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# THE POTENTIAL IMPACT OF LAKE MANZALA ON THE PHYTOPLANKTON AND HYDROGRAPHIC CHARACTERS OF THE SUEZ CANAL, EGYPT

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## ABSTRACT

This study comes to elucidate the potential impact of Lake Manzala on the hydrobiological characters of Suez Canal. Physico-chemical parameters and phytoplankton composition and abundance were studied seasonally during summer 2002 and spring 2003 in Lake Manzala, Suez Canal and El-Qabouty canal. Lake Manzala showed extremely turbid water, low salinity (average: 12 ‰), high nutrient and chlorophyll contents (averages: 1.2, 4.4, 2.4, 101 μM/l and 99.7 μg/l for nitrite, nitrate, phosphate, silicate and chlorophyll, respectively). It attained low species diversity and abnormally heavy phytoplankton blooms, in addition to the dominance of Chlorophyta, and Cyanophyta. Conversely, the Suez Canal was more transparent with higher salinity (average: 27.5 ‰) and lower nutrient and chlorophyll concentrations (averages: 0.5, 2.3, 0.7, 22.4 μM/l and 7.7 μg/l for nitrite, nitrate, phosphate, silicate and chlorophyll, respectively). The number of species in the Suez Canal was much higher with the predominance of marine species, in addition to the occurrence of some blooms from freshwater and brackish water species. From the present study, it can be concluded that the two ecosystems (Lake Manzala and Suez Canal) showed both structural and dynamical differences, as evidenced by their different hydrological characters, species composition and standing crop of phytoplankton population. Although the presence of such difference, the pronounced effect of Lake Manzala water on the northern part of the Suez Canal waters was clearly obvious.

# INTRODUCTION

It is known that the Suez Canal is a transit area that provides a significant short cut for floral and faunal exchange between two ecologically different habitats, the Indopacific Red Sea and the Atlanto-Mediterranean Sea, (Fox, 1926; Steinitz, 1929, 1967; Por, 1970, 1971, 1978, 1990; Casanova, 1973; Dorgham, 1985; Dowidar, 1974, 1976; Halim, 1990; Kimor, 1990). The physico-chemical conditions within the Canal remained inhospitable for marine organisms from both seas for long, and hence, the species that succeeded in crossing the Canal and surviving in the opposite sea must have remained limited in number, until the conditions improved (Halim, 1990). Before High Dam construction in 1965, the northern part of the Canal was subjected to the effect of the Nile freshwater dilution, in addition to discharges from Lake Manzala. The Nile freshwater acted for a long time as a selective salinity barrier which became uplifted and have now disappeared. Nowadays, the northern part of the Canal is subjected to the influence of discharged water from Lake Manzala only. About 17% of the outflow from Lake Manzala to the Suez Canal takes place via short canal called El-Qabouty canal (MEPSI, 1981). El-Qabouty canal (5km length, 40m width and 2-3m depth) connects the north-eastern border of Lake Manzala to the Suez Canal (at km 5).

Lake Manzala is one of the largest Mediterranean lakes which receives agricultural drainage water as well as sewage and industrial wastes from several drains (about 6,525 x$10^6$ $m^3$/year) discharging into its southern and western parts (Aamer, 1999). The annual mean salinity levels of the lake declined from 24 ‰ during the period 1933-1935 (Faouzi, 1936) to 2.04 ‰ during the period 1981-1983 (Hamza, 1985) as a result of successive increase of the waste waters. After the deepening of old Boughaz El-Gamil and the opening of new Boughaz El-Gamil, the salinity increased to 12 ‰ (Aamer, 1999). In general, the lake sustained high levels of nutrient salts which were associated with high concentrations of chlorophyll a (Hamza, 1985; Gab-Allah, 1990; Aamer, 1999). Guerguess (1979) reported that during the period 1962-1979, a decrease in dissolved oxygen was accompanied with an increase in phosphate content which indicated increasing eutrophication.

Several studies were conducted on the hydrography and phytoplankton standing crop of Lake Manzala (Halim and Guerguess, 1978; MEPSI, 1981; Dowidar and Hamza, 1983, 1985; Bishai *et al.*, 1984; Hamza, 1985; Ibrahim *et al.*, 1987; Gab-Allah, 1990). Few studies were performed on the northern part of the Suez Canal (Ghazzawi, 1939;

Dowidar, 1976; El-Sherif and Ibrahim, 1993; Madkour, 2000). This work focuses on the influence of effluents discharged from Lake Manzala on the hydrographical and biological characters of the Suez Canal water, particularly on the variability and seasonal trends of salinity, nutrient salts concentration and phytoplankton community structure and standing crop.

## MATERIALS AND METHODS

To study the influence of water discharged from Lake Manzala on the hydrobiological characters of the Suez Canal water, five sites were selected representing both of the two water bodies and the connection between them as shown in Figure (1). Lake Manzala was represented by site I, which is located at the northern part of the lake and receives agricultural drainage water and sewage from Port Said City. Sites II and III lie in El-Qabouty canal, the former was in the western side while the latter in the eastern side. Two sites were chosen to represent Suez Canal waters (sites IV and V), site IV is located in front of the opening of El-Qabouty canal, whereas site V is situated at 25 km south of site IV. The lake and El-Qabouty canal are shallow with a depth of about 1-3 m, while the depth of the Suez Canal ranged between 13-20 m. Four trips were performed to the study area through the period from August 2002 to March 2003, representing four seasons, namely; summer (August), autumn (October), winter (January) and spring (March).

Water temperature was measured with an ordinary thermometer. Water transparency was carried out by Secchi disc (25 cm in diameter). Photic zone was estimated by multiplying Secchi depth value by 3 (Goldman and Horne, 1983) and expressed as cm. Hydrogen ion concentration was measured using pH meter (Teleko N 5211). Water salinity was measured using Refractometer (Model 8607). Dissolved oxygen was estimated according to Winkler's method (Strickland and Parsons, 1972). Nutrient salts ($NO_2$, $NO_3$, $PO_4$ and $SiO_2$), were determined spectrophotometrically according to Parsons *et al.* (1984) and the results were expressed as µM/l. Chlorophyll *a* was determined by filtering seawater using 0.45 µm membrane filters and 90% acetone as a solvent according to Parsons *et al.* (1984). For phytoplankton investigation, water samples were collected with bottles and phytoplankton standing crop was estimated by sedimentation method and its magnitude was expressed as number of units/l. The phytoplankton species were identified using the following references: Hendey (1964), Prescott (1978), Dodge (1982), Tomas (1996). ANOVA analysis, Correlation coefficient and stepwise multiple regression at a confidence limit 95 % were evaluated for the whole year (n=20) to quantify the phytoplankton biomass in relation to the most correlative environmental factors.

