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PHYTOPLANKTON STANDING CROP, DIVERSITY AND STATISTICAL MULTISPECIES ANALYSIS IN LAKE BUROLLUS, EGYPT.

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Key Words: Phytolpankton, Standing crop, Diversity, Multivariate analysis Egypt.

ABSTRACT

Spatial and seasonal distribution of phytoplankton standing crop in Lake Burollus were estimated the period from January, 1987 to March, 1988 which was prevailed by decreased influx of fresh water as compared to the previous records.

The phytoplankton standing crop showed a remarkable decline to about 1.04 x 10^6 units/l and it represented about 1/3 of the records obtained during the period 1978-1979. The phytoplankton was represented mainly by Bacillariophyceae (49.1 % by number to the total standing crop) and Chlorophyceae (31.6 %) while Cyanophyceae (1.7 %), Euglenophyceae (2.6 %), Dinophyceae (2.2 %) and Cryptophyceae (12.7 %) were infrequently observed. The increased counts of the latter class was attributed to a bloom of Cryptomonadales sp. which was confined to the polluted area infront of Baltim City (St. 1) during May. This was met with lowest diversity in the lake (0.38). The highest phytoplankton counts were recorded in spring and summer and were dominated by the diatoms Nitzschia spp. and Cyclotella meneghiniana, the green algae Scenedesmus spp, Ankistrodesmus spp and Tetraedron spp, beside Crytomonadales sp. at St. 1. Generally, the lake is regarded as unpolluted habitat except at station 1 and this was reflected by the high phytoplankton diversity. The data dealing with clustering and Nulti-Dimensional Scaling (MDS) of the phytoplankton community gave a good example of some statistical analysis.

Results indicate that Lake Burollus tends to mesotrophy as regards to phytoplankton production. This is attributed to the decreased amount of drain water flowing into the lake and the increased density of the submerged hydrophytes, particularly Potamogaton pectinatus.

INTRODUCTION

Lake Burollus is a shallow brackish water habitat, lying at the north of the Nile Delta, along the Mediterranean Coast of Egypt between longitudes 30° 30' and 31° 10' E and at latitude 31° 30' N. It covers an area of about 50,000 hectars (130,000 feddans). The Lake is connected with the Mediterranean Sea at its northern side through Boughaz El-Bourg and it receives most of its water at the southern margins from five main drains. Besides, Brimbal Canal opens into its western extremity and Burollus Drain at its north eastern side (Fig. 1). The Lake received drain water at monthly rates which fluctuated between 78 x 10^6 and 272 x 10^6 m^3/month during January and July, 1987 respectively, and it averaged 2,163 x 10^6 m^3/year in 1987. The average water depth in the lake is about one meter and accordingly its whole area is related to the littoral zone where the phanerogames cover extensive areas.

The present paper deals with spatial and seasonal distribution of phytoplankton standing crop in Lake Burollus, after the decreasing the influx of fresh water, as comaped to the previous estimation carried out during 1978-1979 (El-Sherif, 1983). Besides, the diversity of the phytoplankton population and species similarity (Multivariate methods) between different stations in the different seasons were estimated as statistical aspects of biological effects in field surveys.

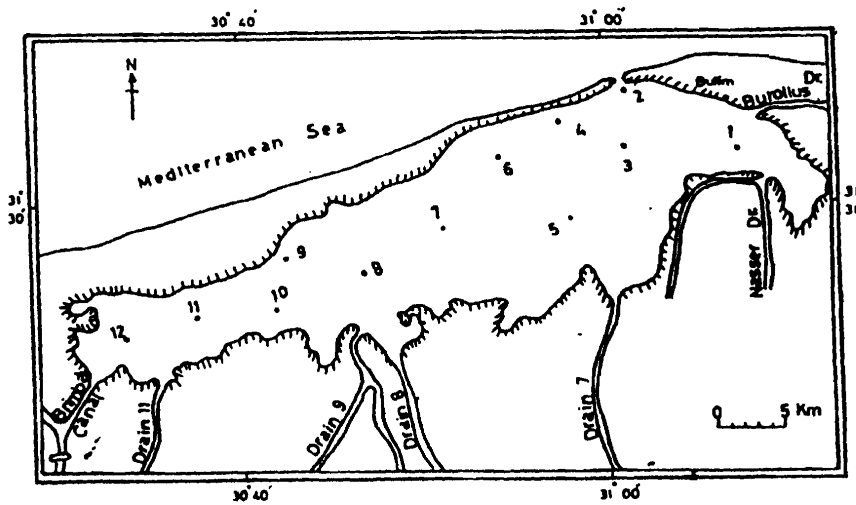

Figure 1: Lake Burollus and position of Stations.

PHYTOPLANKTON STANDING CROP.

MATERIAL AND METHODS

Sampling period and choice of stations :

Quantitative estimation of phytoplankton was carried out monthly in the lake from January, 1987 to March, 1988 at twelve selected stations representing the different habitats in the lake, their locations are shown in figure (1).

Sampling procedure :

Estimation of the standing crop of phytoplankton was carried out by using the sedimentation technique and the results are given as the total numbers of the different species in units per liter (units/l).

Species diversity :

Diversity index of the phytoplankton community was calculated on a computer, according to the equation of Shannon-Wiener (Shannon & Weaver, 1963), using Primary Program.

Species similarity :

The statistical design used to study this similarity is Multivariate Methods: Species analysis (species clustering & MDS), using Primary Program on computer. Where Hierarchical clustering (Cormack, 1971) is used to define species assemblages (spp. co-occur at stations) using Bray-Curtis similarity matrix with aim to find "Natural groupings" of the samples more similar. It is also input on Multi-Dimensional Scaling (MDS) (Kruskal & Wish, 1978) as an attempt to construct a sample map.

