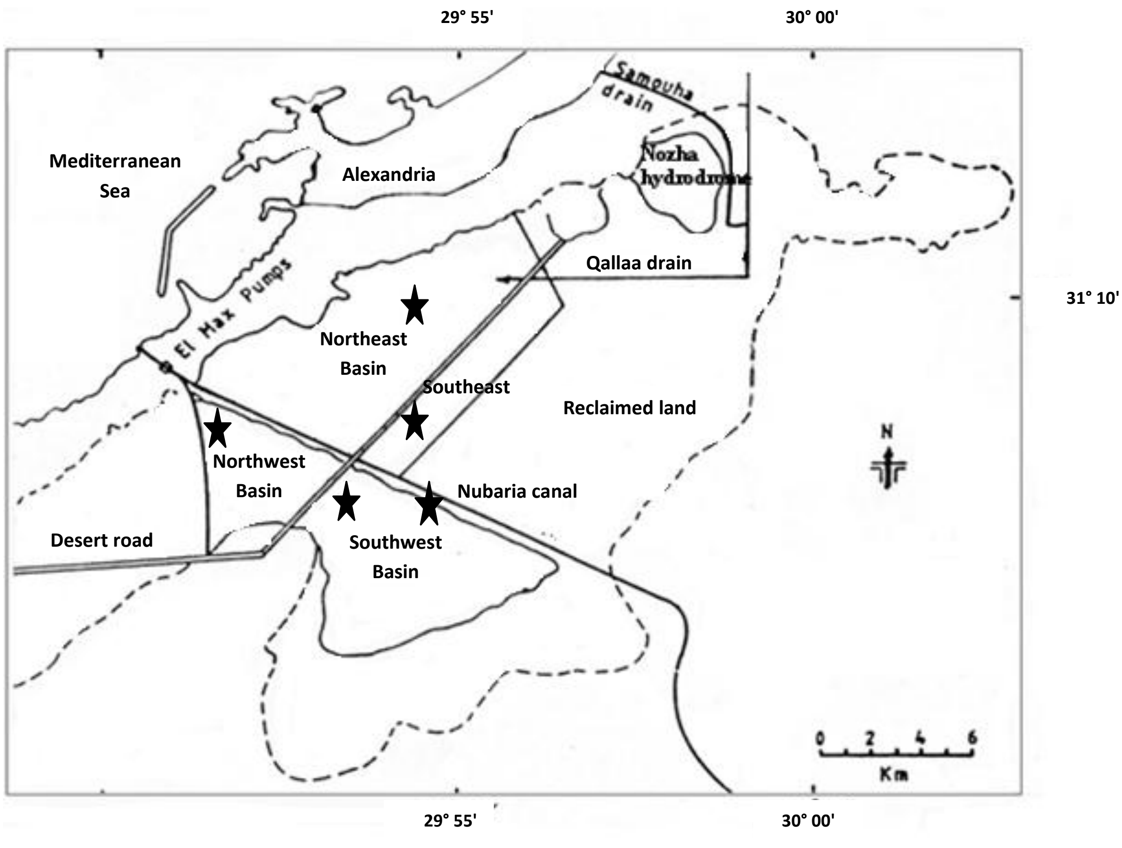

Fig. 1. Location map of Lake Mariut indicating the study basins (Black stars indicate the study stations (after Galal & Farahat, 2015).

Materials and Methods

Phytoplankton sampling

Three composite subsurface water samples (10-30cm depth) were collected from Lake Mariut, during spring season 2015, along five stations representing the four basins of the lake, in addition to Nubaria canal, which is the fresh water source for the lake. The northeast basin receives considerable amounts of sewage drainage, while the southeast basin receives a mixture of agricultural runoff and industrial wastes. In addition, the southwestern basin receives discharges from oil refineries and agriculture, and the northwestern basin receives discharges from oil and gas as well as textile and petrochemical industries (Galal & Farahat, 2015). Phytoplankton samples were fixed with Lugol's solution and species were recorded and enumerated using the inverted microscope method (Utermöhl, 1958). Classification, nomenclature as well as the main characteristics of the recorded species including their status and preferable habitats were gathered from Prescott (1982).

Water chemical analyses

In the field, one liter subsurface water samples (10-30cm depth) were collected from each station (three composite samples) for measuring (during day *in situ*) pH by an electric pH meter (Model 9107 BN, ORION type), and electrical conductivity using electric conductivity meter (60 Sensor Operating Instruction Corning). In the laboratory and prior to analysis, water samples were passed through Whatman glass microfibre filters (GF/C), then dissolved nutrients were measured using the standard methods of Allen (1989). Bicarbonates were determined by titration against 0.1N HCl using phenolphthalein and methyl orange as indicators. Chlorides were estimated by direct titration against 0.01N silver nitrate solution using 5% (*w/v*) potassium chromate as indicator and sulphates were determined turbidimetrically as barium sulphate at 500nm (Allen, 1989). Total N and P were determined using a spectrophotometer (CECIL CE 1021) by applying Indo-Phenol blue and molybdenum blue methods, respectively and N/P ratio was calculated. Calcium and magnesium were determined by titration against 0.01N versenate solution (EDTA disodium salt) using meroxide and eriochrome black T as indicators. Sodium and potassium were determined using flame photometer. All Copper, manganese, zinc, cadmium, lead and iron were determined with Pye Unicam Sp 1900 Recording Flame Atomic Absorption Spectrophotometery. All these procedures for water analysis were outlined by Allen (1989).

