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Present Status and Long Term Changes of Phytoplankton in Closed Saline Basin with Special Reference to the Effect of Salinity

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ABSTRACT

The present status of phytoplankton communities was studied at 10 stations during late summer and mid winter 2011. A total of 8 classes, 84 genera and 197 species were recorded in the lake. The recorded classes were diatoms, chlorophytes, cyanobacteria, dinoflagellates, cryptophytes, euglenophytes, and two groups recorded for the first time which are prasinophytes and coccolithophorbide. Diatoms had 27 genera with 89 species, chlorophytes had 25 genera with 45 species, cyanobacteria had 11 genera with 24 species, dinoflagellates had 13 genera with 26 species, cryptophytese had 4 genera with 5 species, euglenophytes had 1 genus with 2 species. *Prasinophyceae* and coccolithophorbide which represented by 1 genus with 4 species and 2 genera with 2 species, respectively. The application of TWINSPAN, and DCA techniques classified the samples into 4 groups using 197 species. The classification patterns occurred according to the salinity gradient from least salinity at the easternmost stations close to the fresh water inlets to the highest salinity at the westernmost area. CCA biplot showed that transparency, temperature, pH, TP, and salinity had great influence on phytoplankton species compared with the effect of BOD and TIN. CCA biplot indicated that species of stations 9 and 10 were highly positively affected by salinity. The other groups were partially or negatively affected by salinity. The recent changes in phytoplankton groups since the early of the last century till now indicated that, diatoms were the most present group with maximum occurrence during this study. Chlorophytes and dinoflagellates were considerably occurred, especially in the mid of the last century. Cyanobacteria were recorded in all sampling dates with maximum occurrence in early of last century and minimum occurrence in this century. The total number of diatom taxa recorded in the old and present study was 308. Freshwater diatom species decreased from 83% in the old Lake Moeris to 27% in the present Lake Qarun. Contrary, the marine species increased from nil in the old lake to 52% in the present lake. The leftover species were fresh-brackish (13, species) or brackish (11, species). This study leads to the conclusion that the increase of salinity since the beginning of the last century leads to dramatic changes in the phytoplankton species compositions that dominated later with clear marine taxa.

***Key words*:** Phytoplankton, Lake Qarun, Old Lake Moeries, Long term changes, salinity.

Introduction

Lake (Birket) Qarun is an inland closed basin, located in the deepest part of Fayoum depression (Meshal, 1977). Lake Qarun represents the remnant part of the ancient Pre-historic fresh water Lake Moeries. The lake area was about fourteen times, while its volume was about thousand times the present lake (Ball, 1939). Now, Lake Qarun is isolated saline basin, received agricultural drainage water, through two main drains; El Batts Drain (at north-eastern corner) and El Wadi (at the midpoint of the southern shore).

Salinity of Lake Qarun increased throughout the 20th century , being around 11‰ in the early 1900s (Ball, 1939). In the 1980s, mean salinity reached to ~38 ‰ but, since then, has stabilized. Since the lake is located in arid area, soluble salts increase during summer principally due to evaporation (~7 mmh^{-1}, data supplied by the Irrigation Department, El-Fayoum), and low precipitation. The salinity of the lake is not homogenous, being lower near the discharging points of the two drians (Fathi and Flower, 2005).

Lake Qarun is classified as a shallow lake with mean depth of 3.5m, low transparency with mean transparency of about 0.85 m, (Anonymous, 2006). In this saline turbid ecosystem, phytoplankton is the most important productive element where the macrophytes with its associated community is absent from the lake and benthic epipelic algal production is attenuated due to low light penetration (Anonymous, 1997).

Since the early of the last century many scatter investigations has been devoted to study the phytoplankton community structure and abundance (West, 1909, El-Nayal, 1935, Naguib, 1958, El Maghraby and Dowidar, 1969, Salah and Tamas, 1970, Abdel Monem, 1991, Anonymous, 1997, Badawi 2001, Fathi and Flower, 2005 and Anonymous, 2006). Most of these studies, especially recent ones, reported the presence of both fresh and marine phytoplankton species. El-Nayal, (1935) was the first who reported that there was an

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obvious invasion of some marine species. Afterward, several studies reported the obvious increase in both occurrence and abundance of marine species, while the freshwater species are scarcely recorded.

This work aimed to i) studying the present distribution of phytoplankton species in the lake, ii) using multivariate statistical approaches, Canonical Corresponding Analysis (CCA), Detrended Corresponding Analysis (DCA) and TWINSPAN analysis to verify the effect of salinity and other environmental variables on the occurrence and distribution of most frequent taxa, iii) the changes in the occurrence of marine and freshwater taxa in the old Lake Moeries and the present Lake Qarun.

Materials and Methods

Site description

Lake Qarun is a closed saline basin located in the northern part of El-Fayoum Depression, at the margin of the Nile Valley (Fig. 1). The lake located between Lat. 29º 24′ and 29º 33′ N, and Long. 30º 25′ and 30º 50′ E. it is bordered from north by the desert and by cultivated lands from the south side. The lake lies at 43 m below sea level and 85 km to the south west of Cairo (Abd Ellah, 1998). The length of the lake from the east to the west is about 43 km, and the breadth at the widest point is about 6.7 km. The lake has a surface area of 243 km^2 and a volume of 924 million m^3 at 43 m below sea level (Anonymous, 1995). The deepest point (~8.3 m) is located at northwest of El Karn Island.