RESULTS

Community composition :

The phytoplankton community in Lake Burollus comprised about 110 species included in the classes Bacillariophyceae (52 spp), Chlorophyceae (38 spp), Cyanophyceae (15 spp), beside other forms of Euglenophyceae (2 spp), Dinophyceae (2 spp) and Cryptophyceae (1 sp) Appendix I.

Bacillariophyceae, as a whole contributed about 49.1 % of the total phytoplankton in the lake with annual average of 511 $\times 10^3$ cells/l. The genera Nitzschia and Cyclotella (average 294.6 $\times 10^3$ & 109.8 $\times 10^3$ cells/l respectively) were the dominant diatoms, while Melosira, Mastogloia, Synedra and Cocconeis were frequent (average 28.5×10^3, 21.2×10^3, 15.7×10^3 & 15.7×10^3 cells/l respectively). These genera represented collectively 95 % of the diatoms standing crop, the other diatoms remained rare.

Chlorophyceae represented 31.6 % of the total phytoplankton counts during 1987 (average 329×10^3 units/l). The dominant genera comprised Scenedesmus (116.5×10^3 cells/l) and to a less extent Geminella (50.4×10^3 filament/l). Tetraedron (39.7×10^3 cells/l) and Ankistrodesmus (35.7×10^3 cells/l) appeared as frequent genera, while Crucigenia, Pediastrum and Sphaerocystis (average 20.9, 11.2 & 15.1×10^3 units/l respectively) remained less frequent. The previous genera represented collectively about 88.0 % of total chlorophytes in Lake Burollus, while the others persisted as infrequent or rare forms.

Cyanophyceae were infrequently encountered in the plankton and formed only 1.7 % of the total phytoplankton (average 18×10^3 units/l). However, Merismopedia and Oscillatoria appeared in considerable numbers during scattered months. Their annual averages amounted to 7.1×10^3 and 4.97×10^3 units/l respectively. Anabaenopsis and Lyngbya were also rarely recorded with annual averages of 1.3 and 1.1×10^3 units/l. All these genera represented 80.4 % of the total blue green algae.

The other groups, namely; Euglenophyceae (2.6 %) (Euglena & Phacus), Dinophyceae (2.2 %) (Gymnodinium & Peridinium) and Cryptophyceae (12.7 %) (Cryptomonadales sp.) contributed collectively about 17.5 % of the total phytoplankton (average 182×10^3 cells/l). They remained infrequent except a bloom of a Cryptomonadales sp. (19×10^6 cells/l) was recorded in May in the polluted area infront of Baltim City (St. 1).

Spatial distribution of the total phytoplankton :

In general, the annual average standing crop of phytoplankton attained its highest values in the western sector of the lake (stations 10,11 & 12) as well as station (1) in the eastern lake which harboured a bloom of Cryptomonadales sp. (41.2 % of the total community in this station) as mentioned previously (Table 1 & Fig. 2) beside the increased numbers of diatoms (42 %) which were dominated by Nitzschia microcephala and less extent of N. reversa, N. closterium, N. frustulum, Cyclotella meneghiniana and less extent of Synedra ulna, Cocconeis placentula. On the other hand, Nitzchia microcephala, Cyclotella meneghiniana and Geminella minor and to a less extent N. frustulum, Melosira varians and Sc. acuminatus, Tetraedron minimum and Ankistrodesmus falcatus were the dominant species in the western sector.

The lowest standing crop was recorded at stations 2,3 and 4 which lie nearby to the Boughaz area (Lake-Sea connection). This may be attributed to the grazing effect of zooplankton which were more dense in these stations (El-Sherif & Abul Ezz, 1988). In the same time, sea water may also invade this area particularly during winter. Consequently, some marine plankters were

Table . . Monthly variations of total phytoplankton (1000 units/l) recorded at the different Stations of Lake Burollus during the period from January, 1987 to March, 1988.

Station Month	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10	St. 11	St. 12	Average
Jan. 1987	3358	164	585	413	320	893	1053	1893	808	5254	NS	NS	1474
Feb 1987	1629	118	328	573	273	1283	673	1356	328	400	132	2123	773
Mar. 1987	1966	200	246	300	965	164	592	248	246	264	1365	346	575
Apr. 1987	774	518	246	874	191	1128	155	382	592	901	837	1594	766
May 1987	20168	237	364	209	491	546	874	519	1019	774	1547	1219	2332
June 1987	3416	255	164	109	410	965	655	319	592	555	3312	1012	1480
June 1987	[illegible]	446	182	437	810	783	628	428	264	1356	792	1311	787
Aug. 1987	1793	2157	200	337	992	428	460	892	300	1028	2139	946	973
Sep. 1987	1620	528	764	255	746	1511	446	400	3640	655	3995	1665	1351
Oct. 1987	819	127	273	NS	NS	NS	463	482	773	573	237	719	496
Nov. 1987	1119	246	255	664	582	1083	246	355	328	582	182	329	455
Dec. 1987	2211	246	300	456	1338	1365	1238	373	992	673	2202	337	973
Jan. 1988	910	482	373	619	2258	419	1847	328	555	856	1028	519	850
Feb. 1988	592	218	1410	182	637	364	100	573	1438	665	637	1502	693
Mar. 1988	816	191	NS	255	546	473	673	246	300	628	1356	1929	674
Avg 1987	3825	437	326	421	647	923	624	637	824	1085	1526	1235	1047

NS = Not Sampled.

occasionally observed there and these comprised Asterionella japonica at St. 2 in January , 1988 and Thalassiosira rotula and Peridinium sp. at St. 4 in December 1987.

Seasonal Variations :

Generally, the highest phytoplankton counts were recorded in spring, 1987 (average 1,526 x 10^3 units/l). This was followed by a pronounced decrease during summer (1,037 x 10^3 units/l), autumn (657 x 10^3 units/l), winter 1987 (941 x 10^3 units/l) and winter, 1988 (739 x 10^3 units/l). The seasonal variations of the different classes of phytoplankton in the lake are shown in figure (3).

