

Species composition and population density of Phytoplankton of Great Bitter Lake, Suez Canal, Egypt.

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The structure and dynamic of phytoplankton assemblages in Great Bitter Lakes were studied seasonally during the period from May 1999 to February 2000. Population density varied between 1.12198×10^3 cells. l^{-1} in spring and 2.382×10^6 cells. l^{-1} in winter. In terms of cell number, Bacillariophyceae was the most important group (mean annual percentage contribution was 67%), which remained dominant throughout the study period. Cyanophyceae ranked the second abundant group (14 %) dominated in autumn and winter. The contribution of Dinophyceae and Chlorophyceae were 8.6 and 7.3% respectively. The other classes contributed with very low share of the total phytoplankton. The relationship between phytoplankton composition and physico-chemical variables was studied. CCA analysis indicated that water salinity, and temperature are the most important factors affecting phytoplankton distribution. The trophic status index indicated that the lake ranked between mesotrophic and moderately eutrophic. In winter, the lake was under blooming due to the luxuriance growth of *Nitzschia pseudo delicatissima* Hasle. and *Phormidium* sp. The impact of pollution was significantly effective in the western side of the lake compared to the eastern one.

Key words: Phytoplankton, Bitter Lakes, trophic status, C.C.A., ecology, taxonomy.

Introduction

The Great Bitter Lake is the largest water body in the Suez Canal. It is the oldest in its formation in this region, which has specific conditions and plays an important role in the migration of species via Suez Canal between the northern region of Red Sea and the eastern one of Mediterranean Sea. Because of its specific hydrographical and morphological characters, it may be considered, in some cases, as a barrier in the migration of some planktonic species.

With the exception of Ghazzawi (1939) few researchers has been touched upon the area (Halim, 1963 & 1965, Kimor, 1972; Dowider, 1976; and Heimdal *et al.*, 1977) and the record of phytoplankton studies was based on short collecting periods. The only information available consisted of small quantitative and qualitative scale of phytoplankton (Madkour, 1989, El-Sherif & Ibrahim 1993).

Information about the lake now is desirable, since extensive human settlement has taken place there in the last years, leading to a rapid deterioration of the coastal waters where domestic and industrial effluents are continuously discharged and the lake is subjected to continuous drastic changes as a result of urban and tourist projects as well as the operation of widening and dredging the Canal. This, of course, would affect to some extent, the ecological and biological conditions prevailing in the lake. Such changes will be manifested in the flourishing or avoidance of some organisms including

phytoplanktons. Accordingly, the present paper verified the physical and chemical properties of the lake water, species composition and the seasonal fluctuations of the different algal groups. Also, this study is an attempt to give some ecological information upon the trophic status of water quality in the Great Bitter Lakes.

Study area

The Great Bitter Lakes is one of the Suez Canal Lakes. It lies at 30° 14' - 30° 25' latitude and at 32° 17' - 32° 30' longitude. It has a maximum length of about 63 Km, a maximum width of about 13 Km and a maximum depth of about 20 m. The basin of the Bitter Lakes was a Sabkha-like salt swamp, into which very high tides of the Gulf of Suez were flooded. The shores of the lake are generally sandy with some rocky beach area alongside. The current in the lake is likely to be the northward direction throughout the most of the year. This may be due to the higher sea level at Suez than at Port Said, but it is reversed from July-October (Dowidar, 1974) due to the higher sea level at the Mediterranean Sea at the time than the sea level at the Gulf of Suez.

Materials & Methods

Sampling locations are presented in Fig. (1). Sampling started in May, 1999 and was carried out seasonally until February 2000. Samples (2 L) were collected from 6 stations by water sampler. Water temperature was recorded using a standard thermometer (accurately 0.1 °C) and digital pH meter (Cole parmer USA) was used to measure pH. Dissolved Oxygen (DO) was determined by oxygen meter (Cole Parmer USA). Transparency of the water was recorded using a Secchi disc. Chemical analysis of the water were carried out after filtration throughout Whatman (GF/C) filters and were determined according to APHA methods (1992). Chlorophyll a was determined according to Strickland and Pearson 1963.

Phytoplankton sampling

The preserved samples with Lugol's solution were concentrated to 100 ml by decanting. Phytoplankton cells in the concentrated samples were counted with inverted microscope at 16 X 20 and 16 X 40 magnification and were expressed as units per ml (filaments, colonies or single cells). Keys and reference books used for identification were Van-Heurck (1896), Hustedt (1930 - 1937), Perscott (1978), Desikachary (1959), Hendey (1964), and Tomas (1997).

Data Analysis

Principle Component Analysis on a correlation matrix of the standardized physical and chemical variable was used to investigate the seasonal influence of these variables on algal groups. This CCA was performed by using MVSP Package program ver 3.1.

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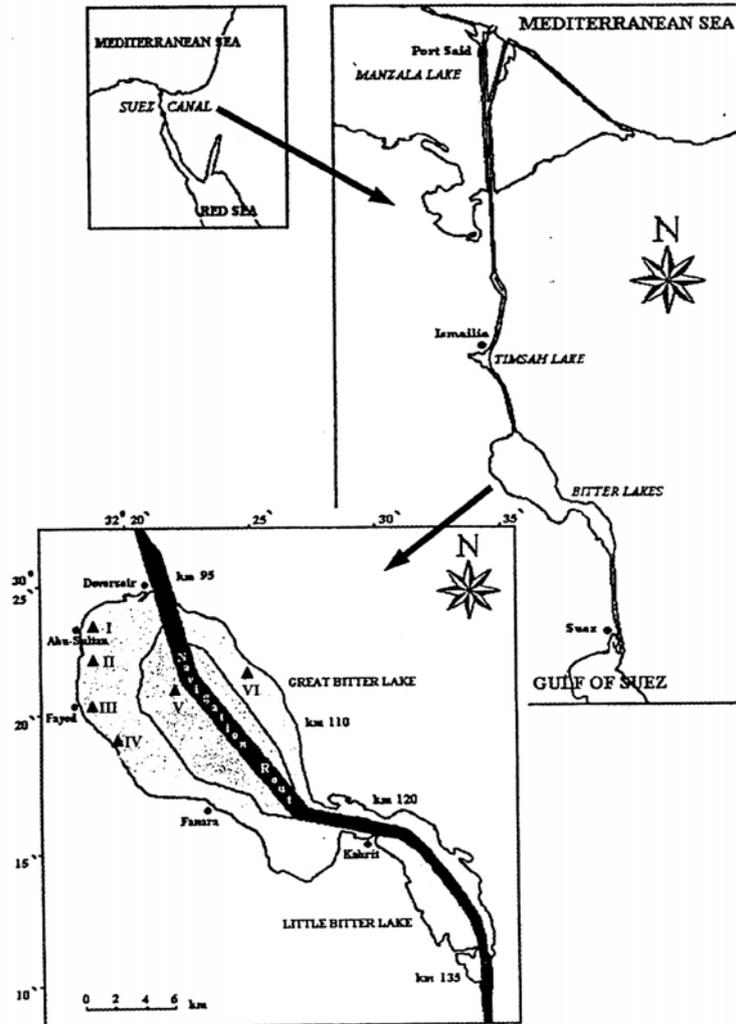


Figure 1. The location of the study sites in Great Bitter Lake (Suez Canal). The triangles indicate the locations of the respective stations. St. I. Inlet of Electric Power Plant (E. P. P.), St. II. Out let of E.P.P, St. III. Palma beach, St. IV. Malaria drain, St. V. Main channel, St. VI. The eastern side.