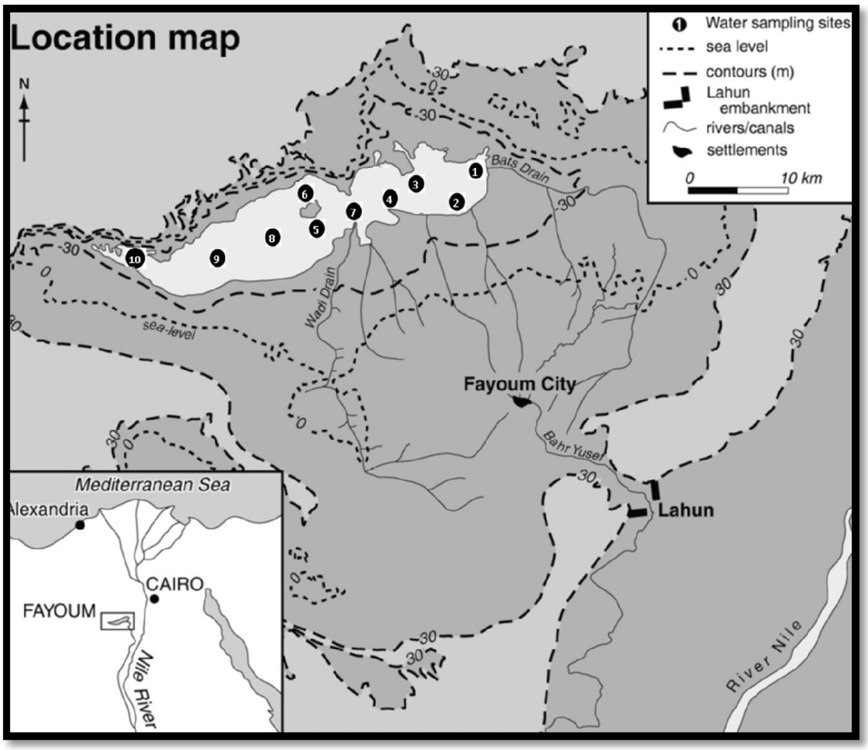

Fig. 1. Map showing Lake Qarun and the sampling stations.

The lake has no connection to the sea, sustained directly by the Nile River via Bahr Yussef Canal. The lake has received predominantly agriculture wastewater since the beginning of the 18th century (Anonymous, 1995). The total water discharging annually into the lake is about 395 million cubic meters (data supplied by the Irrigation Department, El-Fayoum).

Phytoplankton sampling

Surface water samples were collected in mid winter and late summer during 2011 from ten stations as shown in figure (1). Phytoplankton samples were preserved in 4% formalin solution, concentrated in sedimentation chamber (Utermohl, 1958) enumerated and counted using the inverted microscope. For diatom identificaton, samples underwent acid treatment using nitric and sulphuric acids, heated until all organic matter had been oxidized. The samples were washed and concentrated. The keys used for species identification of diatoms were primarily those of Kramer and Lange-Bertalot (1986, 1988 and 1991), Cleve-Euler (1953), Patrick and Reimer (1975) and James (1997). Keys used for species identification of cyanobacteria were Starmach, (1968) and Wehr and Sheath (2004); for chlorophytes the keys used were Tikkanen (1986), Dillard (1991) and James (1997); and for dinophytes the key used was (Popovaky and Pfiester, 1990) and James (1997).

Data analysis

Canonical Correspondence Analysis (CCA), a multivariate technique, was used to summarize changes of phytoplankton community structure and their relation to environmental variables using correlation analysis. 58 species were underwent this analysis, species of frequency less than 10% were excluded. CCA and Detrended Corresponding Analysis (DCA) were performed using CANOCO V. 4.5 (Ter Braak, 1987). Two-way indicator species analysis (TWINSPAN, Hill, 1979) and DCA were used to classify the entire data set based on 197 species. TWINSPAN was used to separate ecologically similar groups of species. The groups were identified on the basis of their indicator and dominant species.

Results

Both salinity and transparency were least at the discharging point of the drains, 50 ‰ and 24.2 cm, respectively. Transparency values were highest in the middle area, whereas salinity values were slightly differed among lake areas (table, 1). Both TIN and TP were much higher at the discharging point of the drains. TIN was higher in the eastern area, whereas TP was higher at the western area compared with the other lake regions. BOD and pH were marginally changed from an area to another with slight increase at the eastern area.

Table 1. The seasonal mean of water physical and chemical parameters at studied stations, (after our colleagues in chemistry lab.).

Stations	Trans (cm)	Salinity ‰	pH	BOD (mg/l)	TIN (µg/l)	TP (µg/l)
1	30.0	18.4	8.1	4.5	1428.5	363.6
2	60.0	32.2	8.5	5.3	224.8	147.6
3	72.5	33.9	8.5	5.6	155.7	142.8
4	100.0	34.3	8.4	5.0	188.8	158.4
5	90.0	34.5	8.4	5.1	134.4	147.6
6	175.0	36.3	8.2	4.6	139.1	141.6
7	70.0	29.9	8.1	4.5	502.1	199.2
8	135.0	36.1	8.2	4.3	112.8	195.0
9	105.0	36.3	8.3	4.6	110.5	157.2
10	135.0	37.1	8.2	4.5	100.5	154.2

A total of 84 genera and 197 species belong to 8 phytoplanktonic groups were recorded; diatoms (27 genera, 89 species), chlorophytes (25 genera, 45 species), cyanobacteria (11 genera, 24 species), dinoflagellates (13 genera, 26 species), cryptophytes (4 genera, 5 species), euglenophytes (1 genus, 2 species), prasinophytes (1 genus, 4 species), coccolithophorbide (2 genera, 2 species).

