Global Veterinaria 2 (6): 343-350, 2008
ISSN 1992-6197
© IDOSI Publications, 2008

Monthly Variations of Phytoplankton Communities in Lake Manzala

Mohamad S. Abd El-Karim

National Institute of Oceanography and Fisheries, Cairo, Egypt

Abstract: The phytoplankton community composition and bivolume were monthly studied in relation to polluted freshwater and saline sea water intrusion into Lake Manzala. The dominant classes in Lake Manzala were chlorophytes, diatoms and cyanoprokaryotes. The three groups altogether constitute more than 90% and 89% of the total phytoplankton abundance and total number of taxa, respectively. Other groups were marginally present like prasinophytes, cryptophytes, chrysophytes, euglenophytes and dinophytes. On biovolume basis, diatoms dominated the phytoplankton communities, whereas, based on cell number, the chlorophtes exclusively dominated the phytoplankton communities year round. The three dominant classes were dominated by single celled, *Dyctiusphaerium pulchellum* (chlorophytes), *Cyclotella menenghiniana* (diatoms), *Microcystis aeruginosa* and *Tetrachloris merismopoides* (cyanoprokaryotes). Six functional groups were mainly represented which are diatoms (D and B), chlorophytes (X1, F and J) and cyanoprokaryotes (X1 and M). These groups are typical representatives of highly mixed, turbid with high nutrient ecosystems. Both the ordination analysis and the correlation matrix revealed an independence of phytoplankton communities with the trophic status of the lake.

Key wards: Lake Manzala · Phytoplankton · Functional groups · Life strategies

INTRODUCTION

Coastal lagoons are unique systems, typically characterized by bidirectional horizontal flows, permanent mixing of the water column and abrupt changes in residence time. In these systems, continues fresh highly enriched water and marine intrusions cause large temporal and spatial variations in phytoplankton composition, production and functional groups [1]. Manzala Lagoon is a typical coastal lagoon ecosystem received two water types from two main sources. Firstly, Mediterranean Sea water via three points, El-Gamil, El-Boughdady and New El-Gamil, which has been recently established [2] and secondly, fresh-highly enriched water from several drains and pumping stations. Together, saline-less productive seawater and fresh highly nutrient loaded drainage water formed a local variation in trophy, salinity and electrical conductivity.

Since the late sixties studies of the phytoplankton of various freshwaters and its seasonal variability have been used to monitor ecological processes in water bodies. Two main approaches have been adopted. The most important approach relies more on a general appreciation of the functional adaptations and a system of classification that has developed steadily [3]. It recognizes assemblages comprising species of similar cell sizes and physiological capabilities, such as light-dependence and dependence on inorganic components similar to sets of environmental conditions, such as lake size, mixing regime, nutrients, light and carbon availability. The functional adaptations become "powerful predictors of optimum dynamic performance [4]. The more recent classification [5] outlined 31 functional groups or species associations. The overall correspondences between the algal associations and their habitats are quite well established.

This study aimed to investigate the phytoplankton composition and functional groups in relation to both sea water and fresh enriched water.

MATERIALS AND METHODS

Site Description: Lake Manzala occupies the north eastern corner of the Nile Delta between the Mediterranean Sea (North), Suez Canal (East) and Damietta Branch (West). Its area has been gradually decreased since the earliest decades of the twentieth century. In 1900 its area was 1,709 km^2 reaching 1,200 km^2 in 1970s. As measured by Landsat imagery in 1981 the area of the lake was 904,785 km^2, while the area of open

Corresponding Author: Mohamad S. Abd El-Karim, National Institute of Oceanography and Fisheries, Cairo, Egypt

Fig. 1: Map showed the selected locations

water was only 699,215 km^2 owing to the presence of a large number (1022) of islets in the lake. Widespread land reclamation and establishment of fish farms have resulted in major reduction in the area of the lake and its marshlands, the present area of the lake is only 120 km^2 [6]. The feeding waters of the lake is mainly from Damietta Branch (4 billion m^3/year) and about 7.7 billion m^3/year from the wastewater drains. About 3.16 billion m^3/year lost through evaporation, while 530 million m^3/year of lake water drains to the Mediterranean Sea through 14 narrow openings; each is not more than 5 m wide and 11 of them are man-made [7]. Ten stations were selected which covered the whole area of the lake (Fig. 1).

