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PHYTOPLANKTON AND BENTHIC COMMUNITIES OF A SMALL WATER BODY (SACRED LAKE, KARNAK TEMPLE) LUXOR, EGYPT

A. F. HAMED[1], H. M. SHAFIK[2,3] and A. S. SHAABAN[1]

[1]*Department of Botany, Faculty of Science, Ain Shams University, Abbassia, Cairo, Egypt*
[2]*Department of Botany, Faculty of Science, Suez Canal University, Ismailia, 41522, Egypt*
[3]*Balaton Limnological Research Institute, Hungarian Academy of Sciences H-8237 Tihany, Hungary*

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The Karnak Temple is a tourist attraction site in Luxor, Egypt. Sacred Lake lies inside the Karnak Temple, it is an important lake from both historical and touristical point of views. About 4,000 years ago the ancient Egyptians used this lake as a saint place. The priests were washing in the lake four to five times a day. The lake area is about 3,200 m^2. The lake was shallow before 1985 and the floras of the lake had been monospecific cyanoprokaryote (*Microcystis flos-aquae* or *Spirulina labyrinthiformis*). In 1985 Nile water was circulated through the lake by the so-called French project. In 1993, the pumping of Nile water was stopped and the water became stored and not renewed again. The increase in the water level of the lake since 1985 followed by stopping the water circulation in 1993 have a negative impact, making the lake similar to a fishpond. Now, sixteen taxa of cyanobacteria and Chlorophyta were determined in the lake together with dense vegetation of the aquatic plant *Potamogeton pectinatus* L. during the two expeditions in April and October 1996. The presence of this diversified flora, especially the bad smell resulting from the growth of algae and aquatic plant has adverse effects on tourism. Restoration of the ancient picture of the lake is recommended and some suggestions were emphasised in this study. We would like to call attention for protection of the lake by continuous cleaning. This suggestion will help in restoring the lake to its ancient status.

Key words: benthic, ecosystem, Egypt, phytoplankton, Sacred Lake

INTRODUCTION

Sacred Lake is an important lake from historical point of view. About 4,000 years ago the ancients used the lake as a saint place. The priests were washing in the lake four to five times a day. The water of the lake mainly gets from the underground water and not from other sources (Gessler-Lohr 1983). Before building of the Aswan High Dam in 1969, the water level was increased in the lake during the time of Nile inundation.

After controlling the hydrodynamics of the Nile water by building up the dam, the water in the lake became shallow throughout the year which fa-

voured the bloom formation caused by *Spirulina labyrinthiformis* in 1974 and *Microcystis flos-aquae* in 1982 (Shaaban, unpublished data). In 1985 Nile water was pumped into the lake through large tubes to renew the water of the lake by the so-called French project. As a result the water gets into the lake from two sources, i.e. the underground water and the Nile water. Accordingly, the water level increased in the lake. Later, in 1993, due to some technical failure in the mechanical system the efficiency of the water circulation gradually lowered and then stopped.

Phycologically, Sacred Lake has received our attention to elucidate and emphasise about the algal flora inhabiting the lake as a result of the impact of the changing its ecosystem. The study calls the attention to protection of the lake by continuous cleaning. This suggestion will help in restoring the lake to its ancient status.