Results and Discussion

Environmental parameters

The seasonal variation of some physico chemical parameters are represented in Figs. (2&3). The minimum & maximum values of them are present in Table (1). The lowest water temperature registered in winter (16°C) and the highest was (29 °C) detected in summer at most sites except at station II (The outlet of E.P.P), the range of its water

temperature was above the ambient one by 20-21°C. pH values recorded in the lake fall in the alkaline range (7.3 – 8.5). Depth ranged from 1.5 and 30.8 m. Secchi disc readings ranged from 0.25 to 2.81 m. The euphotic zone does not extend to the bottom in the main channel and the eastern regions. This may be due to the movements of the ships in this area which cause the water to be turbid. In other stations in the western side, the photic zone may extend to the bottom. Dissolved oxygen in the surface water fluctuated between 3.4 at St II and 10.2 mg O₂ l⁻¹ at St IV. Its lowest values recorded in summer and the highest during winter. Conductivity varied between 42.3 at St III and 107.8 mmohscm⁻¹ at St II. Its highest values recorded in summer and the lowest in winter. Salinity reached its maximum value (45.7‰) in summer and its minimum value of 32.8 ‰ in winter. Their lowest readings (32.8–33.2 ‰) registered at stations III & IV at the western bank of the lake due to the fresh water discharge from Malaria agricultural drainage and the village tours settled at these stations, while its highest readings (45.2–45.7 ‰) occurred in St. II and eastern side. Miller & Munn (1974) stated that salinity will be always high in Great Bitter Lakes often complete dissolution of the salt bed, due to the high evaporation rate. Madkour (1989) pointed out that, the salinity didn't fall below 40‰ during her investigation period. However, the recent uncontrolled development in and around the lake and the discharge of Malaria drainage increases the fresh water into the lake and consequently the salinity may be reduced. NH₄-H values in all sampling sites varied between 30.4 at St II and 253 µg l⁻¹ at St IV. It had higher values in autumn and winter. The results of ammonia in our study was high as compared to that of Madkour (1989) i.e. it didn't exceed 0.02µg l⁻¹ during her investigation period and consequently she considered the lake as an oligotrophic. NO₃-N concentrations ranged between 6.3 at St II and 190 µg l⁻¹ at St IV. It exhibited high values during spring and winter, while the lowest one during summer. The source of high concentration is due to organic matter supply carried with fresh water from domestic sewage from the tourism villages on the western side of the lake. NO₂-N concentrations remained below 35 µg l⁻¹. PO₄-P, which forms about 5% of the total phosphorus in a lake (Wetzel, 1983), and is the most available form for phytoplankton. PO₄-P levels reached its maximum values (55.7 µg l⁻¹) at St IV, and a minimum of 6.4 µg l⁻¹ at St I. Its higher values were observed during winter and the lower during autumn Fig. (3) PO₄-P levels as compared with Madkour (1989), doubled in the past decades. This is could be attributed to eutrophication caused by waste & input of drain terminating in the lake along the western side. SiO₃-Si values fluctuated between 2.7 at St I and 6.6 mg l⁻¹ at St V. Its highest values occurred in spring and the lowest in autumn. The importance of the element lies in its significance for the construction of the cell wall of diatoms. This element is not a limiting factor for diatoms in the lake. Willem (1991) reported dissolved silica content between 0.03 and 0.20 mg l⁻¹ as limiting level for diatom growth.

The N:P ratio in the water is an important variable since it can denote which of these nutrients appears to be in excess for phytoplankton growth. Redfield (1958) found an average ratio of 15 in oceans, a value that also applies to freshwater. In Great Bitter Lakes, the ratio ranged between 2.8 and 22. The lowest value occurred at the outlet of E.P.P. and IV (Malaria). This could be attributed to eutrophication caused by wastewater of heated water and domestic input into the lake. In this connection Knuuttila *et al.* (1994), stated this ratio is lower in eutrophic than oligotrophic lakes.

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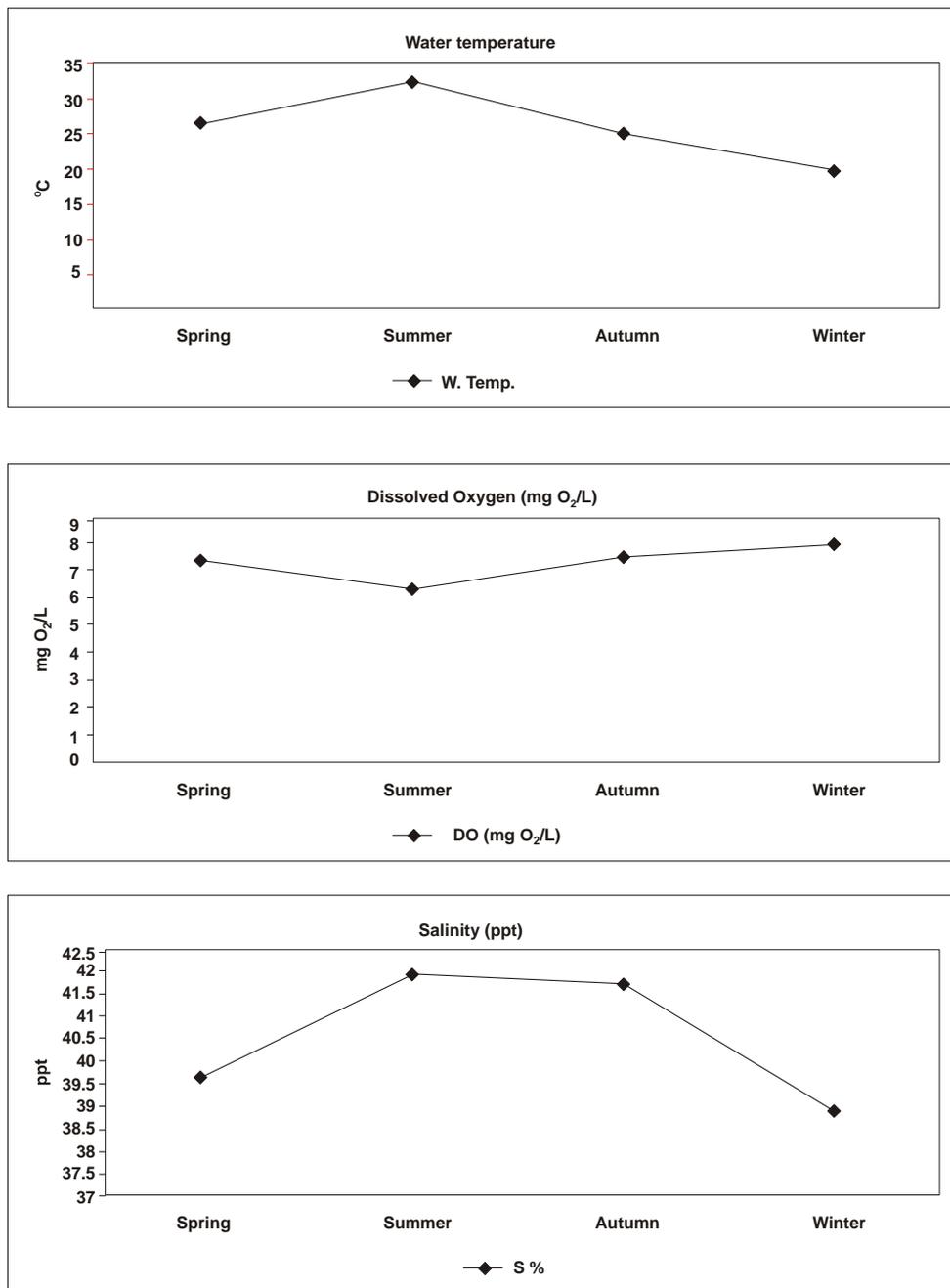


