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# *ZOOPLANKTON OF LAKE BUROLLUS (EGYPT)*

BY

S. M. ABOUL EZZ*

***National Institute of Oceanography and Fisheries, Alexandria (Egypt).**

**Key words : Zooplankton, Diversity, Statistical Multispecies analysis**

## *ABSTRACT*

*Annual average and seasonal variations of zooplankton stocks in Lake Burollus were estimated in the period from April, 1987 to March, 1988 which was characterised by decreased influx of fresh water as compared to the previous records.*

*The zooplankton population showed a remarkable increase during the present investigation (182.8 x $10^3$ organisms/$m^3$) when compared with the records during the period 1978, 1979 (111 x 103 & 45 x 103 organisms/m3 respectively). The zooplankton was mostly composed of crustacean groups which formed 71.8 % by number of the total zooplankton population, followed by Rotifera (15.5 %) and Protozoa (11.4 %). Other groups such as; Insects larvae, free living nematodes, polychaete larvae, veligers of molluscs and fish eggs contributed about 1.3 % of the total population. The highest zooplankton density was recorded in winter and autumn and was dominated by Copepoda specially* ***Acanthocyclops americanus, A. vernalis*** *and* ***larvae*** *of copepods. Generally, the lake is regarded as unpolluted habital and this reflected by the high species diversity. Results indicate that Lake Burollus tends to mesotrophy, this is attributed to the decreased amount of drain water flowing in to the lake and increased density of the submerged hydrophytes, particularly* ***Potamogaton pectinatus*** *(El-Sherif, 1993).*

## INTRODUCTION

Lake Burollus is a shallow brackish water system lying at the north of the Nile Delta along the Mediterranean coast of Egypt between longitudes 30° 30' and 31° 10' and latitude 31° 35' N. It covers an area of about 50,000 hectar (130,000 feddans) with an average depth of 115 cm. (Aboul Ezz, 1984). The lake is connected with the Mediterranean at its northern side through Boughaz El-Bourg and receives most of its water at the southern margins from five drains namely; Nasser Drain, Drains 7,8,9 and 11. Besides, Brimbal canal opens into the western extremity of the lake and Burollus Drain at the north eastrern side of the lake (Fig. 1). The lake received drain water at monthly rates which fluctuated between 78 $X10^6$ and 272 $X 10^6$ $m^3$/month during January and July, 1987 respectively and it averaged 2,163 $X10^6$ $m^3$/year in 1987( compiled from the Ministry of irrigation). The water depth in the lake ranges between 50 & 160 cm. The deepest part lies about the middle of the lake and the depth of water decreases gradually towards the margins. According to the shallowness of the lake, the whole area is related to the littoral zone where the phanerogames are widely distributed and cover most of the eastern sector as well as the margins.

The aim of the present investigation is to study the standing stock and the species composition of the different zooplankton groups in Lake Burollus during the period, April, 1987 to March, 1988, after decreasing the influx of freshwater. The results were compared with the previous studies carried out during 1978-1979 (Aboul Ezz, 1984). Besides, the diversity of the zooplankton population and species similarity (Multivariate methods) between different stations in the different seasons were estimated.

## MATERIAL AND METHODS

The zooplankton samples were collected by filtering 250 litres of the lake water at each station through a small standard plankton net No. 25 (mesh size 50 μm) using a plastic container of ten litres capacity. The collected samples were preserved directly with 4 % formalin solution. The volume of each sample was concentrated to 100 ml and subsamples of 5 ml were transferred into a counting cell and each plankter was counted separately using a research binocular microscope. The density of the zooplankton organisms was calculated as their total numbers per cubic meter.

Quantitative estimation of zooplankton was carried out monthly in the lake from April, 1987 to March, 1988. Twelve stations were selected as representing the different habitats in the lake, their locations are shown in figure (1). The stations were further grouped into three main sectors namely; eastern lake (stations 1-4), middle lake (stations 5-8) and western lake (stations 9-12).

