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EFFECT OF SOME ENVIRONMENTAL FACTORS ON THE BIODIVERSITY OF HOLOZOOPLANKTON COMMUNITY IN LAKE QARUN, EGYPT

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Key words: Holozooplankton, Lake Qarun, biodiversity, environmental parameters.

ABSTRACT

Holozooplankton and water samples were collected from Lake Qarun during the period from 22 January to 27 December 2003, at seven stations.

The minimum water temperature was recorded during December (13.9°C) while the maximum one was observed during July and August (29.1°C). Transparency of the water decreased to the lowest visibility in spring in western region at station I (35 cm) and increased to 80 cm during summer in eastern side at station VI. The pH value of the lake water was toward alkaline medium (8.44). For dissolved oxygen, the maximum values were recorded during winter, particularly in January (10.09 mg/L), while the lowest ones were in July (5.49 mg/L). The highest values of biological oxygen demand (BOD) were recorded in the eastern site of the lake (range 6.99 - 6.46 mg/L), and it decreased in the other sites. The maximum values of the nitrogen compounds and phosphate were measured infront of the drains.

A total of 27 holozooplankton species were recorded in the lake, represented by three groups; Protozoa, Rotifera and Copepoda. The highest species number (18) was recorded at station I while the lowest number (10) was recorded at station VI. The standing stock of the holozooplankton was dominated by Protozoa followed by Rotifera constituting 78.81% and 13.20% respectively. Total average holozooplankton density ranged from 965 animals/l in station I to 1452 animals/L in station IV. The peak of flourishing of holozooplankton was recorded during April (2884 animals/l), while the lowest density was recorded in May (231 animals/l).

Protozoa was represented by 16 species. *Euplots*, *Tintinnopsis* and *Helicostomella* were the most dominant genera representing 46.52%, 33.62% and 16.34% of the total protozoan animals respectively. Eight species were recorded for the first time in the lake during study. *Didinium* was the main new record in the lake. Rotifera was represented by 8 species. *Brachionus* and *Synchaeta* were the most dominant genera forming 88.92% and 10.93% of the total rotifers respectively. Copepoda was represented by *Apocyclops banamensis*, *Paracartia latisetosa* and *Mesochra heldti* respectively. The calanoid *P. latisetosa* was the dominant adult copepod forming 93.03% of the total adult copepods.

By applying the diversity index, the values did not exceed 1.63. This means that the lake ecosystem is unstable or polluted. Species richness maximum value was at station I, while the lowest ones were in stations VI and VII.

INTRODUCTION

Among the metazoan zooplankton, two major groups can be distinguished; the holoplankton forms that spend their entire life cycle in the plankton; and the meroplankton forms that spend only part of their life cycle in the plankton, usually larval forms of benthic or nektonic adults.

Zooplankton group is among the most important components of the aquatic ecosystem. It helps the primary producers to be transferred into higher trophic levels, i.e. they have a major role in energy transfer between the phytoplankton and the fish. So, they support the economically important fish populations.

The abundance of zooplankton depends on the quantity of food resources, heterogeneity of environment, pressure of predatory fish, water temperature, pollution and a great variety of other abiotic and biotic factors, which collectively affect individual species of the zooplankton community.

Lake Qarun, area of investigation, attracts attention of several authors to study its unique ecosystem because of its historic and scientific importance. Several investigations were dealing with different environmental aspects. Zooplankton of Lake Qarun was studied by Wimpenny and Titterigton (1936), and they observed that most of the species were freshwater organisms. Girgis (1959) recorded the marine copepod as abundant form. Naguib (1961), Abdel-Malek and Ishak (1980), Dowidar and El Nady (1982), Ahmed (1994), Mageed (1996), and Radwan (2002) noticed that the lake harbored the marine forms only, as many of the species were transported to the lake through the transplantation of the Mullet fry from the Mediterranean Sea. They noticed the absence of the freshwater cladoceran organisms from the lake ecosystem.

Lake Qarun still suffers nowadays from several environmental problems. The progressive increase of its salinity was considered as the most serious problem which affects the different life aspects in the lake. Also, the exacerbation of eutrophication of the lake's water, that caused by the nutrient load from the agricultural drainage water (Sabae and Ali, 2004). These conditions led to change in the biodiversity of the different biota. The main objective of the present study is to illustrate the monthly variations of holozooplankton inhabiting the different regions of Lake Qarun during 2003. Comparing the recent data with the previous ones to find the effect of pollutants on the resemblance structure of holozooplankton communities with changes of the some environmental variables.

MATERIALS AND METHODS

a- Area of the Study:

Lake Qarun is a closed saline lake, located in the deepest part of El-Fayoum depression at the western desert, 70 km south Cairo-Egypt between longitudes 30º 24´ & 30º 49´ E and latitudes of 29º 24´ & 29º 33´ N. Lake Qarun is the remnant of an ancient prehistioric lake (Lake Moris). It has an area of about 200 km^2. Its greatest length from southwest to northeast is 40 km, and its greatest width is about 5km. It is surrounded by vast desert at the northern shore and cultivated lands at the south. It is used as a reservoir for the drainage water of El-Fayoum province. The drainage water drained into the lake via two main drains; El-Bats at the most eastern part (drains about 207.6 million m^3/year) and El-Wadi (drains about 103.03 million m^3/year) at the middle of the southern side, and from twelve streams, all of which were originally tributaries of the Nile. An undrained depression, in the prevailing climate, provided the conditions for salinization of the lake. The drainage water is loaded with salts, nutrients and pesticides that may accumulate and eventually contaminate the aquatic environment. The drainage water leads to great leaching of salts due to the high evaporation particularly in summer. So, the salinity of the lake increased vigorously with time passes. It has increased from about 12 gm/L in 1922 up to 30 gm/L in 1985 (Payne, 1986). At the present its salinity is somewhat below that of the Mediterranean sea; 32.28‰ (Anon, 2004). The water salinity increases from the eastern to the western side of the lake. Zooplankton was sampled during the period from 22 January to 27 December 2003 at seven stations (St. I – St. VII) along the lake (Fig. 1). The first three stations are represented the eastern site, the second two stations represented the middle, while the last two stations are represented the western site of the lake (Table 1).