Figure 2. Seasonal variations of some physico-chemical parameters

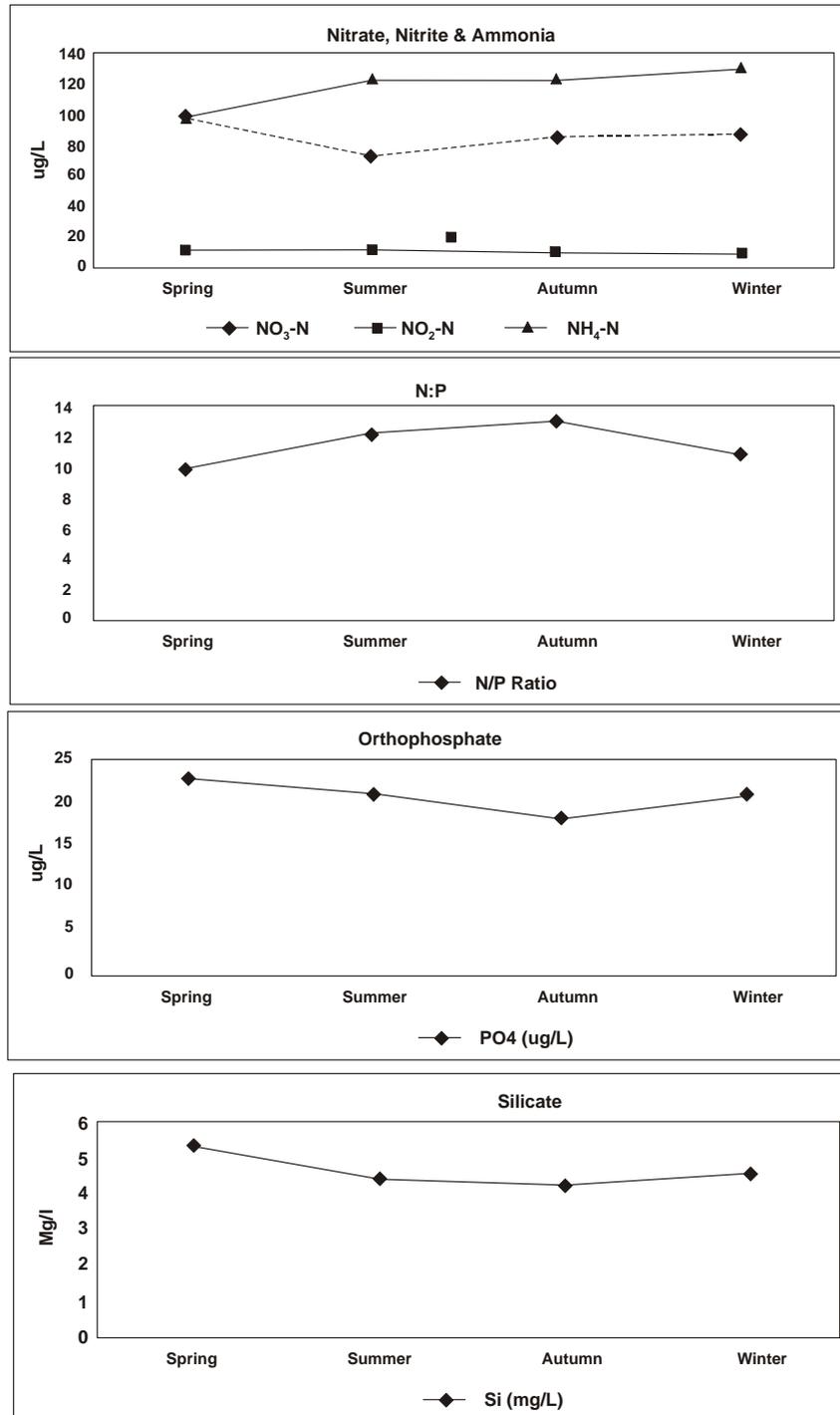


Figure 3. Seasonal variations of some nutrient salts

Table 1. Range of change in some physio-chemical characters of water of Great Bitter Lake at different stations during the period May 1999-February 2000.