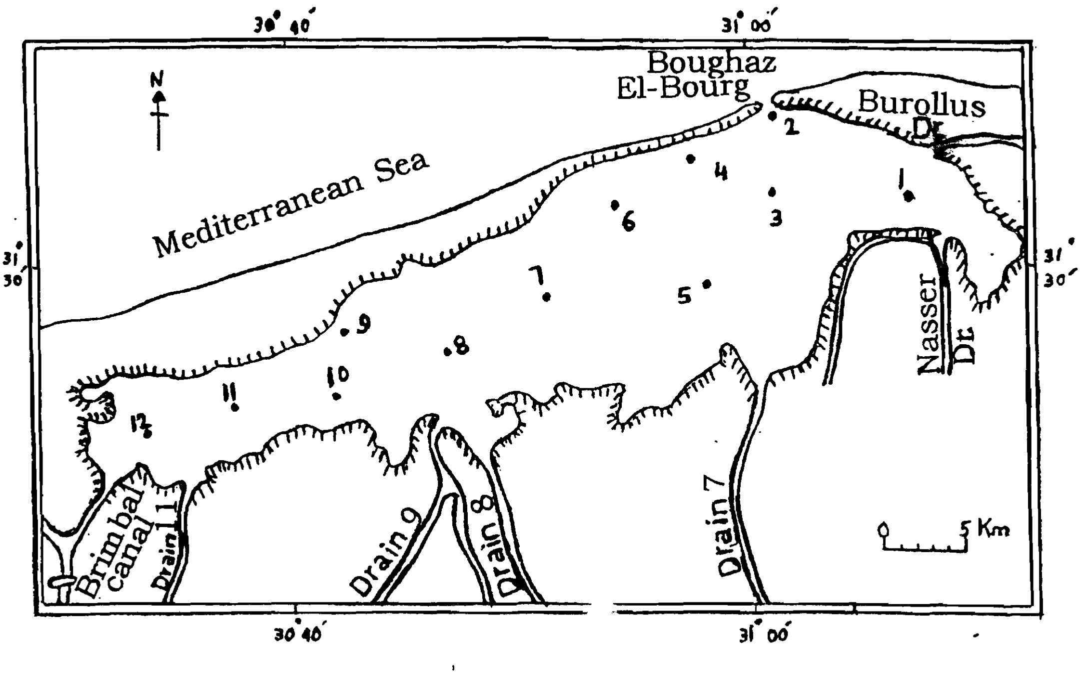


Fig. (1): Lake Burollus and position of stations.

Diversity indices of the zoóplankton community were calculated on a computer according to the equations :

- Shannon and Weaver (1963).

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

where Pi = ni/N is the proportion of the number of individuals of species i to the total number (N) of zooplankton.
ni = the total number of species in the sample.

- Margalef's equation of Richness (1968)

$$D = (S-1) / \ln N$$

where D = richness, S = number of species
N = total number of individuals in the sample

- Heip's equation of Equitability or Evenness (1974) based on the Shannon -Weaver information function H :

$$E = (e^H - 1) / (S-1)$$

where E = equitability
e = 2.1783 (base of natural logarithm)

The statistical design used to study the similarity is Multivariate Methods: Species analysis (species clustering and Multidimensional Scaling (MDS), using primary program on a computer. Where Hierarchial 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 and Wish, 1978) as an attempt to construct a sample map.

Biomass of the total zooplankton was measured gravimeterically by wet and dry weights for each station in the different months.

## *RESULTS*

**Community composition of zooplankton**

The zooplankton population recorded during the present investigation comprised 90 species included in the four main groups namely; Copepoda (26 spp), Cladocera (7 spp), Rotifera (26 spp) and Protozoa (10 spp). They constituted collectively about 85 % by number of the total zooplankton. Other infrequent forms (15 %) were also recorded and these comprised 21 species beside, cirripede larvae, larval stages of decapods, insect larvae, polychaete larvae, veligers of molluscs and free living nematodes (Table 1) .

Copepoda and its larvae were the most important group since it formed about 36.6% by number of the total zooplankton in the lake with annual average of 67 x $10^3$ $m^3$. ***Acanthocyclops americanus*** and ***A. vernalis*** (average 34 x $10^3$ & 10 x $10^3$ organisms.$m^{-3}$ respectively) appeared the most dominant species while, ***Oncychocamptus mohammed*** was frequently recorded with annual average of 5 x $10^3$ organisms.$m^{-3}$ (7.4%). These three species contributed collectively 68.5% of the total copepoda. Other copepod species appeared rare.

Cladocera ranked the second important group in Lake Burollus during this period and formed about 21.8% by number of the total zooplankton with annual average 40.3 x $10^3$ organisms.$m^{-3}$. The dominant species are ***Moina micrura*** and ***Diaphanosoma excisum*** averaged to 20 x $10^3$ (50 %) & 15.8 x $10^3$ (39.5 %) organisms.$m^{-3}$ respectively). ***Alona intermedia*** was frequently recorded with annual average 4 x $10^3$ organisms.$m^{-3}$ (10% of the total cladocera) and to less extent ***Oxyurella longicauda*** (average 473 organisms. $m^{-3}$). While ***Ceriodaphnia reticulata***, ***Bosmina longirostris*** and ***Chydorus ovalis*** appeared very rare.

Rotifera were infrequently encountered and formed 15.5% of the total zooplankon population (average 28.3 x $10^3$ organisms.$m^{-3}$). They were represented by 26 species, dominated by the genus ***Brachionus*** which

Table (1): Check list of Zooplankton species recorded in Lake Burollus.