The phytoplankton densities varied between 324 and 12550 x 10^3 cells L^{-1} with an average of 2969 x 10^3 cells L^{-1}. Figure 2 shows the spatial and seasonal changes of the phytoplankton community in the lake. Memebers of diatoms comprised more than 70 % of the average phytoplankton density in the lake. Species of dinoflagellates belonging to occasional and rare found species except for *Prorocentrum micans* Ehrenberg. On the other hand, dinoflagellates accounted for only 23.2% of the total densities due to the clear dominance of *P. michans,* specifically at the eastern part of the lake (stations, 1-5). *Nannochloropsis* sp. was present and absolutely the dominant species of chlorophytes and phytoplankton community in the middle-east region (stations 2, 3, 4 and 5). The density of this species averaged 4379 x 10^3 cells L^{-1}, this species was not incorporated in figure 2 but in the other phytoplankton analysis.

A total of 144 species were observed during winter, with mean density of 1427 x 10^3 cells L^{-1}. In summer, a total of 164 species were observed with mean density of 4491 x 10^3 cells L^{-1}. Centric diatoms were represented by 13 species. *Cyclotella* spp. and *Chaetoceros* spp. were the most common. *Cyclotella* spp. were more dominant at the eastern part of the lake whereas *Chaetoceros* spp. were dominant at the western side. Pennate diatom species were represented mainly by *Amphora* spp., *Fragilaria* spp., *Thalassionema* spp., *Navicula* spp. and *Nitzschia* spp. Majority of these genera showed maximal abundance at the western part of the lake.

Chlorophytes was represented mainly by chlorococcal species, 46 species, whereas *Volovocales* and desmides were represented by two species for each of them. The filamentous cyanobacteria, *Lyngbya limnetica* Lemm., *Spirulina major* Kutz. & Gom., *Oscillatoria* spp., and *Phormidium* spp., had low abundance at all stations. Cyanobacterial coccoid species were represented by *Chroococcus* spp, *Gloeocapsa* spp, *Merismopedia* spp, *Microcystis* spp,and *Tetrachloris merismopedioides* Skuja. These taxa were rarely present in the eastern part and nearly absent in the western part of the lake.

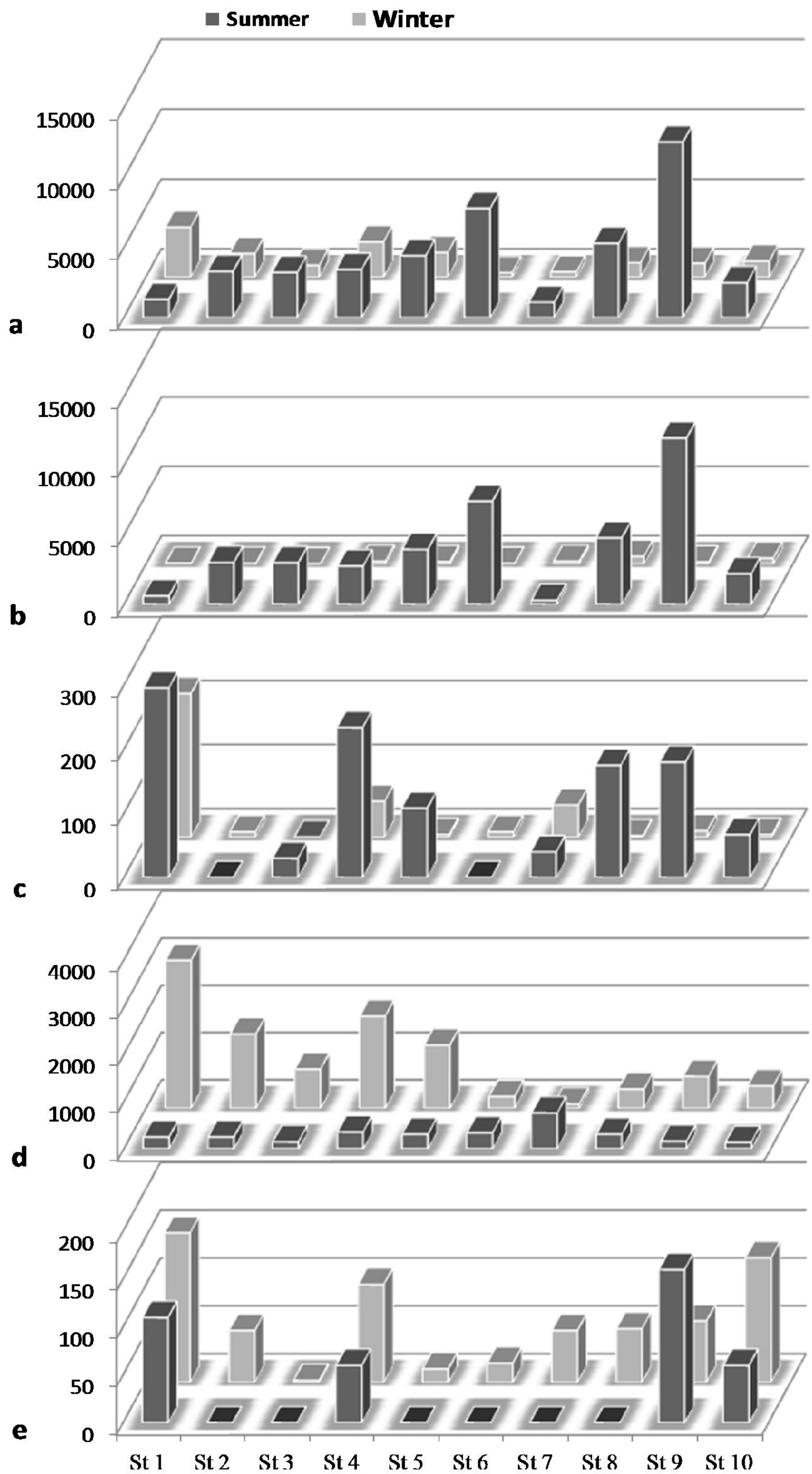

Fig. 2. Total phytoplankton (a), diatoms (b), cyanobacteria (c) dinoflagelates (d) and chlorophytes (e), distribution (x 10^3 cells L^{-1}) in Qarun Lake.

