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PHYTOPLANKTON COMMUNITY STRUCTURE AND DIVERSITY INDEX IN MEDITERRANEAN SEA LAGOON; LAKE MANZALAH, EGYPT

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ABSTRACT

Phytoplankton community and its diversity of Lake Manzalah were studied bimonthly from January 2001 to January 2002. The lake was covered by nine sampling stations. It was characterized by high nutrient load from untreated industrial, domestic, drainage water and agrochemicals (biocides and fertilizers) through several drains located at southern and western sides, beside to discharge of Port Said wastewater treatment plant. The phytoplankton counts attained an average of 1.2 x 10^6 unit/L, it represented by 111 species dominated by Bacillariophyceae (44 spp., 39.5% by number of the total community), Chlorophyceae (31 spp., 38.1%) and Cyanobacteria (14 spp., 14.2%). While Euglenophyceae (12 spp., 4.2%) and Dinophyceae (10 spp. 4.0%) were recorded as frequent forms. The most dominant genera were *Melosira* (20.14% of the total community), *Scenedesmus* (10.18%), *Ankistrodesmus* (9.13%), *Chlamydomonas* (8.91%), *Merismopedia* (8.22%), *Cyclotella* (7.82%), and *Nitzschia* (6.43%). The phytoplankton density showed a remarkable decrease as compared with the previous records and the community was altered since Bacillariophyceae became dominant, instead of Chlorophyceae. Some marin diatom forms appeared at Boughaz area, the south and middle area of the lake dominated by Chlorophyceae, and the western area dominated by Cyanobacteria. The highest average phytoplankton density was recorded at Bahr Kassab (St.4, 1.9x10^6unit/L), while the lowest density was recorded at Bahr Deshdee (St.6, 0.6x10^6unit/L). Phytoplankton flourished during spring (March) like most Egyptian Delta lakes. Diversity Index varied from 0.96 to 2.9 "nats". Lake water affected directly or indirectly by water discharged there, although the nutrient salts decreased than the previously recorded it was not limit to phytoplankton growth. Correlation coefficients were done to describe the dependence of phytoplankton density on some abiotic factors and discussed.

1. INTRODUCTION

Lake Manzalah is the largest among delta lakes, shows a dynamic system that has been undergoing continuous change (El-Sherif and Gharib, 2001 and Shakweer, 2005). It is a shallow brackish water basin (0.6-1.0 m), situated at the northeastern part of Egypt, between the Suez Canal and the Damietta Branch of River Nile (long. 31° 45`, 32° 15`E, lat. 31° 00`, 31° 35`N) (Fig.1). It is separated from the Mediterranean Sea by a narrow sandy fringe at the north. The lake is connected to the sea through a narrow channel (Boughaz El-Gamil) at its northeastern side, and lies between Damietta to the west and Suez Canal to the east. The actual area of open water is only 699 km^2 due to the presence of a large number of islets (Samir, 2000). These islets act as barriers that retard the interchange of water and sediments throughout the lake.

The lake is transversed by a number of small islands of varying sizes dividing it into a number of inter-connected basins each of which is known as "Bahr" having more or less distinctive ecological conditions.

The lake is considered as a sink for disposing industrial and human wastes (Ahmed and Elaa, 2003). A total amount of about 7500 x $10^6 m^3$ of untreated industrial, domestic and drainage water as well as agrochemicals (fertilizers and biocides) are discharged annually into the lake through some main drains (Hadous, Ramsis, Bahr-El Bakr, El Sero and El Gamalia), El Mataria Pumping Station, El Enania and Port Said Canals (Ibrahim *et al.,* 1997 and Samir, 2000).

Phytoplankton structure plays an important role in the economy of the natural water systems and the nature of phytoplankton community is triggered by the combined action of various environmental conditions in the lake. Much informations were available from previous works on the hydrography, chemistry and plankton of Lake Manzalah. (Shaheen and Youssef, 1978 and 1979; Halim and Guerguess, 1981; Toews and Ishak 1984; Dowidar *et al*., 1984; Abdel-Moati 1985; Ibrahim, 1989; El-Sherif *et al*., 1994; Siegel *et al*., 1994; Ibrahim *et al*., 1997; Soliman *et al*., 1998; Samir, 2000, El-Sherif & Gharib, 2001 and Ahmed & Elaa, 2003).

The aim of this work was to determine the impact of different environmental variables on the community composition of phytoplankton in Lake Manzalah and assessment of the lake status.

2. MATERIAL AND METHODS

Samples were collected bimonthly from January 2001 – January 2002 at nine selected stations, representing the different basins as shown in Fig. (1).

The main basins are:

1. Bahr Genka
2. Bahr Lagan
3. Bahr Bashtir
4. Bahr Kassab
5. Bahr El-Gamil
6. Bahr Deshdee
7. Bahr Abwat
8. Bahr Kurumulis
9. Bahr El-Zarka

Phytoplankton counts was carried out according to the sedimentation technique reported in standard methods (A.P.H.A., 1985), and expressed as unit/L.

Diversity index (H) was estimated according to the Shannon and Weaver (1963) given by the equation:

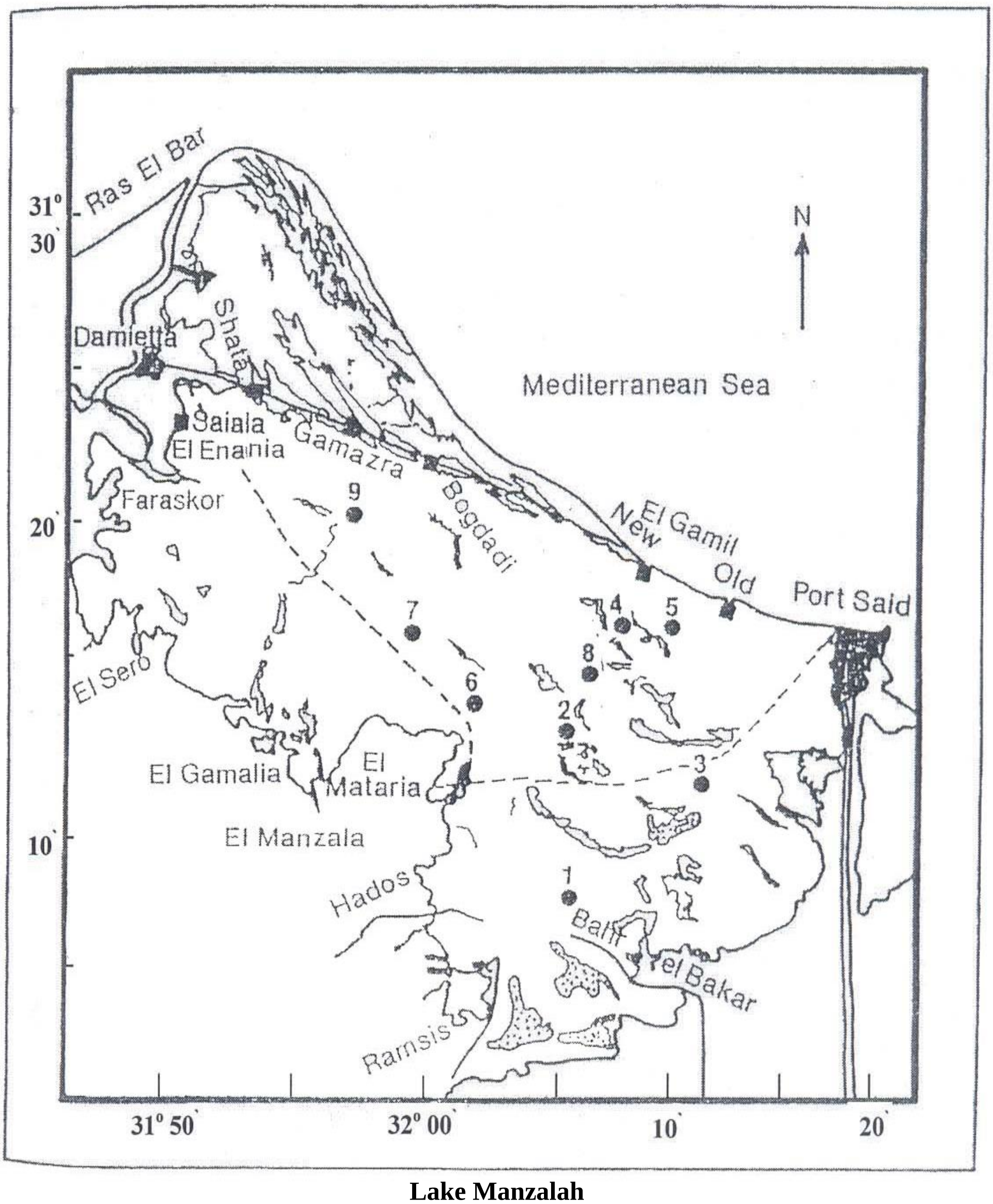
$$H = -\sum_{i=1}^{n} P_i \ln P_i$$

where Pi= n/N is the proportion of the $i^{th}(n_i)$ species to the total number of phytoplankton (N). The results were estimated as "nats".

Shakweer (2005) parallel to the present study of phytoplankton community studied the hydrography and nutritional level of Lake Manzalah.

Correlation coefficients between phytoplankton abundance and physico-chemical parameters were done at a confidence limit 95% (n= 63).

This study is a part of environmental investigation of the research plan of the Fisheries Division of National Institute of Oceanography and Fisheries.



Lake Manzalah

Fig. (1): Lake Manzalah showing the main drains and locations of the sampling stations.

3. RESULTS AND DISCUSSION

3.1. Phytoplankton abundance

3.1.1. Species composition

A total of 111 species were identified, comprising 44 species of Bacillariophyceae (39.5% of the total community), 31species of Chlorophyceae (38.1%), 14 species of Cyanobacteria (14.2%), 22 species of Euglenophyceae and Dinophyceae (Table 1).

The great majority of the identified species were either fresh or brackish water and nine species were purely marine. This was due to low values of total dissolved solids (T.D.S) which ranged between 1.80 gm/L (station 4) and 6.33 gm/L (station 9) with an average of 2.75 gm/L (Table 2).

Most of the recorded species (84) showed seasonal occurrence, while 27 species appeared all the year round. They are: *Melosira varians, Cyclotella meneghiniana, Nitzschia microcephala, Nitzschia closterium, Nitzschia palea, Nitzschia seriata, Navicula dicephala* (Bacillariophyceae); *Ankistrodesmus falcatus, Scenedesmus quadricauda, Sc. bijuga, Sc. longispina, Crucigenia rectangularis, Cr. quadrata, Coelastrum microporum, Oocystis solitaria, Sphaerocystis schroeteri,* (Chlorophyceae); *Merismopedia punctata, Lyngbya limnetica, Microcystis aeruginosa*,(Cyanobacteria); *Protoperidinium latum* (Dinophyceae); *Euglena gracilis, E. acus, E. ehrenbergi, E. candata, Phacus longicauda, Ph. caudatus and Ph. curvicauda* (Euglenophyceae).

The distribution of the recorded species fluctuated between 48 and 71 species (stations 9, 7 respectively). The low numbers of species at station 9 was probably due to high level of water pollution and/or water stagnation (Table 2).

Bacillariophyceae and Chlorophyceae were more abundant both qualitatively (67.5%) and quantitatively (77.6%) than the other taxonomic groups. They were conspicuous as the two most diverse groups with 39.6% and 27.9% in the total species number, respectively, although diatoms and green algae were almost equally in the quantitative proportion (39.5% and 38.1%, respectively).

Table (1): Total phytoplankton counts, number of species of the different phytoplankton groups and their percentage frequencies during 1986-1987 (Ibrahim, 1989), 1990 (El-Shrief *et al.*, 1994), 1992-1993(El-Sherief and Gharib, 2000) and during2001-2002(present study in lake Manzalah.

Phytoplankton groups	1986-1987		1990		1992-1993		2001-2002	
	No.spp.	%	No.spp.	%	No.spp.	%	No.spp.	%
Bacillariophyceae	83	59.7	64	30	64	45	44	39.5
Chlorophyceae	40	30.1	42	50	42	31	31	38.1
Cyanobacteria	29	8.3	24	16.7	24	23	14	14.2
Euglenophyceae	10	1.7	10	3.3	11	1	12	4.2
Dinophyceae	7	0.1					10	4.0
Cryptophyceae	1	0.1						
Total No.of spp.	170	100	140	100	141	100	111	100
T.Phyto. (unit/L)	$2.3x10^6$		$3.9x10^6$		$12.4x10^6$		$1.2x10^6$	

Table (2): Distribution of the phytoplankton counts and main dominant classes and genera at different stations in Lake Manzalah during January 2001-2002, average and range values of physico-cehmical parameters (after Shakweer, 2005)