Data analysis

The agglomerative clustering techniques were applied to classify the phytoplankton communities of the water bodies, based on Euclidean distance (Kruscal, 1964). The relationship between the phytoplankton communities and water gradients was assessed using the ordination diagram produced by principal component analysis (PCA) (Kent & Coker, 1992). The inferred ranking of the species along the more influential environmental variables can be made by dropping perpendicular lines from the species co-ordinates to the environmental arrows. The length and direction of a line represents a given soil variable that provides an indication of the importance and direction of the gradient of environmental variable change. The angle between two lines reflects the correlation between the two variables represented by these lines. After testing the data for normality, the differences in the water variables among the different stations were tested using one-way analysis of variance (ANOVA) according to SPSS software version 15.0 (SPSS, 2006).

Results

The phytoplankton community of Lake Mariut includes 89 algal species: 30 species were bacillariophytes (Diatoms); 27 were cyanophytes; 22 were chlorophytes; 6 were euglenophytes; and 4 were chrysophyta (Table 1). Two species (*Chroococcus disperses* and *Gloeobotrys limneticus*) were recorded in four stations with different pollution types, while 7 species (*Chlorobotrys regularis, Scenedesmus obliquus* and *Cyclotella meneghiniana*) were recorded in three stations, and 28 species (*Nitzchia acicularia, Coelastrum cambricum* and *Phacus longicauda*) were recorded in two stations. Moreover, 52 species were exclusively recorded in one station; of them *Amphipleura* sp., *Oscillatoria pseudominima* and *O. spirulinoides* were restricted to the southeast basin; *Navicula reversa* and *Chlamydomonas sphagnicola* were exclusively recorded in the southwest basin; *Diploneis* sp., *Hormidiopsis ellipsoideum* and *Chlorococcum* sp. were recorded in Nubaria canal; *Cymbella microcephala, Nitzchia inconspicula* and *Coelastrum reticulatum* were present in northeast station; and *Cymbella ventricosa, Cyclotella operculata* and *Chlorococcum humicola* were recorded only in the northwest basin.

TABLE 1. Phytoplanktons species recorded in the water of the five stations of Lake Mariut.

Species	Status	Habitat	Station				
			Southeast	Southwest	Nubaria canal	Northeast	Northwest
Bacillariophyceae							
Cymbella sp.	Holoplanktonic	Fresh water	1	1	1		
Cymbella ventricosa	Holoplanktonic	Fresh water					1
Cymbella microcephala	Holoplanktonic	Fresh water				1	
Cyclotella sp.	Holoplanktonic	Fresh water			1		
Cyclotella operculata	Holoplanktonic	Fresh water					1
Cyclotella ocellata	Holoplanktonic	Fresh water		1			1
Cyclotella meneghiniana	Holoplanktonic	Fresh water	1	1			1
Navicula minima	Meroplankton	Eutrophic water	1	1			1
Navicula reversa	Meroplankton	Eutrophic water		1			
Navicula atomus	Meroplankton	Eutrophic water				1	1
Navicula capitata	Meroplankton	Eutrophic water				1	
Navicula gracilis	Meroplankton	Eutrophic water				1	
Navicula pelliculosa	Holoplanktonic	Polluted water				1	
Synedraacus sp.	Holoplanktonic	Fresh water		1			1
Synedra radians	Epiphetic	Fresh water				1	
Nitzchia inconspicula	Meroplankton	Polluted water				1	
Nitzchia acicularia	Meroplankton	Polluted water				1	1
Nitzchia palea	Meroplankton	Polluted water				1	1
Nitzchia obtusa	Meroplankton	Polluted water			1	1	
Nitzchia communis	Meroplankton	Polluted water				1	1
Fragilaria capucina	Holoplanktonic	Eutrophic water					1
Fragilaria pinnata	Holoplanktonic	Brackish water					1
Denticyla sp.	Holoplanktonic	Fresh water			1		
Amphora sp	Meroplankton	Fresh water			1		1
Achnanthes minutisima	Holoplanktonic	Polluted water				1	1
Diploneis .sp	Holoplanktonic	Fresh water			1		
Opephora sp.	Holoplanktonic	Fresh water	1				
Stauroneis sp.	Meroplankton	Fresh water	1				
Amphipleura sp.	Holoplanktonic	Fresh water	1				
Surirella sp	Meroplankton	Fresh water	1	1			
Chlorophyceae							
Scenedesmus quadricauda	Holoplanktonic	Various habitats			1	1	1
Scenedesmus abundans	Holoplanktonic	Various habitats			1		1
Scenedesmus obliquus	Holoplanktonic	Brackish water	1	1			1
Scenedesmus armatus	Holoplanktonic	Various habitats				1	1
Scenedesmus bijuga	Holoplanktonic	Brackish water				1	1
Hormidiopsis ellipsoideum	Holoplanktonic	Brackish water			1		
Chlorella ellipsoida	Holoplanktonic	Brackish water			1		1
Chlorella vulgaris	Holoplanktonic	Eutrophic water	1	1			1
Chlamydomonas sp.	Holoplanktonic	Eutrophic water	1				
Chlamydomonas sphagnicola	Tycoplanktonic	Brackish water		1			
Selenastrum gracile	Holoplanktonic	Brackish water	1	1			
Coelastrum cambricum	Holoplanktonic	Various habitats		1		1	
Coelastrum indicum	Holoplanktonic	Various habitats				1	
Coelastrum reticulatum	Holoplanktonic	Various habitats				1	