| | Groups | 1978 | 1979 | 1987-1988 |
|---|---|---|---|---|
| | ***I - Protozoa*** | | | |
| | *Ammonia beccarii* Linn | + | + | + |
| | *Centropyxis aculeata* Ehr. | | | + |
| | *Centropyxis ecornis* Ehr. | | + | + |
| | *Cyclogramma trichocystis* Stokes | | + | + |
| | *Urostyla grandis* Ehr. | + | | + |
| | *Amphileptus claparedei* Stein | + | | |
| | *Plagiophyla nasuta* Stein | | + | |
| | *Tintinnopsis cylindrata* Kof. & Campb. | | | + |
| | *Tintinnidium fluviatile* Stein | | | + |
| | *Codonella cratera* Leidy | | | + |
| * | *Favella ehernbergi* Claparede & Lachmann | | | + |
| * | *Stenosemella ventricosa* Claparede | | | + |
| | | | | |
| | ***II - Coelenterata*** | | | |
| | Medusae (Hydroid without tentacles) | | | + |
| | | | | |
| | ***III - Nematoda*** | | | |
| | Free living nematodes | + | + | + |
| | | | | |
| | ***IV - Annelida*** | | | |
| | Polychaete larvae of *Nereis pelagica* | | | + |
| | Spionid larvae | + | + | + |
| | Oligochaete larvae of *Chaetogaster* | + | + | + |
| | | | | |
| | ***V - Rotifera*** | | | |
| | *Keratella quadrata* Muller | + | + | + |
| | *K. valga* Ehr. | + | + | + |
| | *K. tropica* Apstein | + | + | + |
| | *K. cochlearis* Gosse | + | + | + |
| | *Brachionus angularis* Gosse | + | + | + |
| | *B. Calyciflorus* Pallas | + | + | + |
| | *Brachionus caudatus* Barrois & Daday | + | + | + |
| | *B. quadridentatus* Hermann | + | + | + |
| | *B. plicatilis* Muller | + | + | + |
| | *B. urceolaris* Muller *(urceus L.)* | + | + | + |
| | *B. flacatus* Zacharias | | | + |
| | *B. budapestensis* Daday | | | + |
| | *Monostyla lunaris* Ehr. | | + | + |
| | *M. bulla* Gosse | | + | + |
| | *M. closterocera* Schmarda | + | + | |
| | *Lecana lune* Muller | + | + | + |
| | *L. elasma* | + | + | |

Table (1) : cont.

| | | | | |
|---|---|---|---|---|
| | *L. depressa* Muller | + | + | |
| | *L. ohioensis* Muller | + | + | |
| | *Lepadella patella* Muller | + | + | + |
| | *L. ovalis* Muller | + | + | + |
| | *Synchaeta oblonga* Ehr. | + | + | + |
| | *S. pectinata* Ehr. | + | + | + |
| | *Trichocerca cylindrica* Imhof | + | + | + |
| | *Tripleuchlanis plicata* Myers | | + | |
| | *Colurella adriatica* Carlin | + | + | |
| | *C. obtusa* Hauer | + | + | |
| | *Asplanchna priodonta* Gosse | + | + | + |
| | *Harringia rouseleti* Beauchamp | + | | |
| | *Macrochaetus nearsubquadratus* Petry | + | + | + |
| | *Cephalodella megalocephala* Boryde St.Vincent | + | + | + |
| | *Polyarthra vulgaris* Carlin | + | + | + |
| | *Pseudoploesoma formosum* Myers | | + | |
| | *Rhinoglena frontalis* Ehr. | | + | |
| | *Pseudoharringia similis* Fadeaw | | + | |
| | *Kellicottia longispina* Kellicott | | + | |
| | *Filinia longiseta* Ehr. | | | + |
| | *Rotaria* sp. | | | + |
| | | | | |
| | ***VI - Arthropoda*** | | | |
| | ***a- Crustacea*** | | | |
| | ***1 - Copepoda*** | | | |
| | *Acanthocyclops americanus* Marsh | + | + | + |
| | *A. vernalis* Fischer | + | + | + |
| | *A. exilis* Coker | + | + | + |
| | ***Mesocyclops leuckarti*** Claus | + | + | + |
| | *Thermocyclops crassus* Fischer | | + | + |
| | *Paracyclops fimbriatus poppei* Ehr. | + | + | |
| | *Diacyclops bicuspidatus lubbocki* Claus | + | + | + |
| | *D. bicuspidatus thomasi* S.A. Forbes | + | + | |
| | *Cyclops venustus* Norman & Scott | + | + | |
| | *C. capillatus* Sars | + | + | |
| | C. *crassicaudis* Sars | + | + | + |
| | *C. varicans rubellus* Lilljeborg | + | + | |
| | *C magnus* Marsh | + | + | |
| | *C. strenuus* Fischer | + | + | + |
| | *C. scutifer* Sars | + | + | |
| | *C. vicinus* Uljanin | + | + | |
| | *C. sepratus* Lillijeborg | + | + | + |
| | *Eucyclops prionophorus* Kiefer | + | + | |
| | *Eucyclops agilis* Koch | + | + | + |
| | *Halicyclops magniceps* Sars | + | + | + |
| | *Ergasilus sieboldi* Nordman | + | | + |
| * | *Oithona nana* Giesb. | + | + | + |
| * | *O. helgolandica* Claus. | + | + | |
| * | *O. robusta* Giesb. | + | + | |
| | *Oncychocamptus mohammed* Blanchard | + | + | + |

Table (1) : cont.