	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	T. average
Total phatoplankton (unit/l)	0.63 x 10^6	1.12 x 10^6	1.56 x 10^6	1.88 x 10^6	0.69 x 10^6	0.62 x 10^6	1.76 x 10^6	1.79 x 10^6	0.77 x 10^6	1.2x10^6
Range	0.3-1.1x10^6	0.3-2.5x10^6	0.8-3.3x10^6	0.6-4.3x10^6	0.3-1.4x10^6	0.01-1.6x10^6	0.3-4x10^6	1.2-5.6x10^6	0.3-1.8x10^6	
No. of species	67	55	62	61	62	58	71	52	48	111
Diveristy (nats)	2.2	2.21	2.01	2.12	2.18	1.87	2.46	2.08	2.09	
Bacillariophyceae (%)	35.04	34.53	63.72	52.33	29.98	37.27	19.71	39.81	27.55	39.45
Melosira (%)	19.97	19.77	27.44	36.08	16.54	10.03	3.14	25.9	5.22	20.14
Cyclotella (%)		9.86	14.16	7.14		16.18	4.11	9.07		7.82
Navicula (%)				5.06			7.08		13.81	3.95
Nitzschia (%)			19.82		8.04	5.38		3.63	7.04	6.43
Chlorophyceae (%)	43.47	52.13	22.53	39.17	42.32	45.84	37.51	45.32	15.29	38.11
Scenedesms (%)	15.22	10.59	5.46	12.98	14.15	10.57	12.19	6.94	5.86	10.18
Ankistrodesmus (%)	9.65			7.32	12.48	16.47	10.06	13.84	5.4	9.13
Chlamydomonus(%)	10.91	10.87	8.01	12.25		13.67		16.54		8.91
Sphaerocystis(%)		10.01								1.15
Crucigenia(%)		8.44								2.32
Pediastrum (%)							11.46			1.9
Cyanobacteria (%)	3.5	3.98	5.55	6.84	11.88	11.37	34.18	12.79	36.66	14.24
Merismopedia (%)					5.01	3.96	24.43	11.54	13.48	8.22
Anabaena (%)						6.5			15.02	2.06
Oscillatoria(%)									4.35	2.58
Dinophyceae (%)	6.03	0.63	1.55	0.18	6.66	4.22	6.49	0.3	20.4	3.96
Protoperidium (%)					6.11				17.58	2.46
Gonyaulax (%)							4.59			1.5
Euglenophyceae (%)	11.96	8.72	6.65	1.48	9.16	1.3	2.11	1.78	0.1	4.24
Euglena (%)	7.61	5.37			8.98					2.66
Phacus (%)	4.35	3.16								
DO (mg/l)	7.9	8.27	8.64	8.38	8.33	8.22	8.13	8.53	8.16	8.28
Range	7-9.9	6.3-10.8	7.6-10.2	6.9-9.3	6.9-9	7.6-8.9	6.6-11.4	8.2-9.5	7.3-9.5	
TDS (gm/l)	1.94	2.91	2.07	1.81	2.51	2.85	2.17	1.82	6.33	2.75
Range	0.6-3.0	1.2-5.6	1.1-3.8	0.6-2.6	0.8-4.7	1.2-5.1	1.0-2.8	1.3-2.4	1.9-13.6	
NH^{+1}_4 (µmol/l)	8.78	13.46	1.91	0.38	0.55	1.89	0.86	0.7	9.01	4.16
Range	0-24.7	0.9-49.1	0-8.3	0-0.8	0.1-1.0	0-8.2	0-0.9	0.3-1.6	0.8-23.9	
NO^{-1}_2 (µmol/l)	6.94	3.15	2.81	0.73	1.51	2.56	0.62	0.34	3.62	2.5
Range	1.8-12.2	0.1-6.5	0.1-8.3	0.1-2.1	0.01-2.8	.01-11.5	0.1-2.4	0-1.6	0.1-8.0	
NO^{-1}_3 (µmol/l)	14.9	7.21	9.13	2.6	5.29	5.3	2.97	3.14	10.57	6.99
Range	3.3-17.2	1.7-20	.05-41.5	1.1-6.1	.3-17.3	0.9-11.7	1.4-4.8	0.3-3.4	1.4-28.9	
SiO^{-2}_4 (µmol/l)	5.83	8.14	7.13	7.77	11.34	18.1	7.15	15.45	6.9	10.24
Range	0.7-7.6	4.8-10.4	2.5-15.4	3.8-15.8	0-34.3	5.7-74.9	1.4-4.8	2.1-70.6	3.3-12.3	
PO^{-3}_4 (µmol/l)	5.09	5.25	3.88	1.21	2.92	2.71	1.54	2.11	2.84	2.98
Range	2.2-11.9	2.1-9.6	0.6-6.4	0.7-1.8	1.0-5.5	0.4-6.3	0.9-3.12	0.2-7.8	0.3-4.8	

Bacillariophyceae was dominated by *Melosira varians* (20.14% of the total phytoplankton counts), *Cyclotella* (7.82%) was represented by 3 species, *C. meneghiniana* was the leader, *Nitzschia* (*6.42*%) was represented by 7 species, dominated by *N. closterium* ,while *Navicula* (3.95%,10 species) was frequently recorded.

Chlorophyceae was dominated by *Scenedesmus* (10.18%, 7 species), where *Sc. quadricauda* was the first,*Chlamydomonas snowii* (8.91%), *Ankistrodesmus falcatus*

(9.13%) and *Crucigenia* (2.32%) were frequently recorded. Cyanobacteria was dominated by genus *Merismopedia* (8.22%) and *Oscillatoria* (2.58%), while Euglenophyceae and Dinophyceae were represented mainly by *Euglena* spp. 2.66% and *Protoperidinium* spp. 2.46%, respectively.

Comparing the present study with the previous records, it was observed that phytoplankton abundance in Lake Manzalah showed continuous increase during the period from 1986 to 1993 (Table 1). Such increase was associated with parallel decrease in the number of species. They increased from 2.3 x 10^6 unit/L, during 1986-1987 (Ibrahim, 1989) to 3.9 x 10^6 unit/L, during 1990 (El-Sherif *et al.*, 1994) to reach 12.3 x 10^6 unit/L, during 1992-1993, (El-Sherif and Gharib, 2001) and the number of species decreased from 170 (1986-1987) to 141 species during 1992-1993. During the present study, both phytoplankton abundance and number of species were reduced to reach 1.2 x 10^6 unit/L and 111 species, respectively (Table 1). This may be due to the increased amount of wastewater discharged in the lake and indicated that, the lake became less productive region among northern Egyptian Delta lakes, which subjected to inland discharge such as Lake Burrollus, which attained 1.04x10^6unit/L (El-Sherif, 1993) and with 1.9x10^6unit/L (Okba and Hussein, 2006), as well as Lake Edku which reached 7.5x10^6unit/L (Gharib, 1999) and (4.5x106unit/L) (Zaghloul and Hussein, 2000).