TABLE 1. Cont.

Species	Status	Habitat	Station				
			Southeast	Southwest	Nubaria canal	Northeast	Northeast
Westella botryoides	Holoplanktonic	Various habitats	1			1	
Pandorina morum	Holoplanktonic	Various habitats				1	1
Selenastrum gracile	Tycoplanktonic	Brackish water			1		
Chlorococcum humicola	Holoplanktonic	Various habitats					1
Chlorococcum sp.	Holoplanktonic	Various habitats			1		
Oocystis lacustris	Holoplanktonic	Brackish water					1
Chladophora sp.	Meroplankton	Eutrophic water			1	1	
Mougeotia varians	Tycoplanktonic	Fresh water				1	1
Cyanophyceae							
Oscillatoria pseudominima	Meroplankton	Brackish water	1				
Oscillatoria sp.	Holoplanktonic	Eutrophic water			1		
Oscillatoria lacustris	Holoplanktonic	Various habitats				1	1
Oscillatoria sp.	Holoplanktonic	Various habitats		1			1
Oscillatoria planctonica	Holoplanktonic	Various habitats		1			1
Oscillatoria spirulinoides	Holoplanktonic	Various habitats	1				
Oscillatoria amphibia	Holoplanktonic	Brackish water					1
Lyngbia major	Holoplanktonic	Various habitats	1			1	
Lyngbia lagerheimii	Tycoplanktonic	Brackish water			1		
Lyngbia Taylorii	Tycoplanktonic	Brackish water			1		
Lyngbia salina	Tycoplanktonic	Brackish water		1			
Lyngbia spirulinoides	Tycoplanktonic	Brackish water			1		
Lyngbia limnetica	Holoplanktonic	Brackish water					1
Phormidium molle	Tycoplanktonic	Various habitats				1	
Phormidium fragile	Tycoplanktonic	Various habitats					1
Phormidium inundatum	Tycoplanktonic	Various habitats		1			
Phormidium dictyothallum	Tycoplanktonic	Various habitats	1				
Phormidium mucicola	Holoplanktonic	Brackish water			1		
Nostoc punctiforme	Epiphetic	Fresh water				1	
Microcystis aeruginosa	Holoplanktonic	Polluted water	1	1			
Calothrix braunii	Tycoplanktonic	Brackish water				1	
Anabaena augstumalis	Holoplanktonic	Brackish water				1	
Anabaena macrospora	Holoplanktonic	Various habitats				1	
Schizothrix fuscescens	Tycoplanktonic	Various habitats			1		
Microcystis aeruginosa	Holoplanktonic	Brackish water				1	
Spirulina minima	Holoplanktonic	Fresh water					1
Chroococcus dispersus	Holoplanktonic	Various habitats	1	1		1	1
Chrysophyta							
Crysocapsa planctonica	Holoplanktonic	Various habitats			1		
Gloeobotrys limneticus	Tycoplanktonic	Brackish water		1	1	1	1
Chlorobotrys regularis	Tycoplanktonic	Brackish water		1	1		1
Palmella botrydium	Holoplanktonic	Brackish water					1
Euglenophyta							
Phacus caudate	Tycoplanktonic	Brackish water			1		
Phacus longicauda	Tycoplanktonic	Brackish water				1	1
Euglena gracilis	Holoplanktonic	Eutrophic water				1	1
Euglena proxima	Holoplanktonic	Brackish water				1	1
Chroomonas erosa	Holoplanktonic	Various habitats					1
Aphanotheca stagnina	Holoplanktonic	Various habitats			1		

Forty species of phytoplankton were recorded in the northwest basin dominated with bacillariophytes (14 species) followed by chlorophytes (11 species) and cyanophytes (8 species) (Table 1), 35 species were recorded in the northeast basin dominated with bacillariophytes (12 species), followed by chlorophytes (10 species), cyanophytes (9 species), euglenophytes (3 species) and chrysophytes (one species). In addition, Nubaria canal had 24 species; seven of them were chlorophytes, and six were either bacillariophytes or cyanophytes, however chrysophytes and euglenophytes were represented by three and two species, respectively. The southeast and southwest basins had the same distribution pattern with the predominance of bacillariophytes (7 species), followed by cyanophytes (6 species), and chlorophytes (5 species), while two excessive species of chrysophytes were recorded in the southwest basin.