Bacillariophyceae appeared more dominant during spring and summer (average 576 & 698 x 10^3 cells/l). They showed a high peak in the former season at station (1) (average 3,336 x 10^3 cells/l) and was dominated by Nitzschia microcephala and to a less extent by Cycllotella meneghiniana, N. closterium, N. reversa and Cocconeis placentula. Other smaller peaks were also observed at stations 11 and 12 (1,483 & 1,016 x 10^3 cells/l) due to increased numbers of Cyclotella sp. and N. microcephala. The summer diatom peaks were recorded at stations 1,9 and 11 (averages 1,119; 1,393 & 2,135 x 10^3 cells/l respectively). Such peaks were attributed to the increased numbers of N. microcephala, N. Palea and N. frustulum; where the latter species appeared as a dominant species at St. 11; N. closterium was recorded at St. 1 with less extent. Other small increases were also observed during winter of both 1987 and 1988 (averages 406 & 421 x 10^3 cells/l respectively) at stations 1 (1,241 x 10^3 cells/l) and 12 (934 x 10^3 cells/l) respectively and were dominated by Cyclotella sp. N. microcephala and Cocconeis sp. The lowest density of diatoms was recorded in autumn (average 366 x 10^3 cells/l).

Chlorophyceae reached its maximum value in the lake during winter, 1987 (average 415 x 10^3 units/l) with its highest density at St. 10 (1,287 x 10^3 units/l), mainly due to Geminella minor, and to a less extent at stations 8 and 12 (653 & 622 x 10^3 units/l respectively) where the same species dominated the chlorophytes beside Pediastrum simplex at station 8 and Ankistrodesmus falcatus, Sc. quadricauda, Sc. bijugatus and Carteria cordiformis at station 12. On the other hand, the winter of 1988, sustained low density of green algae (average 238 x 10^3 units/l), except of a small peak recorded at St. 5 (841 x 10^3 units/l) mainly due to Sc. acuminatus, Sc. quadricauda and Sc. bijugatus.

The green algae Sc. quadricauda, Sc. bijugatus, Ankistrodesmus falcatus, Tetraedron minimum were frequently recorded at the different stations during spring (397 x 10^3 units/l). In summer, the chlorophytes remained infrequent (average 292 10^3 units/l), but showing relatively higher distribution at stations 10 and 12 (494 & 740 x 10^3 units/l) and were mostly represented by Tetraedron minimum, Ank. falcatus and Sc. bijugatus. Although, the class occupied the second important group in the lake during autumn yet it attained its minimum density with average of 211 x 10^3 units/l, except in St. 11 which harboured relatively higher counts (570 x 10^3 units/l) and was dominated by Sc. quadricauda and Tetraedron minimum.

The blue green algae appeared as infrequent forms all the year round, being more abundant at Stations 11 (100 x 10^3 units/l) and 12 (112 x 10^3 units/l) during winter 1988 and summer, 1987 and was dominated by Oscillatoria limnetica and Merismopedia spp. respectively. The other seasons sustained more or less low counts, but showing small increases in spring and winter 1987 at stations 6 and 5 respectively and these were attributed to Chroococcus dispersus and Anabaenopsis nodsonii respectively.

The other forms, namely; Cryptomonadales sp., Euglena sp. and Gymnodinium sp. showed their maximum persistence in spring (536 x 10^3 cells/l), and to less extent in winter, 1987 (average 108 x 10^3 cells/l), where the Cryptodomanales sp. contributed the main bulk of algae at St. 1 in spring. Other small peaks were recorded in autumn 1987 and winter 1988 at station 1 (616 x 10^3 cells/l) due to the increased numbers of Gymnodinium sp. and at station (551 x 10^3 cells/l) due to Euglena granulata.

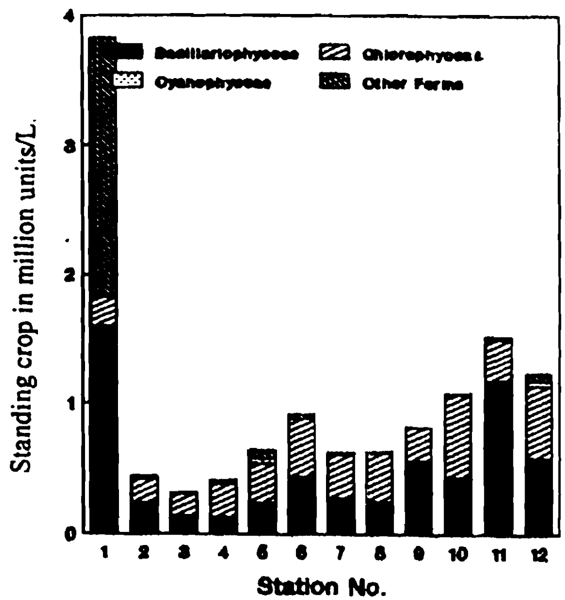

Figure 2: Annual average phytoplankton standing crop and its components (units/l) recorded in the different stations of Lake Burollus.