Phytoplankton Sampling: Water samples were collected year round during 2004. Phytoplankton samples were fixed with Lugol's solution enumerated and counted using the inverted microscope method [8]. Identification of the main phytoplanktonic groups was made with reference of: Cyanoprokaryota [9], Bacillariophyceae [10] and Chlorococcales [11] and [12]. Cell biovolume was calculated based on geometric shapes and the averages of the microscopic dimensions of 10-30 (depending on the abundance of each taxon) cells per taxon were measured [13].

Data Analysis: Canonical correspondence analysis (CCA), a multivariate technique, was used to summarize changes of phytoplankton assemblage's abundance and structure and their relation to environmental variables [14] using correlation analysis. CCA was performed using CANOCO V. 4.0 [15]. Similarity matrix and diversity index were developed by Primer 5.0 soft ware package.

RESULTS

Phytoplankton Abundance and Species Composition: The dominant classes in Lake Manzala were chlorophytes, diatoms and cyanoprokaryotes. The three groups altogether constitute more than 90 and 89% of the total phytoplankton abundance and total number of taxa, respectively. When phytoplankton communities expressed as cell biovolume, diatoms dominated the phytoplankton abundance at different localities with an annual relative abundance of 58.4%, whereas they ranked the second predominant when expressed as cell number with an annual relative abundance of 8.24%. Based on cell number, the chlorophtes ranked the first position of dominance with relative abundance of 76.22% and exclusively dominated the phytoplankton communities year round. The disintegrated colonies of *Dyctiusphaerium pulchellum* were the most representative of the chloophytes year round at the different localities specifically at the highly polluted area (stations 1-5). The chlorophytes showed a comparable development at the stations closest to the highly polluted area (stations 1, 2 and 5) with a small abundance at the less polluted stations (stations 7, 8, 9 and 10). Temporally, the chlorophytes gradually increase from mid winter, reached its climax during early spring followed by a gradual decrease from mid-spring until they showed two minor peaks during mid and lat summer. Other groups were marginally present like prasinophytes, cryptophytes, chrysophytes, euglenophytes and dinophytes. The total number of taxa per site showed no obvious pattern of variation, they ranged from 52 at station 5 to 28 at station 7. The total number of taxa per month was highest during late winter and early spring when it showed highest number of taxa (62) then suddenly decreased from mid spring till the end of autumn when the least number of taxa (30) were recorded. The three dominant classes were dominated by, *D. pulchellum* (chlorophytes), *Cyclotella meneghiniana* (diatoms), *Microcystis aeruginosa* and *Tetrachloris merismopedioides* (cyanoprokaryotes). Other chlorophytes, *Monoraphidium contortum*, *Crucigenia* spp and *Scenedesmus* spp showed a noticeable development and shared the former taxon during the minor peaks of mid and lat summer. Beside The dominance of *C. meneghiniana*, also the centric *C. operculata* was considerably present during the period of study especially during the colder months. The pinnate diatoms *Nitzschia closterium* was also developed throughout the lake. The mid winter pulse of the diatoms was clearly due to the development of *Nitzschia frustulum* var. *perminuta* and few other pinnate diatoms, mainly other *Nitzschia* spp and *Navicula* spp. The cyanoprokaryotes showed their maximum development in midsummer with two minor peaks during mid spring and early summer. Besides *M. aeruginosa* and *T. merismopedioides*, other coccoid cyanoprokaryotes (*Chroococcus* spp) were present in large numbers. During the mid summer climax, the heterocystous *Anabaena* spp were developed in large filaments reached to few millimeters, but disappeared throughout the year with slightly abundance during late spring and late summer.