## RESULTS

The values of all hydrographic parameters of the studied sites are shown in Figure (2). Significant seasonal variations in water temperature (ANOVA, $p<0.01$) were observed with the highest average of 29.5°C in summer and the lowest average of 14.4°C in winter. Since all sites are approximately located at the same latitude, there were no regional differences in water temperature during the same season. Secchi disc readings showed that the transparency of the studied area was generally low (annual average: 20-86.3 cm) with significant regional difference (ANOVA, $p<0.01$). Lake Manzala (site I) attained the lowest transparency (Secchi depth: 15-30 cm). The turbidity decreased gradually towards the eastern side of El-Qabouty canal. The Suez Canal was the most transparent region giving the highest Secchi depth of 120 cm. In spite of the shallowness of the lake and El-Qabouty canal (sites I-III), the photic zone did not reach their bottom through the studied period. Small seasonal variations were found with the lowest average Secchi disc reading (29 cm) in winter and the highest (52 cm) in summer.

Water salinity showed wide seasonal and regional variations which reflect the influence of the discharged wastewaters into Lake Manzala and the dispersion of these discharges through El-Qabouty canal. Lake Manzala (site I) is subjected to intensive dilution giving values of salinity fluctuated between 5 and 20 ‰. The intensity of the freshening appeared clearly at the western side of El-Qabouty canal (site II) with values ranged between 8 and 21 ‰. The salinity increased gradually towards the eastern side of El-Qabouty canal and reached the maximum values (16-37 ‰) in the Suez Canal (sites IV and V). In general, significant seasonal variation (ANOVA, $p<0.01$) was recorded with the lowest seasonal average of 11.6 ‰ in winter and the highest average of 29.6 ‰ in summer. The concentration of dissolved oxygen indicated well oxygenated surface water with regional significant differences (ANOVA, $p<0.01$). Apart from site I, which displayed the lowest values (2.1-5.0 mg/l), the oxygen content of the other sites was relatively high (5.4-10.9 mg/l). On a seasonal scale, dissolved oxygen displayed the lowest values (seasonal average: 5.9 mg/l) in summer, while the highest levels (seasonal average: 8.7 mg/l) appeared in winter.

For all nutrient salts, a marked elevation associated with the low salinity was observed in Lake Manzala (site I). The horizontal distribution of nutrients in the surface water during the whole study period showed a gradual decrease eastward of El-Qabouty canal, whereas, low concentrations occurred at the sites lie in the Suez Canal (sites IV and V) (Fig. 2). This can be signified from the recorded annual averages of nitrite (0.7-1.2 μM/l), nitrate (2.1-4.4 μM/l), phosphate (0.5-2.4 μM/l) and silicate (12-101 μM/l) for sites V and I, respectively. The absolute values of the nutrients demonstrated that the levels of nitrite throughout the whole study area were generally low (below 1 μM/l) except few relatively high values. On the other hand, the levels of other nutrients were considerably high at sites I-III and sometimes at site IV, while the effect of the discharges diminishes at site V giving the lowest values. The absolute values of nutrients amounted between the maximum of 6.8, 3.1 and 123 μM/l, and the minimum of 0.5, 0.1 and 5.0 μM/l, for nitrate, phosphate and silicate, respectively. Based on the seasonal distribution, remarkable variations were observed with the highest values during winter, except few occasions, while the lowest values appeared during summer. Significant distribution patterns (ANOVA, $p<0.01$) were recorded during different seasons for nitrite and nitrate, whereas through study area for phosphate and silicate. Significant and Strong negative correlations ($74<r<0.88$) between salinity and all nutrients were found. The reverse relationships between salinity and nutrients could be as a result of allocthonous origin of the nutrients.

The annual average content of chlorophyll *a* in the lake (99.7 μg/l) was much higher than that in the Suez Canal (7.7 μg/l). As shown in Figure (3), the distribution of chlorophyll *a* in the investigated area illustrated that the absolute values varied widely between a maximum of 129.2 μg/l at site I and a minimum of 2.4 μg/l at site IV. The pattern of seasonal distribution was almost comparable at all sites with a pronounced peak in winter followed by a peak with lower magnitude in spring. The simple regression analysis between chlorophyll *a* and the nutrients indicated significant and strong linear relationships ($r= 0.86$ for silicate, $r= 0.7$ for phosphate, $r= 0.65$ for nitrite and $r=0.54$ for nitrate).

During this study, a total of 204 species and varieties were identified. The phytoplankton organisms belong to 7 classes namely: Bacillariophyceae (97 species), Dinophyceae (59 species), Chlorophyceae

(23 species), Cyanophyceae (17 species), Euglenophyceae (5 species), Cryptophyceae (2 species) and one species of silicoflagellates (Table 1). As shown in Figure (4a), obvious variations in the number of species for the total phytoplankton and for each class were observed among sites. The Suez Canal harbored the highest number of phytoplankton species, with a maximum of 147 at site IV. Bacillariophyceae and Dinophyceae constituted the most phytoplankton community in the Suez Canal giving maximum of 88 species for Bacillariophyceae at site IV and 51 species for Dinophyceae at site V. On the other hand, in Lake Manzala and El-Qabouty canal (sites I-III), the Chlorophyceae and Cyanophyceae were well represented altogether beside Bacillariophyceae with maximum of 21 species for Chlorophyceae at site I and 16 species for Cyanophyceae at site II.