Holoplankton had the highest contribution (64.0% of the total species), followed by Tycoplankton (19.1%), meroplankton (16.9%), and epiphetic algae (2.2%) (Fig. 2). In addition, 29.2% of the total recorded phytoplankton prefer brackish water (*Scenedesmus obliquus*, *Chlorella ellipsoida* and *Phormidium mucicola*), while 21.4% were fresh water (*Cymbella ventricosa*, *Cyclotella meneghiniana* and *Nostoc punctiforme*), 12.4% inhabit the eutrophic water (Navicula minima, Fragilaria capucina and Euglena gracilis) and 8.9% can tolerate polluted water (*Nitzchia inconspicula*, *Nitzchia obtuse* and *Microcystis aeruginosa*) (Fig. 3). Moreover, 28.1% of the total recorded phytoplankton inhabits various habitats (*Scenedesmus quadricauda*, *Oscillatoria lacustris* and *Crysocapsa planctonica*).

The water chemical characteristics of the studied stations (Table 2) indicated that the northwest basin had the highest values of water salinity (8.69mS cm^{-1}), total N, P, Ca, Mg, Na, K, HCO_3 and SO_4 (20.10, 4.39, 5.53, 14.23, 79.13, 2.66, 9.64 and 13.91mg l^{-1}), but the lowest pH (7.47). In addition, the highest water pH value (8.89) was recorded in Nubaria canal, while the highest chloride (89.29mg l^{-1}) was recorded in the water of the northeast basin. On the other hand, the fish farm basin had the lowest water salinity (4.08mS cm^{-1}), Ca, Na, Cl and SO_4 (1.38, 15.49, 21.61 and 0.65mg l^{-1}), while the lowest water N and HCO_3 (1.46 and 3.49mg l^{-1}) were recorded in Nubaria canal. Moreover, the analysis of heavy metals in the water of the different basins (Table 3) indicated that the northwest basin had the highest water Fe, Mn and Cu (0.149, 0.179 and 0.028mg l^{-1}), while the northeast basin had the highest water Zn and Cd (0.023 and 0.006mg l^{-1}), but the lowest Pb (0.117mg l^{-1}). The highest water Pb (0.249mg l^{-1}) was recorded in southwest basin. Nubaria canal had the lowest water Fe, Mn and Cu (0.029, 0.040 and 0.020mg l^{-1}).

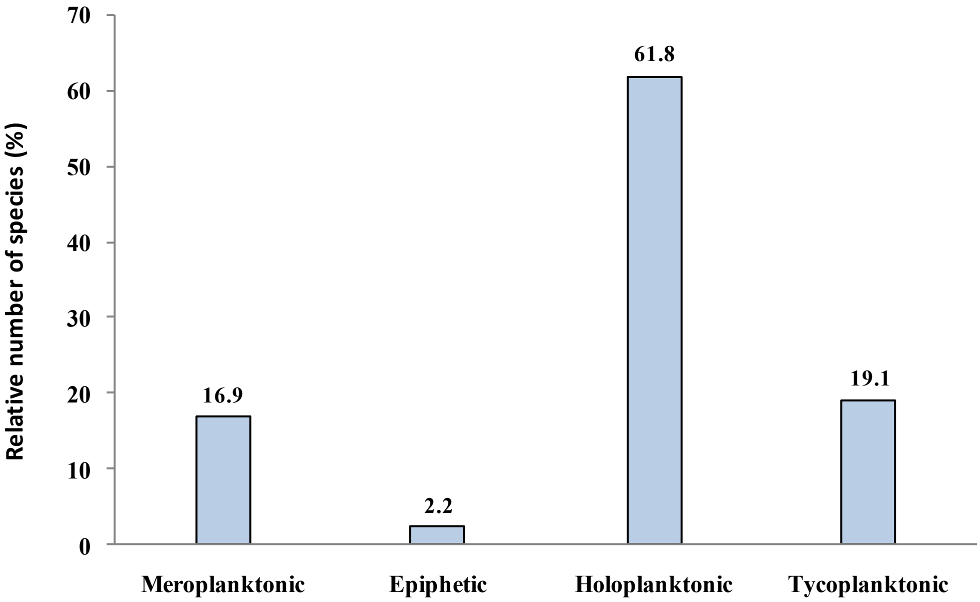

Fig. 2. Status of the phytoplanktons species recorded in the water of the five study stations in Lake Mariut.