3.1.2. Phytoplankton abundance and success ional sequence

The phytoplankton density showed irregular pattern. The average densities at the different stations indicated pronounced variations; stations 3, 4, 7, 8 harboured the maximum density, while stations 1 and 6 sustained the lowest density (Table 2 & Fig. 2), the phytoplankton density ranged from 0.09x 10^6 unit/L (St.6, May) to 4.3 x 10^6 unit/L (St. 4, March). Bimonthly average changes showed pronounced variations with no distinct pattern (Fig. 3). High counts appeared during the period from January, March and May 2001 (1.3 x 10^6, 1.9x10^6 and 1.7 x 10^6 unit/L, respectively), dropped to the lowest count in July (0.51 x 10^6 unit/L) and increased gradually from September 2001 to January 2002 (0.7 x 10^6 – 1.3 x 10^6 unit/L, respectively).

The total average counts were similar during January 2001 and January 2002, while the dominance was relatively different. Diatoms were represented by 60.6% and 57.1% to the total counts at the two months respectively. They represented by *Melosira* (22.6% of the total community), *Nitzschia* (19.7%) and *Cyclotella* (18.3%) during January 2001, and with *Melosira* (40.4%) and *Cyclotella* (16.6%) only at January 2002. Green algae were represented mainly by *Chlamydomonas* (15.4%) during January 2001,while during January 2002, represented by *Ankistrodesmus* (12.0%) and *Scenedesmus* (8.6%).The highest phytoplankton count was recorded during March (1.9 x 10^6 unit/L), dominated by Chlorophyceae (50.5% of the total community), followed by Bacillariophceae (29.9%) and Cyanobacteria (14.4%). Therefore, spring is still the season of highest phytoplankton production in Lake Manzalah as well as in the other Egyptian Delta lakes (El-Sherif and Gharib, 2001). The maximum phytoplankton production during March, was accompanied with relative high range values of pH (8.07-8.72), dissolved oxygen (7.3-8.5 mg/L), nutrient salts (NH_4^{+1}: 0.42-7.69, NO_2^{-1}: 0.0-12.16, NO_3^{-1}: 0.81-17.15, SiO_4^{-2}: 2.09-9.84 and PO_4^{-3}: 0.98-11.87µmol/L).

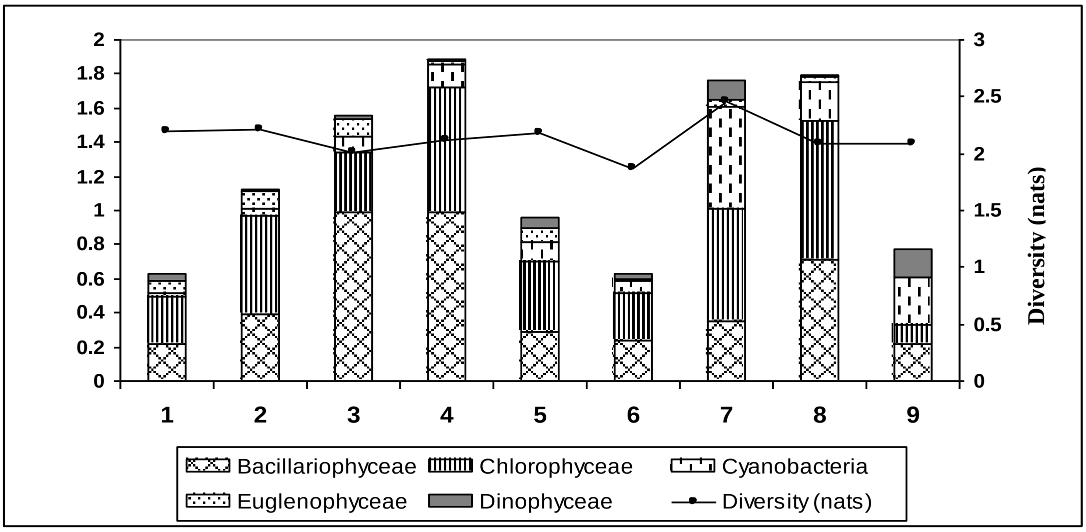


Fig. (2): Distribution of total phytoplankton abundance and its main classes at different stations and diversity values in Lake Manzalah during January 2001 - January 2002.

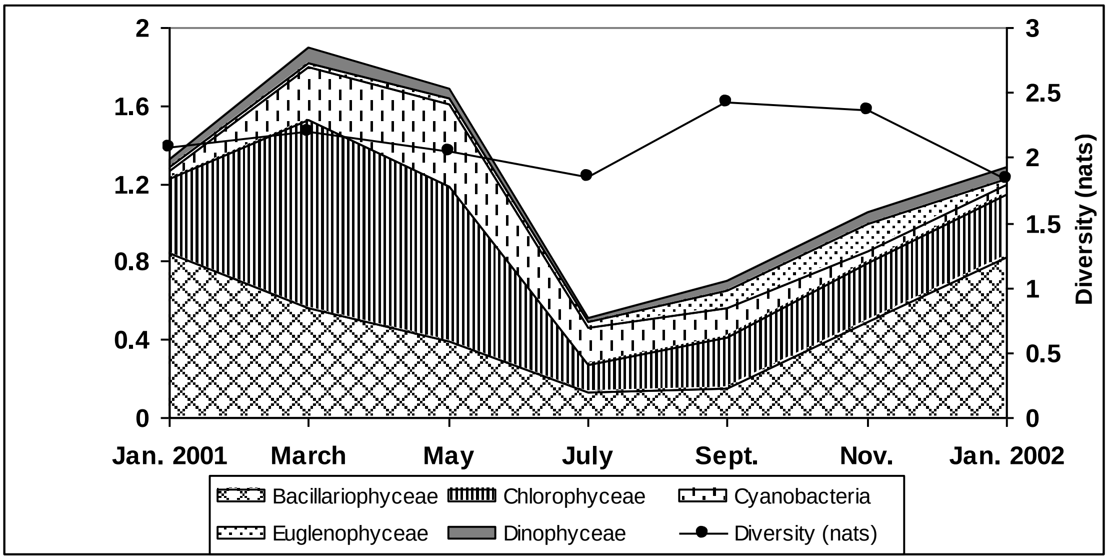


Fig. (3): Bimonthly average variations of the total phytoplankton abundance, its main classes and diversity values in Lake Manzalah during January 2001 - January 2002.