Chlorophytes were the most frequent group, their frequency were 16 records per species. On the other side, cyanoprokaryotes and diatoms were less frequent; their frequencies were 11 and 10 per species, respectively. Among chlorophytes, *D. pulchellum*, *Kirchneriella lunaris* and *Chlorella vulgaris* were the most frequent. *M. aeruginosa* and *Lyngbya limnetica* were the most frequent among cyanoprokaryotes, while *C. meneghiniana* was the most frequent diatom species. The Shannon-Weaner diversity log10 were in general lower (0.58) at the highly polluted area (stations 1-6) near to the drains compared to the stations (0.92) away from the polluted area.

Table 1: Association and functional groups of phytoplankton (after [5])

Association	Representatives	Tolerances	Sensitivities	Strategies
D	*Nitzschia* spp	Flushing	Nutrient depletion	C-R
B	*Cyclotella meneghiniana*	Light deficiency	Si depletion	C-R
F	*Dictyosphaerium* pulchellum		Nutrient deficiency	C
X1	*Monoraphidium*spp			C
	*Chlorella*spp		Nutrient	C
	Chroococcus spp	Stratification	deficiency	C
J	*Scenedesmus* spp			
	Coelastrum spp		Low light	C-R
M	*Microcystis aeruginosa*	High insulation	Flushing, Low light	C-R

Functional Group Representation: During this study, six functional groups were mainly represented and nineteen species registered as dominant from a total of 302 recorded taxa. The associations that showed more relevance were within the diatoms (groups, D and B), chlorophytes (X1, F and J) and cyanoprokaryotes (X1 and M) (Table 1).

Classification of Samples: Among the collected samples, the samples collected from the highly polluted area (stations 1-5) succeeded to form three groups above the similarity level of 50% (Fig., 2a). The resulted groups were labeled A, B and C. The samples of group A were collected mainly from early autumn, summer and late spring. The samples of group B were collected mainly during summer and spring, whereas samples of group C were collected during late winter. In the other side, the other samples failed to formed groups at this level of similarity. Concerned with the species (Fig. 2 b, species with frequencies ≥20% were used in this analysis and signed with a numerical code in Table 2), only the species of the genus *Kirchneriella* and *M. contortum* succeeded to form a group at the similarity level of 50%.

Ordination of Samples: Canonical correspondence analysis (CCA) shows the relations of the species and groups with the environmental variables along the two

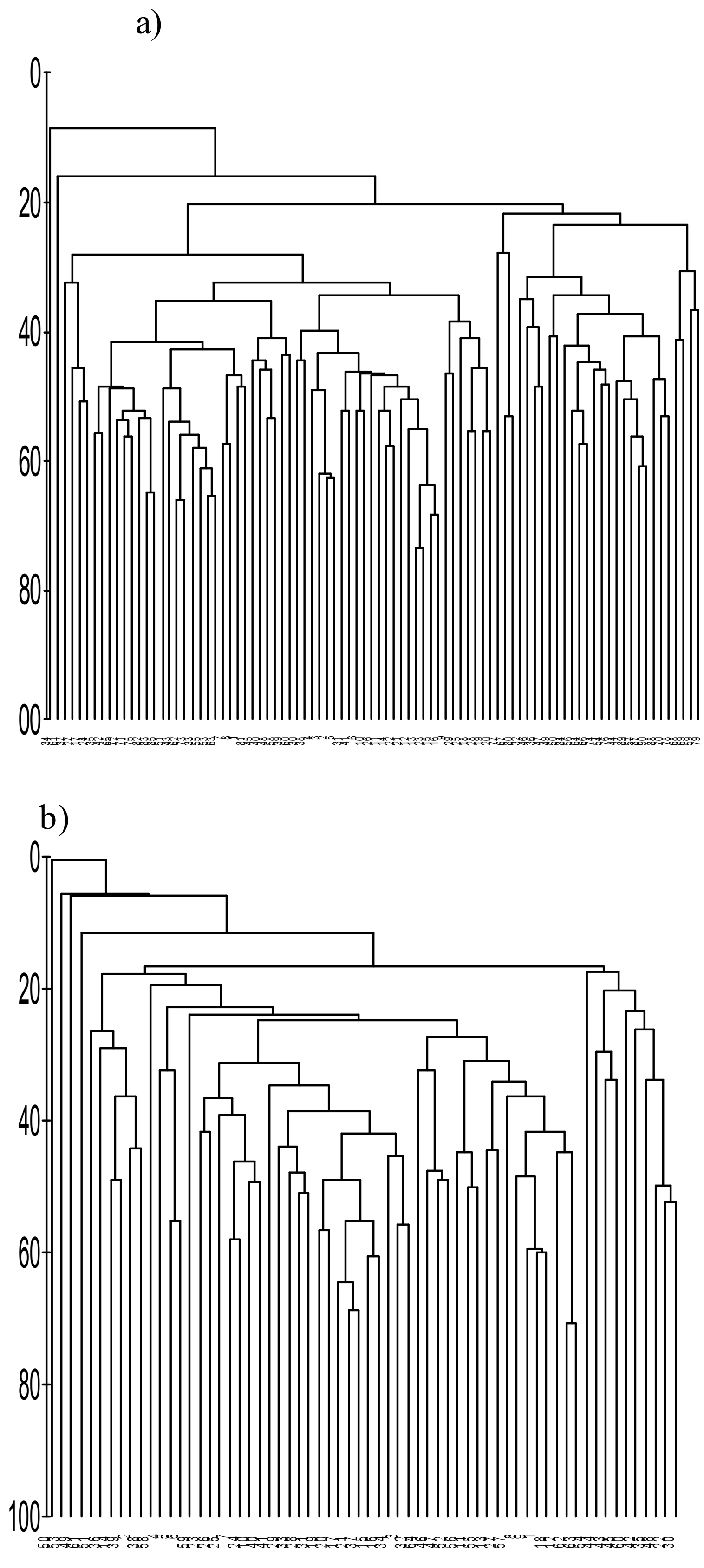
a)
0
20
40
60
80
00
b)
0
20
40
60
80
100