The total phytoplankton standing crop illustrated distinctive variation among sites (Fig. 4b). Lake Manzala (site I) was the most productive area with phytoplankton standing crop varied between 975 and 68351 $x10^3$ individual/l during summer and spring, respectively. The density of the standing crop decreased (530-41397 $x10^3$ individual/l) eastward through El-Qabouty canal (sites II and III), while the lowest values (12-2049 $x10^3$ individual/l) were recorded in the Suez Canal (sites IV and V). Regarding the seasonal variations, it was found that the distribution pattern of total phytoplankton standing crop was nearly similar at all sites with pronounced peaks in spring and winter (averages: 25037 and 15060 $x10^3$ individual/l, respectively). Summer was the lowest season in phytoplankton standing crop (average: 674 $x10^3$ individual/l).

The relative abundance of phytoplankton classes showed that Bacillariophyceae was the predominant component of phytoplankton in the whole study area (Fig. 5). It constituted the main bulk of the phytoplankton standing crop in the Suez Canal region contributing numerically 76% of the total phytoplankton standing crop. On the other hand, Chlorophyceae, and Cyanophyceae represented important part of the phytoplankton population in Lake Manzala and El-Qabouty canal comprising numerically 36 and 23% of the total phytoplankton standing crop, respectively. Dinophyceae was present mostly in the Suez Canal (16%), while it occurred infrequently in the lake. Euglenophyceae, Cryptophyceae and Silicoflagellates remained as rare forms and they constituted collectively 4 and 1% of the total phytoplankton in the lake and Suez Canal, respectively.

As experienced in any phytoplankton community, a small number of the all recorded species are considered as biomass builders. The dominant species varied qualitatively and quantitatively in the two regions showing distinctive horizontal distribution pattern with most abrupt abundance in the areas that exhibit low salinity. The phytoplankton community in Lake Manzala and El-Qabouty canal dominated by *Skeletonema costatum* (16.2 % by number of the total phytoplankton), *Scenedesmus quadricauda* (13.5 %), *Chroococcus minutus* (11.7 %), *Nitzschia closterium* (10 %), *Tetraedron minimum* (8.9 %), *Microcystis aeruginosa* (6.1 %), *Cyclotella meneghiniana* (3.8 %) and *Merismopedia tenuissima* (2.4 %). However, the phytoplankton community in the Suez Canal was dominated by *Skeletonema costatum* (37.6 %), *Nitzschia seriata* (21.3 %) and *N. closterium* (7.9 %) particularly during spring and winter while *Prorocentrum micans* (4.2 %), *Ceratium furca* (2.7 %) and *Peridinium oblongum* (2.3 %) came in the second order of importance.

## DISCUSSION

Mixing of different water masses (Red and Mediterranean Seas) in the Suez Canal creates a unique environment with highly diversified phytoplankton species from different origin (Dowidar, 1976; El-Sherif and Ibrahim, 1993; Madkour, 2000). Furthermore, the Canal is characterized by the presence of different conditions along its length as a result of passing through Lake Manzala, Lake Timsah and Bitter lakes. Although the conditions in the northern part of the Suez Canal had been changed since stopping of the Nile water discharges in 1965, it is still distinguished hydrobiologically from water masses of the rest of the Canal (Dorgham, 1985; El- Sherif and Ibrahim, 1993; Abdel-Rahman, 1997; Madkour, 2000). This is attributed to the flow from Lake Manzala to the northern part of the Canal via El-Qabouty canal. These discharges play an important role in influencing the hydrobiological system of this part in the Suez Canal.

Lake Manzala was characterized by wide fluctuations in the physico-chemical parameters of water. It showed extremely turbid water (average Secchi depth: 20 cm), low salinity (average: 12 ‰) and low oxygen levels (average: 3.8 mg/l). This is accompanied with high nutrient loadings (averages: 1.2, 4.4, 2.4 and 101 µM/l for nitrite, nitrate, phosphate and silicate, respectively), in addition to high chlorophyll *a* content (average: 99.7 µg/l). The levels of nutrients recorded in the present study more or less agree with observations of the earlier investigators (Hamza, 1985; Aamer, 1999) who stated that the level of nutrients in the same area of the lake ranged between 0.1-1.0 µM/l for nitrite, 1.0-6.4 µM/l for nitrate, 0.2-5.8 µM/l for phosphate, except for silicate which registered relatively lower levels than reported before (27-158 µM/l). These levels of nutrients are comparable with those characterizing the eutrophic water as reported by Franco (1983) and Stirn (1988). The lake has turned into highly eutrophic basin as a result of the continuous release of untreated domestic, industrial and agricultural wastewater (Dowidar and Abdel-Moati, 1983; Abdel-Moati, 1985; Hamza, 1985; Ibrahim *et al.*, 1987; Mamdouh *et al.*, 1997; Aamer, 1999). This reflects the efficient role of these wastewater discharges as an important source of different forms of nitrogen, phosphate and silicate (EIMP, 2001).

Compared to Lake Manzala, the Suez Canal showed more transparent water (average Secchi depth: 60.6 cm), higher salinity (average: 27.5 ‰) and higher oxygen content (average: 9 mg/l). Furthermore, nutrient salts and chlorophyll a concentrations were lower (averages: 0.5, 2.3, 0.7, 22.4 µM/l and 7.7 µg/l for nitrite, nitrate, phosphate, silicate and chlorophyll *a*, respectively). The present results confirm those reported previously (El-Sherif and Ibrahim, 1993; Abdel-Rahman, 1997; Madkour, 2000) in the same area of the Suez Canal. Through El-Qabouty canal, the site positioned closer to the lake was greatly influenced by the discharges coming from it compared to that positioned farther. This indicates that the influence of Lake Manzala water diminishes through El-Qabouty canal which connects the lake with the Suez Canal.

The presence and abundance of phytoplankton groups between the two ecosystems were greatly different. For instance, Lake Manzala sustained low species diversity and abnormally heavy phytoplankton blooms, in addition to the dominance of Chlorophyta, and Cyanophyta, which had fresh and brackish water affinity, altogether with Bacillariophyta. This confirms the observations of Gab-Allah (1990), who reported the dominance of these groups in the lake. On the other hand, the number of species in the Suez Canal was much higher with the predominance of euryhaline species where the condition is more suitable for the occurrence of marine species. In addition, the appearance of blooms from fresh water and brackish water species in the Suez Canal indicated that the conditions were available for flourishing of these non-indigenous (allochthonous) species. The occurrence of wide variation in phytoplankton species composition, diversity and standing crop is mainly due to the wide range of salinity and nutrient loading between the two ecosystems (Lake Manzala and Suez Canal). For instance, the presence of phytoplankton with low diversity and high density is accompanied with low salinity and the high values of nutrients that recorded in the lake.