| | | | | |
|---|---|---|---|---|
| | *Canthocamptus gracilis* Sars | + | | + |
| | *C. pygmaeus* Sars | + | | + |
| | *C. Proegeri* Scourfield | + | | + |
| | *C. dentatus* Poggenpol | + | + | |
| | *Nitocra lacustris* Schman kewitsch | + | + | + |
| | *Schizopera clandestina* Klie | + | | + |
| | *Mesocra rapiens* Schmeil | + | + | |
| | *Tachidius descipes* Giesb. | + | | |
| | *Horsiella brevlicornis* Van Dauwe | + | + | |
| | *Maraenobiotus vejdovskyi anglicus* Gurney | + | | |
| | *Bryocamptus hiemalis* Pearse | + | | |
| | *Macrosetella gracilis* Dana | + | | + |
| * | *Canuella perplexa* Scott | | | + |
| * | *Euterpina acutifrons* *Dana* | | + | + |
| | | | | |
| | *Diaptomus minutus* Lilljeborg | + | + | + |
| | *D. purpureus* Marsh | + | + | |
| | *D. saltillinus* Brewer | + | + | |
| | *D. marshianus* M.S. Wilson | + | + | |
| | *D. gracilis* Sars | | | + |
| * | *Acartia latisetosa* Kriczaguin | + | + | + |
| * | *Isias clavipes* Boeck | + | | |
| * | *Paracalanus parvus* Claus | + | | |
| * | *Calanus brevicornis* Lubbock | + | | |
| * | *Centropages sp.* | | | + |
| | *Nauplii of Copepoda* | + | + | + |
| | *Copepodite stages* | + | + | + |
| | | | | |
| | ***2- Cladocera*** | | | |
| | *Moina micrura* *Kruz* | + | + | + |
| | *Diaphanosoma excisum* *Sars* | + | + | + |
| | *D. brachyurum* *Lieven* | + | + | |
| | *Bosmina longirostris* Muller | + | + | + |
| | *Alona intermedia* Sars | + | + | + |
| | *Macrothrix rosea* Jurine | + | + | |
| | *Ceriodaphnia reticulata* Jurine | + | + | + |
| | *Oxyurella longicaudis* Birge | + | + | + |
| | *Alonella nana* Baird | + | + | |
| | *Chydorus ovalis* Kruz | | + | + |
| | | | | |
| | ***3- Ostracoda*** | | | |
| | *Cypria obesa* Sharpe | + | + | + |
| | *C. pellucida* Sars | + | + | + |
| | *Cyprinotus mollis* Furtos | | + | + |
| | *Potamocypris variegata* Brady & Norman | + | | + |
| | *Entocythere illinoisensis* Hoff | + | | + |
| | *Prionocypris longiforma* Dobbin | | + | + |
| | *Canadona subgibba* Sars | + | + | |
| | | | | |

Table (1) : cont.

| | | | | |
|---|---|---|---|---|
| | ***4- Amphipoda*** | | | |
| | *Gammarus lacustris* Sars | + | + | + |
| | *Corophium volutator* Pallas | + | + | + |
| | | | | |
| | ***5- Mysidacea*** | | | |
| | *Mysis relicta* Loven | + | + | + |
| | | | | |
| | ***6- Cirripede larvae*** | + | + | + |
| | | | | |
| | ***7- Decapod larvae of :*** | | | |
| | *Leander squilla elegans* Rathke | + | + | + |
| | | | | |
| | ***b- Insecta*** | | | |
| | *Chironomus larvae of* | | | |
| | *Tendipes tentans* Meigen | + | + | + |
| | | | | |
| | ***VII- Mollusca*** | | | |
| | Veligers of lamellibranches | + | + | + |
| | Shells of gastropods | + | + | + |
| | | | | |
| | ***IX- Urochordata*** | | | |
| * | *Oikopleura dioica* Fol | + | + | + |
| * | *Fritillaria borealis* Lohmann | + | + | + |
| | | | | |
| | ***X- Chaetognatha*** | | | |
| * | *Sagitta sp.* | + | + | |
| | | | | |
| | ***XI- Chordata*** | | | |
| | Fish eggs | + | + | + |

* = Marine species

comprised eight species. ***Brachionus calyciflorus*** was the most dominant species contributing 67.1% of the total rotifer counts (average 19 x $10^3$ organisms.$m^{-3}$). Other species appeared frequent and formed collectively 10.5% of the total rotifers. The genus ***Keratella*** represented in the lake by four species. ***Keratella quadrata*** contributed 14.7 % of the total rotifers (average 4 x $10^3$ organisms.$m^{-3}$). The other three genera appeared frequent (2% of the total rotifer counts). The genera; ***Brachionus*** and ***Keratella*** contributed about 95 % of the total rotifers in the lake. Other genera appeared rare.

Protozoa were represented during the present investigation by Foraminifera, Tintinnida, Ciliophora and Rhizopoda contributing collectively 11.0 % of the total zooplankton population.

The other groups such as crustacean eggs, Ostracoda, cirripede larvae, Mysidacea, Amphipoda decapod larvae, insects larvae, free living nematodes polychaete larvae, veligers of molluscs and fish eggs contributed collectively 15% of the total population.

**Spatial distribution of the total zooplankton :**

The average annual numbers of the total zooplankton community amounted 183 x $10^3$ organisms.$m^{-3}$. The highest standing stock of zooplankton population appeared in the western sector and it decreased gradually towards the eastern sector (Table 2).