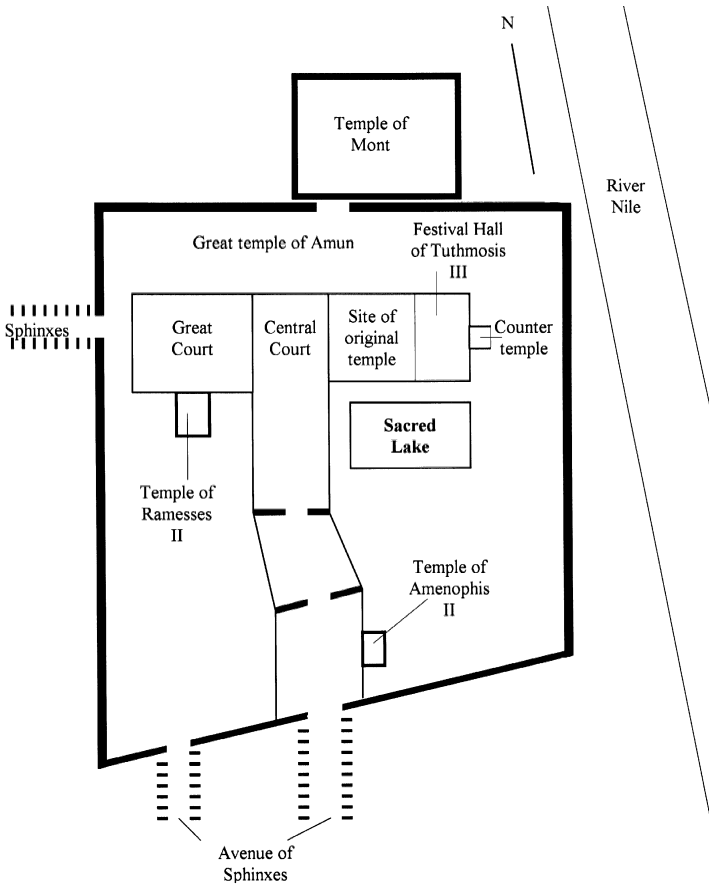

Fig. 1. Map on the Karnak Temple shows Sacred Lake

MATERIALS AND METHODS

The Sacred Lake is a small water body of 80 m long and 40 m wide. It is located in the southern portion of the Karnak Temple, Luxor, Egypt (Fig. 1). Limestone rocks frame the lake and there are seven stairs around it which lead into the water.

Algal sampling of Sacred Lake. The date of collection and the number of algal samples were presented in Figure 2 and Table 1. During April and October

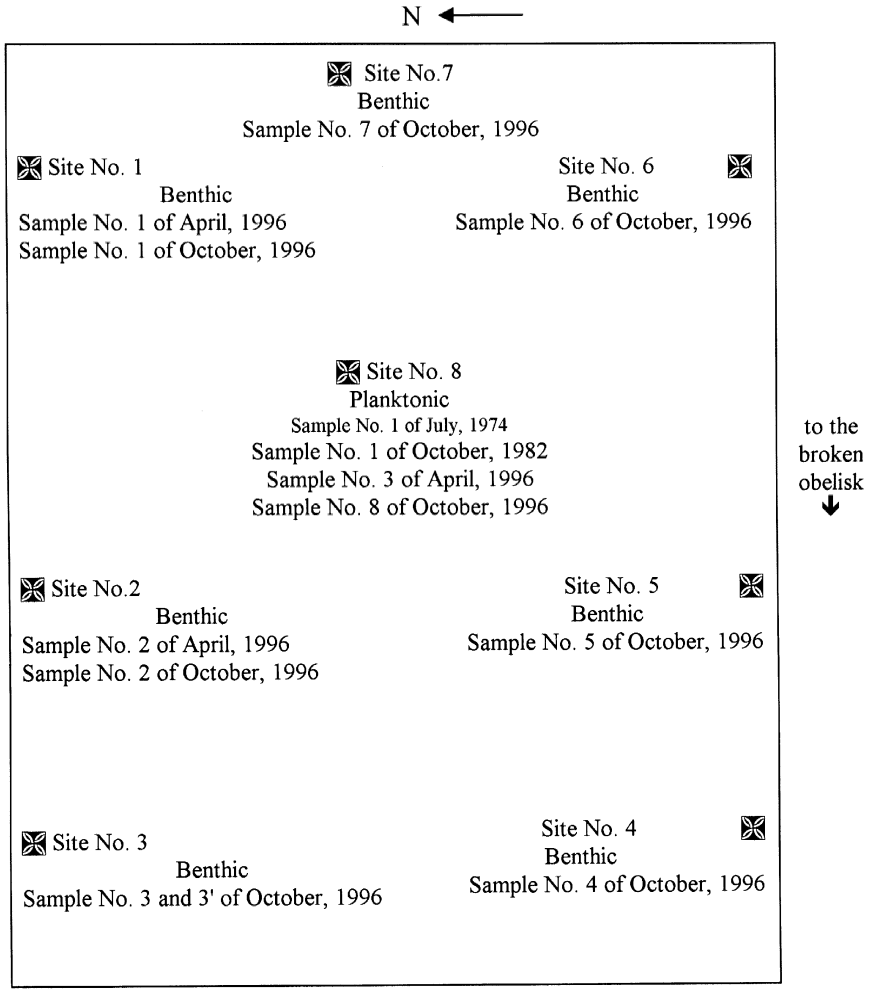

Fig. 2. Sketch map showing the sampling sites and the number designed for each sample collected

Table 1
The date, sites of collection and the number of the algal samples collected

Date of collection	Site of sampling	Number of algal samples
12.04.1996	1, 2, 8 (see Fig. 2)	3
15.10.1996	1–8 (see Fig. 2)	8
15.10.1996	from the Nile bank facing the lake	2