Although phytoplankton standing crop attained high values throughout the whole year, the lake was characterized by a unimodal cycle peak during spring and winter. This could be explained by two mechanisms. Firstly, Lake Manzala receives nutrient inputs persistently throughout the year from largely urbanized watersheds (MEPSI, 1981; Hamza, 1985), which provides nutrients needed for of phytoplankton growth and resulted in high phytoplankton biomass. Secondly, these inputs increase in the winter (Aamer, 1999), as a consequence; the lake exhibited enhanced phytoplankton growth in winter which prompted the onset of spring stratification. The similarity between Lake Manzala and Suez Canal in the timing of phytoplankton standing crop peak, with a lower magnitude, gives an additional sign for the role of waters discharged from Lake Manzala on the phytoplankton dynamic in the Suez Canal.

From the present study, it can be concluded that the two ecosystems (Lake Manzala and Suez Canal) showed both structural and dynamical differences, as evidenced by their different hydrological characters, taxonomic composition and standing crop of phytoplankton population. Although the presence of such difference, the pronounced effect of Lake Manzala water on the northern part of the Suez Canal waters was clearly obvious. During all seasons except winter, the levels of nutrients and the value of transparency recorded in the northern part of the Suez Canal are comparable to those characterizing oligotrophic water, as mentioned by Vucak and Stirn (1982). These values reached that characterize mesotrophic water bodies in winter. These conditions are probably coupled with the maximum values of the wastewaters discharged into the lake. This emphasizes the role of the water discharges from Lake Manzala in changing the water characters of the Suez Canal.

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Table (1). List of the recorded species of phytoplankton in Lake Manzala (LM) and Suez Canal (SC) during 2002-2003.

| Species | LM | SC |
|---|---|---|
| **Bacillariophyceae** | | |
| *Achnanthes brevips* Agardh | + | + |
| *A. lanceolata* (Bréb.) Hüst | | + |
| *Amphiprora alata* Kütz. | + | + |
| *A. hyalina* Eulenstein ex Van Heurck | + | + |
| *A. paludosa* Smith | + | + |
| *Amphora* coeffeaeformis Agardh | + | + |
| *A. cymbifera* Greg. | | + |
| *A. ovalis* var. *ovalis* Kutz. | + | + |
| *Asterionella japonica* Cleve & Möller ex Gran | + | |
| *Bacillaria paxillifer* (Müller) Hendey | + | + |
| *Biddulphia alternans* (Baily) Van Heurck | + | + |
| *B. aurita* (Lyngbye) de Bréb. | + | |
| *B. laevis* Ehrenberg | + | |
| *B. mobiliensis* (Baily) Grun. ex Van Heurck | + | |
| *Caloneis* sp. | | + |
| *Campylodiscus clypeus* Ehrenberg | + | |
| *C. echeneis* Ehrenberg | | + |
| *Ceratulina pelagica* (Cleve) Hendey | + | |
| *Ceratulus smithii* Ralfs | + | |
| *Chaetoceros affine* Lauder | + | |
| *C. decipiens* Cleve | + | + |
| *C. densum* Cleve | + | |
| *C. didymunn* Ehrenberg | + | |
| *C. holsaticum* Schütt | + | |
| *Climacosphenia moniligera* Ehrenberg | + | |
| *Cocconeis scutellum* Ehrenberg | + | + |
| *Coscinodiscus centralis* Ehrenberg | + | + |
| *C. granii* Gough | + | |
| *C. oculus-iridis* Ehrenberg | + | |
| *C. perforatus* Ehrenberg | + | + |
| *Cyclotella menegheniana* Kützing | + | + |
| *C. striata* (Kützing) Grunow | + | + |
| *Cymatopleura elliptica* (Bréb.) Smith | + | + |
| *Diploneis crabro* (Ehrenberg) Wm. Smith | + | + |
| *D. interrupta* (Kütz.) Cleve | | + |
| *Fragillaria brevistriata* Grun. | | + |
| *Gomphonema angustatum* (Kütz.) Rabh. | + | |
| *Grammatophora marina* (Lyngbye) Kützing | + | + |
| *Guinardia flaccida* (Cast.) Perag. | + | + |
| *Gyrosigma acuminatum* (Kütz.) Rabenhorst | + | + |
| *G. attenuatum* (Kütz.) Rabh. | + | |
| *G. balticum* (Kütz.) Rabh. | + | |
| *G. fasciola* (Ehrenberg) Cleve | + | + |
| *G. hippocampus* (Ehrenberg) Hassall | + | |
| *G. littorale* (W. Sm.) Cleve | + | |
| *G. macrum* (W. Smith) Cl. | + | + |
| *Hemiaulus hauckii* Grun. | + | |
| *Lauderia borealis* Grun. | + | + |
| *Leptocylindrus danicus* Cleve | + | |
| *Licmophora gracilis* (Ehr.) Grunow | + | + |
| *Lithodesmium undulatum* Ehr. | + | |
| *Melosira granulata* Ehrenberg | + | + |
| *M. nummuloides* Agardh | + | + |
| *M. sulcata* (Ehr.) Kütz. | + | + |
| *M. variance* Agardh | + | |
| *Navicula abrupta* Greg. | + | + |
| *N. cancellata* Donkin | + | + |
| *N. cuspidata* Kütz. | + | |
| *Navicula dicephala* (Ehr.) W. Sm. | + | + |
| *N. gracilis* Cleve | + | + |
| *N. pygmaea* Kütz. | + | |
| *Nitzschia acicularis* W. Sm. | + | + |
| *N. colsterium* (Ehrenberg) Wm. Smith | + | + |
| *N. hungarica* Grunow | + | + |
| *N. longissima* (Bréb) Ralfs | + | |
| *N. palea* (Kütz.) W. Smith | + | + |
| *N. panduriformis* Gregory | + | + |
| *N. punctata* (W. Sm.) Grun. | + | + |
| *N. seriata* Cleve | + | |
| *N. sigma* Kützing | + | + |
| *N. sigmoidea* (Ehr.) W. Sm. | + | |
| *Pleurosigma angulatum* (Quekett) W. Sm. | + | + |
| *P. cuspidatum* Cleve | + | |
| *P. decorum* W. Smith | + | + |
| *P. elongatum* W. Sm. | + | |
| *P. spencerii* W. Smith | + | + |
| *P. strigosum* W. Smith | + | |
| *Pinnularia rectangulata* (Gregory) Rab. | + | |
| *Podosira stelliger* (Baily) Mann | + | |
| *Rhizosolenia alata* forma *gracillima* (Cl.) Grun. | + | |
| *R. calcar-avis* Schultz | + | |
| *R. setigera* Bright. | + | + |
| *R. styliformis* Bright. | + | |
| *Skeletonema costatum* (Greville) Cleve | + | + |
| *Stauroneis* sp. | + | + |
| *Striatella unipunctata* (Lyngbye) Ag. | + | |
| *Surirella gemma* (Ehr.) Kützing | + | |
| *S. ovalis* Bréb. | + | + |
| *S. striatula* Turpin | + | + |
| *Synedra acus* Kütz. | + | + |
| *S. pulchella* Kützing | + | + |
| *S. ulna* (Nitzsch) Ehr. | + | + |
| *Tabellaria fenestrata* (Lyngb.) Kütz. | | + |
| *Thalassionema nitzschioides* Hüstedt | + | + |
| *Thalassiosira decipiens* (Grun. Ex Van Heurck) Jörg. | + | + |
| *T. excentrica* (Ehr.) Cl. | + | + |
| *Thalassiothrix frauenfeldii* Grun. | + | |
| **Dinophyceae** | | |
| *Amphidinium crassum* Lohmann | | + |
| *Ceratium breve* (Schmidt) Jorg. | + | |
| *C. candelabrum* (Ehr.) Stein | | + |
| *C. egyptiacum* Halim | + | |
| *C. furca* (Ehr.) Clap. & Lachmann | + | + |
| *C. fusus* (Ehrenberg) Dujardin | + | |
| *C. horridum* (Cleve) Gran | + | |
| *C. kofoidii* Jorg. | + | |
| *C. minutum* Jorgensen | + | |
| *C. macroceros* (Ehr.) Vanhoffen | + | |
| *C. massiliense* (Gourret) Jorgensen | + | |
| *C. pentagonum Gourret* | + | |
| *C. trichoceros* (Ehr.) Kofoid | + | |
| *C. tripos* (Muller) Nitzsch | + | |
| *Dinophysis acuta Ehrenberg* | + | + |
| *D. caudata Savile-Kent* | + | |
| *D. ovum* Schutt | + | |
| *Diplopsalis lenticula* Bergh | + | + |
| *Glenodinium monensis* Herdman | + | |