Sampling stations showed ecological differences with regard to the total dissolved solids; nutrients as well as quality of water (Table 2), the phytoplankton community showed marked spatial variations (Fig. 4), which discussed as follows:

Station 1 is situated at the southeastern part of the lake, receives agricultural drainage water with high pesticide content through Hados, Ramsis drains and municipal sewage, industrial effluents through Bahr El-Bakar Drain. Lowest average phytoplankton counts were recorded at this station (0.6 x 10^6 unit/L), with 67 species, phytoplankton density were dominated by Chlorophyceae, Bacillariophyceae and Euglenophyceae (43.5 %, 35.0 % & 12.0 % of the total community, respectively). *Melosira varians* (20.0%), *Scenedesmus* spp. (15.2%), *Chlamydomonas* spp. (10.9%), *Ankistrodesmus* (9.7 %) and *Euglena* (7.6%) were the dominant forms. This station was characterized by high values of nitrate ranged between (3.3-17.2μmol/L), nitrite (1.8-12.2 μmol/L), ammonia (0-24.7 μmol/Ll) and phosphate (2.2-11.9 μmol/L) as shown in table (2).

Bimonthly variations showed that, the highest count was recorded during March (1.1 x 10^6 unit/L) dominated by *Chlamydomonas snowii* (27.4% to the total counts), *Melosira varians* (23.1%) and *Ankistrodemus falcatus* (14.3%). On the other hand, the lowest count (0.3 x 10^6 unit/L) was recorded during November.

Station 2 is situated near the outfall of domestic wastes from El-Mataria. A total of 55 species were recorded amounting totally to an average of 1.1 x 10^6 unit/L (Fig.2). Chlorophyceae and Bacillariophyceae constituted the main bulk of the community (52.1% and 34.5%, respectively), mainly due to *Melosira varians* (19.8%), *Chlamydomonas snowii* (10.9%), *Scenedesmus* spp. (10.6%), *Cyclotella meneghiniana* (9.9%) and *Crucigenia* spp. (8.4%). Euglenophyceae formed 8.7% to the total density, dominated by *Euglena* spp. (5.4%) and *Phacus* spp. (3.2%) Cyanobacteria formed 4% and Dinophyceae 0.6% to the total density. This station was characterized by high average and range values of nutrients (Table 2), nitrate (7.21 μmol/L)and ranged between(1.7-19.9 μmol/L); nitrite (3.15 μmol/L)and ranged from 0.1 to 6.5 μmol/L; ammonia (13.46 μmol/L), the range fluctuated between 0.9 and 49.1μmol/L; silicate (8.14 μmol/L) ranged from 4.8 to 10.4 μmol/L and phosphate (5.25 μmol/L) ranged between(2.1-9.6 μmol/L), while the concentration of dissolved oxygen was reached an average of 8.27 mg/L and the range fluctuated from 6.3-10.8 mg/L. Bimonthly variations showed that, high peak was recorded during May (2.5 x 10^6 unit/L) (Fig. 4),caused mainly by Chlorophyceae (83.4%), and Bacillariophyceae (12.5 %). The most dominant species were *Sphaerocystis schroeteri* (29 %), followed by *Scenedesmus* (3 spp.) forming 17.1% and *Crucigenia* (2 spp.) formed 16.5 % to the total phytoplankton counts. A pronounced increase was recorded during November and January, 2002.November increase shared by Bacillariophyceae, Chlorophyceae and Euglenophyceae (43.8%, 32.5%% and 18.5% respectively). The other increase was caused by diatoms (76.4%), and accompanied with high concentrations of nutrient salts, nitrate (19.87 μmol/L), nitrite (6.47 μmol/L), ammonia (49.15 μmol/L), silicate (10.44 μmol/L) and phosphate (7.1 μmol/L).

Station 3 is located at the eastern sector of the lake. It was characterized by high phytoplankton counts (average 1.6 x 10^6 unit/L Table 2 and Figure 2), with 62 species. Bacillariophyceae constituted 63.7% to the total counts and dominated by *Melosira varians* (27.4%), *Nitzschia* (19.8%) and *Cyclotella* (14.2%). Chlorophyceae formed 22.5% to the total counts, *Chlamydomonas*, *Scenedesmus* and *Ankistrodesmus* were leading. Euglenophyceae, Cyanobacteria and Dinophyceae formed collectively 13.8%.

Highest average value of dissolved oxygen (8.6 mg/L) was recorded and ranged between 7.6-10.2 mg/L and moderate values of nutrient concentrations (Table 2). A pronounced increase was recorded in January 2001 (Fig. 4). Bacillariophyceae formed the main bulk (98.5%) with 17 species, mainly *Nitzschia longissima* (49.4%), *Melosira varians* (23.7%) and *Cyctotella glomerata* (22.1%). During March Chlorophyceae were dominant (64.7%) followed by Bacillariophyceae (17.1%), mainly due to *Chlamydomonas snowii* (12.9%), *Ankistrodesmus falcatus* (12.6%), *Scenedesmus* spp. (28%), *Kirchneriella obesa* (8%) and *Cyclotella glomerata* (8.8%), while during May, the dominance was shared by Chlorophyceae, Bacillariophyceae and Cyanophyceae (47.6%, 35.6% and 14.7% of the total counts, respectively), the dominant species were *Chlamydomonas snowii* 32.1% of the total counts, *Melosira varians* 22.1% and *Ankistrodesmus falcatus* 12.8%, while *Nitzschia closterium, Lyngbya limnetica* and *Oscillatoria putrida* were frequently appeared (6.0, 5.8 and 5.3%, respectively). During May relatively high value of pH (8.7), dissolved oxygen (10.2 mg/L) and total dissolved solid (3.75 gm/L) were recorded.

Station 4 is located near Boughaz El-Gamil, where exchange of water occurs. It was characterized by dense phytoplankton population, average of 1.9 x 10^6 unit/L (Fig. 2), comprising 61 species and relatively high dissolved oxygen 8.38 mg/L, ranged between 6.9-9.3 mg/L and high average of silicate concentration 7.77 μmol/L with the range 3.8-15.8 μmol/L (Table 2). The most dominant group was Bacillariophyceae (52.3%), followed by Chlorophyceae (39.2%). Diatoms were generally favoured by high salinities in both spring and autumn (Carstensen *et al.*, 2004). The most dominant genera were *Melosira* (36.1%), *Scenedesmus* (13%), *Chlamydomonas* (12.3%), *Ankistrodesmus* (7.3%) and *Cyclotella* (7.1%). An outstanding peak was observed in March (4.3 x 10^6 unit/L) and less one during May (2.1 x 10^6 unit/L). The March peak was composed of 34 species and dominated by Chlorophyceae and Bacillariophyceae (50.9% and 46.3%, respectively), *Melosira varians* (30.1%), *Chlamydomonas snowii* (21.1%), *Scenedesmus* spp. (17.2%), *Ankistrodesmus falcatus* (9.5%), *Cyclotella* spp. (8.6%) and *Navicula* spp. (6.8%) were the most representative forms. This peak was associated with relatively high content of dissolved oxygen (8.5 mg/L), total dissolved solid (2.11 gm/L), and low concentrations of nutrient salts. The May increase comprised 41 species and dominated by Bacillariophyceae (73.3%), *Melosira varians* (60.3%) was the leading species, followed by *Nitzschia* spp. (6.7%) and *Cyclotella* spp. (5.2%). Chlorophyceae formed (21.9%), dominated by *Chlamydomonas sonwii* (12.9%) and *Scenedesmus* spp. (7.1%), while Cyanobacteria (6 species) formed 4.5%. During May, high concentration of dissolved oxygen (9.3 mg/L) was recorded, total dissolved solid was 2.7gm/L as well as nutrient salts constituted 2.97, 2.13, 5.65 and 1.22 μmol/L for $NO_3^{-1}, NO_2^{-1}, SiO_4^{-2}$ and PO_4^{-3} , respectively.