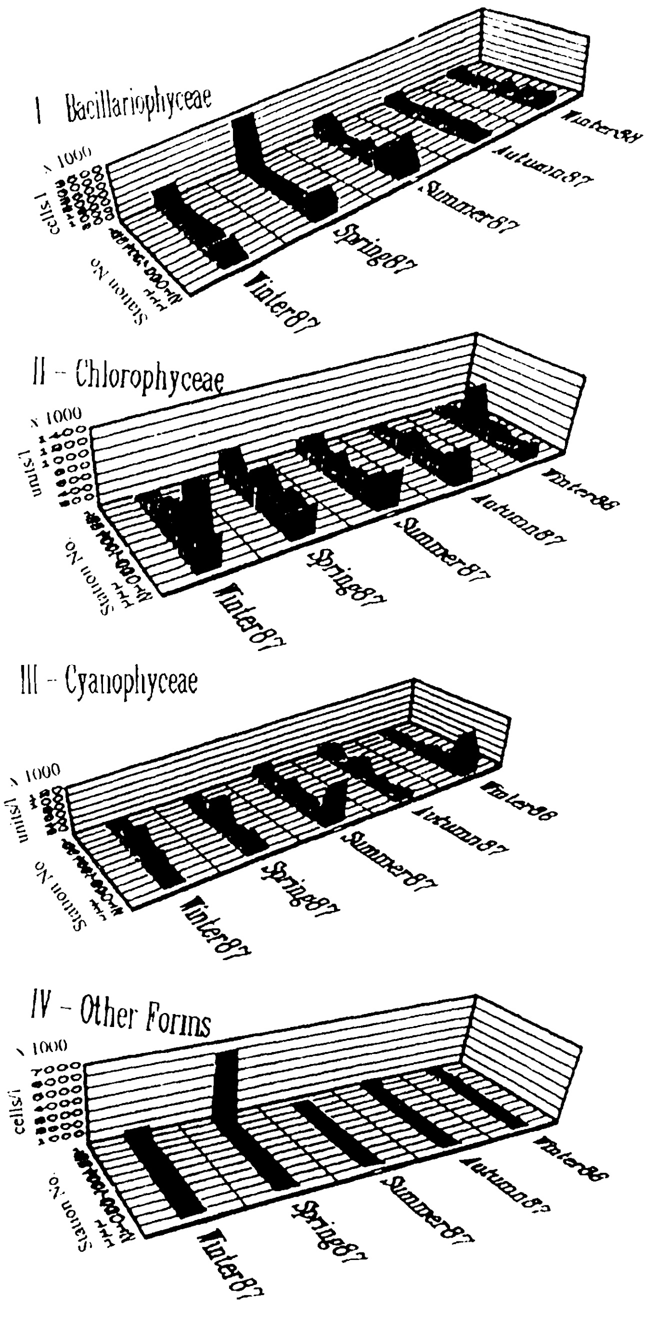

Figure 3: Seasonal variations of the standing crop of various phytoplankton classes (1000 Units/L) at the different stations in Lake Burollus.

PHYTOPLANKTON STANDING CROP.

Species diversity :

Throughout the period of investigation, the diversity differed from one month to another and within the same month from station to station. Generally, the diversity fluctuated within a wide range, the relatively higher values ranged from 1.03 to 2.93 during March and November at Stations 11 and 6 respectively. While the low diversity were observed in spring (May & June) at St. 1, attaining 0.38 and 0.75 respectively, in summer (August & September) at St. 9 with values 0.93 and 0.43 respectively and in winter (January, 1987) at stations 6 and 7 with average value 0.89.

Multivariate Methods (Species similarity) :

The dendrogram and multidimentional scaling (MDS) illustrating station affinities based on the mean root-root transformed abundance of 110 species of phytoplankton were estimated at the different stations in the lake, using the Bray-Curtis measure of similarity and group-average sorting throughout 15 months, which were further grouped into 5 seasons as follows :

Winter, 1987: (Jan,m Feb. & March) :

As shown in Figure (4 A) stations affinities with similarity level 49 % delineates two groups, the first one comprises stations 12,5,10,8,9,7,6,4,3 and it is further divided into four homogeneous subgroups, namely; stations (5-12), (10-8), (9,7-6,4,3) and St. 2 with 61 % similarity level. The second group comprises stations 1 & 11. Figure (5A) illustrates multidimentional scaling (MDS) using the same similarity matrix as above, delineating groups of stations from the dendrogram (Fig. 4A), This analysis gives essentially the same picture as the dendrogram. The minimum amount of drain water was discharged into the lake during this season (average 105.9 x 10^6 m^3/month).

Spring 1987: (April, May & June) :

The dendrogram showing stations similarity level of 48 %, delineates two groups: The first one is divided into 2 homogeneous subgroups, namely stations (12-8, 11, 5-10) and stations (9-6, 3-2, 4,7) with similarity level of 52 % (Fig. 4B). The second group was represented only by St. 1 which harboured a bloom of Cryptomonadales sp. during this season (May) as a result of intensive pollution. These results were confirmed by MDS (Fig. 5B), where the drained water introduced to the lake was about 171.4 x 10^6 m^3/month.

Summer, 1987: (July, Aug. & Sept.) :

The similariy level of 48 % delineates two groups of stations (Fig. 4C). Group 1 represents the major one and it is divided into three homogenous subgroups which comprise stations (12,5-1); stations (10-8,7-4,6,2) and stations 3 with 54 % similarity level. Group 2 comprise stations (9-11). Figure (5C) shows the results of MDS using the same similarity matrix as above, delineating