Table (1). Continue

| Species | LM | SC |
|---|---|---|
| *Gonyaulax polyedra* Stein | + | |
| *G. polygramma* Stein | + | |
| *G. spinifera* (Clap. & Lach.) Diesing | + | + |
| *G. turbynei* Murr. et Whitt | + | + |
| *Gymnodinium abbreviatum Kof. & Swezy* | | + |
| *G.* simplex (Lohmann) Kof. & Swezy | | + |
| *G. splendens* Lebour | + | + |
| *Gyrodinium britannicum* Kof. & Swezy | | + |
| *Minuscula bipes* Paulsen | + | + |
| *Oxytoxum sceptrum* (Stein) Schroder | + | + |
| *Podolampas palmips* Stein | + | |
| *Prorocentrum compressum* (Bail.) Abe ex Dodge | + | + |
| *P. dentatum* Stein | + | |
| *P. gracil* Schutt | + | |
| *P. micans* Ehrenberg | + | + |
| *P. minimum* (Pavillard) Schiller | + | + |
| *P. triestinum* Schiller | + | + |
| *Protoperidinium achromaticum* (Lev.) Balech | + | + |
| *P. brevipes* (Pauls.) Balech | + | |
| *P. cerasus* (Pauls.) Balech | + | + |
| *P. conicum* (Gran) Balech | + | |
| *P. curtipes* (Jorg.) Balech | + | |
| *P. depressum* (Bail.) Balech | + | |
| *P. diabolum* (Cleve) Balech | + | |
| *P. divergens* (Ehrenb.) Balech | + | |
| *P. globulum* (Stein) Balech | + | |
| *P. mite* (Pav.) Balech | + | |
| *P. oblongum* (Aurivillius) Parke & Dodge | + | |
| *P. oceanicum* (Vanhoffen) Balech | + | |
| *P. pallidum* (Osten.) Balech | + | |
| *P. pellucidum* Bergh | + | |
| *P. pentagonum* (Gran) Balech | + | + |
| *P. punctulatum* (Pauls.) Balech | + | |
| *P. steinii* (Jorg.) Balech | + | |
| *P. subinerme* (Pauls.) Loeb. III | + | |
| *P. thulesense* (Balech) Balech | + | + |
| *Pyrocystis noctiluca* Murray ex Haeckel | + | |
| *Pyrophacus horologium* Stein | + | |
| *Scrippsiella trochoidea* (Stein) Loeb. III | + | + |
| *Spatulodinium pseudonoctiluca* (Pouch.) Cach. & Cach. | + | |
| **Chlorophyceae** | | |
| *Actinastrum hantzschii* Lagerh. | + | |
| *Ankistrodesmus falcatus* Ralfs | + | |
| *Chlamydomonas ehrenbergii* Goroschankin | + | |
| *Closterium lunula* Müll. | + | + |
| *Coelastrum microporum* Nag. | + | |
| *C. reticulatum* Dang. | + | |
| *Cosmarium circulare* Reinsch. | + | |
| *Gonium angulatum* Lemm. | + | |
| *Kirchneriella lunaris* Kirchner | + | |
| *Oocystis parva* W. and G.S. West | + | |
| *Pediastrum simplex* Meyen | + | |
| *P. boryanum* (Turpin) Wenegh. | + | + |
| *P. duplex* Meyen | + | + |
| *Pyramimonas montana* Geitl. | + | |
| *Scenedesmus dimorphus* Turp. | + | + |
| *S. quadricauda* Breb. | + | + |
| *S. bijuga* Turp. | + | + |
| *S. armatus* Chodat. | + | |
| *Schroederia setigera* (Schroder) Lemm. | + | |
| *Selenastrum bibraianum* Reinsch. | + | |
| *Staurastrum paradoxum* Menegh. | + | + |
| *Tetraedron minimum* A. Br. | + | + |
| *T. trigonum* Hansg. | + | |
| **Cyanophyceae** | | |
| *Anabaena flos-aquae* Lyngb. | + | |
| *Chroococcus limneticus* Lemm. | + | |
| *C. minutus* (Kuetz.) Naeg. | + | |
| *C. turgidus* (Kuetz.) Naeg. | + | |
| *Coelosphaerium kuetzingianum* | + | |
| *Gomphosphaeria aponina* (Kuetz) | + | |
| *Merismopedia elegans* A. Br. | + | + |
| *M. punctata* Meyen | + | |
| *M. tenuissima* Lemm. | + | + |
| *Microcystis aeruginosa* Kutz. | + | + |
| *M. grevillei* Hass. | + | |
| *Tetrapedia* sp. | + | |
| *Oscillatoria borneti* Zukal. | + | |
| *O.tennis* Ag. | + | + |
| *Phormidium* sp. | + | |
| *Spirulina gigantea* Schmid. | + | + |
| *S. platensis* (Nordst.) Geitl. | + | + |
| **Euglenophyceae** | | |
| *Euglena acus* Ehr. | + | |
| *E. acusformis* Schiller | + | + |
| *E. viridis* Ehr. | + | + |
| *Eutreptiella hirudiodea* Butcher | + | + |
| *Phacus longicauda* (Ehr.) Duj. | + | |
| **Cryptophyceae** | | |
| *Mallomonas caudata* Conrad. | + | |
| *Prymnesium parvum* Carter | + | + |
| **Silicoflagellates** | | |
| *Dictyocha fibula* Ehrenberg | + | + |