1996, precise collections of both benthic and planktonic algae were taken and placed in clean plastic tubes (Falcon 50 ml). From each sampling station (sites 1–8, Fig. 2), two groups of samples were collected. One group of samples was preserved by few drops of formalin (4% final concentration) and the identical group was carried in the ice-box to the laboratory by aeroplane within two hours after collection. The natural benthic assemblages were inhabited the walls and the stairs which had different pictures of growth such as green scum, filaments of green colour and yellowish-brown spherical bodies; these growths were easily removed by hand. The planktonic algae were collected from the centre of the lake by phytoplankton net of mesh 25 micrometer. The water level of the lake was one-meter deep and the turbid-dark green colour water resulting from the reflectance of the dense vegetation of the aquatic plant *Potamogeton pectinatus* L.

Algal sampling of the Nile. Benthic and phytoplankton samples of the Nile water bank facing the Karnak Temple were also collected during October 1996 to compare the flora of the Nile to that of Sacred Lake. The same methods of collection and preservation were used as described above.

Enrichment experiments. In the laboratory, one ml from each sample was inoculated into 50 ml enrichment medium of Chu's, No. 10 (1942). The Erlenmeyer flasks were incubated in illuminated incubator (Preceion, model 818) for two weeks. The cultures were illuminated continuously by cool-white fluorescent tubes and the light intensity was 220 μMol m^{-2} sec^{-1} and the temperature was 26±1 °C. The cultures were examined at different intervals to observe algal growth.

Water chemistry. The water samples from the lake and the Nile bank facing the Karnak Temple were collected in the expedition of October 1996 in one litre dark glass bottle for chemical analysis. Some physicochemical data were also recorded in the sites of sampling. Water temperature was measured using a standard thermometer accurate to 0.1 °C and the pH was measured by digital pH-meter (Cole Parmer, USA). The dissolved oxygen (DO) was measured using digital oxygen meter (Cole Parmer, USA), and electric conductivity (μS cm^{-1}) was measured by EC meter (Chemtrix 700, USA). Chemical oxygen demand (COD) was determined by titration using the dichromate method and

total suspended solids (TSS) was determined by filtration of known volume of effluent samples through GF/C (Whatman) filters and dried at 150 °C (APHA 1985). Soluble reactive phosphorus (SRP) was determined according to Murphy and Riley (1962). The concentrations of NO_3-N, Ca^{2+}, Mg^{2+} and Cl^- (mg l^{-1}) were determined according to APHA methods (1985).

RESULTS

There was a dense growth of the macrophyte *Potamogeton pectinatus* L. that covered most of the area of the lake. The results of the microscopic examination of algal species (benthic and phytoplankton) for natural waters and from the enrichment experiments during the two expeditions were summarised in Table 2.

Table 2

List of algal taxa observed in this study during April and October, 1996 with their occurrence. E = enrichment, N = natural, 1 = benthic samples, 2 = planktonic samples

	12.04.1996				15.10.1996							
	Sacred Lake				Sacred Lake				River Nile			
	N		E		N		E		N		E	
Algal taxa	1	2	1	2	1	2	1	2	1	2	1	2
CYANOBACTERIA												
Calothrix minima Fremy	+				+							
Chroococcus turgidus (Kütz.) Nägeli	+				+							
Cylindrospermum musicola (Kütz.) Born.				+				+				
Gloeocapsa atrata Kütz.	+				+		+					
Gloeocapsa minor (Kütz.) Hollerb.			+				+					
Leptolyngbya golenkiniana Gomont	+				+							
Lyngbya dendrobia Bruhl et Biswas									+			
Lyngbya epiphytica Hieron	+											
Merismopedia tenuissima Lemm.					+	+			+	+	+	+
Microcoleus delicatulus W. et G. S. West	+				+							
Microcystis flos-aquae (Wittr.) Kirchner.	+				+					+		
Oscillatoria limosa (Roth) Ag. ex Gomont	+											
Oscillatoria obscura Bruhl et Biswas									+			
Planktolyngbya limnetica (Lemm.) Kom. et Cron.									+			
Spirulina jenneri Stez	+				+							
Spirulina major Kütz.	+				+							
Synechocystis aquatilis Sauv.			+				+					
Synechocystis pevalekii Erceg.										+		+
BACILLARIOPHYCEAE												
Amphora pediculus (Kütz.) Grunow									+			
Aulacoseira granulata (Ehr.) Simonsen									+	+		
Bacillaria paradoxa Gmelin									+			