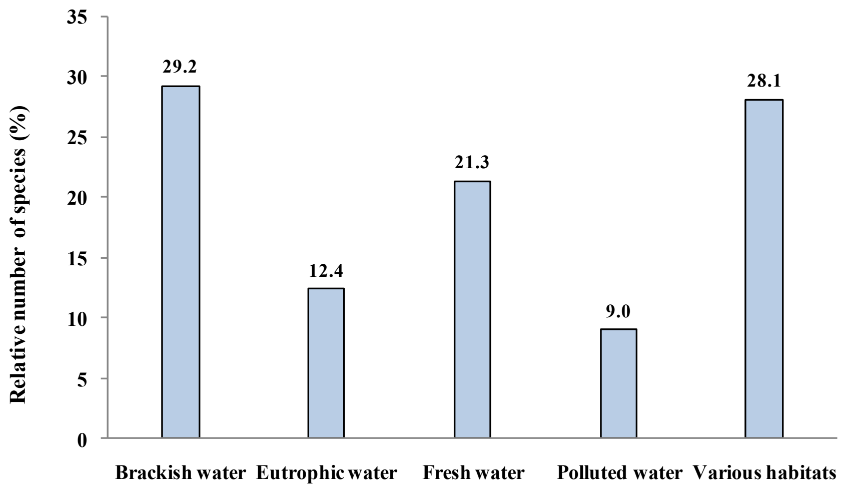

Fig. 3. Preferable habitats of the phytoplanktons species recorded in the water of the five study stations in Lake Mariut.

TABLE 2. Water chemical characteristics (mean±SD) of the five stations of Lake Mariut.

Water variable		Station					
		Southeast	Southwest	Nubaria canal	Northeast	Northwest	F-value
pH		8.19±0.57	7.65±0.67	8.89±1.17	7.68±1.08	7.47±0.18	6.19**
EC (mS cm^{-1})		4.08±1.56	5.52±1.89	4.39±0.55	8.17±1.03	8.69±1.57	10.37**
N	mg l^{-1}	4.25±0.39	3.87±0.41	1.46±0.52	5.23±1.03	20.10±3.18	65.78***
P	mg l^{-1}	3.95±0.28	3.51±0.42	4.05±0.23	3.50±0.28	4.39±1.05	3.38
Ca	mg l^{-1}	1.38±0.56	1.47±0.35	2.31±0.33	3.07±0.70	5.53±0.35	36.77***
Mg	mg l^{-1}	3.77±0.72	2.97±0.65	5.83±0.57	8.60±1.35	14.23±3.46	23.34***
Na	mg l^{-1}	15.49±2.55	24.80±2.42	33.98±2.73	74.41±3.39	79.13±4.65	242.88***
K	mg l^{-1}	1.38±0.41	0.83±0.45	1.07±0.40	2.54±0.46	2.66±0.46	11.47**
HCO_3	mg l^{-1}	4.81±1.31	3.52±0.52	3.49±0.37	3.50±0.40	9.64±2.22	18.98***
Cl	mg l^{-1}	21.61±3.15	28.58±1.88	33.82±3.27	89.29±6.11	84.63±3.19	244.27***
SO_4	mg l^{-1}	0.65±0.29	1.21±0.55	6.49±1.73	3.45±0.44	13.91±2.06	56.20***

TABLE 3. Mean and standard deviation of water trace metals concentrations (mg l^{-1}) of the five stations of Lake Mariut.

Water variable	Station					
	Southeast	Southwest	Nubaria canal	Northeast	Northwest	F-value
Fe	0.068±0.002	0.051±0.001	0.029±0.002	0.063±0.001	0.149±0.018	91.08***
Zn	0.001±0.00	0.022±0.002	0.01±0.002	0.023±0.001	0.018±0.011	9.86**
Mn	0.080±0.003	0.064±0.005	0.040±0.004	0.178±0.003	0.179±0.11	367.73***
Cu	0.023±0.001	0.022±0.002	0.020±0.002	0.021±0.001	0.028±0.008	2.19
Pb	0.242±0.005	0.249±0.005	0.168±0.002	0.117±0.009	0.136±0.014	166.57***
Cd	Nd	0.004±0.00	0.003±0.00	0.006±0.001	0.005±0.001	134.25***

The dendrogram resulting from the application of the agglomerative clustering technique based on the water characteristics of the five studied station leads to the recognition of three groups: The first comprised the southeast and southwest basins; the second included Nubaria canal; and the third group comprised the northeast and northwest basins (Fig. 4 a). On the other hand, the dendrogram resulting from the application of the agglomerative clustering technique based on the phytoplankton composition produced four groups: The first comprised the southeast and southwest basins; the second one included the northeast basin; the third included Nubaria canal; and the fourth comprised the northwest basin (Fig. 4 b).