Table (1): Latitude, longitude and depth (m) of selected stations during the study

Site	St. No.	Depth	Latitudes	Longitudes
EAST	I	2	29^{0} 25.70$^{\backslash}$	30^{0} 28.40$^{\backslash}$
	II	4	29^{0} 26.30$^{\backslash}$	30^{0} 32.20$^{\backslash}$
	III	3.5	29^{0} 27.70$^{\backslash}$	30^{0} 36.00$^{\backslash}$
MIDDLE	IV	6.5	29^{0} 28.30$^{\backslash}$	30^{0} 39.00$^{\backslash}$
	V	2	29^{0} 29.70$^{\backslash}$	30^{0} 41.50$^{\backslash}$
WEST	VI	4.5	29^{0} 29.60$^{\backslash}$	30^{0} 43.80$^{\backslash}$
	VII	3.2	29^{0} 29.60$^{\backslash}$	30^{0} 46.50$^{\backslash}$

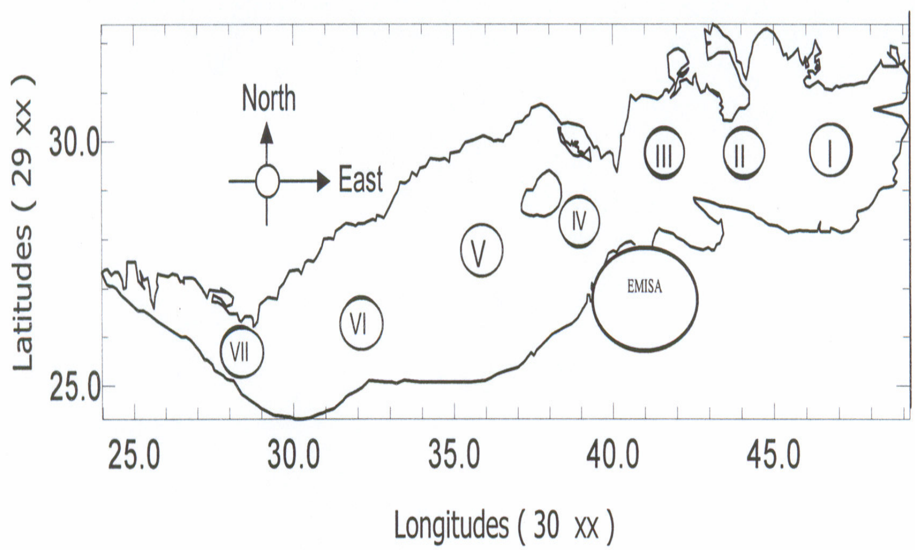

Fig. 1. Map of Lake Qarun showing sampling stations of study

b- Sampling, counting and identification:

The physico-chemical parameters of the lake were collected and analyzed during the study by the team work of the Freshwater and Man-made Lakes Branch, National Institute of Oceanography and Fisheries. Three vertical zooplankton tows from 2 m deep up to top were taken from each station using an 24 cm-diameter, 20 μm-mesh plankton net. Samples were preserved in 4% sugar formalin. The contents of triplicate 1m*l*subsample were counted from each sample. All the organisms in a sample were identified to species level as possible and counted. The organisms were identified according to Rose (1933), Rudescu (1960), Bick (1972), Grell (1973) and Yamaji (1978).

c- Statistical analysis:

The diversity of the species was calcu lated using the formula: $DI = -\sum_{i=1}^{m}(\frac{ni}{n}\ln\frac{ni}{n})$ where "m" is the number of species, "n_i" is the number of individuals in the "i_{th}" species and n is the total number of individuals in the sample (Shannon and Weaver, 1963).

Species richness was calculated according to Margalefs (1958) equation, were $SR = \frac{S-1}{LnN}$ where "S" is the species number, and "N" is the total individuals number.

Equitability (E) was calculated according to Shannon and Weaver (1963) by the equation $E = \frac{DI}{Log_2 S}$ where "DI" is the diversity index and "S" is the number of species.

Index of Biotal Dispersity (IBD) (cf. Green, 1971) was calculated according to the equation $IBD = \frac{T-S}{S(n-1)}x100$ where "T"is the arithmetical sum of species living in each of "n" compared associations and "S" is the total number of species in "n" compared associations.

Community dominance index (CDI) was described by Mc Naughton (1968). It is expressed as follows, $CDI = \frac{y1+y2}{y}x100$ where, y1 is the abundance of the most abundant species; y2 is the abundance of the second abundant species and y is the total abundance of all species.

Correlation and cluster analysis were carried out using Minitab 12 under windows program.

RESULTS

Physicochemical parameters:

The results of these parameters of Lake Qarun are shown in Table 2. The variation in water temperature followed the changes of air temperature. The minimum water temperature was recorded during December (13.9 ºC), while the maximum one was observed during July and August (29.1ºC). Transparency of the water decreased to the lowest visibility in spring at station I (35 cm) and increased to 80 cm during summer at station VI. The pH values of the lake water were slightly alkaline, with the lowest reading in station VII during June (7.74), while the maximum record was in station IV during January (8.95). For dissolved oxygen, the maximum values were measured during winter, particularly in January (10.09 mg/L), while the lowest reading was recorded in July (5.49 mg/L). The highest values of biological oxygen demand (BOD) was recorded in the eastern site of the lake (range 6.99-6.46 mg/l), and it was very low in the other sites. The maximum values of the nitrogen compounds (ammonia, urea, NO_2 and NO_3) and PO_4 were measured at stations I and V (infront of the drains).

Table (2): General characteristics of Lake Qarun during the study (after Sabaa and Ali, 2004)

Parameter	Min.	Max.	Avg.	St Dev	SE Mean
Transparency (Cm)	35	80	55	16.55	6.25
Salinity (gm/l)	29.707	37.120	32.416	1.845	0.312
Temp. (ºC)	13.100	31.400	22.906	5.257	0.628
pH	7.7400	8.9500	8.4443	0.3018	0.0329
DO (mg/l)	4.000	14.000	7.882	1.983	0.226
BOD (mg/l)	2.720	13.920	5.968	2.004	0.239
Cl (mg/l)	10458	14975	13805	658	72
Na (mg/l)	7357.0	10511.0	9064.4	772.6	84.3
K (mg/l)	280.00	485.85	363.90	51.39	5.61
Urea (mg/l)	0.0000	1.8100	0.5782	0.4062	0.0443
NH_3 (mg/l)	0.0300	0.6800	0.1632	0.1079	0.0118
NO_2 (µg/l)	0.60	51.80	13.77	9.68	1.06
NO_3 (µg/l)	9.0	776.0	93.9	101.5	11.1
PO_4 (µg/l)	21.00	152.00	59.52	25.96	2.83
SO_4 (mg/l)	6846.0	11556.9	8785.6	911.1	99.4
Chl. *a* (mg m^{-3})	8.05	41.48	26.38	-	-
Phytoplank. (Cellx10^4/l)	130	24280	4752	5387	588

Holozooplankton assemblages:

Twenty seven taxa of holozooplankton, included in three groups; Protozoa (16 taxa), Rotifera (8 taxa) and Copepoda (3 taxa) were identified in Lake Qarun during the study. The highest species number (18 species) were recorded at station I, while the lowest number (10 species) were recorded in station VI (Table 3). The standing stock of the holozooplankton was dominated by Protozoa followed by Rotifera constituting 78.81% and 13.20% from the total holozooplankton number respectively. While Copepoda was ranked in the third order representing 8.00% of the total holozooplankton number (Fig. 2). Total average zooplankton density ranged from 965 animals/l in station I to 1452 animals/L in station IV (Fig. 3). The peak of flourishing of holozooplankton was recorded during April (2884 animals/L) while the lowest one was in May (231 animals/L). From the areal distribution (Fig. 4), most of animals (4000-8000 animals/L) were concentrated in the middle of the lake and station VII during February-April period.