Table 2: Numerical code of frequency species used in CCA and Similarity matrix

Code	Species	Code	Species
1	Ankistrodesmus braunii (Naeg.) Brunn	33	*S. intermedius* Chodat
2	A. falcatus (Corda) Ralf.	34	*S. quadricauda* Breb.
3	A. falcatus var. acicularis (Braun) West	35	*S. quadricauda* var *quadrispina* (Chodat) Smith
4	A. falcatus var mirabilis (West & West) West	36	*Selenastrum capricornatum* Printz
5	Chlamydomonas globosa Snow	37	*S. gracile* Rein.
6	*C. snowiae* Printz	38	*M. minuta* (Nag.) Komar.-Legen.
7	*Chlorella vulgaris* Beij.	39	*Selenastrum westii sp. Nov*
8	*Choricystis chodatii* (Jaag.) Fott	40	*Tetraedron minimum* (Braun) Hans.
9	*Crucigeniella quadrata* (Nag.) Komark.	41	*T. trigonum* (Naeg.) Hans.
10	*C. tetrapedia* (Kirch.) West& West	42	*Chroococcus dispersus* (Keiss.) Lemm.
11	*Dictyosphaerium pulchellum* Wood	43	*C. dispersus* var *minor* Smith
12	*D. ehrenbergianum* Naeg	44	*C. limneticus* Lemm.
13	*Franceia ovalis* (Frence) Lemm.	45	*C. minutus* (Kutz.) Naeg.
14	*Fusola viridis* Snow	46	*Lyngbya limnetica* Lemm.
15	*Kirchneriella aperta* Teil.	47	*Microcystis aeruginosa* Kutz.
16	*K. irregularis* (Smith) Kors.	48	*Oscillatoria limnetica* Lemm.
17	*K. lunaris* (Kirch.) Moebius	49	*Phormidium dictyothallum* Skuja
18	*K. obesa* (West) Schm	50	*Pseudanabaena papillaterminata* (Kiss.) *Kukk*
19	*K. subcapitata* Korsch.	51	*Rhabdoderma lineare* Holl.
20	*K. subsolitaria* West	52	*Tetrachloris merismopedioides* Skuja
21	*Monoraphidium contortum* (Thur.) Komar.	53	*Cyclotella meneghiniana* Kutz.
22	*M. komarkovae* Nyga.	54	*C. ocellata Pant.*
23	*Oocystis borgei* Snow	55	*C. operculata* (Ag.) Kutz.
24	*O. elliptica* West	56	*Nitzschia closterium* Smith
25	*O. marssonii* Lemm.	57	*N. frustulum var perminuta* Grun.
26	*O. solitaria* Witt.	58	*N. microcephala Grun*
27	*O. sp*	59	*Gymnodinium simile* Skuja
28	*Scenedesmus acuminatus* (Lagerh.) Chodat	60	*Gymnodinium sp*
29	*S. acutus* Meyen	61	*Nephroselmis olivacea* Stein
30	*S. bernardii* Smith	62	*Pyramimonas orientalis* Butc.
31	*S. bicaudatus* (Hans.) Chodat	63	*P. sp*
32	*S. ecornis* (Ehren.) Chodat	64	*P. virginica* Schm.