Based on annual averages, the western sector harboured the highest standing stock with 345.8 x $10^3$ organisms.$m^{-3}$ followed by the middle sector with 124 x 10 organisms.$m^{-3}$ while the eastern sector maintained the lowest stock with an annual average of 75.6 x $10^3$ organisms.$m^{-3}$. In the western sector, stations 9 and 10 harboured the highest stocks averaging 530.6 x $10^3$ organisms.$m^{-3}$ and 439.2 x $10^3$ organisms.$m^{-3}$ respectively due to the increased number of copepods and their larvae and less so rotifers and cladocerans. In the middle sector, the highest standing stock are 198 x $10^3$ and 177 x $10^3$ organisms.$m^{-3}$ attained at stations 7 and 8 respectively. While in the eastern sector the higest average density was recorded at stations 3 and 4 with 107.7 x $10^3$ and 91.5 x $10^3$ organisms.$m^{-3}$ respectively. On the other hand, the minimal values of 53 x $10^3$ organisms.$m^{-3}$ was recorded at stations 5. These wide variations reflect in

Table (2): Monthly variations of the total zooplankton recorded at the different stations of Lake Burollus during the period from April, 1987 to March, 1988.

| Stations / Months | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April, 1987 | 5,800 | 3,600 | 7,560 | 21,600 | 6,000 | 22,720 | 13,120 | 20,800 | 43,680 | 17,760 | 16,000 | 169,920 | 29,046 |
| May | 1,200 | 720 | 20,880 | 5,980 | 15,760 | 31,200 | 8,880 | 23,760 | 40,240 | 25,120 | 19,240 | 33,520 | 18.875 |
| June | 7,760 | 3,280 | 42,080 | 7,360 | 107,840 | 30,160 | 151,360 | 1,840 | 51,120 | 63,600 | 97,840 | 45,600 | 50,820 |
| July | 16,560 | 11,760 | 40,800 | 3,600 | 5,040 | 1,520 | 140,680 | 166,720 | 2,140,564 | 93,800 | 58,140 | 12,960 | 224,345 |
| August | 62,240 | 143,360 | 25,440 | 103,856 | 21,910 | 181,280 | 2,720 | 23,200 | 1,677,876 | 226,240 | 33,601 | 304,000 | 233,810 |
| September | 7,200 | 159,200 | 60,320 | 356,800 | 11,840 | 228,480 | 129,040 | 429,600 | 473,440 | 1,409,040 | 29,760 | 87,840 | 281,880 |
| October | 10,080 | 13,680 | 104,880 | - | - | - | 64,080 | 382,800 | 168,720 | 614,840 | 185,760 | 60,480 | 178,368 |
| November | 28,320 | 2,800 | 237,600 | 62,640 | 22,560 | 17,760 | 542,880 | 14,160 | 40,800 | 202,320 | 10,800 | 1,080 | 98,643 |
| December | 6,800 | 9,360 | 4,800 | 15,120 | 3,120 | 11,760 | 8,160 | 2,560 | 5,200 | 5,760 | 2,640 | 7,920 | 6,933 |
| January, 1988 | 22,750 | 114,000 | 134,000 | 67,500 | 86,150 | 88,500 | 795,825 | 9,000 | 34,500 | 342,000 | 1,092,750 | 3,000 | 232.497 |
| February | 34,000 | 397,500 | 230,000 | 66,000 | 226,500 | 88,000 | 88,000 | 992,250 | 1,432,000 | 934500 | 1,314,800 | 1,168,000 | 580,963 |
| March | 138,500 | 36,750 | 382,500 | 296,600 | 85,500 | 60,000 | 436,000 | 60,000 | 259,500 | 1,336,000 | 52,500 | 152,500 | 274,695 |
| average | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 69,216 | 198,395 | 177,224 | 530.637 | 439,248 | 242.819 | 170,568 | 183.100 |

environmental conditions prevailing in each region (Fig. 2).

Monthly variations of the total zooplankton counts and for the different zooplankton groups is given in figure 3. Three peaks of abundance were observed, the major one was recorded in February (average 581 x $10^3$ organisms.$m^{-3}$) due to the increase of cyclopoid copepods, the second peak appeared in September with an average of 281.9 x $10^3$ organisms.$m^{-3}$ resulting mainly from Cladocera. Relatively small peaks were noticed in July and August with averages of 224 x $10^3$ and 233.8 x $10^3$ organisms.$m^{-3}$ respectively and mainly comprised rotifers and cladocerans. The lowest values were attained in December (average 6,933 organisms.$m^{-3}$) (Table 2).

**Seasonal variations :**

Generally, the highest zooplankton counts were recorded in winter (average 273,465 organisms.$m^{-3}$). This followed by a pronounced decrease during the other seasons. The lowest values attained in spring (107,539 organisms.$m^{-3}$) (Table 8).

Copepoda appeared more dominant during winter (average 155,294 organisms.$m^{-3}$) (Table 8). They showed their peak at the western sector (St. 11) (average 456,250 organisms.$m^{-3}$) and was dominated by ***Acanthocyclops americanus*** and ***A. vernalis***. Other small peaks were also observed at stations 9 and 10 ( average 411,893 and 358,780 organisms.$m^{-3}$ respectively) due to the increased numbers of ***Acanthocyclops*** spp. and ***Eucyclops separtus***. While the minimal values was in summer at the eastern sector.

Cladocera attained their highest values in autumn and summer (averages 97,729 and 42, 177 organisms.$m^{-3}$ respectively), and they were dominated by ***Moina micrura*** and ***Diaphanosoma excisum***. Their maximum abundance attained at stations 9 and 10 (averages 273,733 and 542,480 organisms.$m^{-3}$ respectively).