Protozoa was the main holozooplankton group in the lake. It was dominated in the middle of the lake particularly at station IV (average 1211 animals/L), while the lowest density was recorded at the east of the lake, particularly at station I (average 708 animals/L). Its monthly variations cleared that, the highest peak was recorded during February-April period with the maximum number in April (2773 animals/L). The lowest number was observed in May (119 animals/L). Spatial distribution (Fig. 5) showed, more or less similar pattern of distribution of the total holozooplankton. Protozoa was represented by 16 species included in 13 genera. *Euplots*, *Tintinnopsis* and *Helicostomella* were the most dominant genera representing 46.52%, 33.62% and 16.34% of the total protozoan animals respectively. *E. vannus* and *T. strigosa* were the most dominant protozoan animals (46.52% and 33.62% of the total protozoans respectively) (Fig. 6). Eight protozoan species were recorded for the first time in the lake during study (Table 4). Genus *Didinium* was the main new record in the lake. *D. nasutum and D. balbianii* formed collectively 32.32% of the other forms of Protozoa. Figures 7&8 showed distribution and monthly variations of the different recorded protozoan animals.

Rotifera was the second abundant group in the holozooplankton in Lake Qarun. It formed 13.2% of total holozooplankton density. It was dominated in the east of the lake particularly at station II (average 252880 animals/L), while the lowest number was recorded at the middle of the lake, particularly at station V (average 24043 animals/L). Its monthly variations cleared that the flourishing period of rotifers was recorded during summer and autumn, maximally in July (894551 animals/L). The lowest density was observed in spring (8493 animals/L) with the minimum number in May (1019 animals/L). Spatial distribution (Fig. 9) showed increasing of rotifers density in the eastern site of the lake during July. Rotifera was represented by 8 species included in 6 genera. *Brachionus* and *Synchaeta* were the most dominant genera, forming 88.92% and 10.93% of the total rotifers respectively (Fig. 10). *Brachionus plicatilis* was the most dominant rotifer and was represented by 88.72% of the total rotifers. Three rotifers species were recorded in the lake for the first time during the study. Figures 11&12 showed distribution and monthly variations of the different recorded rotiferan animals.

Copepoda occupied the third abundant rank. It formed 8.00% of the total holozooplankton density. Copepoda was dominant in the middle of the lake particularly at station V (average 159613 animals/L), while the lowest number was recorded at the east of the lake, particularly at station III (average 61543 animals/L). Its monthly variations revealed that the flourishing season of copepods was during September-October period with a maximum density in October (256799 animals/L).

Table (3): Number of species (SN), dominant species, average number of animals and flourishing month of the holozooplankton in Qarun Lake.

Site	*Station*	*SN*	*Dominant species*	*Avg.org.l^{-1}*	*Peak*
EAST	St. I	19	*E.vannus* (41%)	0,965.228	April
	St. II	16	*E.vannus* (39%)	1,238.981	April
	St. III	14	*E.vannus* (43%)	1,330.636	March
MIDDLE	St. IV	17	*E.vannus* (42%)	1,451.729	Feb.
	St. V	15	*T.strigosa*(49%)	1,223.845	March
WEST	St. VI	9	*E.vannus* (46%)	1,124.246	July
	St. VII	11	*T.strigosa*(43%)	1,413.786	April

Table (4): Diversity index (DI), equitability (E), species richness (SR) and Community dominance index (CDI) of the holozooplankton in Qarun Lake.

Site	*Station*	*DI*	*E*	*SR*	*CDI*
EAST	St. I	1.486	0. 35	1.31	62.20%
	St. II	1.627	0.407	1.07	61.00%
	St. III	1.219	0.32	0.92	73.99%
MIDDLE	St. IV	1.478	0.362	1.13	72.60%
	St. V	1.148	0.294	1.00	82.38%
WEST	St. VI	1.379	0.435	0.57	69.80%
	St. VII	1.432	0.414	0.71	72.50%

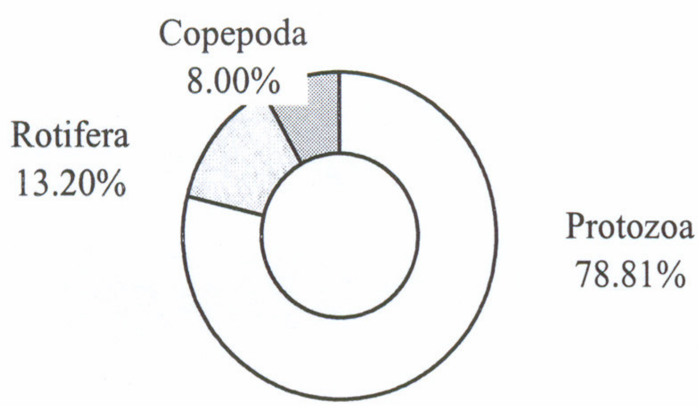

Fig. (2): Percentage of holozooplankton groups to the total number

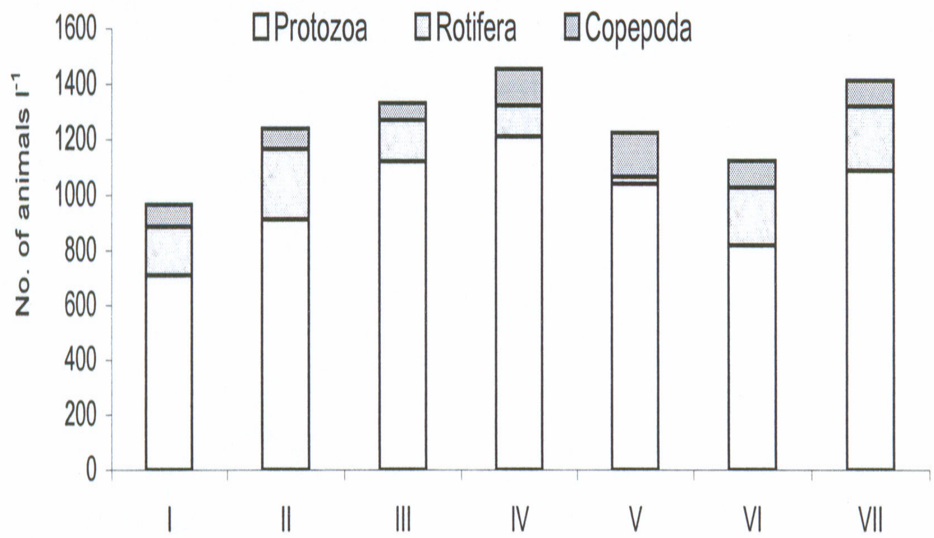

Fig. (3): Distribution of holozooplankton groups (No. of animals l^{-1}) in stations of Lake Qarun