Table 2 (continued)

	12.04.1996				15.10.1996							
	Sacred Lake				Sacred Lake				River Nile			
	N		E		N		E		N		E	
Algal taxa	1	2	1	2	1	2	1	2	1	2	1	2
Cocconeis placentula Ehr.									+			
Cyclotella meneghiniana Kütz.									+	+		
Cyclotella ocellata Pant.									+	+		
Cymatopleura solea (Breb.) W. Sm.									+			
Cymbella affinis Kütz.									+			
Cymbella prostrata (Berk.) Cl.									+			
Fragilaria acus (Ehr.) Grun.												+
Fragilaria brevistriata Grun.									+			
Fragilaria construens (Ehr.) Grun.									+			
Fragilaria ulna var. *amphirhynchus* (Ehr.) Schonf.									+		+	+
Fragilaria ulna var. *biceps* (Kütz.) Schonf.									+		+	
Fragilaria ulna var. *impressa* Hust.									+			
Gomphonema parvulum var. *micropus* (Kütz.) Cl.									+			
Navicula cincta Kütz									+			
Navicula cryptocephala Kütz									+			
Navicula gastrum Ehr.									+			
Navicula mutica f. *lanceolata* Frenguelli									+			
Navicula pupula var. *capitata* (Grun.) Hust.									+			
Nitzschia amphibia Grun.									+			
Nitzschia frustulum (Kütz) Grun.									+			
Nitzschia palea (Kütz) W. Smith				+					+			
Nitzschia scalpelliformis Grun.									+			
CHLOROPHYCEA												
CHLOROCOCCALES												
Ankistrodesmus falcatus (Corda) Ralfs							+		+	+	+	+
Chlorella vulgaris Beijerinck												+
Chlorococcum infusionum (Schrank) Menegh.			+									
Coelastrum microporum Näg.							+		+	+	+	
Desmodesmus armatus var. *spinosus* (Fritsch et Rich) Hegew.												+
Desmodesmus communis (Hegew.) Hegew.	+				+				+	+		
Micractinium pusillum Fresenius										+		
Oocystis naegelii A. Braun.							+			+	+	+
Pediastrum boryanum (Turp.) Menegh.									+			
Pediastrum duplex var. *genuinum* (A. Braun) Hansg.										+		
Pediastrum integrum Näg.									+			
Pediastrum simplex Meyen									+	+	+	
Pediastrum tetras (Ehr.) Ralfs												+
Pediastrum tetras var. *tetrodon* (Corda) Hansg.											+	
Scenedesmus acuminatus (Lagerh.) Chod.									+	+	+	+
Scenedesmus arcuatus Lemm.									+			
Scenedesmus bijugatus (Turp.) Kütz.										+		
Scenedesmus obliquus (Turp.) Kütz.									+	+	+	
Tetraedron minimum (A. Braun) Hansg.												+
Westella botryoides (W. West) de Wildeman											+	+

Table 2 (continued)

	12.04.1996				15.10.1996							
	Sacred Lake				Sacred Lake				River Nile			
	N		E		N		E		N		E	
Algal taxa	1	2	1	2	1	2	1	2	1	2	1	2
DESMIDIALES												
Cosmarium botrytis Menegh.	+				+							
Cosmarium meneghinii Breb.	+				+	+						
Euastrum dubium Näg.	+				+	+						
Staurastrum crenulatum (Näg.) Delp.	+				+	+				+		
VOLVOCALES												
Eudorina elegans Ehr.										+		
Pandorina morum (Müll.) Bory								+				
DINOPHYCEAE												
Peridinium sp.										+		

The natural and cultured flora of Sacred Lake

A total of 16 algal species representing 14 genera were identified from the natural assemblages of the lake. The species composition belonged to two algal divisions of Cyanobacteria (prokaryotes) and Chlorophyta. The phytoplankton samples of October 1996 revealed the presence of few species of *Merismopedia tenuissima*, *Cosmarium meneghinii*, *Euastrum dubium* and *Staurastrum crenulatum*, while the benthic samples showed relatively high productivity of 16 algal taxa. From the distribution pattern of the 16 algal species recorded along the benthic samples, the most dominated species were found to be the previously planktonic desmid ones.