Rotifera reached their maximum abundance during summer and winter (averages 79,976 and 20,548 organisms.$m^{-3}$ respectively) mainly due to the

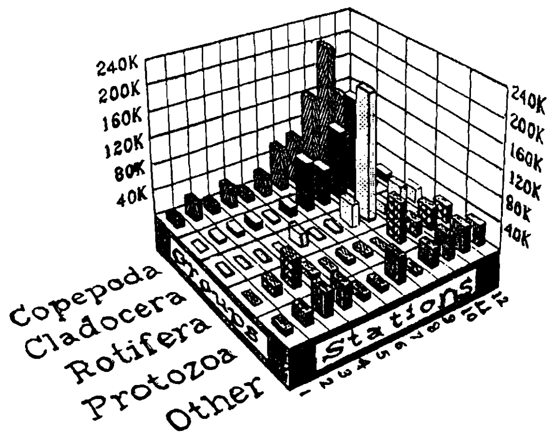


Fig. 2: Average annual values of the different groups of zooplankton (Organisms/m³) recorded at the different stations in Lake Burollus during the period April- 1987- March 1988.

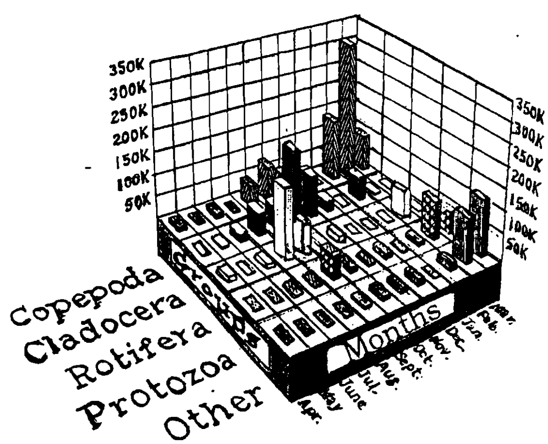


Fig. 3: Monthly variations of the total counts of zooplankton groups (Organisms/m³) in Lake Burollus during the period April- 1987- March 1988.

N.B. $K = 10^3$

increased numbers of ***Brachionus*** spp. and ***Keratella*** spp. Specially at the western sector.

Protozoa attained their maximum abundance during winter with average of 34,174 organisms.$m^{-3}$ specially at the western and eastern sectors and mostly represented by foraminiferans and to less extend with tintinnids.

Regarding the biomass of the total zooplankton, the dry weight showed annual average of 0.18 g/$m^3$ against the wet weight 4.4 g/$m^3$. The highest dry and wet weights reached on the western sector. Seasonal variations showed the highest weights in autumn (6.96 g/$m^3$) and the minimal weights were recorded in winter (2.69 g/$m^3$) as shown in table (3).

The results revealed that the western sector was dominated during autumn with crustacean copepods, ostracods, insect larvae and veliger of molluscs (lamellibranchs & gastropods), which they relatively of high weights.

The relationship between the number of individuals, species composition and total biomass was illustrated in figures (4 & 5). They showed the highest wet weight (5 g/$m^3$) attained at station 10, where the community composition was mainly dominated by copepoda. At the same time the highest counts of zooplankton reached at st. 9 metwith the low wet and dry weights, as the community was mainly dominated with Cladocera and Rotifera. December sustained the lowest community of zooplanton but showed high wet weight as it was dominated by organisms of high water content such as free living nematodes, polychaete larvae and medusae.

## Species diversity

In Lake Burollus the diversity differed from one month to the other and from station to station within the same season. The average diversity fluctuated between 1.7 and 2.00 in spring and winter respectively (Table 4). The relatively higher values ranging from 2.23 and 2.17 at stations 12 & 1 respectively. Generally the highest and lowest values of diversity were attained at stations 12 (2.683) and 4 (0.75) in spring (table 4). While in summer the highest diversity was recorded at station 11 (2.54) and the lowest value at station 8 (1.22). During autumn the highest diversity was at stations 12, 7 & 1(2.336, 2.159 &

Table (3): Annual average and seasonal variations of dry & wet weights in g wt/m³

| Sectors | Dry wt g/m³ | Wet wt g/m³ | Seasons | Dry wt g/m³ | Wet wt g/m³ |
|---|---|---|---|---|---|
| Eastern | 0.16 | 4.0 | Spring | 0.17 | 3.6 |
| Middle | 0.16 | 3.31 | Summer | 0.20 | 4.7 |
| Western | 0.21 | 4.83 | Autumn | 0.21 | 6.96 |
| | | | Winter | 0.12 | 2.6 |
| Average | 0.18 | 4.4 | Average | 0.18 | 4.4 |

Table (4): Annual averages of diversity index (Shannon & Weaver) recorded at different stations during the four seasons of 1987-1988.

| Stations | Spring | Summer | Autumn | Winter | Average |
|---|---|---|---|---|---|
| St. 1 | 1.928 | 2.196 | 2.04 | 2.526 | 2.17 |
| 2 | 1.949 | 2.077 | 1.92 | 2.323 | 2.07 |
| 3 | 1.065 | 2.249 | 1.51 | 2.18 | 1.75 |
| 4 | 0.75 | 1.877 | 1.58 | 2.082 | 1.57 |
| 5 | 1.861 | 2.194 | 1.55 | 1.488 | 1.77 |
| 6 | 2.153 | 2.076 | 1.997 | 2.432 | 2.16 |
| 7 | 1.408 | 1.495 | 2.159 | 1.642 | 1.68 |
| 8 | 1.761 | 1.22 | 1.555 | 1.604 | 1.53 |
| 9 | 1.417 | 1.372 | 1.576 | 2.002 | 1.59 |
| 10 | 1.651 | 1.764 | 1.537 | 2.247 | 1.80 |
| 11 | 2.3 | 2.536 | 1.6 | 1.924 | 2.09 |
| 12 | 2.683 | 2.31 | 2.336 | 1.589 | 2.23 |
| Average | 1.7 | 1.95 | 1.78 | 2.00 | 1.87 |