The application of PCA ordination indicated that water pH, P, Cd, Zn and HCO_3 were the most effective variable in the distribution of phytoplanktons in Lake Mariut (Fig. 5). It was found that cyanophytes were present on a high gradient of K and moderate gradients of salinity, Na, Cl and Mn, while bacillariophytes were greatly affected with water pH and Pb. euglenophytes were present on high gradients of Ca and Mg, while chrysopytes were the least affected group by water chemistry. Moreover, chlorophytes were greatly affected with water P and moderately affected with HCO_3, Cu and Fe. Furthermore, the ordination axes of PCA separated the phytoplanktons into three groups: The first included cyanophytes; the second one comprised euglenophytes, chrysophytes and chlorophytes; and the third group included bacillariophytes.

a)

b)

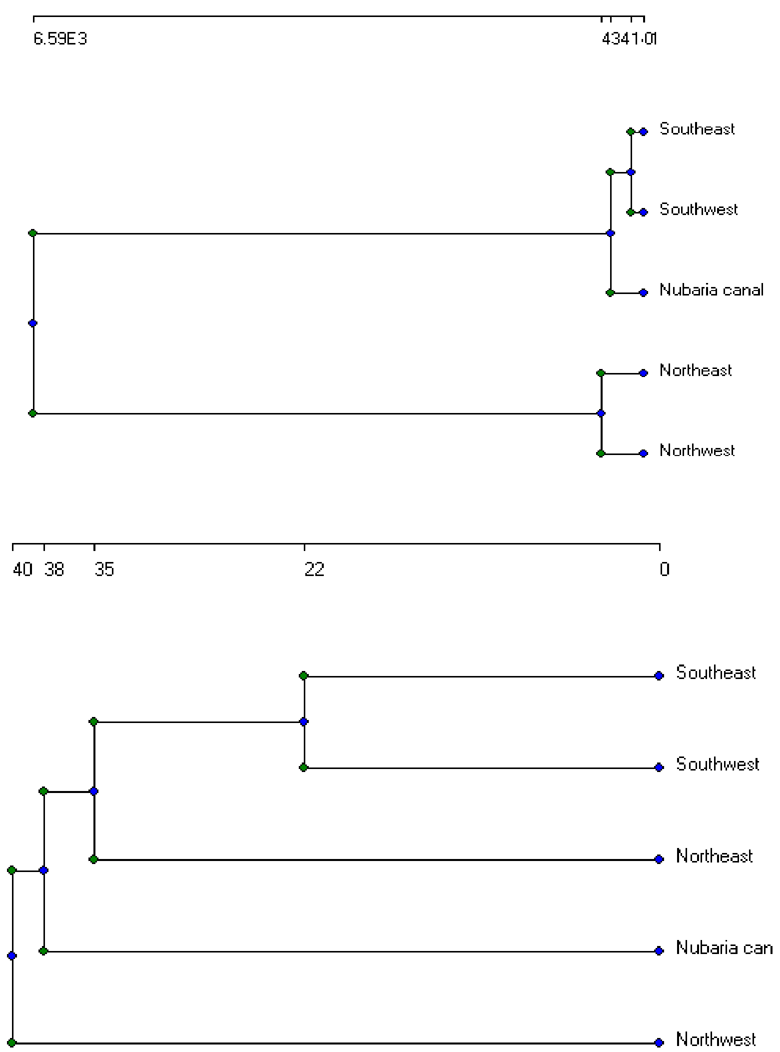

Fig. 4. The dendrogram resulting from the application of the agglomerative clustering technique on the water characteristics (a) and phytoplankton composition (b) of the five study stations in Lake Mariut.