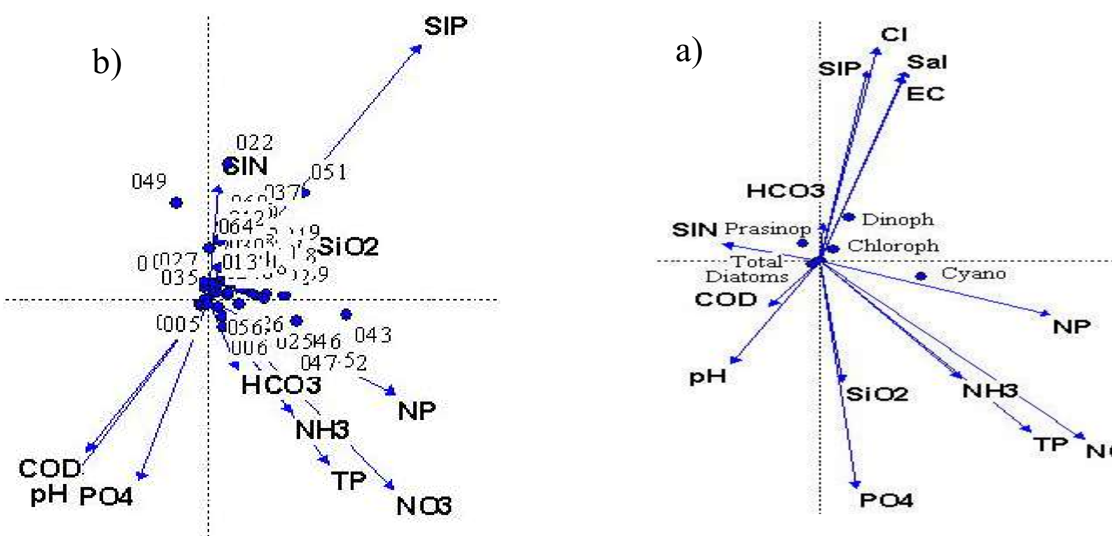

Fig. 3: CCA analysis of phytoplanktonic groups a) and species b) in relation to different environmental parameters

ordination axes. The length of the arrow indicates the relative importance of the environmental variable. In Fig. (3a), the two axes were responsible for 43% of the variations in the dependent variables. Most of the environmental variables were more correlated with axes 2 than axes 1. Cyanoprokaryotes were positively correlated with the different inorganic nitrogen forms and NP ratios, whereas prasinophytes and dinophytes were positively correlated with salinity and electrical conductivity. On the other side, the total phytoplankton abundance and diatoms showed centriod distribution revealed independence or cumulative effect of different environmental variables.

In Fig. (3b), the two axes were responsible for 38% of the variations in the dependent variables. Most of the species were centriod distributed. The species *Monoraphidium komarkovae*, *Oocystis marssonii*, *Chroococcus dispersus* var *minor*, *Phormidium dictyothallum* and *Rhabdoderma lineare* showed differential response with the environmental variables. *M. komarkovae*, *P. dictyothallum* and *R. lineare* were negatively correlated with the different nutrient salts where they were positively correlated with SiO_2, Si/P and Si/N ratios, while the species *O. marssonii* was negatively associated with silicate and its ratios.