| Parameters, unites | St I | | St II | | St III | | St IV | | St V | | St VI | |
|---|------|-------|-------|-------|--------|------|-------|------|------|------|-------|------|
| | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max |
| Temperature °C | 16 | 28 | 36 | 50 | 17 | 28 | 16.5 | 28 | 17 | 29 | 18 | 29 |
| pH | 7.4 | 7.6 | 7.3 | 7.8 | 7.4 | 7.9 | 7.4 | 7.9 | 8.2 | 8.5 | 7.4 | 7.8 |
| Secchi disk m | 0.25 | 0.35 | 0.3 | 0.4 | 2 | 2.1 | 1.3 | 1.5 | 1.4 | 2.8 | 1.2 | 2 |
| Depth m | 10 | 12 | 1.5 | 1.75 | 6.5 | 7 | 3.6 | 4.5 | 25.6 | 30.8 | 3.2 | 25 |
| Conductivity m | 54.7 | 71.5 | 78 | 107.8 | 48.5 | 57 | 42.5 | 51.5 | 52.5 | 69 | 51 | 64 |
| Dissolved Oxygen mgO ₂ l ⁻¹ | 7.2 | 8 | 3.4 | 6.2 | 7.2 | 7.9 | 6.3 | 10.2 | 7.4 | 8.2 | 7.3 | 8.2 |
| Salinity % (ppt) | 42.6 | 44.8 | 42.4 | 45.2 | 32.8 | 36 | 33.2 | 35.8 | 41.8 | 43.8 | 40.6 | 45.7 |
| Nitrate µgl ⁻¹ | 42.6 | 70.8 | 6.3 | 15.4 | 65.5 | 12.5 | 130 | 150 | 65.6 | 111 | 65 | 148 |
| Nitrite µgl ⁻¹ | 2.7 | 8.2 | 0.0 | 1.4 | 15.4 | 21.4 | 25.6 | 35 | 20.5 | 29.6 | 10 | 18 |
| Ammonia µgl ⁻¹ | 67.6 | 115.6 | 30.4 | 90.6 | 75 | 121 | 178 | 253 | 114 | 153 | 92 | 150 |
| PO ₄ -p µgl ⁻¹ | 6.4 | 12.2 | 13.4 | 17.8 | 15.3 | 20.4 | 30.8 | 55.7 | 20.5 | 29.6 | 10.8 | 18 |
| Silicate mg l ⁻¹ | 2.7 | 5.6 | 4.6 | 5.8 | 4.8 | 5.2 | 3.4 | 4.8 | 4.3 | 6.6 | 4.3 | 5.3 |
| Chlorophyll a µgl ⁻¹ | 5.8 | 25.3 | 2.5 | 15.2 | 0.3 | 8.5 | 5.2 | 9.5 | 4.8 | 10.4 | 3.3 | 8.9 |
| Nip ratio | 12.9 | 22 | 2.8 | 6.6 | 10.4 | 12.8 | 7.2 | 12.5 | 3.5 | 11.4 | 13.7 | 20.8 |

CCA Ordination

Figures 4&5 presents the graphic representation of the Canonical Correspondence Analysis for axis 1 and 2. Community structure and distribution along the gradient of 11 variables are clear. Fig. 4 indicates that PO₄ and NO₃ are positively correlated with axis 1 and S %, EC and water temperature are negatively correlated with algal groups. Fig. 5 indicates that PO₄-P, Si-SO₃ are negatively correlated with the leading species of phytoplankton while N:P, S%0 and NO₃ are positively correlated.

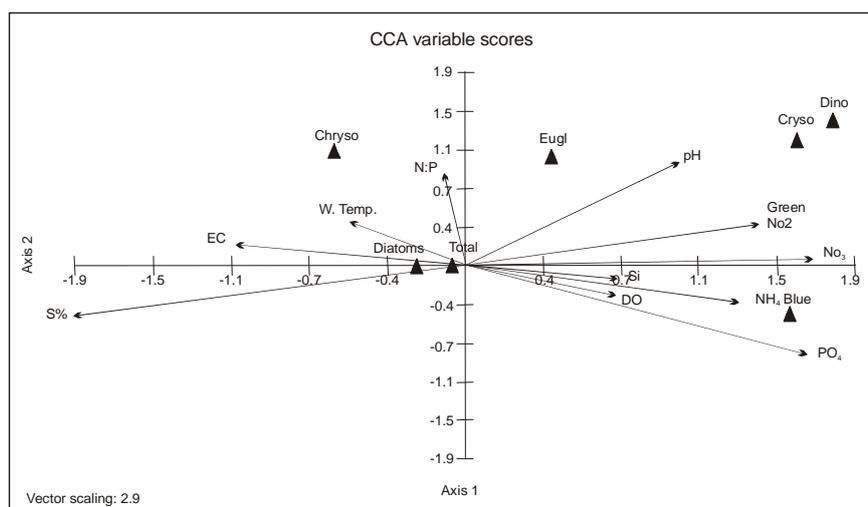


Figure 4: CCA ordination of some environmental variables represented by arrows and the algal represented by triangle legand. Dino.: Dinophyceae, Blue: Cyanophyceae, Eugl.: Euglenophyceae, Diatoms: Bacillariophyceae, Crypt.: Cryptophyceae, Cryso: Crysophyceae, Green: Chlorophyceae, Total: Total phytoplankton

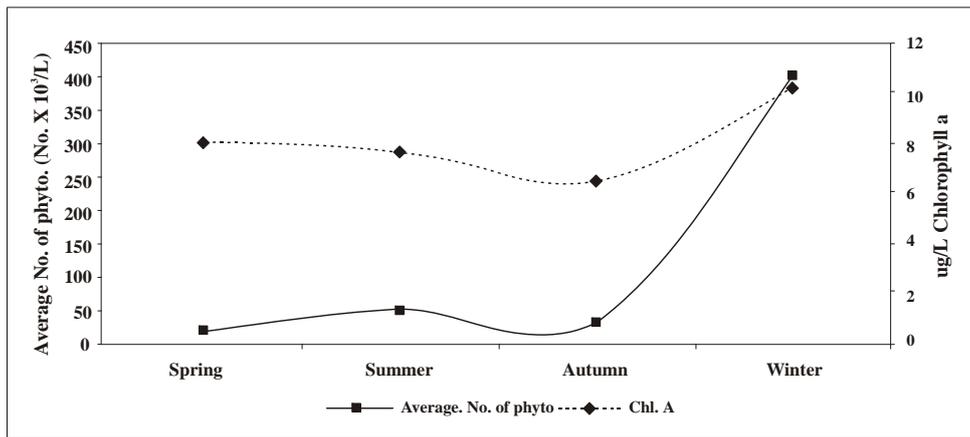


Figure 5: Relationship between average number of Phytoplankton density & Chlorophyll a during the period of investigation

Biological Parameters

Chlorophyll a

Phytoplankton biomass that is represented by Chlorophyll a varied between 0.3 and 15.2 $\mu\text{g}\cdot\text{l}^{-1}$. Its concentration is reflecting the number of individuals. Its value in the past decades (Madkour, 1989), ranged between 0.29 and 1.5 $\mu\text{g}\cdot\text{l}^{-1}$ and the cause of increase off now due to the general increasing of nutrients. Chlorophyll a values coincided with the total number of phytoplankton cells (Fig. 6).

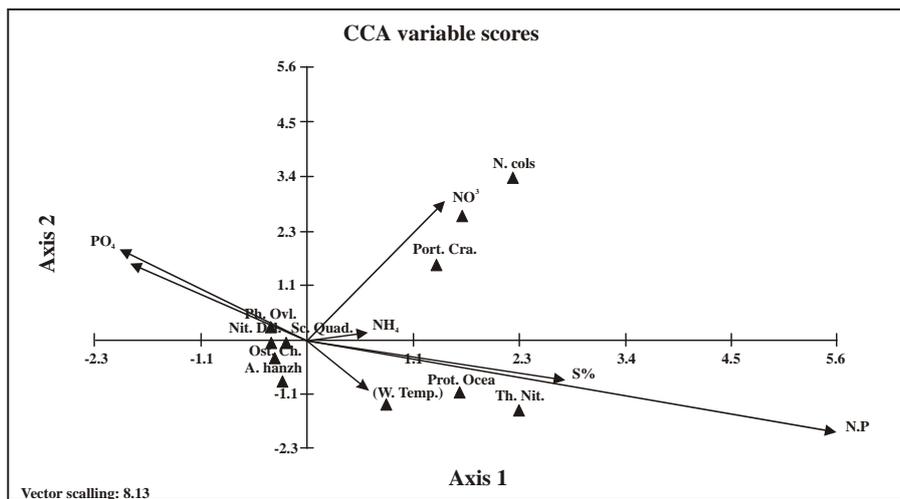


Figure 6: CCA ordination of some environmental variables represented by arrows and leading species of phytoplankton represented by triangle. N. cols.: *Nitzschia closterium*, Prot. Ocea.: *Protodinium oceanicum*, Ph. Ovl.: *Phormidium*, A. hanzh : *Actinastrum hanzhii*, Nit. Del.: *Nitzschia delictissima*, Th. Nit.: *Thalassionema nitzschoideae*, Prot. Cra.: *Protodinium crassus*, Ost. Ch.: *Oscillatoria chalybae*, Sc. Quad.: *Scendesmus quadricauda*.