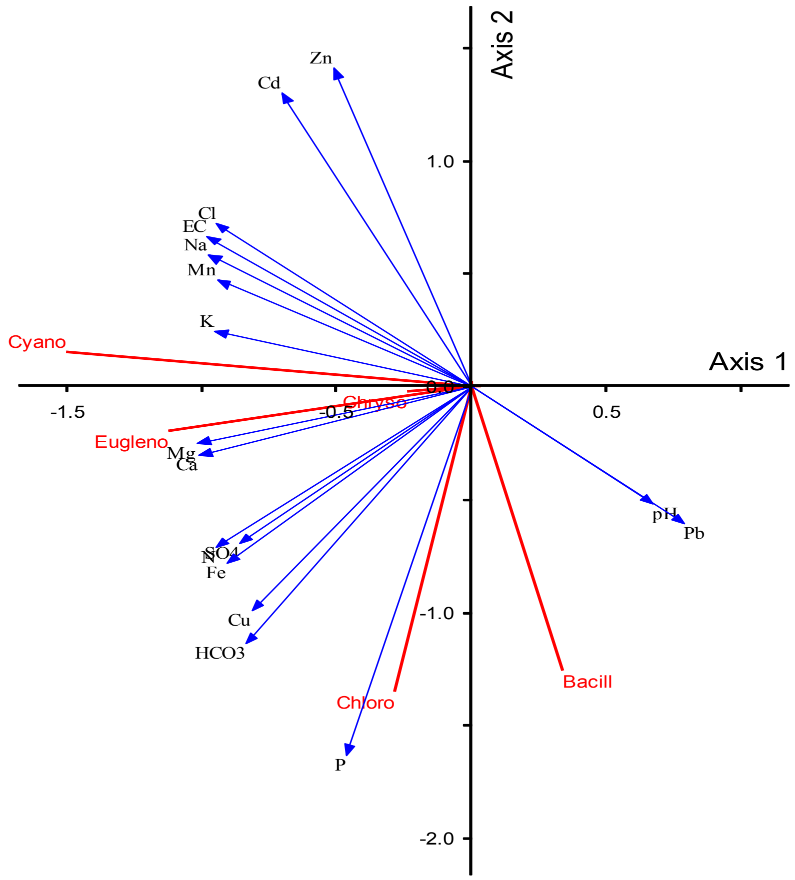

Fig. 5. Principal component analysis (PCA) ordination of the five phytoplankton groups (lines) along the gradient of environmental variables (arrows) in Lake Mariut.

Discussion

The phytoplankton community of Lake Mariut is considered rich, whereas most of the species are fresh, brackish water or various forms. These results coincided with El-Sherif (1989, 1993), El-Sheekh & Zalat (1999), Fathi et al. (2001) and Radwan (2002) on the phytoplankton communities of Lake Burullus. Lake Mariut contributed 89 phytoplanktonic species predominated with bacillariophytes (Diatoms), followed by chlorophytes, cyanophytes, euglenophytes, chrysophyta and cryptophyte. Kobbia (1982), El-Sherif (1993) and Khairy et al. (2015) recorded 49, 113 and 247 species, respectively in Lake Burullus, while Essa (2013) recorded 383 species in Lake Manzala along the Mediterranean coast. The number of phytoplankton taxa recorded in the present study represents about 10.3% of the total taxa (867 species) recorded in the five Mediterranean lakes (Khairy et al., 2015). However, a preliminary estimation of the phytoplankton in the fresh water habitats in Egypt approximated 871 species and 39 varieties (EEAA, 1995). According to Fathi et al. (2001) and Chen et al. (2017), light availability, salinity and nutrients are the main causes for the reduction of phytoplankton communities in Lake Mariut compared with the deltaic lakes. Moreover, disturbance and pollution of Lake Mariut degrades the phytoplankton communities by encouraging greater abundance of blue-green algae, and consequently increased threats to water quality (Fathi et al., 2001).

The predominance of bacillariophytes in the different basins of Lake Mariut was also reported by El-Sherif (1989), Okbah & Hussien (2006) and El-Sherif & Gharib (2001) in Burullus; Fathi et al. (2000) in Edku; and Okbah & Hessien (2005) in Mariut. In addition, Khairy et al. (2015) reported that bacillarophytes are the most dominant, while Kobbia (1982) and Radwan (2002) reported the dominance of chlorophyta in Burullus, and Koussa (2000) reported that cyanophytes are the most abundant followed by bacillarophytes in Lake Mariut. According to Khairy et al. (2015), the dominance of bacilariophytes may be attributed to the high concentration of silica, while the high amount of nitrate, phosphate and sulphate increase the abundance of chlorophytes and cyanophytes.

Thirty diatom species were recorded in Lake Mariut dominated with *Cyclotella meneghiniana*. However, El-Sherif et al. (1989) and Okbah & Hessien (2005) recorded 59 and 68 species, respectively in Burullus, and El-Sheekh & Zalat (1999) recorded 114 and 76 species in Edku and Burullus, respectively with the same dominant species. The lower number of diatoms in the present lake, compared with the other lakes, may be attributed to the high eutrophication and the higher water salinity of Lake Mariut. Abdalla et al. (1991) exhibited that the high concentrations of dissolved N and P may cause excess stress and load on the lake ecosystem, which in turn exceeds the phytoplankton requirements and decline its community. In addition, excessive nutrients trigger phytoplankton blooms, which create hypoxic "dead zones" in the water body (Dai et al., 2017). Moreover, Abdalla et al. (1991) attributed the predominance of diatoms over chlorophytes to the increased pollution in the lake.

It is well known that any changes in the water physico-chemistry in any lake have lead to concomitants qualitative and quantitative changes in the structure of planktonic communities (Fathi et al., 2001). Our results showed that most environmental stressors and their effects on the phytoplankton community vary in the sites highly affected by different pollution types. As a result of the extensive input of nutrients from Alexandria city, the enclosed nature of the lake, and the shallowness of the water, heavy algal blooms and domination of plankton occurs. According to El-Sheekh (2009), phytoplankton varied with waste type and with environmental conditions. The highest number of phytoplankton was recorded in the northwest basin polluted with sewage wastes and rich in nutrients, while the lowest was recorded in the southeast and southwest basins contaminated with oil and industrial wastes. The high concentrations of nutrients and phytoplankton densities show signs of eutrophication at the polluted sites. Eutrophication is characterized by excessive algal growth due to the increased availability of one or more limiting growth factors needed for photosynthesis (Schindler, 2006), such as sunlight, carbon dioxide, and fertilizers (Chislock et al., 2013). Moreover, El-Sheekh et al. (2000) and El-Dib et al. (2001) found that oil pollution decreased phytoplankton communities in polluted locations.