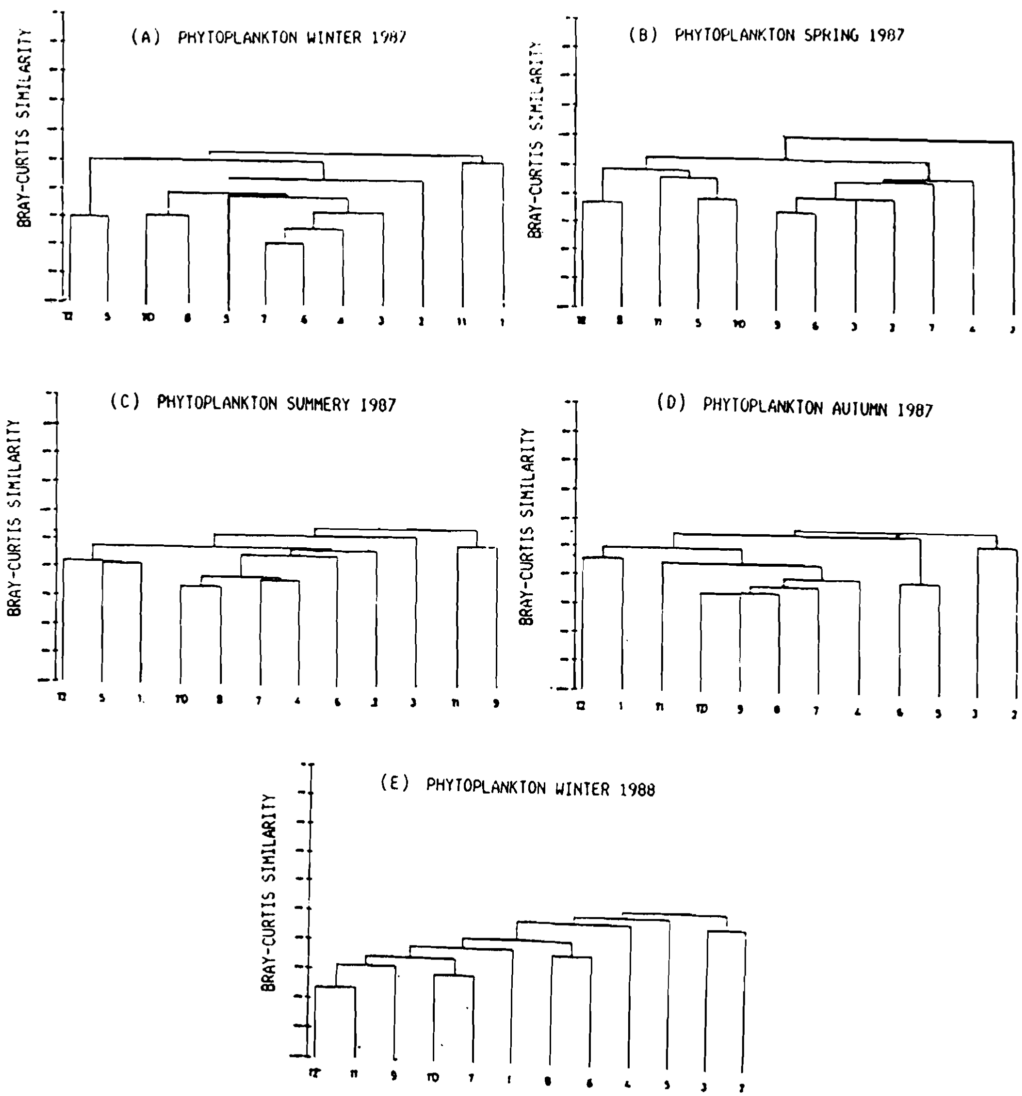

Figure 4: A-E. Dendrogram for group-average clustring of Bray-Curtis similarities for 110 species form a2 stations (after reduced species by including those with counts > 4 % of total at any one station) during 5 seasons.

group of stations from the dendrogram (Fig. 4C). This analysis has essentially the same picture as the dendrogram. This period coincided with maximum discharge of drain water into the lake which amounted to 258 x 10^3/ month.

Autumn, 1987: (Oct., Nov. & Dec.) :

The dendrogram classification in autumn, 1987 (Fig. 4D) showing similarity level of 45 % delineates two groups. The first is divided into three homogeneous subgroups which include stations (1-12); stations (4,7,8,9-10, 11) and stations (5-6) with similarity of 54 %. Group two includes stations 2 and 3 which lie nearby to the Bougaz area. In MDS (Fig. 5D) ordination delineating groups of stations from the dendrogram (Fig. 4D). This analysis possesses the same picture as the dendrogram: Stations [(1-12), (5-6) and (4,7,8,9,10,11)] and (2 & 3) are closely clustered and conform to grouping defined from the dendrogram. The amount of drain water in this season amounted to 185.7 x 10^6 m^3/month.

Winter, 1988: (Jan., Feb. & March) :

The dendrogram classification in winter, 1988 (Fig. 4E) showed similarity level of 50 % delineates two groups. The first one comprised most stations, namely; (5,4,6-8,1) and (7-10,9,11-12) where the last subgroup was closely clustered with 67 % similarity level which is confirmed with MDS (Fig. 5E). The second clustered group included stations 2 and 3 and conform to a group. This season was similar to the previous one in clustering stations and in both the amount of drainage water introduced into the lake (180.3 x 10^6 m^3/month) and the magnitude of the standing crops of phytoplankton.

DISCUSSION

Results of the present investigation indicate that Lake Burollus harboured lower phytoplankton standing crop during the year 1987 when compared with that previously recorded during 1978-1979 (El-Sherif, 1983). This is attributed to a direct effect of the decreased amount of drain water flowing into the lake, as a result of the decreased annual Nile flood in 1987.

Significant changes in the nutrient load of the lake were also traced during the last decade. Thus, the level of nitrogen (mainly nitrate) has decreased by about two times since 1978, while on the contrary, the concentration of the reactive phosphorus and silicon have increased about 8 and 2.5 times respectively (Table 2). The ratios between these elements were also subjected to wide variations. The probable cause of such variations may be attributed to the quality of the drainage water entering the lake of which a big portion comes from reclaimed lands. The reduction of rich silicon Nile water reaching the lake was opposed by the continual invasion of marine water through the lake-Sea connection. Such changes were reflected on the present status of phytoplankton population and consequently on fish yield of the lake. Thus, the average standing crop of phytoplankton showed a remarkable decline to about 1.04×10^6 units/l and it represented about 1/3 of the previous records which amounted to 2.7×10^6 and 3.4×10^6 units/l during 1978 and 1979 respectively (El-Sherif, 1983). The Community composition was also reduced to 110 species, including 52 diatoms, 38 green algae, 15 blue-green algae and 5 species of other forms. The former class (Bacillariophyceae) formed numerically the main bulk of the population during the present investigation. The percentage frequency of the three main groups changed to 49.1 %, 31.6 % and 1.7 % for diatoms, chlorophytes and cyanophytes respectively while these values were 26.8 %, 53.5 % and 18.7 % in 1978-79. The increased numbers of diatoms may be attributed to the increased concentration of silicon since it is contributed in the formation of their frustules (Donoso & Phinney, 1988; Gouni & Tsekos, 1989). The more dense growth of hydrophytes particularly Potamogaton pectinatus in Lake Burollus, specially at the eastern region, was accompanied by a drop in nitrite as a result of its consumption by these plants (Riely & Chester, 1971). These aquatic plants have inhibiting effect on the growth of green algae (Tilman et al., 1986).