DISCUSSION

One of the most important finding of this study is the dominance of diatoms based on biovolume measurements even though green algae were numerically exclusively dominant. Numerically, [16] and [17] indicated that diatoms dominated the lake, whereas [18] and [19] reported that cyanoprokaryotes dominated over the other groups. In fact, this contradict of the authors results was not due to change in the lake trophic status but mainly attributed to their expression of class abundance as cell number. [20] speculated that the routine estimation of standing stock of phytoplankton as cell numbers is an imprecise and inadequate measure of algal abundance for use in studies of algal-grazing relationships, on species or size-class contributions to total algal abundance or total algal primary productivity. Cell volume (biovolume) provides a much more accurate evaluation of cellular biomass and the other algal ecological indices because of the great differences in cell dimensions among various species and sometimes seasonally among the same species under different growth conditions. The dominant diatom species of this study was *C. meneghiniana* with cell biovolume exceed 6000 μm^3, which is tens of time larger than the dominat taxa of both chlorophytes and cyanoprokaryotes.

Enhanced diatom growth would be expected as a result of high silicate concentrations (2-7 mgl^{-1}). Furthermore, transition from non-diatom to diatom species occurs at Si:N from 0.3 to 1 [21] and Si:P from 3 to 20 [22]. Si:N ratio was higher than 1 at all sampling stations throughout the sampling period sometimes reached to 20, whereas Si:P was predominantly higher than 10 sometimes reached to 35. For polluted ecosystems, where pollution provides the bulk of the phosphorus input but silicate supplies are smaller relative to supplies of phosphorus than the proportions required for diatom growth. For continued diatom production, demand will be made on the lake reservoir of silica until such time as the supplies of silica are limited and the excess supplies of phosphorus can then be used by green and blue-green algae [23]. So it is expected that green and/or cynaoprokaryotes will be dominated the lake based on both cell number and biovolume. This transition has been frequently attributed to enhanced growth of diatoms in response to increased N and P availability and a resultant exhaustion of DSi supplies [24].

A pronounced phenomenon of disintegrate colonies of *D. pulchellum* were obviously observed during this study, which was recorded in Lake Manzala [19] and Lake Mariut [25]. Like a few other non-mucilaginous, colonial Chlorococcales *D. pulchellum* colonies may disintegrate into single cells in cultures [26]. A predominantly unicellular habit of *D. pulchellum* has also been reported from natural habitats [27]. The unicellular state of *D. pulchellum* is considered as a part of the life cycle, as colonies are occasionally found to disintegrate at the end of the vegetative period [28]. But predominance of unicellular forms can also be a response to extreme nutrient conditions [27]. The causal factor for near-exclusive unicellular *D. pulchellum*, is the very high nutrient conditions [29]. In Delamere Lake, Bangladesh, [29] hypothesized that low Ca concentrations (0.6 mg Ca l^{-1}) can also be responsible for disintegration of colonies, which is not essential in Lake Manzala where averaged concentrations of Ca was 258 mg l^{-1}. So, the extreme nutrient conditions is expected as the causal factor for the disentegration of *D. pulchellum* colonies in the lake.

In the CCA analysis, (Fig., a and b) total phytoplankton biovolume, different groups (Fig., 3a) and species (Fig., 3b) exhibit a weak intercorrelation (through the correlation matrix) and slight correlation with the different trophic parameters, which revealed an obvious independence of phytoplankton communities with the trophic state of the lake. [30] postulated that in shallow tropical environments, nutrient availability does not provide a good indicator of the trophic level where the concentrations of dissolved inorganic nutrients fractions do not represent the true availability of resources to the organism metabolism, owing to high cycling and uptake rates. Thus, the effect of the nutrient availability on the phytoplankton is greatly modified by extensive shallows. Also the stability of species list and number of taxa since 2001 suggesting that the lake system is close to saturation and the species composition has been well studied. These results agree with the results of [3] in Lake Nero, Russia.