Station 5 located in El-Gamil area and is affected by sea water. Low phytoplankton average counts were recorded (0.96 x 10^6 unit/L), with 62 species. Chlorophyceae, Bacillariophyceae and Cyanobacteria constituted, respectively, (42.3%, 30% & 11.9 %) of the total counts. The most dominant species were *Melosira varians* (16.5%) *Scenedesmus* spp. (14.2%), *Ankistrodesmus falcatus* (12.5%), *Euglena* spp. (9%), *Nitzschia* spp. (8%) and *Protoperidinium* spp. (6.1%). Dense phytoplankton counts were observed in January 2001 (1.3x 10^6unit/L), September (1.4x 10^6unit/L), November (1.3x 10^6unit/L) and January 2002 (1.1x10^6unit/L). The dominance was varied from month to the other, during January 2001, Chlorophyceae was dominant (50.6%) followed by Bacillariophyceae, Dinophyceae and Cyanobaceria (17.2, 17 and 15.2%, respectively), they were represented by *Scenedesmus* (3 species, 16%); *Protoperidinium* (4 species, 15.4%); *Ankistrodesmus falcatus* (13.6%); *Merismopedia punctata* (11.3%); *Nitzschia* (3 species, 12.5%); *Chlamydomonas snowii* (8.7%) and *Chlorella vulgarus* (8%). During September, the dominant species were *Melosira varians* (21.8%), *Scenedesmus aramatus* (14.4%), *Sc. acuminatus* (10.9%), *Merismopedia punctata* (10.8%) and *Sc. quadricauda* (9%). Physico-chemical parameter showed that, pH value reached 8.6, relatively high dissolved oxygen concentration (8.1 mg/L), total dissolved solid (2.1mg/L), while low nutrients salts concentration were recorded 1.4 μmol/L, 0.1 μmol/L and 2.1 μmol/L for nitrate, ammonia and phosphate, respectively.

Euglenophyceae were occasionally abundant (45.3%) in November followed by Chlorophyceae (43.8%), Bacillariophyceae (10.3%). The dominant species were *Euglena caudate* (32.9%), *E. acus* (12.3%), *Ankistrodesmus falcatus* (16.5%), *Nitzschia microcephala* (9%), *Kirchneriella obsea* (6.4%) and *Carteria cordiforms* (5.6%). The genus *Euglena* tops a list of sixty most tolerant genera to pollutions (Palmer, 1969) and is considered as a biological indicator for organic pollution (Munawar, 1972). During November, station 5 showed high pH value (8.6), low T.D.S concentration (0.9gm/L) and relatively high nutrient salts (8.91 μmol/L for NO_3^{-1} 5.52 μmol/L for SiO_4^{-2} and 5.51 μmol/L for PO_4^{-3}).

Station 6 is located at the southern west of the lake near the outfall of domestic wastes from El-Mataria. The total average density of phytoplankton amounted to 0.6 x 10^6 unit/L, comprising 58 species. Chlorophyceae and Bacillariophyceae represented, respectively 45.8% and 37.3 followed by Cyanobacteria (11.4 %). The highest counts were recorded in January of both 2001 and 2002 (1.5 x 10^6 and 1.6 x 10^6 unit/L, respectively) with 25 and 37 species, respectively. Chlorophyceae formed 59.5% and 51.2% followed by Bacillariophyceae 39.6% and 19.8% for each, respectively, *Chlamydomonas snowii* (35.1%), *Cyclotella glomerata* (30.1%), *Scenedesmus quadricauda* (21.7%), and *Melosira varians* (6.1%), were the leading during 2001, while *Ankistrodesmus falcatus* (41.5%), *Melosira varians* (15.5%), *Cyclotella meneghiniana* 10.7% and *Navicula gracilis* (5.9%) were the dominant during 2002. *Cyclotella* was usually found in low salinity water (Smith and White, 1985). During January, 2002 low dissolved oxygen was recorded (7.58 mg/L), low dissolved solid (1.23 gm/L), and nutrient salts (0.97 μmol/L for ammonia, 0.79 μmol/L for nitrite and 5.35 μmol/L for nitrate).

Station 7 is located at the southern west part of the lake. It is not directly affected by saline water from Boughaz El-Gamil, where T.D.S ranged from 1.05-2.8 gm/L and was devoid of hydrophytes except some scattered patches of *Potamogenton* (El-Sherif and Gharib, 2001). The phytoplankton average density reached 1.8 x 10^6 unit/L, with 64 species. Two peaks were observed in March and May where the density reached 3.9 x 10^6 and 4.0x10^6 unit/L, with 36 and 29 species, respectively. Chlorophyceae were dominant during March followed by Cyanobacteria (55.3 and 25.8%, respectively) followed by Bacillariophyceae (18%). The most dominant Chlorophycean genera were *Pediastrum* (25.6%) *Scenedesmus* (3 species, 20.3%), Cyanobacteria (24%) were represented by 2 species; *Merismopedia elegans* and *Mer. Punctata*. During May, Cyanobacteria was the most dominant group (52.3%) followed by Chlorophyceae (37.8%). *Merismopedia* (2 species, 30.2%), *Oscillatoria putrida* (18.8%), *Ankistrodesmus falcatus* (22.1%), *Pediastrum* (2 species, 10.1 %) were the most dominant species. The Dinophycean species *Gonyaulax palustre* was frequently recorded (7.4%). Cyanobacteria usually prefer the warm water (Komar- Kova and Hejzlar, 1996), they favoured high concentrations of dissolved organic matter (Planas, 1991) as well as nutrient salts, (Annika *et al.,* 2003). The concentrations of dissolved oxygen were relatively low (average 6.6 mg/L). Cyanobacteria are the dominant type of phytoplankton in most fresh water blooms (Crosby *et al*., 1990 and Prepas and Charette, 2003). Relatively high concentrations of nutrient salts were recorded during March and May (2.93, 2.76 µmol/L for NO_3^{-1};4.43 ,6.61 µmol/L for SiO_4^{-2} and 3.12 ,2.14 µmol/L for PO_4^{-3}, respectively).