In the enrichment cultures some cyanobacteria species such as *Synechocystis aquatilis*, *Gloeocapsa minor* and *Cylindrospermum musicola*, one diatom species *Nitzschia palea* and some Chlorophyceae such as *Pandorina morum*, *Chlorococcum infusionum*, *Oocystis naegelii*, *Ankistrodesmus falcatus* and *Coelastrum microporum* were appeared and recorded in Table 2.

Algal flora in natural and enrichment cultures of Nile water

A total of 46 algal taxa (species and varieties) representing 24 genera were identified from the natural assemblages of the Nile water samples from the bank facing the Karnak Temple. The species composition was belonging to four algal divisions of Cyanobacteria, Heterocontophyta (class Bacillariophyceae), Chlorophyta and Dinophyta.

The algal community was qualitatively dominated by Bacillariophyceae (24 taxa) followed by Chlorophyta (15 taxa), Cyanobacteria (6 taxa) and Dinophyta (1 taxon).

In the enrichment cultures of the Nile water, *Fragilaria acus* (Bacillariophyceae); *Pediastrum tetras*, *Pediastrum tetras* var. *tetrodon*, *Tetraedron minimum* and *Chlorella vulgaris* (Chlorophyceae) were appeared and other species disappeared (Table 2).

Water chemistry results

Table 3 shows samples, time of collection, water temperature, the pH values, dissolved oxygen and electric conductivity of samples collected from both of the lake and the Nile waters.

The temperature of Nile water was 24 °C; it was lower than that of recorded in the lake (26–28 °C). The recorded pH values were between 9.14 and 9.39 in the lake, and it was 7.74 in the Nile water. Dissolved oxygen in the lake water was much higher (8–9 ppm) than that in the Nile water, where it was 3.5 ppm. The electric conductivity was between 141 and 151 μS cm^{-1} in the lake and was 60 μS cm^{-1} in the Nile water. Table 4 shows the results of chemical water analysis of the lake and the Nile. The NO_3-N concentration was undetected in lake water and was 0.28 mg l^{-1} in the Nile water, and chemical oxygen demand was much lower in the lake water than in the Nile water. The major cations (Ca^{2+} and Mg^{2+}) in the lake water were higher than that in the Nile water,

Table 3
Samples and some physical and chemical characters of each sample collected at 15.10.1996 between 9 a.m. and 2 p.m. See sites location in Figure 2

Sample	Time of sampling	Temperature (°C)	pH	DO (ppm)	EC (μS cm^{-1})
		Sacred Lake			
1	9.00 a.m.	26	9.14	3.7	141
2	9.30 a.m.	27	9.20	8	150
3	10.00 a.m.	27	9.25	9	151
3′	10.15 a.m.	27	9.25	9	151
4	10.30 a.m.	27	9.26	8	150
5	11.00 a.m.	28	9.26	8	149
6	11.30 a.m.	28	9.28	8	149
7	12.00 a.m.	28	9.29	9	145
8	12.00 a.m.	27	9.39	8	149
		River Nile			
9	1.00 p.m.	24	7.74	3.5	60
10	2.00 p.m.	24	7.74	3.5	60

Table 4
Some chemical measurements of Sacred Lake and the Nile waters, October, 1996.

Parameter	Lake water	Nile water
PO_4-P	0.22±0.001	0.21±0.01
NO_3-N	–	0.28±0.02
Si	0.307±0.003	0.314±0.02
COD	25±3	210±12
TSS	0. 43±0.02	0. 46±0.05
Ca^{2+}	15±0.5	6±0.2
Mg^{2+}	50±3	8±0.03
Cl^-	5.2±0.05	5.0±0.01
Total hardness	65±3.2	14±0.2

TSS = total suspended solids, COD = chemical oxygen demand, SRP = soluble reactive phosphorus, – = undetected. All measurements are given as mg l^{-1}

while the concentration of Cl^-, PO_4-P and Si were at the same level approximately in both waters. The total hardness was about 4 times higher in the lake water than in the Nile water.