Species Composition and Population Density

A total of 171 taxa have been identified (Table 2). Most of them belong to Bacillariophyceae (88), Dinophyceae (29), Chlorophyceae (26), Cyanophyceae (24), Euglenophyceae (2), Chrysophyceae (1) and Cryptophyceae (1); (Table 3). The seasonal variation of these groups presented in (Fig. 7).

The maximum occurrence of the total phytoplankton density (2810×10^6 cells l^{-1}) was recorded in winter (Fig. 6) and can be attributed to concurrent increase of Bacillariophyceae (69.7 %) and Cyanophyceae (27.2 %) which coincided with high concentrations of NH_4-N , PO_4-P and NO_3-N and relatively higher values of salinity (32 – 42 ‰). The blooming of Bacillariophyceae and Cyanophyceae developed when the concentration of PO_4-P and NH_4-N are high and NO_3-N is comparatively low (Abdul Hussein and Mason, 1985), and according to Greenwald & Hurburt (1993), stated that the phytoplankton abundance increases as salinity ranges from (17–42 S‰). The above statements seem to be in agreement with our results. The total phytoplankton and diatoms were located towards the center of the ordinations, indicating their apparent indifference to the environmental variables and yearround persistence in the lake (Fig. 4).

Bacillariophyceae constituted the dominant algal groups in terms of cell numbers and taxa. This was also recorded by Madkour (1989). The minimum occurrence of diatom observed during spring (62 %), while the maximum one (69.7 %) recorded in winter when water temperature was 16.5–18°C, NH_4-N , and NO_3-N were high (Fig. 3) when compared to PO_4-P concentrations. The increase in populations of this group at high nitrogen concentrations and low temperatures agrees with the findings of Tilman *et al.* (1986), who stated that diatoms are good competitors for phosphorus but weak competitors for nitrogen.

The dominance of Bacillariophyceae over the other phytoplankton groups was documented by Gab Allah (1985 & 1991) on lake Timsah & Manzalah, this may be due to their tolerance to salinity.

Among the dominant species of diatoms were *Nitzschia closterium* (Her.) W. Smith, *Thalassionema nitzschoides* Grum, and *Nitzschia delicatissima* Cleve. Their correlations with variables presented in (Fig. 5).

Nitzschia closterium is a marine form and was recorded by (Ezz. EL-Din, 1990 and Shafik *et al.*, 1999) in Bardawil lake. It was common in Great Bitter lakes and its maximum percentage contribution abundance to total diatom (98.9 %) was observed in spring when NO_3-N concentrations reached maxima. Due to this it was positively correlated with high values of NO_3-N , and N:P ratio and negatively correlated with PO_4-P and SiO_3 values. *Thalassionema nitzschoides* (Grum.) which was recorded by Gab-Alla (1985), in Timsah lake is known as an indicator of high nutrient conditions and tolerates extreme variable conditions (Van Iprene *et al.*, 1993). Its peak (82.23 %) occurred in summer when water temperature and salinity were high. Consequently it was more positively correlated with high N:P ratio, S ‰ and low concentration of PO_4-P and SiO_3 values.

Nitzschia pseudo delicatissima Hasle., attained its high contribution abundance to total diatoms (65.35 %) forming a bloom in winter. It was positively correlated with high values of PO_4-P and low concentration of NO_3-N . It is geographically widely distributed genus restricted to marine plankton (Tomas, 1997). It is worth mentioning that

at the time of predomination of this genus, it produces domoic acid (Martin *et al.*, 1990). Domoic acid may be a worldwide threat on temperate coasts.

Table 2. Species composition of phytoplankton in Great Bitter Lake-Suez Canal-Egypt during the study period (May 1999-February 2000).