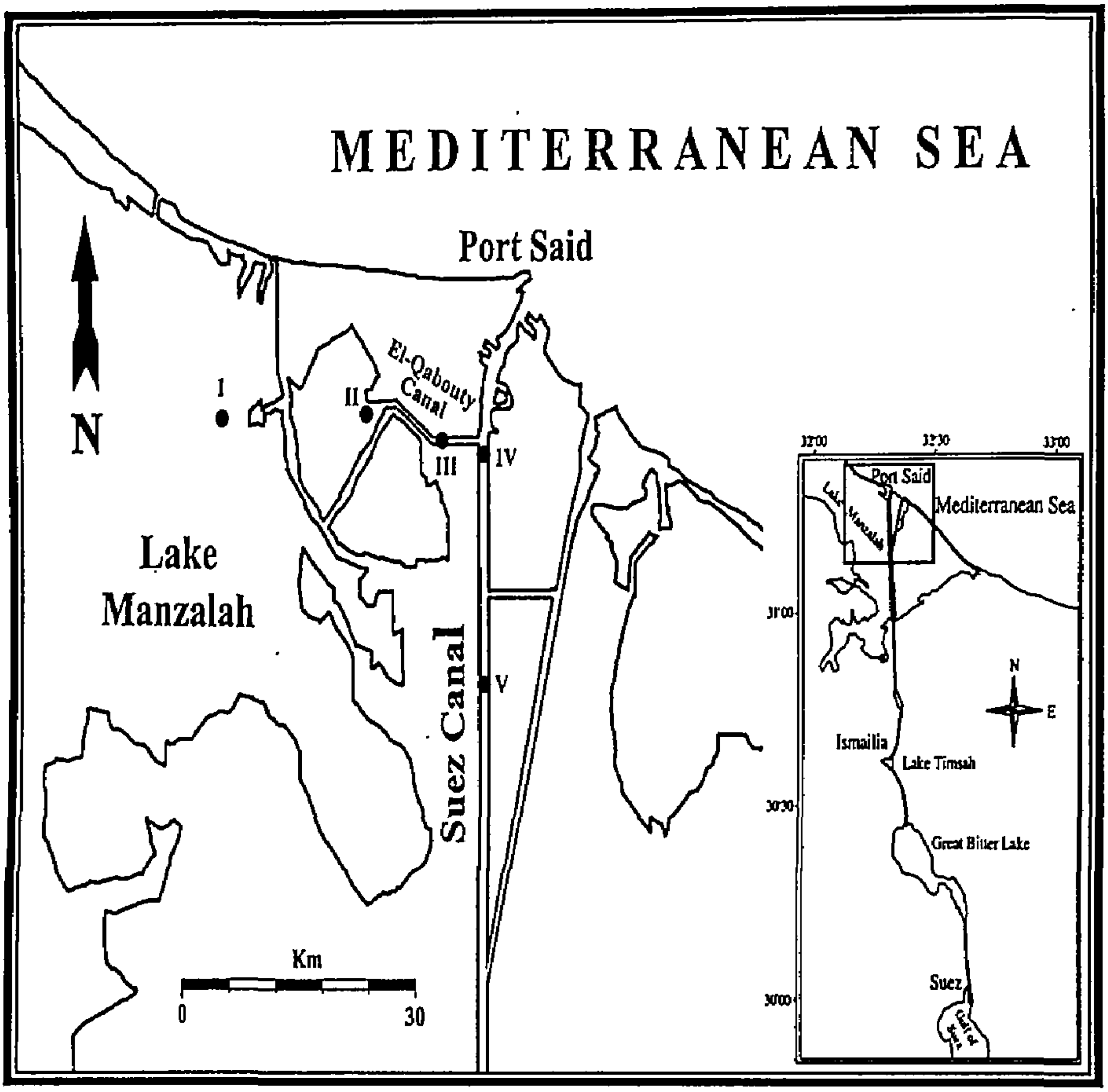

Figure (1): Map of the investigated area.