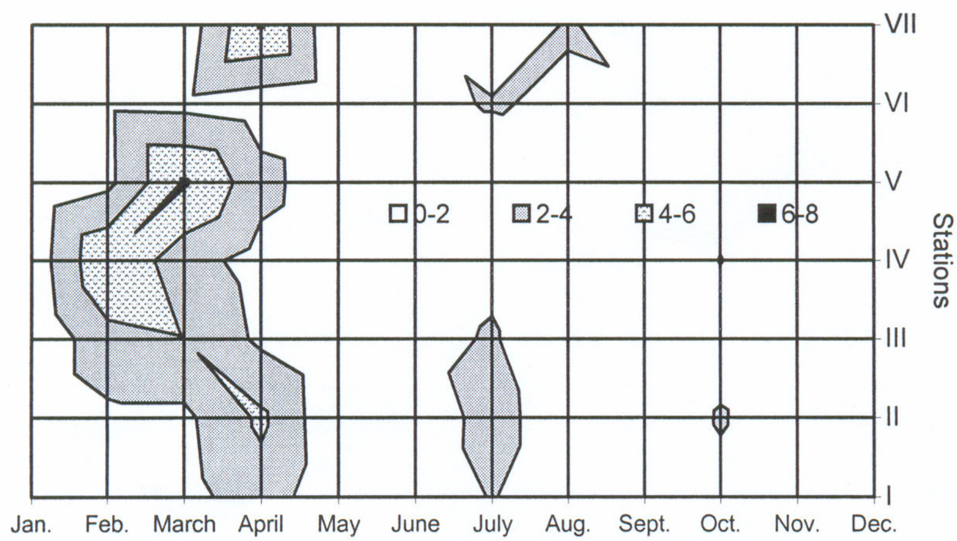

Fig. (4): Spatial distribution of the total number of holozooplankton (animals x10^3 l^{-1})

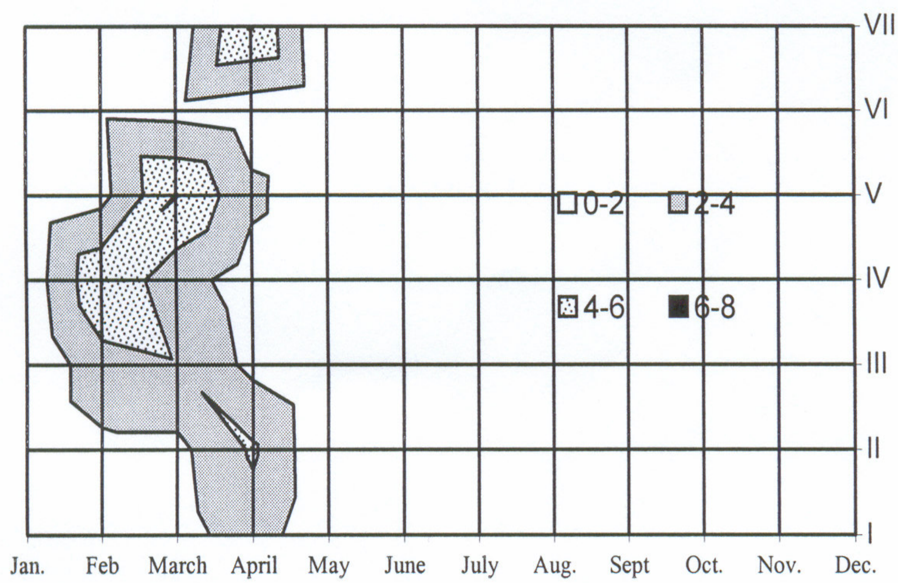

Fig. (5): Spatial distribution of the total number of Protozoa (animals x10^3 l^{-1})

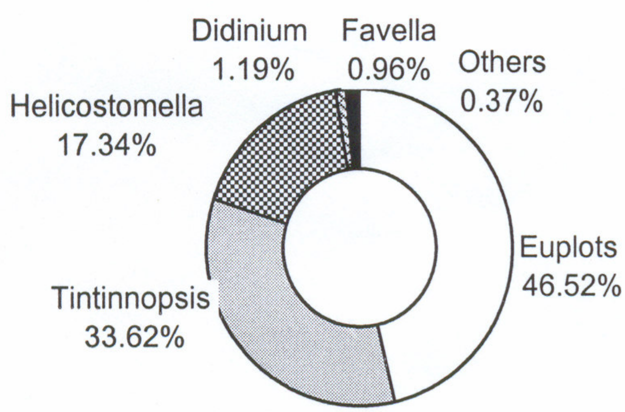

Fig. (6): Percentage of the genera of protozoans to the total number of Protozoa

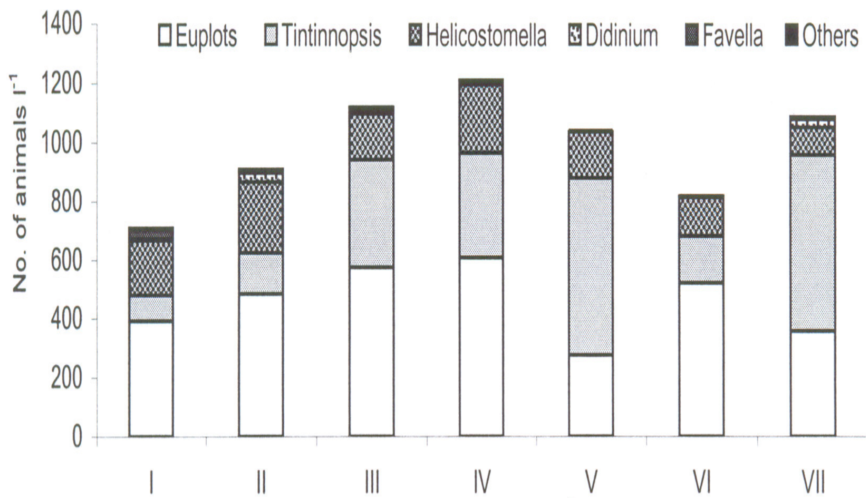

Fig. (7): Distribution of the dominant protozoan genera(animal l^{-1}) in stations of Lake Qarun