The morphological/functional strategies of the phytoplankton organisms, established by [32] seem to co-vary with the trophic gradient. The S stress tolerant species dominate when nutrients become depleted or when they are chronically in low concentrations; C species do the opposite; and R species are tolerant of low light and many live in eutrophic environments [32]. From Table 1 it is appeared that the phytoplankton taxa dominated the lake are of types C and R whereas the S species are completely absent from the lake. [31] indicated that for shallow, highly eutrophicated water bodies, high abundances of R-C-strategists are characteristics. The R-C-strategists species in the lake are belonging to the functional groups D, B, X1, F, J, X1 and M. According to [5], diatoms of groups B and D belong to more enriched lakes co-exist in softer-water lakes. Groups B form larger units (10^4–10^5 μm^3 in volume) but shape contributes to the maintenance of high s/v and efficient light-harvesting. Diatoms of Group D are mostly found in shallow, nutrient-enriched, well-ventilated waters, liable to be turbid systems. Chlorophytes and cyanophytes of groups F, X1, J and M have the same tendency like proposed for diatoms of groups B and D. They have the ability to resist high nutrient levels, high turbidity and heavy organic loads [33].

It was concluded that both the sea water intrusion and treated/untreated polluted fresh water drained into the Lake Manzala display a major role in the phytoplankton composition, distribution and dominant functional groups. The functional groups in the lake are characterized by their ability to resist highly enriched water, high mixing and low light-high turbid ecosystem.

REFERENCES

1. Bollina, S., D. Conde, L. Aubriot and M.C. Perez, 2005. Influence of Hydrology on Phytoplankton Species Composition and Life Strategies in a Subtropical Coastal Lagoon Periodically Connected with the Atlantic Ocean. Estuaries, 28: 884-895.
2. Fayed, D.B., 2004. Aspects of Manzalah Lake Pollution on Mugil Species. M. Sc. Thesis, Girls' College, Ain Shams University.
3. Babanazarova, V. and O.A. Lyashenko, 2007. Inferring long-term changes in the physical–chemical environment of the shallow enriched Lake Nero from statistical and functional analyses of its phytoplankton. J. Plankton Res., 29: 747-756.
4. Reynolds, C.S. and A.E. Irish, 1997. Modelling phytoplankton dynamics in lakes and reservoirs: the problem of in-situ growth rates. Hydrobiologia, 349: 5-17.
5. Reynolds, C.S., V. Huszar and C. Kruk, 2002. Towards a functional classification of the freshwater phytoplankton. J. Plankton Res., 24: 417-428.
6. Maclaren Engineers, Planners and Scientists, 1981. Lake Manzalah study. EGY/76/001-07. Draft Report to Arab Republic of Egypt. Ministry of Development and New communities and UNDP Scientists, Inc. Toronto, Canada, 12 Vols.
7. Dewedar, A., A.M. Diab and M.M. Zaky, 1995. The Distribution of Bacterial Pollution Indicators in Lake Manzala, Egypt. German Egyptian Conference Proceeding. Pesticides and Environmental Contaminants In Water and Food, Ismailia. 288-297.
8. Utermohl, H., 1958. Zur vervollkommung der quantitativen phytoplankton-methodik. Internationale Vereinigung fur Theoretische 'and Angewandte Limnologi, 9: 1-38.
9. Starmach, K., 1968. Flora Slodkonda Polaki Toms. pp: 594.
10. Krammer, K. and H. Lange-Bertalot., 1986. Bacillariophyceae. Teil: Naviculaceae. Susswasserflora von Mitteleuropa, 2/1:1-876. Gustav Fisher Verlag, Stuttgart, Germany.
11. Dillard, G.E., 1991. Freshwater Algae of the Southeastern, United States, By J. Krammer, Berlin, Stuttgart.
12. Tikkanen, T., 1986. Kasviplanktonopas. Suomen Luonnonsuojelun Tuki Oy (Italia.), Helsinki. pp: 278.
13. Hillebrand, H., C.D. Durselen, D. Iorschtbl, U. Pollingher and T. Zohary, 1999. Biovolume calculation for pelagic and benthic microalgae. J. Phycology, 35: 403-424.