DISCUSSION

The relatively higher DO and lower COD in the lake compared to in the Nile water may be a result of the massive growth of *Potamogeton pectinatus* rather than the growth of algae. For the same reason, the pH value increased from 9.14 measured in the morning, up to 9.39 measured at 12 o'clock (average 9.26±0.07). The DO increased from 3.7 to 9 ppm in the lake at the same period of time, as a result of the rapid consumption of inorganic carbon by photosynthesis when sunburnt. At midday, the pH value (7.74) and DO (3.5 ppm) were lower in the Nile water than in the lake water. The relatively higher values of temperature, pH and conductivity of the lake water than that of the Nile water may be due to the excessive growth of *Potamogeton pectinatus* (Aboal *et al*. 1996) and the water current in the Nile, while the water is calm in the lake. Soluble reactive phosphorus (SRP) has the same concentration of 0.215 mg l^{-1} in both of the Nile and the lake waters. Reynolds (1991) reported that while SRP concentration remains above 10 µg l^{-1}, however the probability is that many phytoplankton species will not be simultaneously limited by phosphorus deficiency. The NO_3-N concentration was 0.28 mg l^{-1} in the Nile and undetected in the lake water. This indicates that the nitrogen is the limiting element in both water bodies with low N:P ratio of 1.3 in the Nile. Under that condition, Chlorophyta may be the dominant species as shown from the species compo-

sition of the Nile (Zidan 1983). Silicate concentration was at the same level in both waters and it is not the factor that prevents the appearance of diatoms in the lake.

Unfortunately, the algal community of the lake was not studied before the construction of Aswan High Dam. After building up the dam and before the French project, Shaaban did the first investigations in 1974 and in 1982. In 1974, he recorded a bloom of *Spirulina labyrinthiformis*, which had a pale blue colour and in 1982 another bloom of *Microcystis flos-aquae* with bluish colour. This finding may be ecologically correlated with the water shallowness where the cyanobacteria are the most prominent when the water levels are low (Gordon *et al*. 1981). After the French project, where the water level was increased by pumping water from the Nile and the appearance of the macrophyte *Potamogeton pectinatus*, more benthic and phytoplankton species were observed in the natural lake water (16 taxa). From the sixteen algal species 11 taxa of Cyanobacteria and 5 taxa of Chlorophyta appeared as new records inhabiting the lake (Table 2). The changing in the algal composition from monospecific algal character in 1974 and 1982 to multispecific algal character now, might be expected as a result of introducing nutrients and new species with the Nile water. This favours the growth of many species especially the desmids, which were influenced by the aquatic vascular vegetation (*P. pectinatus*) environment with which they were closely associated (Akin and Meyer 1996). In addition, some species of desmids such as *Staurastrum* spp. grow well in eutrophic waters and they may be tolerant of high pH values (Reynolds and Butterwick 1979) that confirmed our findings in the lake.

Now, the natural flora of the Nile was completely different from that of the lake in the followings: i) the natural algal community of the lake was represented by benthic species, except for three planktonic species of Chlorophyta and one cyanobacterium in October 1996 (Table 2); ii) more planktonic species were recorded in the Nile samples, this might be a result of the claming water in the lake and the water current in the Nile; iii) the natural flora of Sacred Lake assemblages did not show any diatoms. This may be correlated with the dense vegetation of *P. pectinatus* which create a very specialised and continually changing microenvironment in the water (Moss 1976), that in turn prevent the growth of the diatoms coming from the Nile into the lake. In addition, such observation goes parallel with the findings of Jones (1990). He stated that the phytoplankton biomass, especially diatoms was negatively related to macrophytic density. On the other hand, diatoms occupied the first rank in the order of dominance within the natural algal assemblages of the Nile bank facing the Karnak Temple. This observation is consistent with the findings of many investigators (Nassar 1980, El-Shimi 1984, Ahmed *et al*. 1986) who surveyed the phytoplankton populations of the Nile and its tributaries. The results of the en-

richment experiments supported the previous observations where *Nitzschia palea* was recorded in the Nile water and was not found in the lake water. This species appeared in the enrichment cultures, where *P. pectinatus* was absent; iv) with the exception of *Merismopedia tenuissimum* and *Microcystis flos-aquae*, the species composition of cyanobacteria was different through both water bodies. *Synechocystis aquatilis, Gloeocapsa minor* and *Cylindrospermum musicola* appeared only in the enrichment cultures indicating unfavourable conditions for growth of these species in nature, at least at the time of the investigation.

In order to keep the lake in a good picture for tourism we would like to call the attention for the protection of the lake by suggesting of the aquatic macrophyte removal. In addition to some chemical treatment by using a certain continuous dose of Alum throughout the year (Souza *et al*. 1994) or by biomanipulation and harvesting nutrient inactivation (Alum and Alum surrogates) or algaecide application (Kortmann 1994). Other method for treatment is the aeration, according to El-Faky (1998) who suggested the reconstruction of the pumping system and the recycling of the Nile water. But, the introducing of the Nile water must subjected to filtration from the algal species as well as the suspended matter. This suggestion will help in restoring the lake to its ancient picture.

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