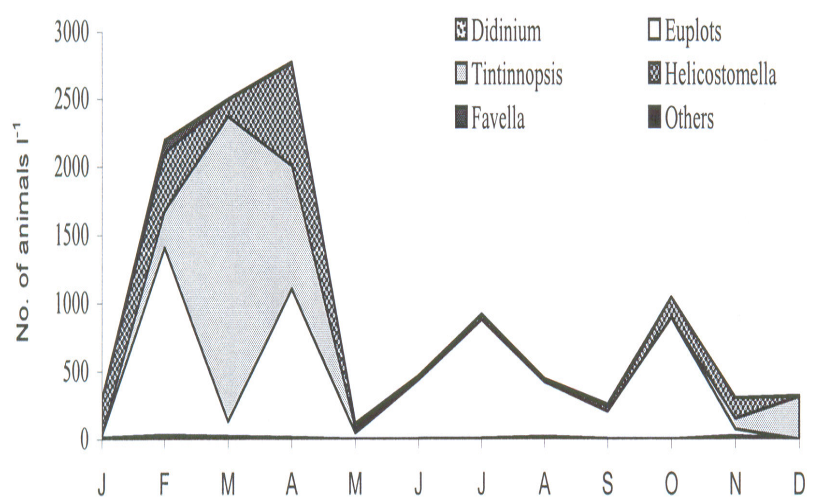

Fig. (8): Monthly variations of the dominant protozoan genera (animals l^{-1})

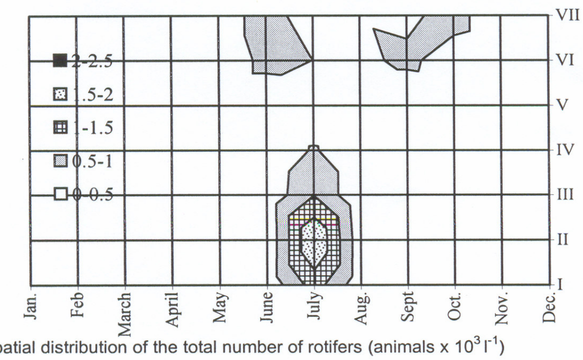

Fig. (9): Spatial distribution of the total number of rotifers (animals x $10^3 l^{-1}$)

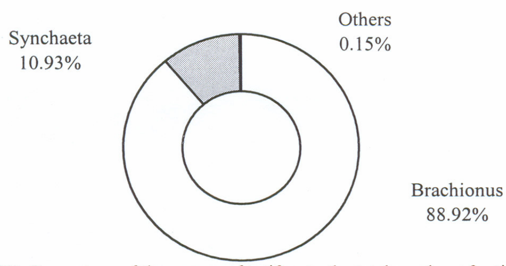

Fig. (10): Percentage of the genera of rotifers to the total number of rotifers

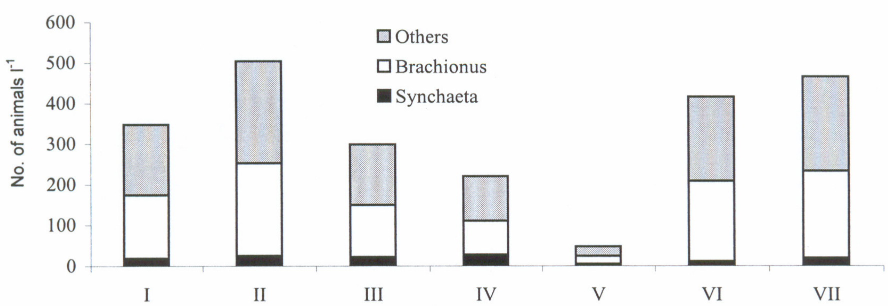

Fig. (11): Distribution of the dominant rotiferan genera (animals l^{-1}) in stations of Lake Qarun

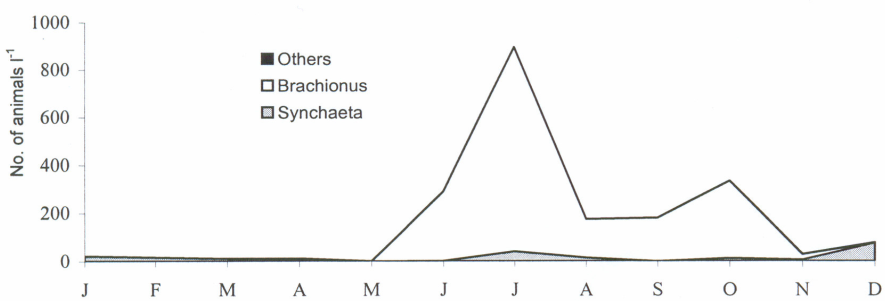

Fig. (12): Monthly variations of the dominant rotiferan genera (animals l^{-1})

The lowest number was observed in January (30816 animals/L). Spatial distribution (Fig. 13) showed concentration of copepods in stations IV, V & VII during October and in station VI during September. Copepoda density was represented by the three developmental stages; nauplius, copepodite and adult stages (82.61%, 14.53% and 2.86% of copepods number respectively) (Fig. 14). Copepoda was represented by three orders (Cyclopoida, Calanoida and Harpacticoida). Each order was represented by one species; *Apocyclops banamensis*, *Paracartia latisetosa* and *Mesochra heldti* respectively. The calanoid *P. latisetosa* was the dominant adult copepod, forming 93.03% of the total adult copepods. Figures 15&16 show the distribution and monthly variations of the different stages of the recorded copepod animals.

By applying the cluster analysis to categorize and show similarity among stations of Lake Qarun (Fig. 17), we can conclude that: A) for protozoan organisms; the stations can be categorized into two sets; the first one included stations I, II and VII (similarity 94%) with high similarity between stations I&II (99%); the second set represented the other stations with similarity between them ranging between 89-91%. The similarity between the two sets was 73%. B) for rotifers, the lowest similarity was between stations VI&VII (west) and the others (89%). C) for copepods, station I had the lowest similarity with the other stations (67%).

<u>Species diversity measures:</u>

Species diversity measures (Table 5) was based on the Diversity Index of the species (DI), Equitability (E), Species richness (SR), Index of Biotal Dispersity (IBD) and Community Dominance Index (CDI).

By applying the Diversity index, the values did not exceed 1.627 (Station II), while the lowest DI value was for station V (1.148). For Equitability values, the maximum values were at the west of the lake, while the lowest values were at the middle of the lake. Species richness reached the maximum value station I (1.31) while the lowest values were recorded at stations VI and VII (0.57 and 0.71 respectively). IBD value was 48% while CDI was the minimum at station II (61.00%) and its maximum was at station V (82.38%).

DISCUSSION

The climate of El-Fayoum is hot and dry so, the rate of evaporation from Lake Qarun is high (173.95 cm/year) particularly during summer (Anon, 2004). The drainage water of the neighboring agricultural lands discharges into the lake. The total salt content in the l ake water increased with time. Soliman (1989) showed that the best-fit curve relating the total salt content with time is a straight line with a slope of 0.101.