Table (2): The annual average values of different nutrient components (ug at/l) and the mean N/P and Si/P ratios in Lake Burollus during 1978, 1979 & 1987.

Year	1978	1979	1987
Auther	El-Sherif, 1983		Abdel-Moati et al, 1988
NO_3	1.97	1.56	0.84
PO_4	0.25	0.13	1.61
SiO_2	--	25.5	66.83
N/P	12:1	17:1	7:1
Si/P	--	196:1	41:1

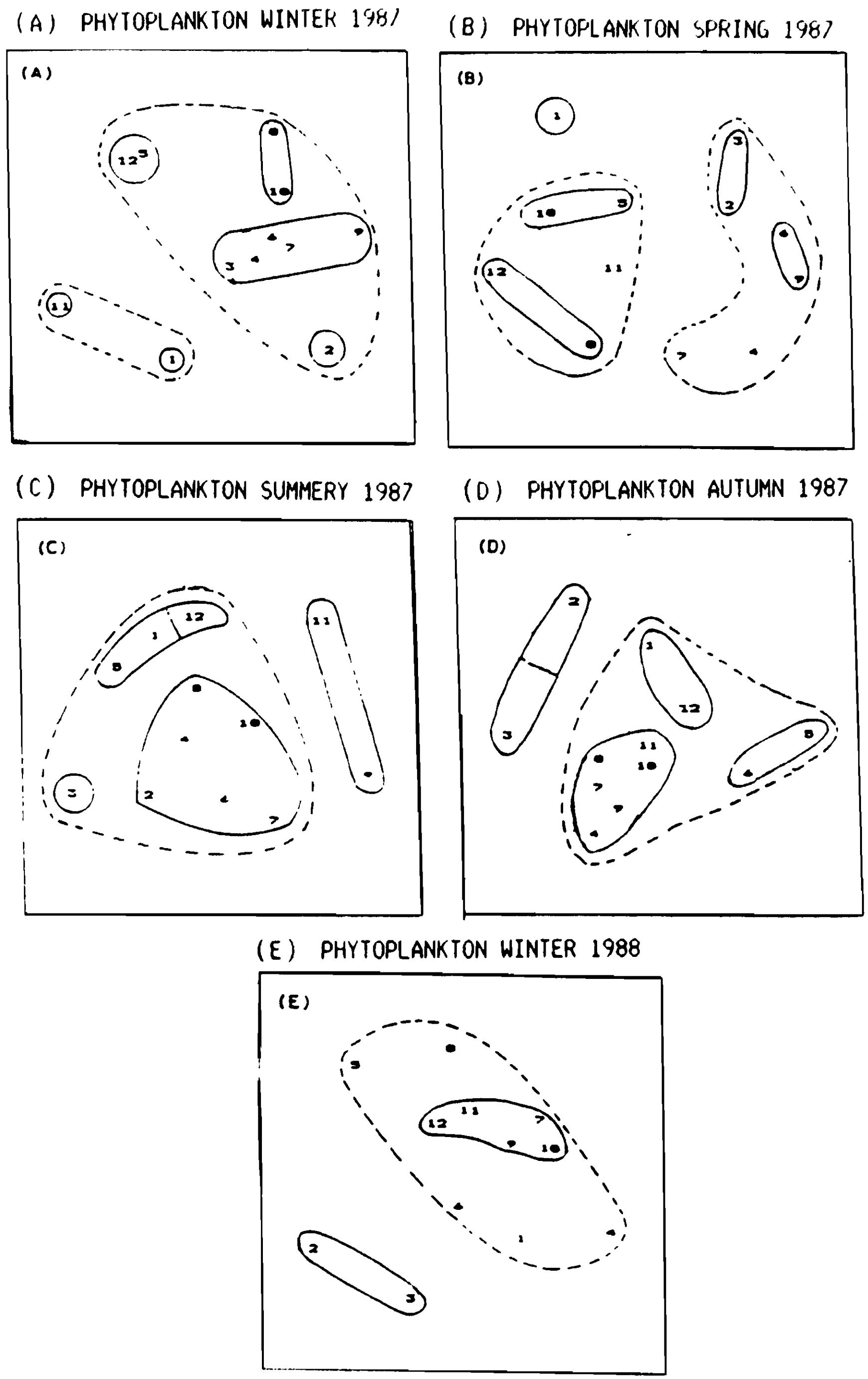

Figure 5: A-E. Multi-Dimentional Scaling (MDS) ordination Main groups from cluster analysis indicated, by similarly in species counts during 5 seasons. (Stress: (A) 0 12, (B) 0.17, (C) 0.16, (D) 0.14, (E), 0.15).

Generally, a reverse relationship existed between phytoplankton production and the growth of hydrophytes where the highest standing crop of phytoplankton recorded at western stations coincided with the lowest density of hydrophytes. This is similar to the previous estimations carried out on the same Lake (El-Sherif, 1983) and in Lake Maruit (Aleem & Samaan, 1969 II). Also the controlling effect of zooplankton on phytoplankton production in Lake Burollus was discussed by El-Sherif and Aboul Ezz (1988). The annual averages of the two communities showed a linear relationship at the western sector of the lake which harboured highest standing crop of both phytoplankton and zooplankton i.e. Thus, the consumption rate of phytoplankton by zooplankton is less pronounced. On the other hand, a monthly reverse relation was observed between them as a direct effect of grazing. The increased frequency of the other forms is attributed to its blooming of Cryptomonadales sp. during May infront of Baltim City (St. 1) as result of increased organic pollution. This was met with lowest diversity in the lake (0.38).