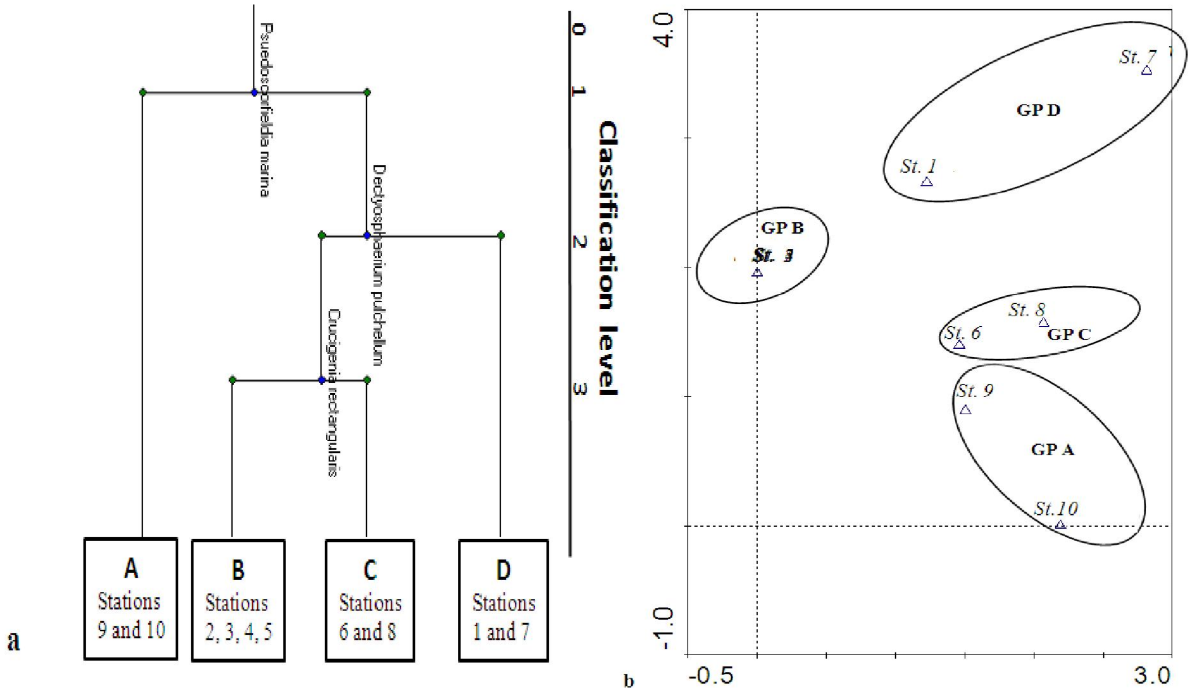

Fig. 3. Classification the four phytoplankton groups resulting from the application of (a) TWINSPAN, and (b) DCA techniques.

Two phytoplankton classes were recorded for the first time in the lake, *Prasinophyceae* was represented by four species belonging to the genus *Pyramimonas*. *Pyramimonas verginica* was the most important with clear dominance during winter at stations 4 and 5. Coccolithophorbide was the second class that represented by *Umbilicosphaera sibogae* (Weber-van Bosse) Gaarder and *Crystallolithus hyalinus* Gaarder & Markali, which found only at station 6, to the north of El-Karn Island.

Statistical analysis

TWINSPAN classification

According to the third level for TWINSPAN and the experience of traditional phytoplankton classification, 10 samples were classified into 4 groups (labeled A–E) using the 197 species (figure, 3). Each association group was named after dominant or indicator species. The classification pattern occurred according to the salinity gradient from least salinity stations close to the fresh water inlets (stations 1 and 7, group D) to the highest salinity at the westernmost area (stations 9 and 10, group A). Assemblage A separated at division level 1, assemblage D at level 2, assemblages B and C at level 3 (figure, 3). Assemblage A includes *Gloeocapsa crepidinum* Thuret, and *Prorocentrum gracile* Schutt as dominants. This assemblage was present at stations 9 and 10, and referred to the westernmost side assemblages. Assemblage B includes *Nannocloropsis sp.*, and *Thalassionema nitzschioides* as dominants. This assemblage was present at stations 2, 3, 4 and 5. Assemblage C includes *T. bacillare*, *T. nitzschiode* and *T. sp* as indicators. This assemblage was present at stations 6 and 8. The D assemblage includes *Prorocentrum micans* and *T. nitzschioides* as dominants.

CCA analysis between phytoplankton distribution and environmental factors

There were 58 species of phytoplankton and 7 environmental factors screened for CCA analysis based on abundance and frequency of phytoplankton species (table, 2). The eigenvalues of the first two axes were 0.867 and 0.477, respectively (table, 3). The correlation coefficient between the first environmental factors axis and species axis (table, 3) was 0.99, while that for the second axes was 0.938, indicating a close relationship between phytoplankton composition and environmental variables analyzed. Transparency, temperature, pH, TP, and salinity had great influence on phytoplankton as indicated by their high correlation with the two significant canonical roots.

Species of group (A) in figure (4) were highly positively affected by both transparency and salinity but negatively affected by TP and TIN. This group includes all species of stations 9 and 10 in the TWINSPAN and DCA biplot. Group C species has a partial positive correlation with transparency but high positive correlation with eutrophication (TP and TIN) but negative correlation with salinity. Group C species has a partial positive correlation with eutrophication (TP and TIN) but positive correlation with transparency and temperature.