14. Ali, M.H, 2008. Heavy metals and trophic status of lake Manzala. Egyptian J. Aquatic Biology and Fisheries, 12: 1369-1387.
15. Ter Braak, C.F., 1987. CANOCO – a FORTRAN program for canonical community ordination by partial detrended canonical correspondence analysis, principle component analysis and redundancy analysis (Version 4.1) Agriculture Mathematics Group, Wageningen
16. Khalil, M.T., 1990. Plankton and primary productivity of Lake Manzala. Egypt. Hydrobiologia, 196: 201-207.
17. El-Sherif, Z.M. and S.M. Gharib, 2001. Spatial and temporal patterns of phytoplankton communities in Manzalah Lagoon. Bulletin of National Institute of Oceanography and Fisheries, 27: 217-239.
18. Gaballah, M.M, 1990. Ecological studies on phytoplankton in Lake Manzalah. Ph.D. Thesis, Faculty of Science, Suez Canal University.
19. Sobhy, E.H., 2007. Distributions of phytoplankton and epipelic microalgal communities of Lake Manzala. Girls College, Ain-Shams University. pp: 267.
20. Smayda, T., 1978. From phytoplankters to biomass. In: Sournia A.(ed): Phytoplankton manual. Prented by UNESCO (1981).
21. Sommer, U., 1996. Nutrient competition experiments with periphyton from the Baltic Sea. Marine Ecology Progress Series, 140: 161-167.
22. Tilman, D., R. Kiesling, R. Sterner, S.S. Kilham and F.A. Johnson, 1986. Green, bluegreen and diatom algae: taxonomic differences in competitive ability for phosphorus, silicon and nitrogen. Archiv fur Hydrobiologie, 106: 473-485.
23. Domingues, R., A. Barbosa and H. Galv, 2008. Constraints on the use of phytoplankton as a biological quality–element within the Water Framework–Directive in Portuguese waters. Marine Pollution Bulletin, 56: 1389-1395.
24. Rocha, C., H. Galvão and A. Barbosa, 2002. Role of transient silicon limitation in the development of cyanoprokaryotes blooms in the Guadiana estuary, south-western Iberia. Marine Ecology Progress Series, 228: 35-45.
25. Abd El-Karim, M.S., 2008. Spring-Summer dynamic of phytoplankton composition in Lake Mariut. Egyptian Journal of Aquatic Research. Under press.
26. Ragsdale, H.L. and E.E.C. Clebsch, 1970. Temperature and light intensity effects on growth of *Dictyosphaerium pulchellum*. Am. J. Botany, 57: 234-238.
27. Bucka, H. and E. Wilk-Wozniak, 2003. Morphology and ecology of selected coccal green algae occurring in different types of water bodies. Biologia, Bratislava, 58: 483-487.
28. Komarek, J. and J. Perman, 1978. Review of the genus *Dictyosphaerium* (Chlorococcales). Achieve of Hydrobiologia/Suppl. 51 Algol. Stud, 20: 233-297.
29. Irfanullah, H.M. and M. Brian, 2006. Ecology of *Dictyosphaerium pulchellum* Wood (Chlorophyta, Chlorococcales) in a shallow, acid, forest lake. Aquatic Ecology, 40: 1-12.
30. Huszar, V., L. Silva, P. Domingos, M. Marinho and S. Melo, 1998. Phytoplankton species composition is more sensitive than OECD criteria to the trophic status of three Brazilian tropical lakes. Hydrobiologia, 369/370: 59-71.
31. Anonymous, 2007. Ecological studies on Lake Manzala. Report of National Institute of Oceanography and Fisheries. pp: 93.
32. Reynolds, C.S., 1988. Functional morphology and adaptive strategies of freshwater phytoplankton. In Sandgren C. D. (ed), Growth and survival strategies of freshwater phytoplankton. Cambridge University. Press, Cambridge, pp: 388-433.
33. Zarauzi, L., I. Xabier and J. Fernandes, 2008. Modelling the influence of abiotic and biotic factors on plankton distribution in the Bay of Biscay, during three consecutive years (2004–06). J. Plankton Research, 30: 857-872.

(Received: 20/08/2008; Accepted: 27/09/2008)