The fresh water of Nubaria canal was dominated with chlorophytes, while the brackish water of the other basins was dominated with diatoms. Iliopoulou-Georgudaki et al. (2003) reported that the diatoms are less sensitive to water pollution. According to El-Sheekh (2009), euglenophytes and bacillariophytes were potential indicators for water pollution. In addition, the abundance of euglenophytes in the northeast basin can be attributed to the entry of nutrients through the influx of domestic sewage, which is an indication of organic pollution (Laskar & Gupta, 2009). Moreover, nutrients such as N and P usually limit the algal growth in natural seawater. Their pollution is one of the main factors of harmful algal blooms, such as blue-green algal blooms (Zhao et al., 2017). The fluctuations in N/P ratio severely affected the existence of phytoplankton community (Ali & Khairy, 2016). This ratio, known as the Redfield ratio, is generally assumed to be the parameter according to which these nutrients are ultimately required by algal cells (Reynolds, 1984). In our stations, the mean N/P ratio at the anthropogenically affected sites is lower than 7, which demonstrate that a large concentration of P is loaded there from domestic discharges and N is the limited nutrient for algal growth (Abboud-Abi Saab & Hassoun, 2017).

Changes in phytoplankton communities in lakes have been regarded as a good bioindicator of water quality, ecosystem health and trophic status of the system (Zeng et al., 2017). While phytoplankton are amongst the most widely used indicators of biological integrity and physico-chemical conditions in aquatic ecosystems, this study revealed that the species present in Lake Mariut consisted of a mixture of sensitive, tolerant and resistant responses to anthropogenic stressors. The application of PCA ordination indicated that water pH, P, Cd, Zn and HCO_3 were the most effective variable in the distribution of phytoplanktons in Lake Mariut. It was found that cyanophytes were present on moderate gradients of salinity; while bacillariophytes were greatly affected with water pH and Pb. Harsha & Malammanavar (2004) indicated that cyanophytes constitutes one of the major phytoplanktonic groups mostly confined to freshwater zones (George et al., 2012). The occurrence of this group could be related to high temperature, slightly alkaline conditions, nutrient rich freshwater discharge, and turbidity due to suspended sediment, which favors their growth.

Conclusion

The low diversity of phytoplankton in Lake Mariut compared with the other Mediterranean lakes may be attributed to the higher salinity and the high pollution load of the lake. The predominance of the bacillariophytes in the lake indicates the tolerance of this group to the different pollution types, while cyanophytes preferred the fresh water and dominated the least polluted water of Nubaria canal.

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تأثير نوع التلوث على تركيب مجتمع العوالق النباتية فى بحيرة مريوط، مصر

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تم دراسة تأثير جودة المياه على مجتمع العوالق النباتية في الأراضي الرطبة ببحيرة ماريوت، مصر. تم جمع عينات المياه من البحيرة من خلال خمس محطات تمثل أحواض البحيرات الأربعة (شمال شرق، شمال غرب، جنوب شرق وجنوب غرب)، بالإضافة إلى ترعة النوبارية. تم تسجيل تسعة وثمانون نوعًا من العوالق النباتية، تسودها الطحالب الذهبية والطحالب الخضراء المزرقة. سجل الحوض الشمالي الغربي أعلى عدد من العوالق النباتية، يليه الحوض الشمالي الشرقي، وترعة النوبارية، ثم الأحواض الجنوبى الشرقى والغربى. سادت العوالق هولوبلانكتون على تايكوبلانكتون والطحالب الفوقية. كانت الأشكال النثرية الناتجة عن تقنية التكتل التجميعي القائمة على خصائص الماء والتركيب الهضمي على نفس الأتجاه تقريباً. وعلاوة على ذلك، أشار تطبيق تحليل المكونات الرئيسية إلى أن درجة حموضة الماء، الفوسفور، الكادميوم، الخارصين والبيكربونات كانت أكثر المتغيرات التي تؤثر على توزيع العوالق النباتية. وقد تأثرت الطحالب الخضراء المزرقة بدرجة كبيرة بالبوتاسيوم وملحة الماء، بينما تأثرت الطحالب الذهبية بدرجة الحموضة في الماء و الرصاص، والطحالب اليوجلينية بالكالسيوم والماغنسيوم، والطحالب الخضراء بالفوسفور والنحاس والحديد. تشير هيمنة الطحالب الذهبية في البحيرة إلى مقاومة هذه المجموعة من العوالق النباتية لأنواع التلوث المختلفة، في حين تفضل الطحالب الخضراء المزرقة المياه العذبة حيث تسود المياه الأقل تلوثًا.