Table 2. Most frequent species recorded in Lake Qarun

No.	Species	No.	Species
	Chlorophyceae	32	*Nitzschia amphibia* Grun.
1	*Ankistrodesmus falcatus* (Corda) Rslfs	33	*N. closterium* (Ehren.) Smith
2	*Characium limneticum* Lemm.	34	*N. granulata* (Grun.) Mann
3	*Chlamydomonas coccifer* Gorosch.	35	*N. ovalis* Arnott
4	*Crucigeniella rectangularis* (Nag.) Kom.	36	*N. paleaeformis* Smith
5	*Golenkinia radiata* (Chodat) Wille	37	*N. reversa* Smith
6	*Nannochloropsis* sp.	38	*N.* sp
7	*Oocystis* sp.	39	*N. trybionella* Hant.
8	*Scenedesmus ecornis* (Ehren.) Chod.	40	*Stephanodiscus* sp.
9	*S. quadricauda* v. *quadrispina* (Chodat) Smith	41	*Tetracyclus* sp.
10	*Selenastrum gracile* Reinsch	42	*Thalassionema nitzschioides* (Grun.) Meres
11	*Tetraedron trigonum* (Naeg.) Hans.	43	T. sp
	Bacillariophyceae		*Dinoflagellates*
12	*Amphora holsatica* Hust.	44	*Amphidinium rhynchocephalum* Anis.
13	*Aulacoseira granulata* (Ehren.) Simon.	45	*Glenodinium limos* Harris
14	*Azpetia africana* (Jan. ex Schm) Fry & Wat	46	*Gymnodinium simplex* (Loh.) Kof. & Swezy
15	*Chaetoceros lorenziana*	47	*G.* sp.
16	*C.* sp	48	*Katodinium hyperxanthum* (Har.) Loeb.
17	*Cooconeis placentula* v. *euglypta* (Ehren.) Grun.	49	*Peridinium* sp.
18	*Cosinodiscus divius* Schmidt	50	*P. wellei* Huitfeld-Kaas
19	*C. decrescens* Grun.	51	*Prorocentrum gracile* Schutt.
20	*C.* sp.	52	*P. micans* Ehren.
21	*Cyclotella meneghiniana* Kutz.		Cyanobacteria
22	*C. ocellata* Pant	53	*Chroococcus minutus* (Kutz.)Nag.
23	*C. operculata* (Agard.) Kutz.	54	*Microcystis aeruginosa* (Kutz.) Kutz.
24	*C. stelligera* Grun.	55	*Oscillatoria* sp.
25	*Cymbella affinis* Kutz.		*Cryptophyceae*
26	*C. minuta* Hilse	56	*Hillea fusiformis* (Schill.) Schill.
27	*Fragilaria construens* (Ehren.) Grun	57	*Chroomonas marina* (Butt.) Butch.
28	*F. pinnata* Ehren.		*Prasinophyceae*
29	*Gomphonema exigua* (Kutz.) Med.	58	*Pyramimonas virginica* Pennick
30	*Melosira* sp.		
31	*Navicula* sp.		

Table 3. Eigenvalues and species-environment correlation coefficients for the first four axes of CCA

Axes	1	2	3	4
Eigenvalues	0.867	0.477	0.185	0.090
Species-environment correlations	0.990	0.938	0.818	0.650

Long term changes of phytoplankton occurrence and Class composition

Since the early of the last century diatoms were the most present group with slight decrease in the present study, 1935, and 1993-1996 with maximum occurrence in 2006 (figure, 5). Chlorophytes and dinoflagellates were considerably occurred. Chlorophytes floureshed in 1935 and 1993-1996, whereas dinoflagellates floureshed in 1964-1965, but were rarely occurred in 1996-1993. Cyanobacteria were occurred in all sampling dates with maximum occurrence during this study and 1935 followed by 1996-1993 with minimum occurrence in 1964/1965 and 2006. The other recorded groups were scarcely and rarely present in different sampling dates.

The most important abundant species recorded in the lake from 1980-1982 till the present study

Totally, 37 species were recorded as the most abundant species during this period. 12 species were recorded during the present study as abundant species, 16 species were recorded during 1980-1982, 11 were recorded in 1989, whereas 15 taxa were recorded in 1998. The results of the present study showed that, *Thalassionema* sp., *Amphidinium rhynchocephalum* and *Nitzschia closterium* were recorded as more abundant taxa when *Nannochloropsis* sp., *Prorocentrum micans and Thalassionema nitzschiodes were recorded as the most important species.* Between 16 abundant taxa found in 1980-1982, 5 species were found as dominants which were *Chaetoceros affinis*, *Thalassionema nitzschiodes*, *Thalassiothrix frauenfeldii* and *Prorocentrum micans* when *Nitzschia closterium* was the most dominant taxa, with density of 306 cells X 10^3/l. In 1989, only *Nitzschia closterium* was recorded as the sole dominant with density of 236 cells X 10^3/l. 7 species were recorded in 1993-1996 as dominants. These taxa were; *Chaetoceros* sp, *Cyclotella glomerata*, *C. kuetzingiana*, *Nitzschia closterium*, *N. frustulum* var *perpusilla*, *N. sigma* with *Peridinium* sp. as the most common with density of 943 cells X 10^3/l.