| Bacillariophyceae | |
|---|---|
| 1. <i>Achnanthes exigua</i> var <i>heterovalvata</i> Krasske | 45. <i>L. minimus</i> Grun. |
| 2. <i>A. lanceolata</i> (Breb.) Hüst. | 46. <i>Licmophora flabellata</i> (Greve.) Agar. |
| 3. <i>Amphiprora alata</i> Kütz. | 47. <i>Lithodesmium undulatum</i> Ehr. |
| 4. <i>A. ornate</i> Bail. | 48. <i>Navicula abrupta</i> Greg. |
| 5. <i>A. coffeaeformis</i> Ag. | 49. <i>N. cryptocephala</i> Kütz. |
| 6. <i>A. decussata</i> Grun. | 50. <i>N. dicephala</i> (Ehr.) W.Sm. |
| 7. <i>A. ovalis</i> var. <i>ovalis</i> Kütz. | 51. <i>N. hungarica</i> Grun. |
| 8. <i>A. ovalis</i> var. <i>pediculus</i> Kütz. | 52. <i>N. pupula</i> var <i>pupula</i> Kütz. |
| 9. <i>Astrionella formosa</i> Hass. | 53. <i>N. pygmaea</i> Kütz. |
| 10. <i>A. glacialis</i> (Japonica) Castr. | 54. <i>N. salinarum</i> Grun. |
| 11. <i>Aulacoseira granulata</i> var. <i>gnnulata</i> (Ehr.) Sim. | 55. <i>N. viridulla</i> var <i>viridula</i> Kütz. |
| 12. <i>A. granulata</i> var. <i>angustissima</i> (O. Mull) Hüst. | 56. <i>Nitzschia amphibia</i> Grun. |
| 13. <i>A. moniliformis</i> (O. Mull) Ag. | 57. <i>N. closterium</i> (Ehr.) W. Sm. |
| 14. <i>Bacillaria paxillifer</i> (O.F Mull) Hendey | 58. <i>N. hungrica</i> Grun. |
| 15. <i>Bidulphia mobiliensis</i> (Bail) Grun. Ex Van Haurk | 59. <i>N. palea</i> var. <i>capitata</i> (Kütz.) W. Sm. |
| 16. <i>B. tuomeyi</i> Bail. | 60. <i>N. panduriformis</i> Ehr. |
| 17. <i>Caloneis permagna</i> (Bail.) Cl. | 61. <i>N. parvula</i> Lewis. |
| 18. <i>Chaetoceravis debile</i> Cl. | 62. <i>N. pseudo-delicatissima</i> Hasle. |
| 19. <i>C. densum</i> Cl. | 63. <i>N. punctata</i> (W. Sm.) Grun. |
| 20. <i>Cocconies calcare</i> Cl. A. Cl. | 64. <i>N. sigma</i> (Ehr.) W. Sm. |
| 21. <i>C. placentula</i> var. <i>rouxii</i> (Brun. Et Herib.) Cl. | 65. <i>N. sigma</i> var. <i>rigidula</i> Grun. |
| 22. <i>Cocindiscus asteromphalus</i> Ehr. | 66. <i>N. sigmoeodea</i> (Ehr.) W. Sm. |
| 23. <i>Cyclotella meneghiniana</i> Kütz. | 67. <i>N. trybionella</i> var. <i>victoriae</i> Grun. |
| 24. <i>C. ocellata</i> Pant. | 68. <i>Pleurosigma aestusii</i> (Breb ex Kütz.) W. Sm. |
| 25. <i>Cymatopleura elliptica</i> (Breb.) W.Sm. | 69. <i>P. angulatum</i> Hendey. |
| 26. <i>Cymbella parva</i> (W. Sm.) Cl. | 70. <i>P. elongatum</i> W. Sm. |
| 27. <i>C. microcephala</i> Grun. | 71. <i>Rhabdonema adriaticum</i> Kütz. |
| 28. <i>Diatoma</i> sp. | 72. <i>Rhizosolenia alata</i> forma <i>gracillima</i> (Cl.) Grun. |
| 29. <i>Diploneis interrupta</i> (Kütz.) Cleve. | 73. <i>R. clacar-avis</i> Schult. |
| 30. <i>D. ovalis</i> (Hilse) Cl. | 74. <i>R. fragilissima</i> Berg. |
| 31. <i>D. pillella</i> (Sch.) Cl. | 75. <i>R. styliformis</i> Brighwell. |
| 32. <i>Ditylum brightwellii</i> (West.) Grun. | 76. <i>Stephanodiscus hanzschii</i> (Grim.) |
| 33. <i>Eucampia</i> sp. | 77. <i>Surirella ovalis</i> var. <i>ovata</i> Kütz. |
| 34. <i>Fragilaria brevistriata</i> Grun. | 78. <i>S. robusta</i> Ehr. |
| 35. <i>F. construens</i> (Ehr.) Grun. | 79. <i>Synedra acus</i> var. <i>radians</i> Ehr. |
| 36. <i>Gomphonema angustatum</i> (Kütz.) Rab. | 80. <i>S. pulchella</i> Kütz. |
| 37. <i>G. parvulum</i> var. <i>parvulum</i> (Kütz.) Grun. | 81. <i>S. ulna</i> var. <i>biceps</i> (Kütz.) Grun. |
| 38. <i>Grammatophora marina</i> (Lyngb.) Kütz. | 82. <i>S. ulna</i> var. <i>ulna</i> (Nitzsch) Ehr. |
| 39. <i>Guinardia flaccida</i> (Cast.) Perag. | 83. <i>Tabellaria</i> var <i>asterion alloides</i> (Roth.) Kütz. |
| 40. <i>Gyrosigma attenuatum</i> (Kütz.) Rabh. | 84. <i>Thalassionema nitzschoides</i> Grun. |
| 41. <i>G. balticum</i> (Kütz.) Rabh. | 85. <i>Thalassissira decipiens</i> (Gum.) Gorg |
| 42. <i>Gyrosigma macrum</i> (Wm. Sm.) Cl. | 86. <i>Th. excentrica</i> (Ehr.) Cl. |
| 43. <i>Hemiaulus hauckii</i> Grun. | 87. <i>Thalassiothrix frauenfeldii</i> Grun. |
| 44. <i>Leptocylndrus danicus</i> Cl. | 88. <i>Triceratium reticulatum</i> Ehr. |

Table 2. Continued

| | |
|---|---|
| Chlorophyceae | 129. <i>Oscillatoria chalybea</i> (Mert) Gom. |
| 89. <i>Actinasrtum hanzschii</i> Lag. | 130. <i>O. geminata</i> f. <i>sulphurea</i> (Stesz.) Elenk. |
| 90. <i>Ankistrodesmus falcatus</i> (Corda) Ralfs | 131. <i>O. limosa</i> Ag. Ex Gom. |
| 91. <i>Chlamydomonas</i> sp. | 132. <i>O. splendida</i> Grev. Ex Gom. |
| 92. <i>Chlorella</i> sp. | 133. <i>O. subtilissima</i> Kütz. |
| 93. <i>Chlorogonium</i> sp. | 134. <i>Phormidium</i> sp. |
| 94. <i>Closteriopsis</i> sp. | 135. <i>Pseudoanabaena limnetica</i> (Lemm.) Kom. |
| 95. <i>Closterium</i> sp. | 136. <i>Spirulina subsalsa</i> Ostred. |
| 96. <i>Coelastrum microporum</i> Naeg. in A.Br. | 137. <i>S. subtilissima</i> (Kütz.) ex. Gom. |
| 97. <i>Crucigenia rectangularis</i> (A.Br) Gay | 138. <i>Symehocystis salina</i> Wisl. |
| 98. <i>C. tetrapedia</i> (Kirch.) W & G. S. Wes. | 139. <i>S. pervalekii</i> Ercegovic |
| 99. <i>Dictyosphaerium pulchellum</i> Wood | 140. <i>Synechococcus elongatus</i> Nag. |
| 100. <i>Kirchnerella obesa</i> (W. West.) Schm. | |
| 101. <i>Koliella</i> sp. | Dinophyceae |
| 102. <i>Oocystis borgii</i> Snow | 141. <i>Amphidinium acutum</i> Loh. |
| 103. <i>O. solitaria</i> Wittrock | 142. <i>A. globosum</i> Schroder |
| 104. <i>O.</i> sp. | 143. <i>Ceratium extensum</i> (Gour.) Cl. |
| 105. <i>Pandorina morum</i> (O. Muller) Bory | 144. <i>C. furea</i> Her. |
| 106. <i>Pediastrum boryanum</i> (Turp.) Menegh. | 145. <i>C. gibberum</i> Gour. |
| 107. <i>P. simplex</i> (Meyen) Lemm. | 146. <i>C. trichoceros</i> (Ehr.) Koifoid |
| 108. <i>P. tetras</i> (Ehr.) Ralfs. | 147. <i>C. trupos</i> var. <i>pulchellum</i> Shroder |
| 109. <i>Scenedesmus acuminatus</i> (Lag.) Chodat | 148. <i>Dinophysis caudata</i> Saville-Kent |
| 110. <i>S. bijuga</i> (Trup.) Lag. | 149. <i>D. homunculus</i> Stein |
| 111. <i>S. quadricauda</i> (Trup.) De Breb. | 150. <i>D. rudgei</i> Murray & Whiiting |
| 112. <i>Shroederia robusta</i> Kors. | 151. <i>Gymnodinium auratum</i> Koifoid |
| 113. <i>Tetraedron minimum</i> (A.Br) Han. | 152. <i>G. mitratum</i> Schil. |
| 114. <i>T. trigonium</i> (Naeg.) Han. | 153. <i>G. simplex</i> Loh. |
| | 154. <i>Ornithocercus magnificus</i> Stein |
| Chrysophyceae | 155. <i>Oxytoxum variable</i> Shil. |
| 115. <i>Dictyocha trichantha</i> Ehr. | 156. <i>O. sceptrum</i> (Stein) Shroder |
| | 157. <i>Prorocentrum comprssum</i> (Baily)ABFP& DoDge |
| Cryptophyceae | 158. <i>P. dentatum</i> Stein. |
| 116. <i>Rhodomonas minuta</i> var. <i>nannoplanktonica</i> Skuja. | 159. <i>P. gracile</i> Shutt. |
| | 160. <i>P. micans</i> Ehr. |
| Cyanophyceae | 161. <i>P. minimum</i> (Pavillard) Schil. |
| 117. <i>Anabaena bergii</i> f. <i>minor</i> (Kissel.) Ka. | 162. <i>P. obtusidens</i> Schil. |
| 118. <i>A. constica</i> (Szalf) Geitler. | 163. <i>P. triestinum</i> Schil. |
| 119. <i>A. laxa</i> (Rabench.) Born et Flah. | 164. <i>P.</i> sp. |
| 120. <i>Anabaenopsis</i> sp. | 165. <i>Protoperidinium cerasus</i> Paul. |
| 121. <i>A.</i> sp. | 166. <i>P. depressum</i> Baily |
| 122. <i>Arthrospira jenneri</i> Stizen ex. Gom. | 167. <i>P. oblongum</i> (Auriv.) |
| 123. <i>Chroococcus limneticus</i> Lemm | 168. <i>P. oceanicum</i> Van. Hoffen |
| 124. <i>Coelosphaerium Kutzinginum</i> Kütz. | 169. <i>Pyrocystis lunula</i> Schütt. |
| 125. <i>Cylindospermum majus (maius)</i> Kütz. | |
| 126. <i>Merismopedia tenuissima</i> Lemm. | Euglenophyceae |
| 127. <i>Microcystis elabens</i> (Bréb.) Kütz. | 170. <i>Euglena acus</i> Ehr. |
| 128. <i>Nodularia</i> sp. | 171. <i>E. oxyhrius</i> Schm. |