Station 8. It was characterized by dense phytoplankton population (average 1.8 x 10^6 unit/L, with 52 species). The highest phytoplankton counts were attained during January, March and May (2.1x10^6, 3.4x10^6 and 2.6x10^6 unit/L, respectively). Bacillariophyceae (74.6%) was the most dominant group during January, 2001 followed by Chlorophyceae (21.5%). *Melosira varians* (48.9 %), *Cyclotella* spp. (23.9%) and *Chlamydomonas snowii* (20.4 %) were the leading. During March, Chlorophyceae were dominant (54.9%) followed by Bacillariophyceae and Cyanobacteria (33.4% and 11.7% of the total community, respectively), *Melosira varians* (27%), *Ankistrodesmus falcatus* (23.5%), *Chlamydomonas snowii* (17.7%)and *Merismopedia* spp. (11.2%), were mainly represented. During May, Chlorophyceae showed their maximum occurrence (50.0%) followed by Cyanobacteria and Bacillariophyceae (27.1% and 21.6%, respectively). The dominant species were, *Merismopedia punctata* (24.0%), *Chlamydomonas snowii* (15.0%), *Ankistrodesmus falcatus* (13.50%), and *Scenedesmus* spp. (4 species, 10.5%). So silicate concentration was higher during May than March (8.4 µmol/L and 2.09 µmol/L respectively), and phosphate concentration reached 7.77 µmol/L during March, while nitrate, nitrite and ammonia were lower (0.42, 0 & 1.61 µmol/L respectively), the observed relatively high number of Cyanobacteria could be attributed to several factors, the most appropriate is the nitrogen and phosphorus concentration, this agrees with the result of Stirn (1988) and Annika *et al*. (2003) they are more characteristic to eutrophic waters than oligotrophic (Trimbee and Prapes, 1987). Also Prepas and Charette (2003) stated that, the nitrogen in marine water and / or phosphorus in fresh waters is typically responsible for eutrophication.

Station 9 is located at the northwestern part of the lake. It sustained low phytoplankton average density (0.77 x 10^6 unit/L), and small number of species (48 species). It has its own character where Cyanobacteria was dominant (36.7%), followed by Bacillariophyceae, Dinophyceae and Chlorophyceae (27.6, 20.4 and 15.3%, respectively). This may be attributed to the dense vegetation that causes water stagnation and suppression the phytoplankton growth (Abdel Baky and El- Ghobashy, 1990), decreasing also zooplankton and zoobenthos communities in the area (Ibrahim *et al.,* 1997). Hamza (1999) illustrated that the low phytoplankton density may be the result of a direct competition between the macrophytes especially the submerged population. This station showed high concentrations of nutrient salts; 9.01 µmol/L for NH_4^{+1}, with the range of 0.8-23.9 µmol/L ;10.57 µmol/L for NO_3^{-1},ranged from 1.4 to 28.9 µmol/L; 6.9 µmol/L for SiO_4^{-2},the range 3.3-12.3 µmol/L and 2.84 µmol/L for PO_4^{-3} ranged between 0.3-4.8 µmol/L, also T.D.S was ranged from 1.9 to 13.6gm/L. Two high peaks were observed during March and November. The March peak reached 1.8 x 10^6 unit/L, with 39 species; Cyanobacteria formed 42.9 % to the total counts and dominanted by *Merismopedia punctata* (22.4%) and *Anabaena hassallii* (16.2 %), Chlorophyceae (20.9%) was the second where *Scenedesmus bijuga* formed 6%, Bacillariophyceae (18.4%) and Dinophyceae (17.7%) was mainly represented by *Protoperidinium minutum* (5.9 %), while Euglenophyceae was scarcely recorded (0.2%).This met with high value of T.D.S. (13.6gm/L), low concentrations of nutrient salts (1.44, 0.36 and 0.94 µmol/L) for NO_2^{-1}, NO_3^{-1} and NH_4^{+1}, respectively,as well as low silicate(SiO_4^{-2}) and phosphate (PO_4^{-3}) concentration (3.08 and 3.43µmol/L).

During November, the density reached 1.1 x 10^6 unit/L, represented by 17 species. Bacillariophyceae was the most dominant class (42.0% of the total count), followed by Dinophyceae (35.3%), Cyanobacteria (20.4 %), and Chlorophyceae (2.3%). The most dominant species were *Navicula cryptocephala* (16.2% of the total counts), *Anabaena* sp. (11.8%), *Nitzschia seriata* (10.7%), *Protoperidinum latum* (8.8%), *Protoperidinium willei* (8.5%), *Melosira varians* (7.8%) and *Protoperidinium pusillium* (6.9%). The concentration of nutrients were 23.89, 7.98, 28.87 µmol/L for NH_4^{+1}, NO_2^{-1} and NO_3^{-1} respectively, while total dissolved solid reached 4.75 gm/L.

3.2. Diversity cycle

Diversity in Lake Manzalah showed irregular pattern, it ranged between 0.96 "nats" (St.6, July) and 2.91 "nats" (St.7, September). The results were nearly similar to previous estimation by El-Sherif and Gharib (2001). A steady-state period was observed during which more than 80% of the total phytoplankton counts were shared by no more than three phytoplankton species (Sommer *et al*., 1993). Lower diversity values were recorded at station 6 during July 2001 (0.96 "nats") and number of species reached 21 and at station 3 in January2002 (1.07"nats"). During July, the community represented by *Anabaena hassallii* (79.6%) of the total phytoplankton counts (0.3x10^6 unit/L), while in January 2002, lowest diversity took place at station 3 due to dominance of *Melosira varians* (68.3%) and *Cyclotella meneghiniana* (22%), where phytoplankton density reached 1.3x10^6 unit/L

The highest diversity values were recorded during September at stations 2 and 7 (2.77, 2.91 "nats",respectively) . Maximal value (2.91"nats") accompanied by 29 species, which were dominated by; *Oocystis solitaria* (17%) and *Merismopedia punctata* (15%), *Gonyaulax apiculata* (8.5%), *Phacus longicauda* (8.3%) and *Euglena acus* (8.3%). The value of 2.77 "nats" ,where phytoplankton density attained 0.3x10^6 unit/L with 24 species,the dominancy shared by *Phacus longicauda* (15.6%), *Oscillatoria limnetica* (9.7%), *Protoperidinium willei* (9.12%), *Ankistrodesmus falcatus* (8.6%), *Melosira varians* (7.3%) and *Scenedesmus aramatus* (6.9%). The high average diversity value (2.18"nats") recorded at station 5 (Fig.2), may be resulted from aggregation of both fresh water and marine species in convergent area frequently formed at this station, this agrees with the observation of Margalef (1960) who admitted that, the diversity index would be higher when two different communities mixed together. Also station 7 showed higher phytoplankton density (1.76x10^6 unit/L) and higher diversity value (2.46 "nats"), the dominancy shared by *Scenedesmus* spp. (12.19%), *Pediastrum* spp. (11.46%), *Ankistrodesmus falcatus* (10.06%), *Navicula* spp. 7.08% and *Oscillatoria* spp. (6.16%). Regarding the bimonthly variation, the maximal diversity was recorded in September (2.42 nats) and November (2.3 nats) (Fig. 3).