In the lakes rich with drain water, both electrolytes (chloride and carbonate of sodium) and nutrient salts (phosphate, nitrogen compounds) accumulate, making these regions more saline and eutrophic (Wilbert, 1995). The salts dissolved in the water are present in the form of ions. These are chiefly the anions Cl^-, SO_4^{2-}, HCO_3^- and CO_3^{2-}, plus the cations K^+, Na^+, Ca^{2+} and Mg^{2+}. Water is distinguished on the basis of the most abundant anion: carbonat, sulfate or chloride (Loffler, 1961). Salt lakes with ionic composition like that of the oceans are called thalassic; those with a different composition are athalassic. Lake Qarun is thalassic in character, with sodium and chloride ions dominating. According to radiocarbon tests of fossil pollen in the lake sediment, it has existed for 9000 years (Mehringer *et al.* 1979). At that time, the lake was a freshwater lake at an altitude of *ca* 20m, whereas now it is about 45m below sea level.

The discharging drainage water from the drains in the eastern and middle sections is loaded with suspended particles led to decreasing transparency compared with the western part. Abdel Monem (2001) measured the photosynthetic capacity of the algal populations in Lake Qarun; it varied between 3.53 and 4.38 mg C mg/Chl. The drastic spatial distribution of productivity showed a maximal values in the eastern side. Consequently, the lake turbidity was autochathonous and allochathonous in its nature which mainly due to suspended non biological particles that enters with the drainage water, in addition to the generated biological particles in the lake. Transparency in the lake is not more than 80 cm. Abdel Monem (2001) reported that the euphotic layer does not exceed than 3.13 m. So, the holozooplankton samples were collected from the upper two meters; the most trophic layer.

The water temperature in Lake Qarun ranged from 13 ºC in December to 31.4 ºC in August. The difference in temperature between surface and bottom is no more than 2 ºC. There is no thermal stratification in the lake (Boulos, 1959). According to Loffler (1958), Lake Qarun is a tropical lake in its features with frequent general circulation; it is "warm polymictic".

Wimpenny and Titterington (1936) noticed the presence of one species of copepods namely, *Diaptomus salinus* Daday, beside the decapod *Leander squilla* var *elegans* Rathke and the cladoceran *Moina salinarum* Gurney, in 12‰ during 1928. They also observed that the cold period was characterized by a simple community abundant in individuals while the warm period showed a more complex community and fewer individuals. The marine plankton was introduced into the lake between 1928 - 1933 during the transplantation of the mullet fry in the lake, which were transported from the Mediterranean Sea. Abdel Malek (1981) reported the changes in the composition and biomass of ichthyofauna, phytoplankton, zooplankton and zoobenthos as a result of increasing salinity. He reported that, *Diaptomus salinus* and *Moina salinarum* disappeared completely. However, some rotifers were able to withstand the high salinity. During 1989, Ahmed (1994) recorded 27 species. She recorded 15 protozoan species, 11 rotiferans and a copepod species. She found the dominance of tintinnids, representing about 97.6% of the total zooplankton number. List of species of Ahmed (1994) was changed during 1996 (Mageed, 1998a). He recorded 25 species (16 Protozoa, 6 Rotifera and 3 Copepoda) and found rotifers as the main dominant group. The picture has been changed during this study in 2003 (Table 5).

During the present study, the maximum number of holozooplankton was recorded in the middle of the lake particularly at station IV. Mageed (1998a) also observed the maximum number of zooplankton organisms at the middle of the lake, and this is due to that most of the agricultural drainage water inflow through the drains at the middle of the lake through El wadi Drain which carries the fertilizers of the agricultural lands and the discharge of the fish farms. The community was dominated by protozoan organisms (78.81% of total holozooplankton number), and its peak of flourishing was noticed during February-April period. Mageed (1998a) showed that the flourishing of zooplankton occurs during summer due to the dominance of *Brachionus plicatilis* which is a summer form (he collected zooplankton by 55 µm plankton net). *B. plicatilis* is mainly a marine form with euryhaline affinities (Capuzzo, 1979). Egborge (1994) recorded it in the Lagos Harbour - Badagry Creek system (Nigeria) at salinity ranges between 0.27‰ and 32‰, while Williams (1987) observed it in Pyramid Lake (Nevada - USA) and Victorian Salt Lakes (USA) at salinity ranges from 0.4‰ to 50‰. Mageed (1998b) recorded it in salinity 167‰ at Fayoum depression. The zooplankton population in the Suez Canal is dominated by copepods and protozoans (tintinnids), as recorded by El-Serehy and Shalaby (1994).

Ciliated protozoans and rotifers become more important in the zooplankton among eutrophic lakes. Protozoa has the ability to develop in organic-rich and polluted waters. Populations of ciliates often develop in strata greatly reduced in oxygen in which bacterial populations tend to be dense (Wetzel, 1983). In Lake Qarun, Sabaa and Ali (2004) recorded the high probable number of bacterial counts, ranged between 0.8x1011 and 115x1011 CFU/ml and between $0.9x10^{11}$ and $140x10^{11}$ CFU/ml^{-1} at 22 ºC and 37 ºC respectively.

The didinid ciliated protozoan, *D. nasutum* was recorded for the first time in Lake Qarun. Its peak was recorded during winter particularly during February. According to Bick (1972), *D. nasutum* is a cosmopolitan species, lives in temperature between 5 ºC – 25 ºC, pH= 6 - 8 and NH_4^+= 0 - 1.8 mg/L. According to Liebmann (1962), it is considered as beta-mesosaprobic species. It is the tiger of protozoan organisms.

Rotifera was mainly dominated by *B. plicatilis*. It is considered as a summer form, and correlated positively with water temperature ($r = 0.41$, $P < 0.001$). Its peak of flourishing was during summer. This result coincided with observations of Mageed (1998a). *Keratella valga*, *K. cochlearis*, *Notholca* sp., *C. adriatica* and *M. bulla* were recorded as rare rotifer forms in Lake Qarun during the present study.

Copepoda species was represented by three species; namely *Paracartia latisetosa, Apocyclops panamensis* and *Mesochra holdeti*. The community composition of copepods has not change for the last twenty years (Khalifa, 1994 and Mageed, 1998a).

On the other hand, diversity index (DI) values did not exceed 1.627 (Station II), while the lowest DI was at station V (1.148). This means that, the lake water is unstable or polluted, as values less than "1" indicate instability or heavy pollution, while values exceeding "3" indicate stability or clean water (Shannon and Weaver, 1963). For Equitability (E) values, the maximum values were at the west of the lake, while the lowest ones were at the middle of the lake. Species richness figures indicated that the maximum SR was at station I, while the lowest values were in stations VI and VII. The difference in species number in the different stations of the lake is mainly due to an increase in the number of protozoans. Index of biotal dispersity (IBD) is used to asses how widely dispersed species are among the seven stations; its value was 48%. Community dominance index (CDI) measures the abundance percent contributed by the two most abundant species in the community (Mc Naughton, 1968), its minimum one was at station II (61.00%), while the maximum value was at station V (82.38%).