Table 3. Distribution of phytoplankton species among the algal groups of Great Bitter Lake.

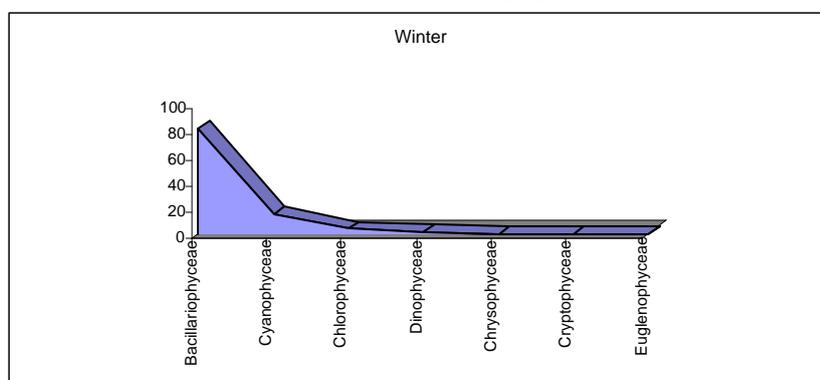
| Groups | No. of taxa | % of the total number |
|-------------------|-------------|-----------------------|
| Bacillariophyceae | 88 | 51.46 |
| Dinophyceae | 29 | 16.96 |
| Chlorophyceae | 26 | 15.20 |
| Cyanophyceae | 24 | 14.04 |
| Euglenophyceae | 2 | 1.17 |
| Crysophyceae | 1 | 0.58 |
| Crysophyceae | 1 | 0.58 |
| Total | 171 | 100 |

Cyanophyceae constituted the second important group in terms of cell numbers, being dominant in autumn (21.70 %) and winter (27.2 %). Its high regional occurrence observed at the outlet of E.P.P. and III-VI stations during the study period and coincided with relatively low N:P ratios (2.8–6.6). It was correlated more with low N:P ratio (Fig. 4). Confirming our results, Smith (1983) stated that Cyanophytes generally dominate in conditions of reduced N:P Ratio and Shapiro., (1990) stated that the lowering in N:P ratio reflects the trophic level that enough for these organisms.

Oscillatoria chalybea (Nert.) Gomont *Phormidium* sp. and *Cylindrospermum majus* (majus) kutz. were the most dominant species. *Phormidium* sp. forming the blooming with *N. pseudo delicatissima* and were correlated more with high PO₄ and low N:P ratio (Fig. 5).

The percentage contribution of Chlorophyceae to the total phytoplankton density fluctuated between 0.7% and 15.5%. Its highest population density of 16810 X 10³ cells l⁻¹ observed in winter when PO₄-P, NO₃-N and NH₄-N were high while its lowest value registered in summer when salinity and water temperature were high (Fig. 2). Its high regional occurrence observed at station III & IV where they receive organically polluted water from domestic sewage.

Conforming our result, its population density exhibited a high positive and significant correlation with *Faecal coli* form (Ashour *et al.*, 2000). *Scenedesmus quadricauda* (Turp.) de Breb and *Actinastrum hanzschii* (Lagerh) were the most dominant species. Together, these formed 47% of the total Chlorophyceae cells in winter. They are known to be common in various conditions of sewage ponds, Gray (1989).

**Figure 7.** The seasonal variation of algal groups during the study period (1999-2000).

Species composition and population density of phytoplankton of Great Bitter Lake, Suez Canal, Egypt.