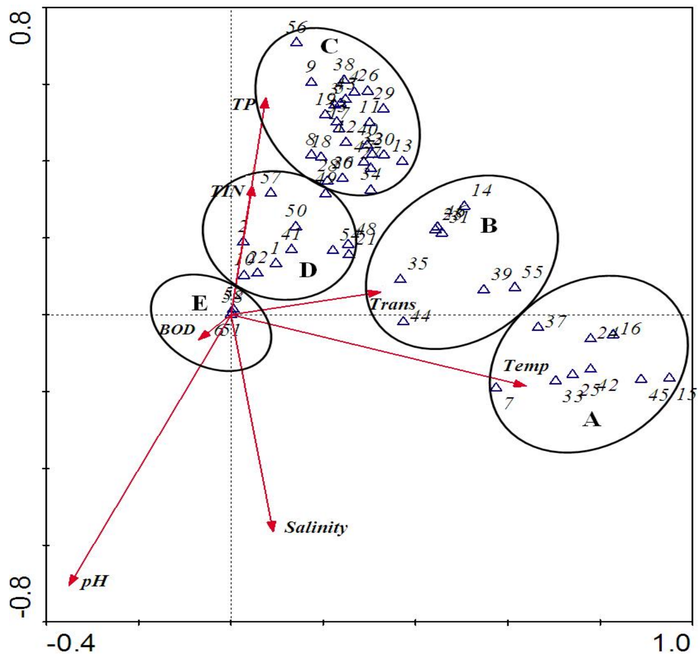

Fig. 4. CCA biplot of phytoplankton and environmental factors in Lake Qarun.

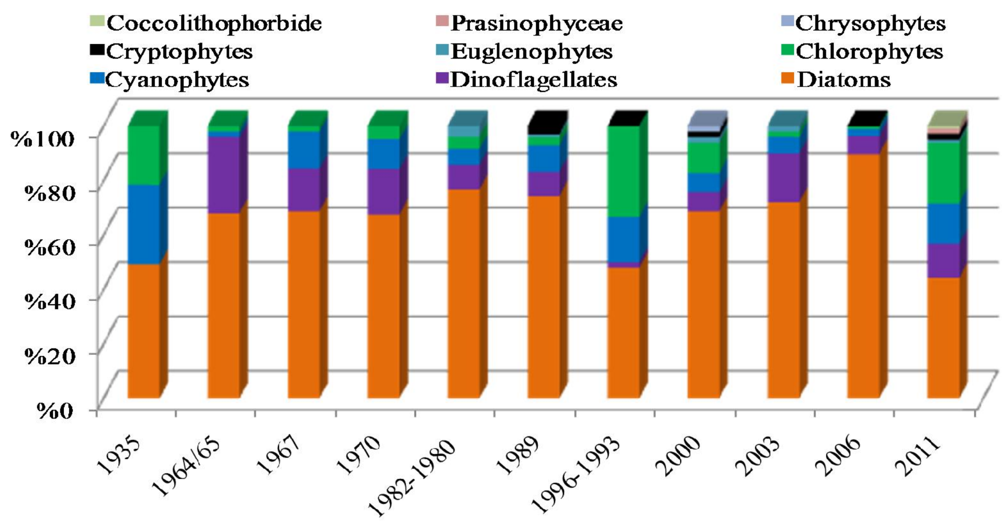

Fig. 5. Long term changes of percentage occurrence of different class composition

Long term changes in the diatom flora in Lake Qarun

Salinity in Lake Qarun (figure, 6) showed gradual increase from 10.2 ‰ in 1906 to a maximum of 40.93 ‰ in 1996 followed by a slight and constant decrease till now when salinity was 33.6 ‰. As salinity waxed in Lake Qarun, the phytoplankton composition changed and the marine taxa appeared with increase of salinity. Comparing the diatoms flora recorded by this study and by El-Nayal (1935), Nossier and Abou El-Kheir (1970) and Anonymous (1997) with those fossils recorded from the extinct old Lake Moeris by Aleem (1958) and El-Saadawi *et al.,* (1977), it was found that the total number of diatom taxa recorded in the old and present lake was 308. Of them there were 143 taxa recorded as fossils did not record in the present lake. The fresh water forms decreased from 83% in the old Lake Moeris to 27% in the present Lake Qarun. Contrary, the marine forms increased from nil in the old Lake Moeris to 52% in the present lake during this study (table, 4). The leftover species were fresh-brackish (13, species) or brackish forms (11, species).

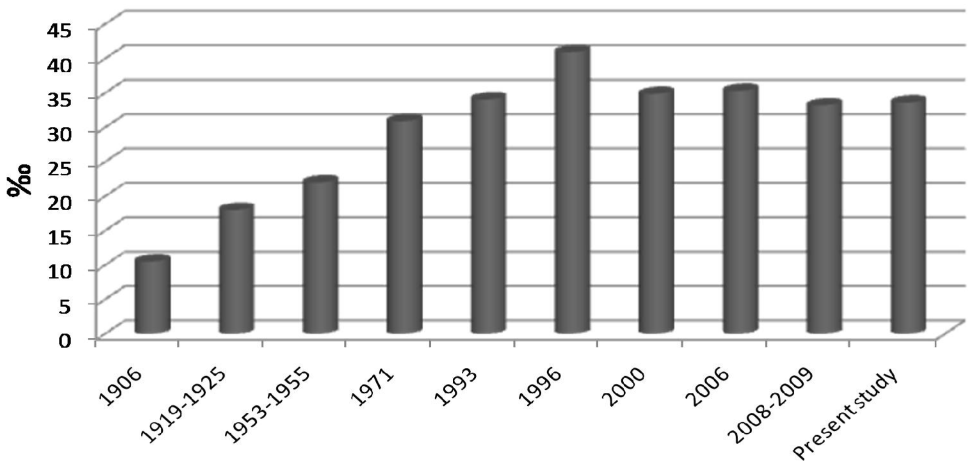

Fig. 6. Long term changes of salinity in Lake Qarun (after, Ramsar Project for Wet lands, 2011)