The distribution of phytoplankton was generally similar to the previous data, where the highest standing crop was recorded in the western lake and it decreased gradually towards the east, except St. 1 as mentioned before. However, the phytoplankton community showed different seasonal periodicity within the years 1978-1979 and in the present study (1987). The peaks were generally observed in late summer, 1978 due to the increased numbers of the blue-green algae Lyngbya limnetica and in autumn, 1979 as produced by green algae Dictyosphaerium pulchellum. These two species were recorded as rare forms in the present study, while the other peak was observed in late spring 1987 due to Cryptomonadales sp. at St. 1 and to the diatom Nitzschia microcephala in most stations.

Most of the species inhabiting the lake are eurythermic forms and can tolerate a wide range of temperature. They appeared all the year round but showing maximum persistence during one season or the other. Thus, the dominant diatom Nitzschia microcephala beside N. palea and N. frustulum showed their maximum abundance during summer, while Cyclotella meneghiniana and N. microcephala prevailed in spring. This is similar to the previous results on Lake Burollus, except that Cyclotella was more abundant in autumn, 1979 (El-Sherif, 1983). Also, the maximum persistence of green algae in the lake was recorded in spring and winter, 1987 and it was dominated with Scenedesmus quadricauda, Sc. bijugatus, Tetraedron minimum and Ankistrodesmus falcatus. They showed the same distribution pattern in Lake Burollus during 1978-79. While Geminella minor flourished well in winter 1987, which is in contrast to the previous data on the lake, since it was more abundant in spring 1978 and autumn 1979. For blue green algae, their highest counts appeared in summer and were dominated by Merismopedia punctata and M. minimum. This is dissimilar to the results of 1978, since they appeared more abundant in autumn and were dominated by Lyngbya limnetica and Merismopedia minimum, by similar to the previous records in Lake Edku (Samaan, 1974) and Lake Maruit (Aleem & Samaan, 1969 II). Thus, the individual groups of the community showed seasonal succession in accordance with change of temperature similar to the observations of Behrendt (1990) and Sommer et al, (1986).

The results of diversity revealed that the lake has a greater variety of species (high diversity). Its maximum 2.93 was recorded in November at St. 6, due to the increased number of species. On the other hand, the lower diversity appeared at stations 6 and 7 (0.89) in January 1987 and at St. 9 (0.93) in August, 1987 (6,6 & 5 species respectively) and this was accompanied with a pronounced decrease in the standing crop of phytoplankton. The same case was met with at St. 1 in June (0.75) where Nitzschia microcephala formed about 86.5 % of the total phytoplankton, while the minimum diversity appeared there in May (0.38) and was accompanied with a bloom of Cryptomonadales sp. which represented numerically about 93.6 % of the total phytoplankton. Lower diversity was also observed at St. 9 in September (0.42) and the community was dominated by Nitzschia palea (92.5 % of the total). Villegas and De-Giner (1973) reported that the non polluted water, have a greater variety of aquatic life, and substantial additions of pollutants reduce the number of species. Generally, Lake Burollus is regarded as an unpolluted habitat with the exception of St. I.

Both the spatial distribution and monthly variations discussed above are based on the abundance of species at each station from the monthly series samples. Each individual sample was run on the clustering and MDS programs to get a picture of the sample variability and the samples were further grouped into 5 seasons. Multidimensional Scaling (MDS) confirmed the existance of clear groups which were emphasized by delineating the dendrogram groups on the MDS plot. Where MDS analysis (after excluding the rarer species to reduce computer storage and time) produced clusters of species which correspond well with the station group. According to Warwick and Clarke (1991), Multivariate methods (Clustering & MDS) have the advantage of great sensitivity and generality of response, but in themselves are indicative only of aommunity changes which can be difficult to interpret in terms either of value judgments or of the possible cause.

In all the phytoplankton species presented above, the results of the multivariate analysis indicate the robustness of multivariate analysis to species aggregation at stations 2 and 3 during most seasons due to the effect of sea water intriduced into the lake, while the other stations were subjected to different amounts of fresh water flowing into the lake during the different seasons. Besides, the increase of temperature throughout spring and summer and increase in species diversity, with except St. 1 during spring (May).

These analysis illustrate 2 or 4 groups of stations existing in different seasons, 2 or 4 habitats, with more or less similarity in species composition as follows: Group I: Comprise stations (2-3) which lay nearby to the Boughaz region and are affected by sea water invasion. They were closely clustered and conform to group in spring 1987, autumn 87 and winter 88. This was restricted to station 2 in winter, 87. The marine diatoms, Thalassiosira rotula and Asterionella japonica were occasionally recorded at these two stations. Group II: It comprises stations (6,9,4,7) at the southern side of the lake, where it was accasionally affected by sea water during winter, 78 and spring i.e. it is a brackish water habitat. Group III: It is represented by stations (5,8,10,12) located at the northern side and being mostly fresh water habitat. Group IV: It comprises stations 1 and 11 where they were grouped in winter, 78, but separated in spring, when St. 1 was subjected to pollution.

The two seasons, autumn, 87 and winter, 88 are similar, delineate two groups of stations, the first one comprises stations of group I (2 & 3) as mentioned before. The second group comprises the other ten stations (Group II, III & IV), where the two seasons had the same standing crop and received the same amount of drain water (185.7 & 180.3 x 10^6 m^3/month respectively)> While the summer is classified into two different groups, the major one comprises stations (1,2,3,4,5,6,7,8,10,12) and it coincided with the maximum amounts of drain water introduced in this season, and the latter indludes stations (9-11) which possess lower diversity with few number of species.

The phytoplankton community in Lake Burollus consists mostly of fresh water forms which can exist under brackish conditions and the variations of chlorosity have but little effect on their distribution.