Pearson correlation coefficients between the number of the three different taxonomic groups of zooplankton and environmental variables were ranged between insignificant to highly significant, reaching to the maximum 0.43 (Table 6). Among the fifteen variables in the water quality category, Protozoa was negatively correlated by high significance with Na and Urea (P= 0.001). While temperature and potassium displayed the strongest positive correlation in the case of rotifers (P= 0.001). Pinel-Alloul and Patoine (1999) recorded Potassium (K) as he most common parameters correlated to rotifers (P< 0.038). The strongest positive correlation for copepods was with urea (P= 0.001). Phytoplankton was negatively correlated with Protozoa (P= 0.01) and was not significant with others. Salinity was not effective variable in the lake during the annual cycle along the lake, but it is a very important variable in the long run. Soliman (1989) expected that the rate of increase of the total salt content will remain constant during the period 1982 - 2050, while the mean salinity of the lake may show a progressive increase with time, which intern must lead to a drastic change in the lake fauna. So, salinity is the most important factor affecting the lake ecosystem in the long run.

Table (5): Comparative study of zooplankton species recorded in Lake Qarun during 1989-2003

Taxa	*-89*	*-96*	*-03*	*Taxa*	*-89*	*-96*	*-03*
Protozoa:				*F. brevis* (Kofoid&Campell)	#	-	-
Didinium nasutum Muller	-	-	#	*Coxliella decipens* (Jorgensen)	#	-	-
D. balbianii Bütscli	-	-	#	*C. annulata* (Daday)	#	-	-
Amphileptus sp.	-	-	#	*Textularia* sp.	#	#	-
Trachelius ovum Ehrenberg	-	-	#	*Globigerina bulloides* d'Orbigny	#	#	-
Strobilidium sp.	-	-	#	*Quinqinquilina* sp.	-	-	#
Loxophyllum sp.	-	-	#				
Acineta limnetis(Good.&Jahn)	-	-	#	**Rotifera:**			
Euplots vannus Muller	-	#	#	*Keratella tropica* Apstein	-	#	#
Tintinnopsis kofoidi Hada	-	#	#	*K. valga* (Ehrenberg)	#	-	-
T. strigosa Meunier	-	#	#	*K. quadrata* (Muller)	#	-	-
T. amphora Kofoid&Campb.	-	#	-	*K. cochlearis* Gosse	-	-	#
T. beroidea Stein	#	#	-	*Notholca salina* Foecke	#	#	#
T. campanula Ehrenberg	-	#	-	*Brachionus plicatilis* Muller	#	#	#
T. cylindrical (Daday)	#	-	-	*Testudinella patina* Hermann	-	#	-
T. levigata (Kofoid&Camph.)	#	-	-	*Colurella adriatica* Hauer	#	-	#
T. accuminata (Daday)	#	-	-	*Synchaeta pectinata* Rousselet	#	#	#
T. lobiancoi (Daday)	#	-	-	*Monostyla bulla* Gosse	#	-	#
Leprotintinnus bottnicus Nord.	-	#	-	*M. closterocerca* Schmarda	-	#	-
Helicostomella subulata Ehr.	#	#	#	*Rhinoglena frontalis* (Ehren.)	#	-	-
H. edentate (Faure-Fremiet)	#	#	-	*Proales decipiens* (Huds.&Gosse)	#	-	-
Favella taraikensis Hada	-	#	#	*Trichocerca* sp.	#	-	-
F. sp.	-	#	-	*Asplanchna priodonta* (Gosse)	#	-	-
F. ehrenbergi Clap.&Lach.	#	#	#				
F. panamensis Kofoid&Camp.	-	#	-	**Copepoda:**			
F. adriatica Imhof	-	#	-	*Apocyclops panamensis* (Marsh)	-	#	#
F. markuzowskii (Daday)	#	-	-	*Paracartia latisetosa* Kricz.	#	#	#
F. fistulicauda (Jorgensen)	#	-	-	*Mesochra heldti* Monard	-	#	#

Note: #, recorded; -, not recorded; -89, 1989 (Ahmed, 1994); -96, 1996 (Mageed, 1998); -03, 2003 (present study).

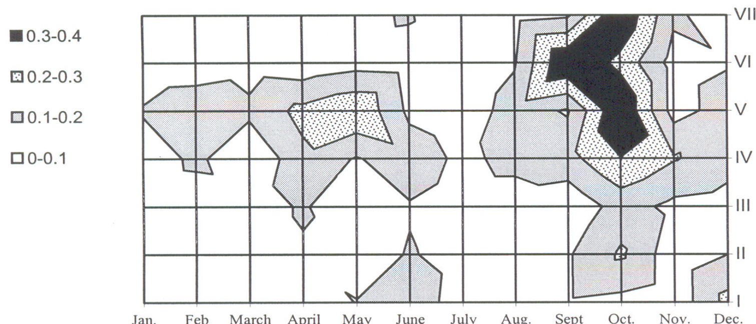

Fig. (13): Spatial distribution of the total number of copepods(animalsx10^3 l^{-1})

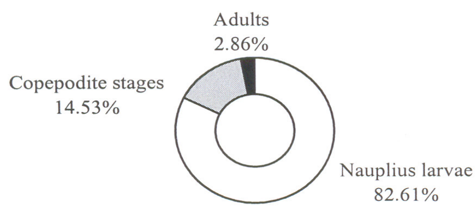

Fig. (14): Percentage of the developmental stages of copepods to the total number of copepods

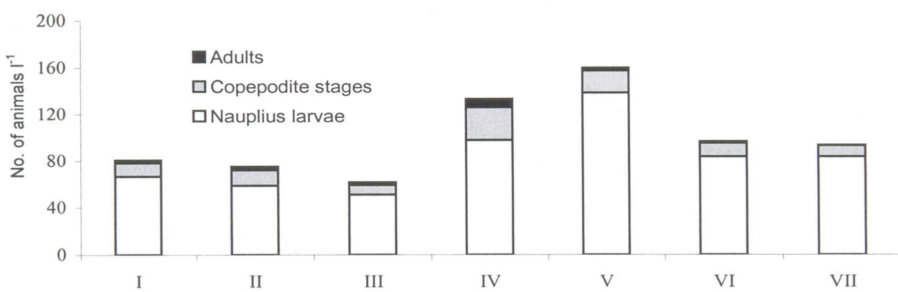

Fig. (15): Distribution of the developmental copepod stages (animals l^{-1}) in stations of Lake Qarun

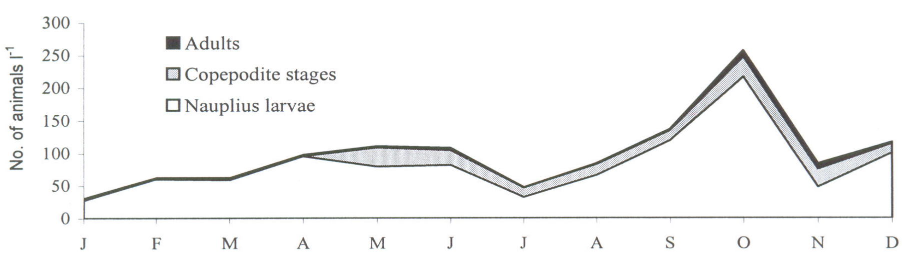

Fig. (16): Monthly variations of the developmental copepod stages(animals l^{-1})