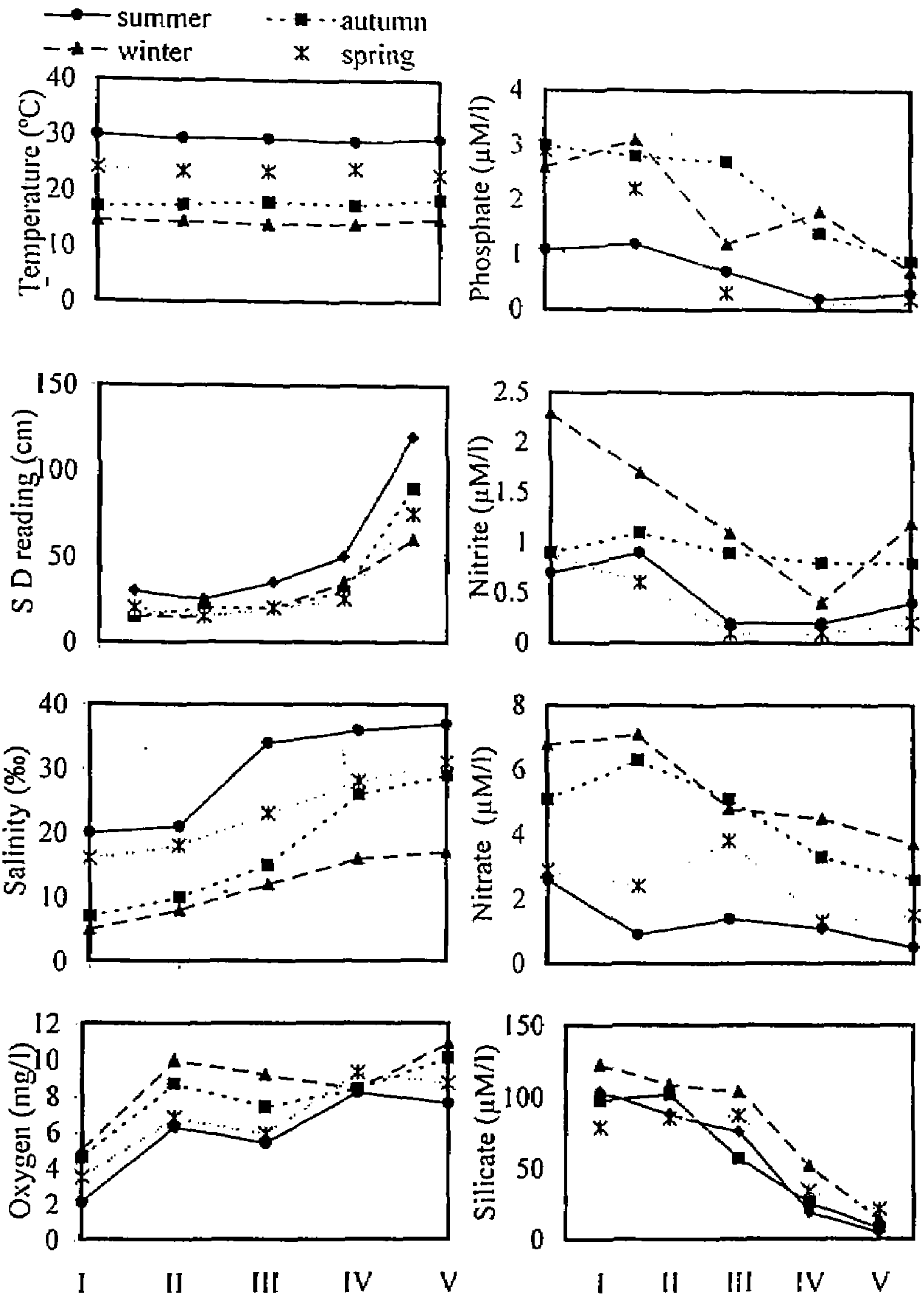

Figure (2). Seasonal variatios of physico-chemical parameters in the study area during summer 2002-spring 2003.