Table 4. State of occurrence of fossil and recent recorded diatom taxa in Lake Qarun

State of Occurrence	I		II		III		IV		V		VI		VII	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Fresh water taxa	119	83.2	11	38	26	35.6	7	41.2	31	34	23	32	54	27
Fresh-Brackish water taxa	13	9.1	3	10.3	8	11	2	11.8	12	13.2	10	14	14	7
Brackish water taxa	11	7.7	11	38	12	12	4	23.5	15	16.5	6	8	27	14
Marine water taxa	__	0	4	13.7	27	27	4	23.5	33	36.3	34	47	102	52
Total Number of Taxa	143		29		73		17		91		73		197	

I= Taxa recorded by Aleem (1958) and El-Saadawi et al., (1977), II= Taxa recorded by West (1909) and El-Nayal (1935), III= Taxa recorded by Nosseir and Abou El-Kheir (1970), IV= Taxa recorded by El Maghraby and Dowidar (1969), V= Taxa recorded by Abou El-Kheir and Ismail (1986), Abou El-Kheir and Mekkey (1986), VI= Anonymous (1997) and V11= present study (2011).

Discussion

One problem with assessing multiple variables potentially influencing phytoplankton abundance in shallow lakes is that predictor variables are potentially correlated with each other, making it difficult to identify actual causal factors. For example, total phosphorus (TP) levels in lakes are potentially influenced by agriculture in watersheds (Knuuttila *et al.,* 1994), regional differences in soil and geology (Heiskary *et al.,* 1987), and abundance of benthivorous fish that translocate P from sediments to the water column by bioturbation (Breukelaar *et al.,* 1994) and by feeding on benthic prey and excreting P into the water column (Persson, 1997; Zimmer *et al.,* 2006).

The CANOCO statistical program helped us to identify the major factors that impacted the studied communities on the basis of the species-environmental variables relationships. Due to its complex in Qarun ecosystem, environmental factors were crucial to the distribution of phytoplankton. Locations of phytoplanktonic species in CCA bioplot indicated its dependence on environmental factors. Phytoplanktonic species were mainly concentrated in the first quadrant corresponding to high TN, moderate TP and low salinity and pH. In Changjiang River estuary there were many environmental factors affecting the growth and distribution of phytoplankton. Transparency was the primary factor effecting phytoplankton distribution, followed by TN and silicate with CCA analysis (Luan *et al.,* 2007). In Loch Lomond, environmental factors affected phytoplankton community with the order of temperature, DO, transparency, and COD (Habib *et al.,* 1997). The main factors impacting phytoplankton community in Xiaoqing River estuary were Salinity, pH, COD, and TIN (Yan *et al.,* 2012).

Emergence of marine species in Lake Qarun

The results of West (1909) and El-Nayal (1935) revealed that there were equal numbers of fresh and brackish forms (38% of the total species). It must be mentioned that El-Nayal (1935) was the pioneer who reported the presence of marine species in the lake but he could not described how these marine species introduced to the lake. The author identified 4 marine diatoms (14% of the total recorded diatom species); *Nitzschia fasciculata* Grun. was the typical marine species accompanied with 3 other marine species that can survive in brackish environment; *Amphora coffaeiformis* Agard., *Melosira borrei* Grev. and *Surirella steriatula* Turp. He reported also the occurrence of two typically marine macroalgae, *Polysiphonia utricularis* Zan. (Rhodophyta, Family; *Rhodomelaceae*) and a form of *Enteromorpha plumose* Kutz. (Chlorophyta, family *Ulvaceae*). It is worth to mentioned that the marine species recorded by El-Nayal (1935) were introduced to the lake during the transplantation program established by the ministry of agriculture in mid 1920s developed to transport mullet, shrimp and sole fishes from the Mediterranean Sea to the lake to overcame the high increase in salinity (personel communication)

Nosseir and Abou El-Kheir (1970) found that the common marine species (42% of the total diatoms) exceeded the fresh water ones (40% of the total diatoms). The most important marine species were: *Grammatophora marina* (Lyngb.) Kutz., *G. maxima* Grun., *Licmophora tincta* (Agard.) Grun., *L. ehrenbergii* (Kutz.) Grun., *Biddulphia laevis* f. *Minor* V. H., *B. pulchella* Grey, *B. eurgida* Smith, , *Asterionella Formosa* Hass.

Abou El-Kheir and Mekkey (1986) recorded 43 species of diatoms, most of them were of marine type and the fresh water forms were in fact fossil forms. They recorded also two rhodophytes marine species namely: *Goniotrichum elegans* (Chauvin) Zanardini and *Polysiphonia utricularis*. The former one was a new record to the lake, whereas the latter was reported earlier by El-Nayal (1935). In 1997, Anonymous studied the lake phytoplankton from 1993 till 1996 and reported that, the freshwater forms percentage occurrence was 32%, whereas the marine forms reached to the highest percentage occurrence of 47%.

The fossil diatoms of Fayoum Depression and their tendency towards salinity

Aleem (1958) and Faris and Girgis (1979) studied the fossil diatoms in the diatomaceous deposites of the extinct Fayoum Lake in Fayoum depression at two different regions, Um El-Katl and Kom-Osheem, respectively. The examined diatoms flora of the lacustrine deposite near "Um El Katl" was predominantly a freshwater speices, since over a 75% of the species were freshwater forms. Whereas Faris and Girgis (1979) decided that at Kom-Osheem region, the water body was a separate pond rather than a part of the ancient lake characterized by a slightly brackish aquatic ecosystem.