3.3. Correlation coefficient analysis

Lake Manzalah was characterized by relatively high nutrient concentration with an average of 4.16, 6.99, 10.24 µmol/L and 2.98 µmol/L for NH_4^{+1}, NO_3^{-1}, SiO_4^{-2} and PO_4^{-3}, respectively as well as high dissolved oxygen 8.27 mg/L (Shakweer, 2005), such values were lower than that previously recorded during May 1992- April 1993 particularly silicate content (36.43 µmol/L); (El-Sherif and Gharib, 2001), dissolved oxygen value was higher in the present work. The correlation coefficient between phytoplankton counts, its main groups and dominant genera with some physico-chemical parameters showed that, the most important factor affecting Bacillariophyceae were water temperature($r = -0.4$, $p < 0.05$), dissolved oxygen ($r = 0.27$ $p < 0.05$), and nitrate($r = 0.33$, $p < 0.05$), while *Melosira*, *Cyclotella* and *Navicula* were reflect their dependence on water temperature ($r = -0.27$,-0.43 and -0.23, $p < 0.05$ $n = 63$, respectively).

4. CONCLUSION

Lake Manzalah is highly dynamic aquatic system, it receives high quantity of sewage, industrial and agricultural waste waters at southern and western side. Although these conditions affected directly and/or indirectly the water quality of the lake, while the nutrient salts were lowered than that previously recorded, but it is not limited the phytoplankton growth, so dissolved oxygen concentration increased. The occurrence of species composition and its dominance were different and more diversified except at southern and western side which affected by the water discharged into the lake. Finally, it is recommended to control the water discharged or at least treated it to improve its water quality.

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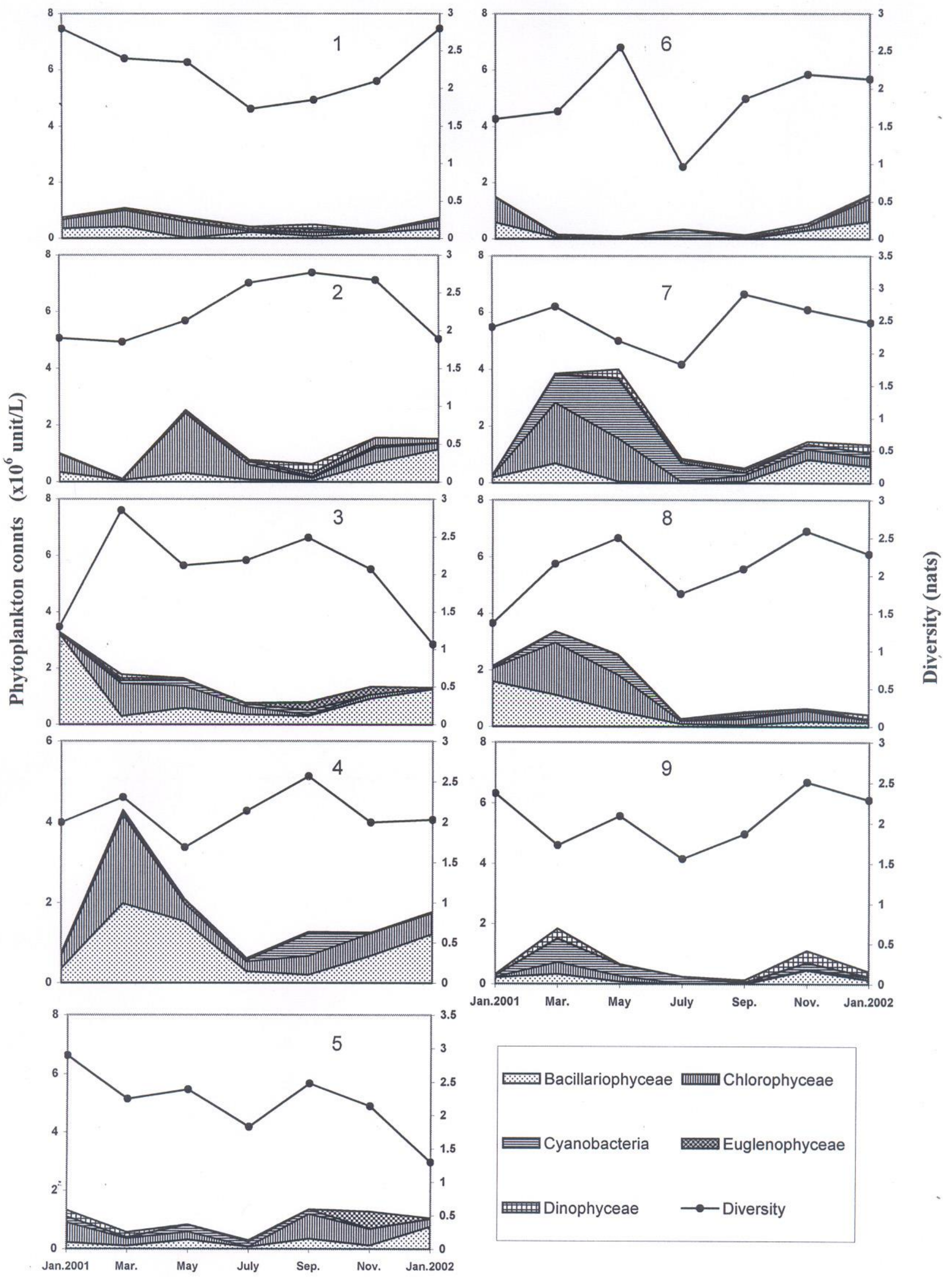

Fig. (4): Bimonthly variations of phytoplankton abundance, its main classes and diversity values at different stations of Lake Manzalah during January 2001 - January 2002.

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