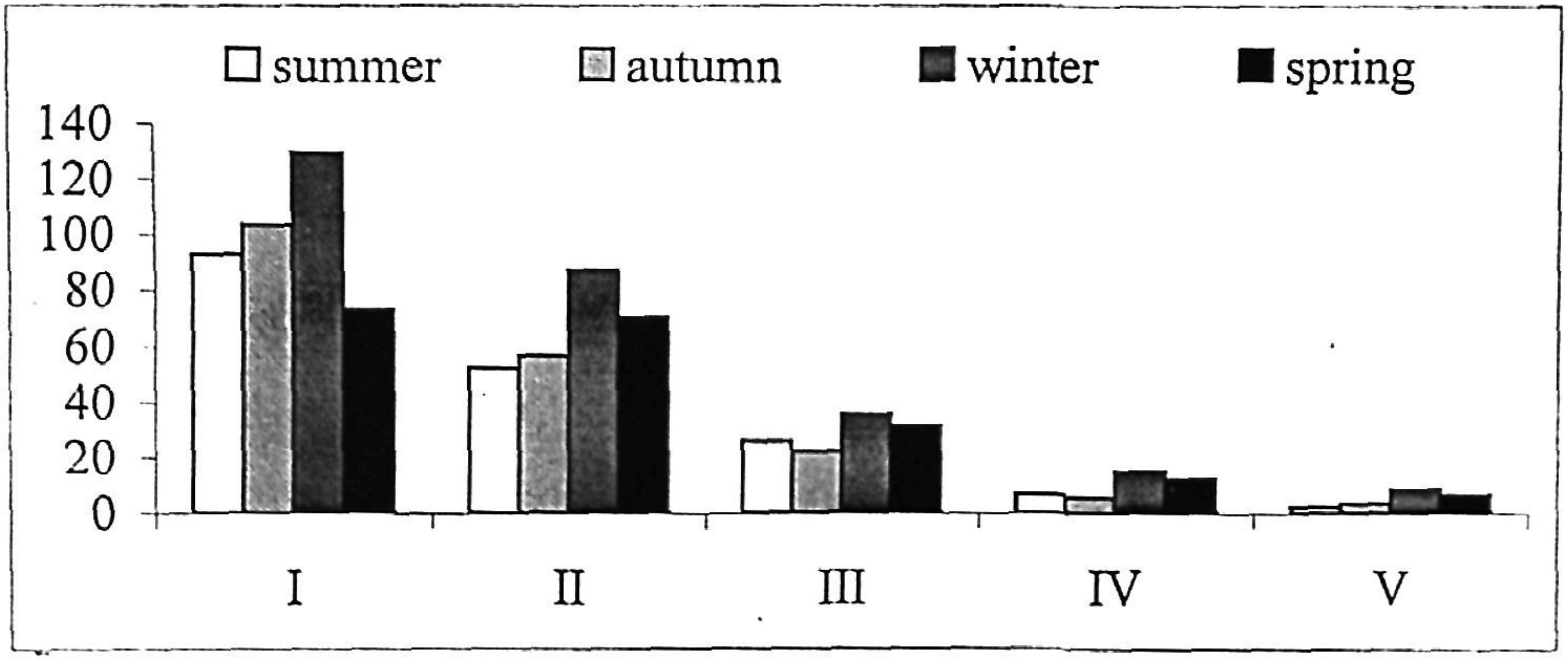

Figure (3). Seasonal distribution of chlorophyll *a* in the study area during summer 2002-spring 2003.

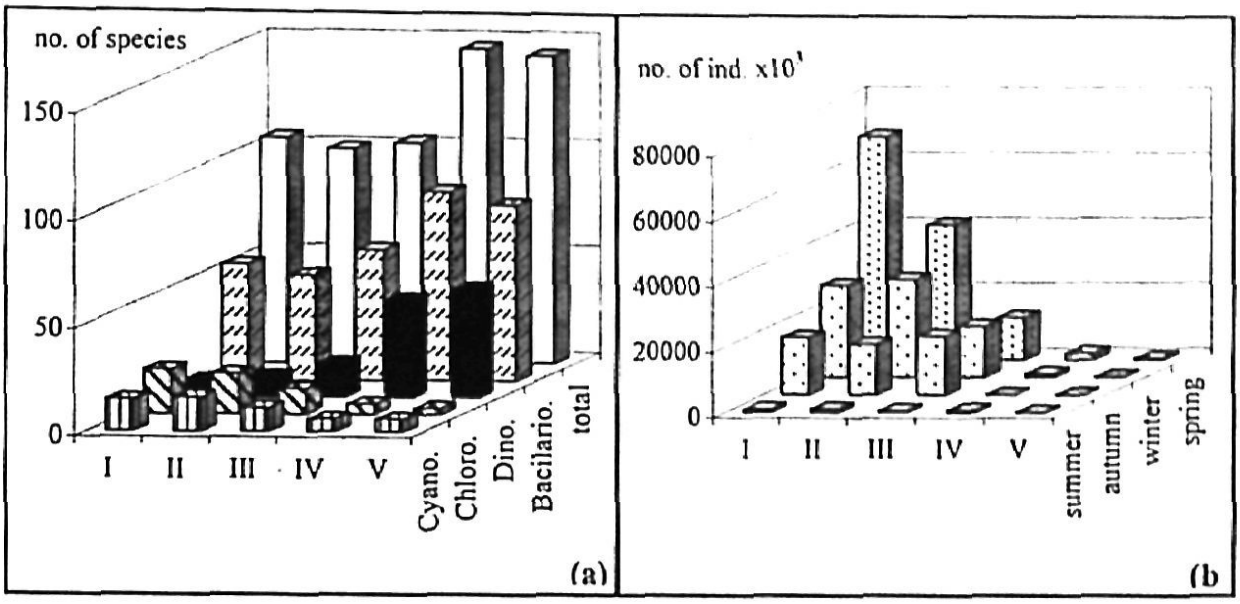

Figure (4). (a) Variations in number of species for all phytoplankton and each class, and (b) seasonal distribution of total phytoplankton standing crop at different stations through the period of study.

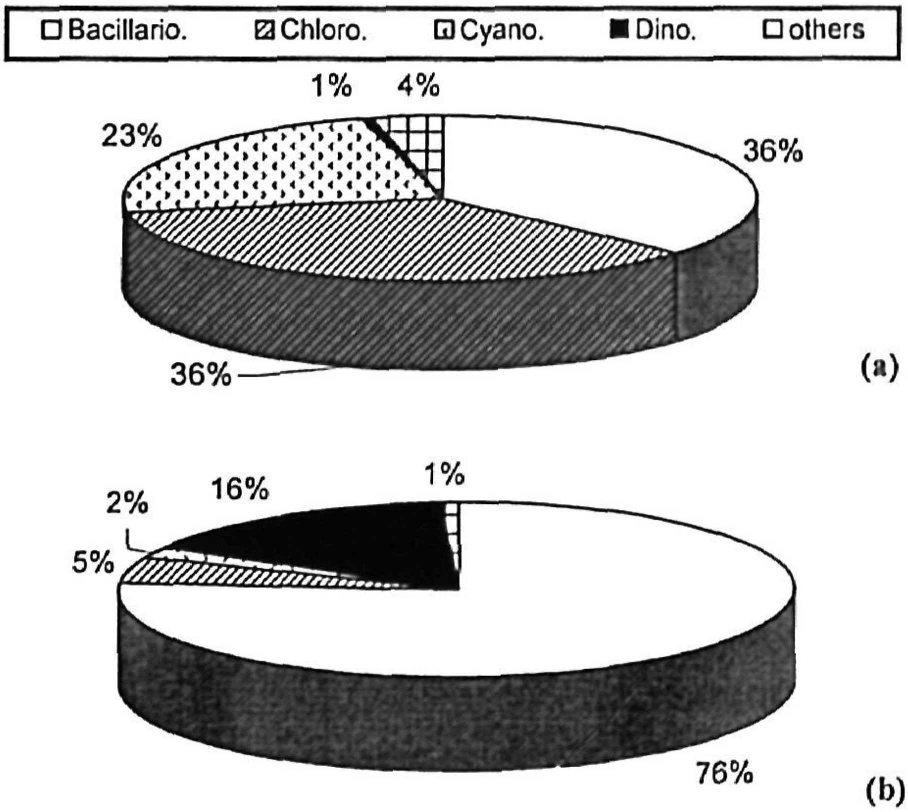

Figure (5). Relative abundance of each phytoplankton class in (a)-Lake Manzalah and El-Qabouty canal, and (b) Suez Canal.