Twenty four species were recorded as fossils from the old Lake Moeris still recorded as life taxa in the present Lake Qarun; *Cocconeis placentula* var *euglypta* (Ehren.) Clev. (fresh-brackish), *Cyclotella kutzingiana* Thw., *C. meneghiniana* Kutz., *C. ocellata* Pant., *Cymbella cymbiformis* (Agard.) Kutz., *Denticula tenuis* Kutz., *Diatoma elongatum* Agard., *Epithemia sorex* Kutz., *Fragilaria construens* (Ehren.) Grun., *Gomphonema parvumlum* (Kutz.) Grun., *Hantzschia amphioxys* (Ehren.) Grun., *Melosira granulata* (Ehren.) Ralfs, *M. granulata*. var *angustissima* Mull., *Navicula cincta* (Ehren.) Kutz. (fresh-brackish), *N. gracilis* (Kutz.) Grun. (fresh-brackish), *N. radiosa* Kutz., *Nitzschia apiculata* (Greg.) Grun., *N. communis* Rab. (brackish), *N. palea* Smith, *N. sigma* Smith (brackish), *Rhoicosphenia curvata* (Kutz.) Grun., *Stephanodiscus astraea* (Ehren.) Grun., *Synedra ulna* (Kutz.) Ehren. (fresh-brackish) and *S. ulna* var. *danica* (Kutz.) Grun. Among these taxa, only four taxa were identified as fresh-brackish forms and two brackish taxa, whereas the others were classified as fresh water taxa. *Cyclotella*, *Stiphanodiscus*, *Melosira*, *Cocconeis*, *Cymbella*, *Gomphonema*, *Achnanthes*, *Epithemia* and *Mastogloia* were well represented in both, present and extinct lakes.

Cyclotella kutzingiana Thw.*, C. ocellata* Pant.*, C. meneghiniana* Kutz.*, Melosira granulate* (Ehren.) Ralf*, M. granulata* var *angistissima* Mull.*, M. italic* (Ehren.) Kutz.*, Stiphanodiscus astrea* (Ehren.) Grun. and *Epithemia zebra* var. *procellus* (Kutz.) Grun., which are all fresh-water fossil forms found to be abundant in the lake deposits by El-Saadawi *et al.,* (1978).

Achnanthes delicatula (Kutz.) Grun*.*, *A. dispar* Cleve*.*, *Amphora veneta* Kutz*.*, *Caloneis silicula* (Ehren.) Clev*.*, *Cocconeis diminuta* Pant*.*, *Epithemia intermedia* Fricke *Navicula cincta* Ehren*.*, *N. rhynchocephala* Kutz*.*, *Nitzschia frustulum* (Kutz.) Grun*.* and *N. sigma* Smith, all are brackish or fresh-brackish forms. They were identified by Alemm (1958) and Faris and Girgis (1979) as marginally abundant in the diatomaceous deposits of the extinct Moeris Lake.

In Kom-Osheem and Um El-Katl deposits the difference between the fossils of both localities could be a result of variation in local conditions probably pH and salinity values. Aleem (1958) believed that the diatomaceous deposit of Um El-Katl was a part of Fayoum lake Bed (Lake Moeris, which was being almost 2800 km^2) which had a pH slightly above 7, and, therefore, belonging to the constantly alkaline type lakes. The evidence he decided to support his conclusion was the absence or extreme paucity of species that classified as low pH indicators (acidic side). In Kom-Osheem deposits, frequent to abundant forms of *Eunotia* and *Pinnularia* were present. They were *Pinnularia viridis* var *intermedia* Cleve, *Eunotia pectinalis* var *neglecta* Grand, *E. proerupta* var *inflate* Grun. and *E. tschirchiana* Mull. The latter one was abundant. These findings lead to the conclusion that locality in Kom-Osheem was so different from that of Um El-Katl. So, it is believed that Kom-Osheem deposits probably accumulated in a small separate water body rather than a part of the ancient lake characterized by acidic pH (Jenkins *et al.,* 1990 and Birks *et al.,* 1990) and high nutrients.

The forms identified are in general oligohalobous (fresh water forms) with a salinity of about 5‰ according to Halobion system of Kolbe (1927). Some of these oligohalobous forms are halophilic i.e. freshwater forms which can survive in water slightly saline than customary, where they flourish and increase their numbers as *Cyclotella meneghiniana* and *Diploneis ovalis*. Other forms are somewhat indifferent to salinity i.e. ordinary freshwater forms which can exist in brackish water although they decrease in number as *Epithemia turgida* var *granulata* Ehren*.* Another group of this oligohalobous forms are halophobous forms which are exclusively fresh water forms which cannot exist when the concentration of salts slightly increase as *Rhopalodia gibba*, *Amphora ovalis*, *Gomphonema gracile* and *Melosira granulata*. The mean of halophobous, the water in which they were living was fresh, without the increase in salt concentrations.

In Kom-Osheem area, the water in which the diatoms were living must have calcium carbonate hardness above 3 and silica above 0.5 mgl^{-1}. The water body was eutrophic (rich in nutrients). In general, the pond was characterized by an abundance of diatom forms which are known as indicators for the excess of nutrient salts as the genera, *Synedra*, *Cyclotella*, *Nitzschia*, *Melosira*, *Cymbella* and *Gomphonema*. Water and some of the diatoms flora presented in Um El Katl in the past were probably of Nile origin where the water of the Nile flood carried new crops of diatoms and nutrient every year.

It can be concluded, although the origin of Lake Qarun was a freshwater system, the increase of salinity since the beginning of the last century leads to dramatic changes in the phytoplankton species compositions that dominated with clearly marine taxa. Furthermore, Phytoplankton structure in Lake Qarun may be exposed to further changes as the water salinity may be unstable**.**

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