In conclusion, Lake Burollus tends to a gradual mesotrophy when considering the decrease in the standing crop of phytoplankton (average 1.04 x 10^6 units/l), compared with the previous data on the same Lake (averages 2.7 & 3.4 x 10^6 units/l during 1978 & 1979 respectively). This may be attributed to the decreased amounts of drain water flowing into the lake and the increased density of the submerged hydrophytes in the lake which cover extensive areas nowadays. Thus, the cover of these hydrophytes should be reduced to increase the phytoplankton production.

The results presented as clustering and MDS give a good example of some statistical analysis that can be applied to the biological data.

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APPENDIX I

Check List of Phytoplankton Species Recorded in Lake Burollus (1987-88).

I - Bacillariophyceae :

Cyclotella meneghiniana Kiitz
Nitzschia obtusa W. Sm.
Nitzschia microcephala Grun
Nitzschia longissima (Breb.) Ralfs.
Nitzschia palea (Kiitz.) W. Sm.
Nitzschia closterium Sm.
Nitzschia punctata (Sm.) Grun.
Nitzschia apiculata (Greg) Grun.
Nitzschia amphibia Grun.
Nitzschia sigma (Kiitz.) Sm.
Nitzschia frustulum (Kiitz.) Grun.
Nitzschia acuminata W. Sm.
Nitzschia reversa W. Sm.
Synedra ulna Ehr.
Synedra tabulata Kiitz.
Synedra longissima W.Sm.
Cocconeis placentula Ehr.
Bacillaria paradoxa Gmel.
Gomphonema subclavatum Grun.
Gomphonema olivacum Kiitz.
Gomphonema constrictum Ehr.
Gomphonema intriactum Kiitz.
Gomphonema gracile Ehr.
Mastogloia braunii Grun.
Mastogloia elliptica (Ag.) Cleve
Mastogloia smithii Thw.
Epithemia zebra (Ehr.) Kiitz.
Rhoicosphenia curvata Grun.
Rhopalodia gibba (Ehr.) O. Miller
Rhopalodia gibberula (Ehr.) O. Miller
Diploneis didyma Ehr.
Navicula humerosa Breb.
Navicula schizonemoids H. Van Heruck
Navicula cryptocephala Kiitz.
Navicula sp.
Navicula yarrensis Grun.
Navicula cuspidata Kiitz.
Pleurosigma elongatum Sm.
Pleurosigma macrum W. Sm.
Melosira granulata (Ehr.) Ralfs.
Melosira varians Ag.
Amphiprora paludosa Sm.
Amphora ovalis Kiitz.
Amphora coffeoformes Ag.

APPENDIX 1 (Cont.)

Cymbella affinis Kiitz.
Campylodiscus clypeus Ehr.
Campylodiscus echeneis Ehr.
Podosira montagnei Kiitz.
Biddulphia laevis Ehr.
Surirella striatula Turp.
Thalassiosira rotula Meun.
Asterionella japonica Cleve

11 - Chlorophyceae :

Tetraedron minimum (A. Braun) Hansg.
Tetraedron proteiforme (Turn) Brunnthaler
Carteria cordiformis (Carter) Dill.
Scenedesmus quadricauda (Turp.) Breb
Scenedesmus bijugatus (Turp.) Kiitz.
Scenedesmus bijugatus var. alternans Hansg.
Scenedesmus diagonals S. Fang.
Scenedesmus opliensis Rich.
Scenedesmus acuminatus (Lagerh.) Chodat.
Scenedesmus armatus (Chodat) G.M. Smith
Cosmarium sublateraundulatum W. & G.S. West
Cosmarium galeatum W. & G.S. West.
Cosmarium elfungii Racib.
Cosmarium subtumidum Nordst.
Cosmarium subcrenatum Hantzach.
Sphaerocystis schroeteri Chodat.
Ankistrodesmus falcutus var mirabile W. & G.S. West.
Ankistrodesmus falcutus var spirilliformis G.S. West.
Ankistrodesmus falcutus var acicularis (A. Broun) G.S. West
Ankistrodesmus setigerus (Schrod) G.S. West
Pediastrum duplex Meyen
Pediastrum simplex Meyen
Pediastrum tetras (Ehr.) Ralfs
Pediastrum boryanum (Turp.) Menegh.
Crucigenia tetrapedia (Kirchn.) W. & G.S. West.
Crucigenia quadrata Morren.
Pandorina morum (Mill.) Bory.
Kirchneriella lunaris (Kirchn.) Moebius
Closterium parvulum var angustum W. & G.S. West.
Oocystis borgei Snow.
Actinastrum hantzschii Lagerh
Nephrocytium limneticum G.M. Smith
Selenastrum gracile Reinsch.
Geminella minor (Nag.) Hansg.

APPENDIX I (Cont.)

Golenkinia radiata Chod.
Franceia droescheri (lemm.) G.M. Smith
Chodatella subsala Lemm.
Dictyosphaerium pulchellum Wood.
Oedognium sp.
Spirogyra hassallii (Jenner) Petit.
Chlamydomonas reinhordi Dang.

III - **Gyanophyceae :**

Merismopedia punctata Meyen.
Merismopedia minima Beck.
Microcystis aeruginosa Kiitz.
Aphanocapsa pulchra (Kiitz) Rabenhorest
Coelosphaerium confertum W. & G. West
Dactylococcopsis irregularis G.M. Smith
Chroococcus turgidus (Kiitz) Naegeli
Chroococcus dispersus (Keissl.) Lemm.
Chroococcus tenuis Agardh.
Oscillatoria limnetica Lemm.
Oscillatoria lacustris (Kleb) Geitl.
Oscillatoria princeps Vaucher.
Anabaenopsis circularis (G.S. West) Wol. & Miller
Lyngbya limnetica Lemm.
Anabaena sp.

IV - **Other Forms :**

Phacus setosa France.
Euglena granulata (Klebs) Lemm.
Gymnodinium sp.
Peridinium sp.
Cryptomonadales sp.