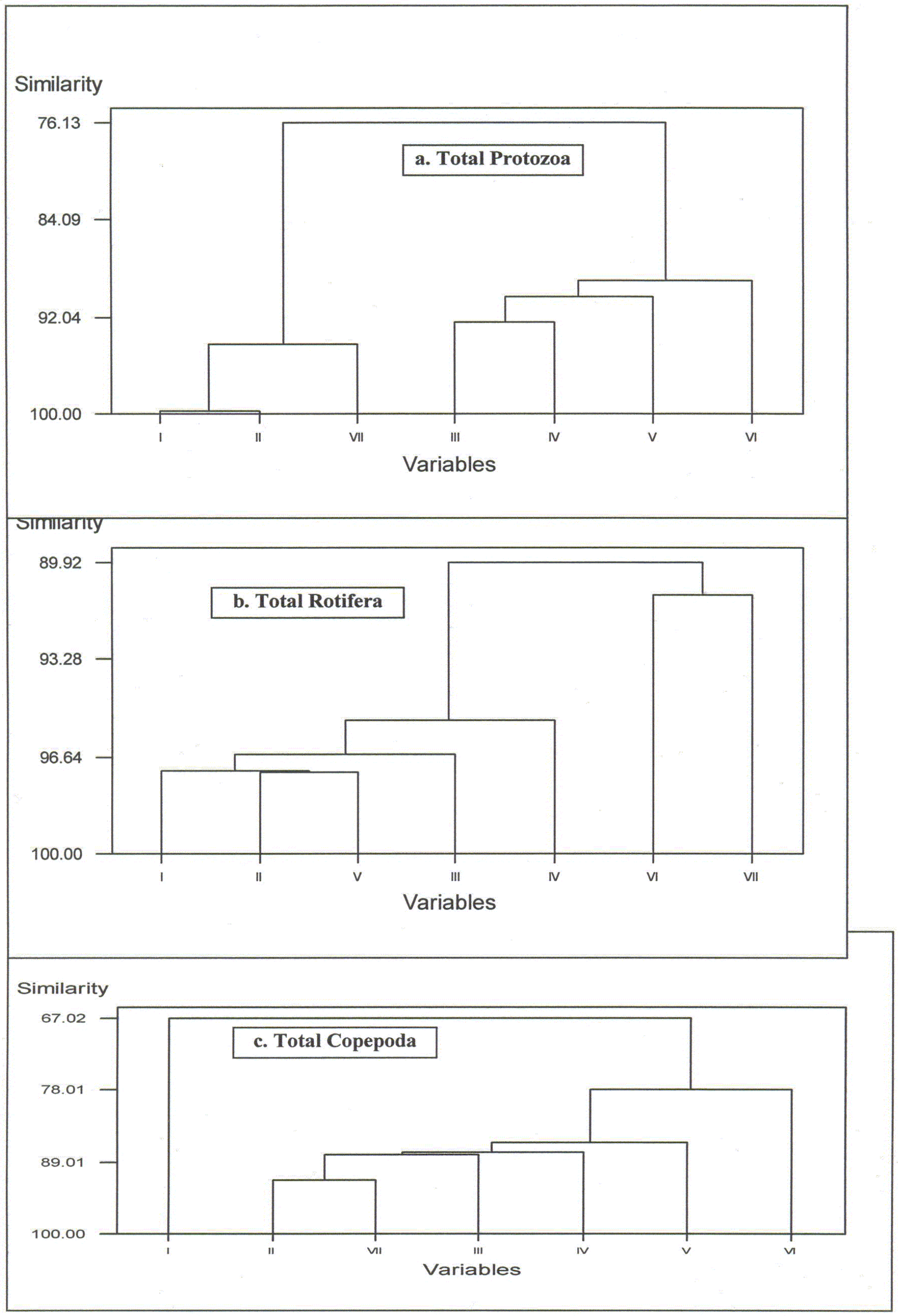

Figure (17): Clustering of the stations of Lake Qarun according to their; a. protozoans, b. rotifers and c. copepods number

Table (6): Pearson correlation coefficients between holozooplankton number (groups and the dominant species) and environmental variables using 84 cases.

Parameter	***Protozoa***		***Rotifera***		***Copepoda***	
	Total	D. species	Total	D. species	Total	D. species
Transparency	-0.25*	ns	ns	ns	-0.25*	ns
Salinity	0.35*	ns	ns	ns	ns	ns
Temperature	Ns	0.26*	0.41***	0.43***	ns	ns
pH	Ns	ns	-0.26**	-0.26**	ns	ns
DO	-0.29**	-0.33***	-0.25*	*0.26*	ns	ns
Cl	Ns	ns	ns	ns	-0.22*	ns
Na	-0.40***	ns	ns	ns	ns	0.23*
K	Ns	ns	0.36***	0.35***	ns	ns
Urea	-0.30***	ns	ns	ns	0.37***	ns
NH3	Ns	0.37***	ns	ns	ns	ns
NO2	Ns	ns	ns	ns	ns	ns
NO3	Ns	ns	ns	ns	ns	0.28**
PO4	-0.24**	-0.25*	ns	ns	-0.24*	0.22*
SO4	ns	ns	0.28**	0.26**	ns	ns
Phytoplankton	-0.29**	ns	ns	ns	ns	0.28**

Note: ns, not significant (P>0.05); * 0.05>P>0.01; ** 0.01>P>0.001; *** P<0.001
D. species, dominant species.

Zooplankton is an essential component of lake biota; by grazing on the phytoplankton community, zooplankton can control algal biomass and size structure (Christoffersen *et al.*, 1993). As nutrient inputs from watersheds significantly increase, this enrichment is susceptible to affect bottom-up interactions and plankton (phytoplankton and zooplankton). Shabrawy and Taha (1999) recorded that zooplankton regulates phytoplankton biomass in Lake Qarun during summer. *B. plicatilis* as the main dominant rotifer, feeds exclusively on *Nitzchia sigma* and *N. frustulum* var. *perpnsilla*. The great grazing pressure of zooplankton was mainly on nano- and picofractions of phytoplankton. Size fractionation of total Chl *a* in Lake Qarun has cleared by Abdel Monem and Konswa (2001), the dominance of nanoplankton representing about 69.4% of total plankton, while netplankton composed only 30.6% of it.

As fish yield and recruitement is strongly correlated to lake productivity and plankton food availability (Godbout and Peters 1988), so any change in zooplankton resources may thereafter impact on fish populations. In conclusion, Lake Qarun is a highly eutrophic lake. It is suitable for transplantation of the marine fishes, particularly the planktonic feeder species, to consume the high quantities of plankton, which did not utilize properly up till now.

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