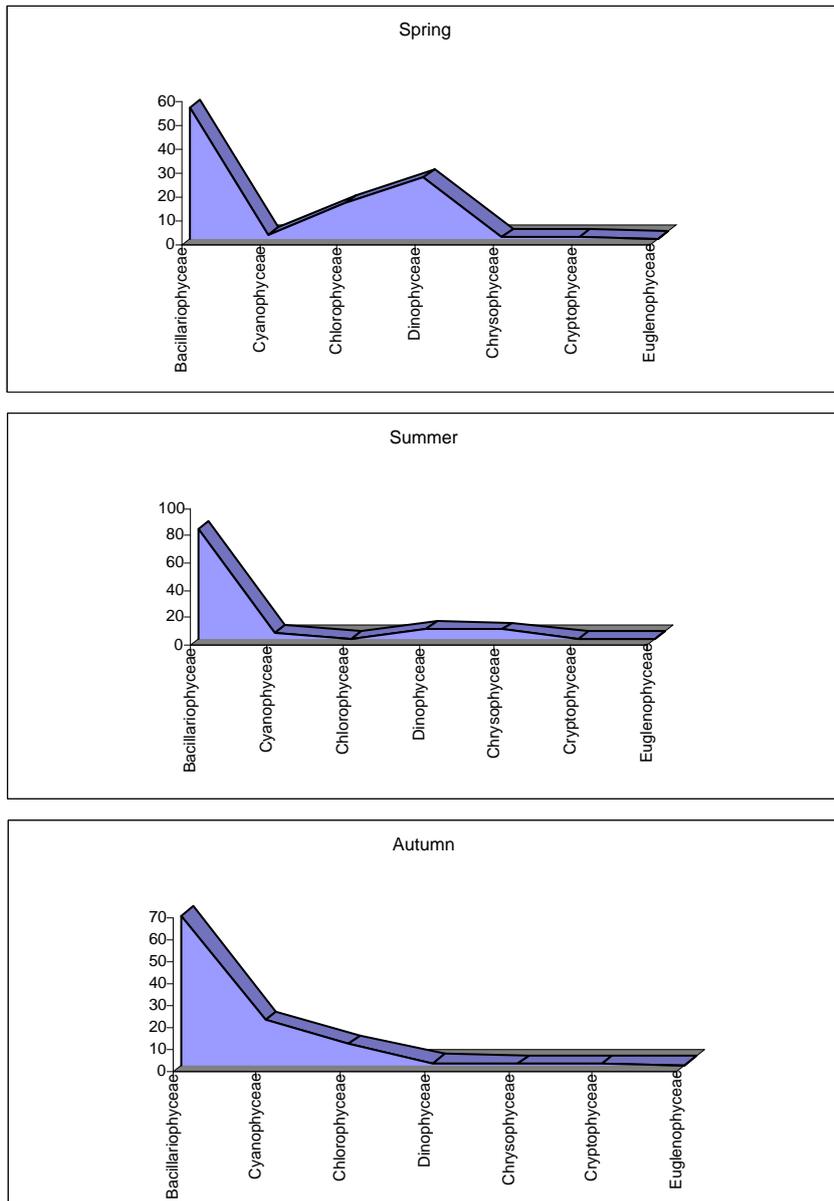


Figure 7. Continued.

Dinophyceae increased during spring due to the luxuriance growth of *Prorocentrum* spp e.g. *P. micans* Ehr., *P. dentatum* Stein and *P. minimum* (Pav.) Sch. The mixture of their contribution abundance to the total Dinophyceae (43%). *Ceratium furca* Ehr. was dominant throughout the study period but in few numbers. *Protoperidinium oceanicum* Van Hoffen showed an increase of 6450×10^3 cells l^{-1} in summer when salinity, N:P ratio and temperature were high. Its regional occurrence was away from western side in connection of this Dinoflagellates are known for their euryhalinity (Smayda, 1983), and relatively high temperature tolerances (Boney, 1975). Dinophyceae revealed a positive correlation with NO_3 , and PO_4 and this finding disagree with Pollinger (1981); Pant *et al*; (1985) in that they are negatively correlated with SRP concentration.

Cryptophytes showed a seasonal variation. It was undetected in summer and winter seasons. Their absence during summer may be coincided with high numbers of ciliates and rotifers which are believed to apply high grazing pressure on small cryptophytes (Nauwerck, 1963); while in winter, their absence may be due to tremendous growth of other algal groups.

Confirming to this, Steward & Wetzel (1986) stated that the decline of Cryptophytes coincided with population increase of other groups. Data indicate (Fig. 4) that Cryptophytes in Great Bitter Lakes were negatively correlated with water temperature and salinity. Cryptophytes are known to develop substantially under low temperature and light conditions (Morgan and Kalff, 1979). It was represented only by *Rhodomonas minuta* var. *planktonica* Skuja.

Chrysophytes contributed all the investigation period except in winter and this counteract the opinion of Steward & Wetzel, (1986) that this group seems to be relatively common in temperate lakes in winter. They were represented only by *Dictyocha trichantha* Ehr. It revealed a positive correlation with salinity and water temperature and negatively correlated with PO_4 -P.

This finding is in agreement with several studies in which a negative correlation between PO_4 -P and the abundance of Chrysophytes existed (Eloranta, 1986, Sand Gren, 1986 & Siver, 1995).

Euglenophyceae were represented by two species: *E. oxyhrius* Schm. and *E. acus* Ehr. Its contribution to the total crop was very small as compared to the above-mentioned groups. They are positively correlated with PO_4 & NO_3 levels and low salinity. Its higher occurrence recorded in polluted water near the drain.

Species richness varied between 2 at Station 1 in winter and 55 at Stn. IV in spring, while the mean values of species diversity index (Shannon & Wiener; 1963) ranged from 1.3 to 2.4 bits ind. l^{-1} . Generally, it was relatively low and this in accordance with Heimdal (1977).

The richness of the phytoplankton and the number of taxa of the various algal classes have been used often as an indicator for the trophic state of a lake. In eutrophic waters, a large number of Cyanophyta species is usually present, whereas in oligotrophic lakes, desmids and Chrysophytes dominate (Round, 1981; Eloranta, 1986). However, in Great Bitter Lakes, Chrysophytes and desmides were very low when compared to the other groups, especially Cyanophyceae. The seasonal average of the Trophic State Index, (Carlson, 1977), was between 47.7 and 50.3 indicating that the lake status lies between mesotrophic to moderately eutrophic condition. (Table 4).

Table 4. Trophic Status index of Great Bitter Lake during the study period (1999-2000)

| | Spring | Summer | Autumn | Winter |
|-------------|--------|--------|--------|--------|
| Input | 55.807 | 53.026 | 47.926 | 54.70 |
| Output | 39.558 | 51.448 | 46.591 | 48.72 |
| Palma Beach | 51.564 | 49.131 | 47.352 | 48.04 |
| Malaria | 50.336 | 46.743 | 56.685 | 51.60 |
| Main | 53.543 | 50.026 | 46.026 | 49.18 |
| Kabryet | 49.984 | 52.015 | 42.282 | 41.814 |
| Min | 39.558 | 46.743 | 42.282 | 19.986 |
| Max | 55.807 | 53.026 | 56.685 | 62.264 |
| Average | 50.132 | 50.398 | 47.810 | 47.727 |

Conclusion

The present investigation is essentially providing a base information concerning the population density and species composition of phytoplanktons in relation to the water quality of the Great Bitter Lake, mandatory for further limnological studies. In contrast to the unexploited eastern region, the western side of the lake has to be watched very carefully and frequently due to the over-exploitation of economic and tourism activities. Moreover, the study provides a sort of data-base necessary for water lake management and predictions for further evaluations of ecosystems.

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