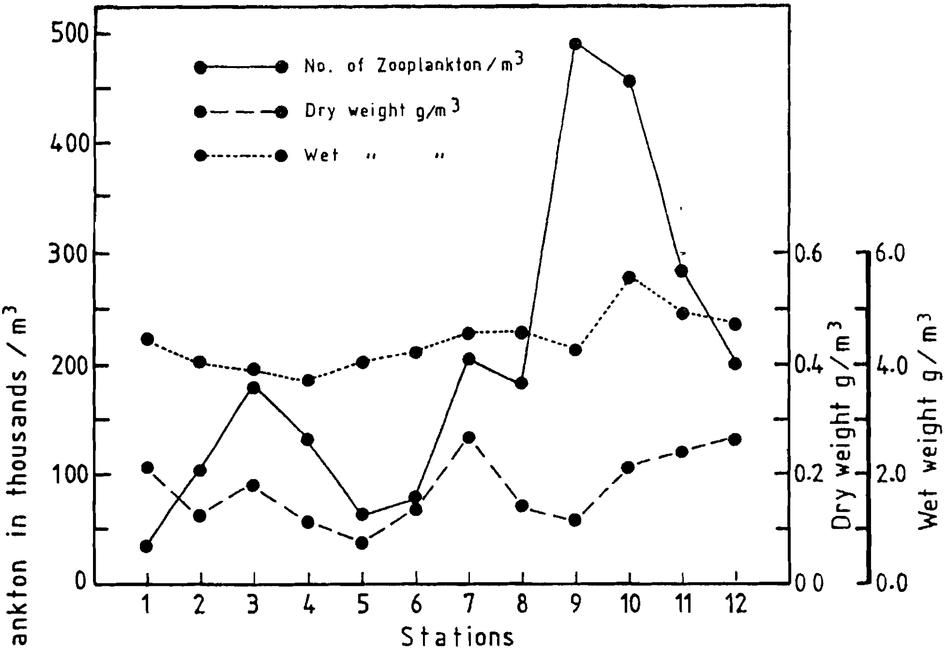


Fig. (4): Relation between the horizontal distribution of the total number (organisms.$m^{-3}$) and biomass (g/$m^3$) of zooplankton organisms Lake Burollus during 1987-1988.

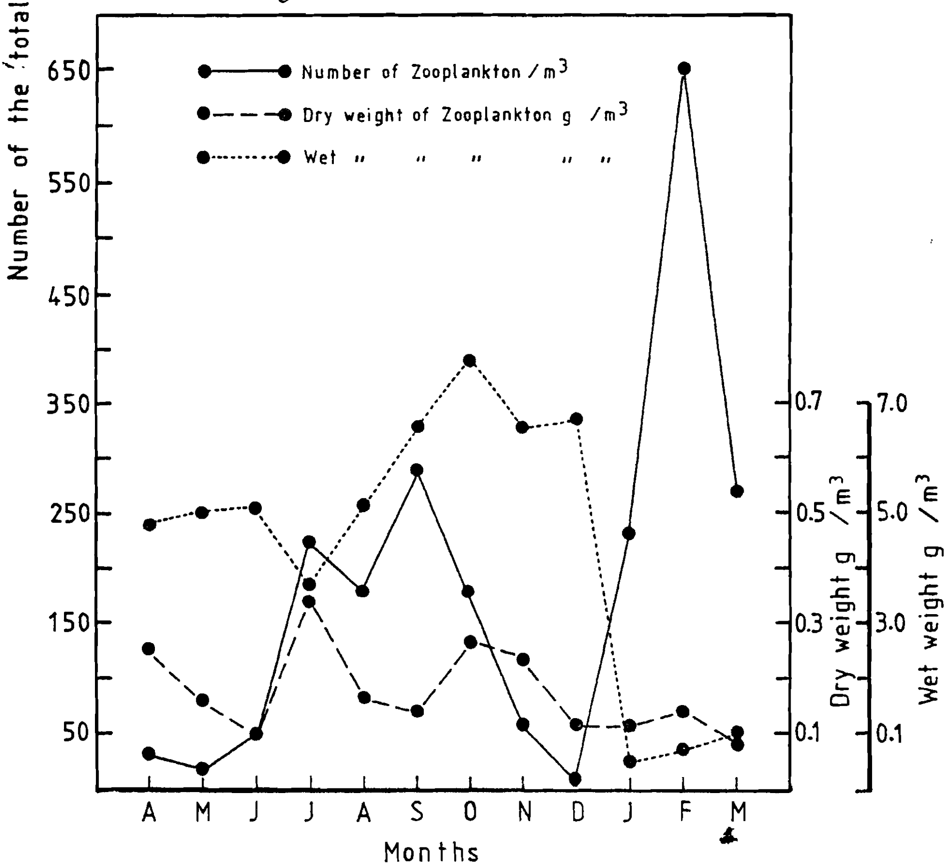


Fig. (5): Relation between the monthly varations (organisms.$m^{-3}$) and biomass (g/$m^3$) of zooplankton organisms in Lake Burollus during 1987-1988.

2.04 respectively), while other stations recorded low diversity values ranging between 1.51 at station 3 and 1.997 at station 6. Although, the winter season recorded the lowest number of individuals it showed the highest species diversity at most stations. The highest value 2.526 attained at station I and the lowest 1.5 reached at station 5.

**Multivariate Methods (Species similarity) :**

The dendrogram and multidimensional scaling (MDS) showing classification of 12 stations in Lake Burollus based on mean the mean root-root transformed abundance of 90 species of zooplankton were estimated at the different stations using the Bray-Curtis measure of similarity and group-average sorting through 12 months, which were further grouped into four seasons as follows:-

**Spring (March, 1988; April & May, 1987) :**

As shown in figure (6 A) stations affinities with similarity level 15% delineates two groups. The first one comprises stations 12,10,3,9,7,4, and it is further divided into three homogeneous subgroups, namely; (10-3) with similarity level 65%, (9,7,4) with 54% similarity and station 12 with similarity level 27.5%. The second group with similarity level 20% comprises stations 11,6,2,8,5,1 which inturn divided into four subgroups namely; stations (6-2) with high similarity level 43%, station 11 having 37.5%, station 8 with 35% similarity and stations (1-5) with 32% similarity level. Figure (7 A) illustrates multidimensional scaling (MDS) using the same similarity matrix as above delineating groups of stations from the dendrogram (Fig. 6 A). This analysis gives essentially the same picture as the dendrogram. Stations (6-2) affected by introduced sea water from Boughaz El-Bourg while stations (5-1) affected by drained water from Drain 7 and Nasser Drain where the drained water introduced in to the lake was about 171.4 x $10^6$ $m^3$/month. (Ministry of irrigation).

***Summer, 1987 (June, July, August) :***

The similarity level of 7% delineated two groups of stations (Fig. 6 B). The first, represented the major one, it comprised stations 12,7,6,4,2,3,11 and divided into three homogeneous subgroups which comprised stations (12-7) with similarity level 41%, stations 6-4,2,3 having high similarity levels 66%, 58% and 47% respectively and station 11 with 30% similarity level. The second group comprised three subgroups namely; stations (10-8) with similarity

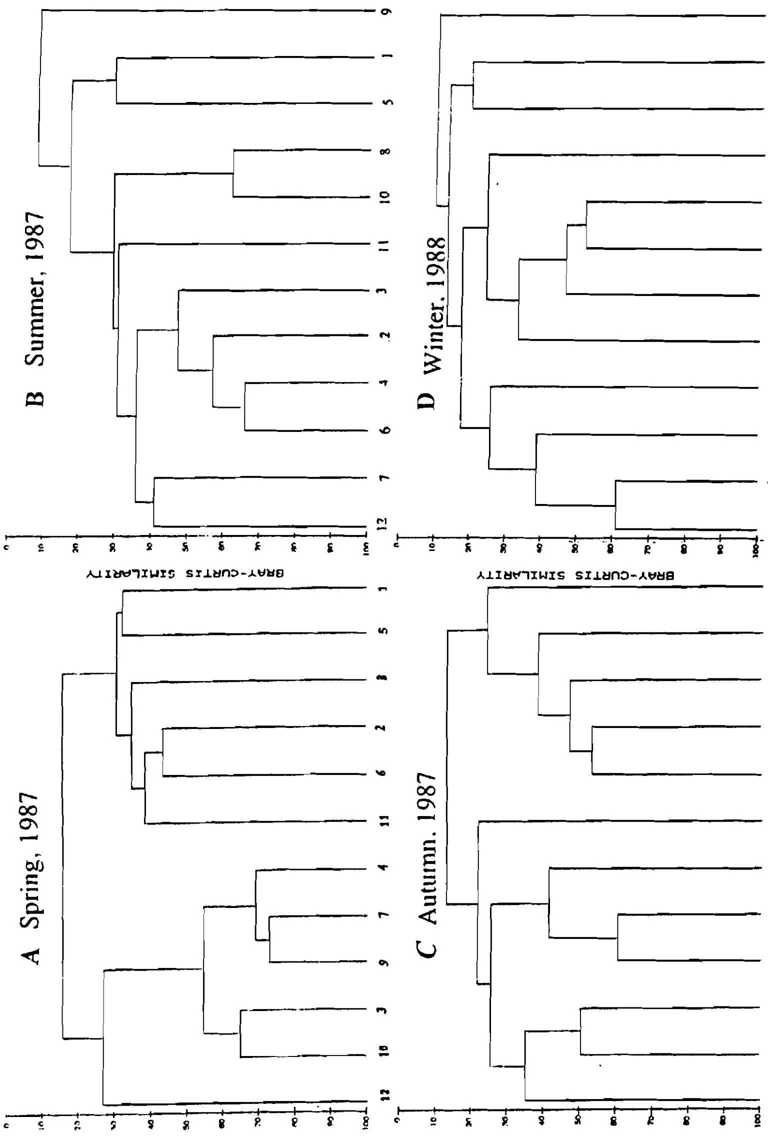


Fig. (6): Dendrogam showing classification of 12 station in Lake Burollus on mean seasonally abundance of zooplankton. The dendrogram formed by group-average clustering of Bray-Curtis similarities for 90 species.

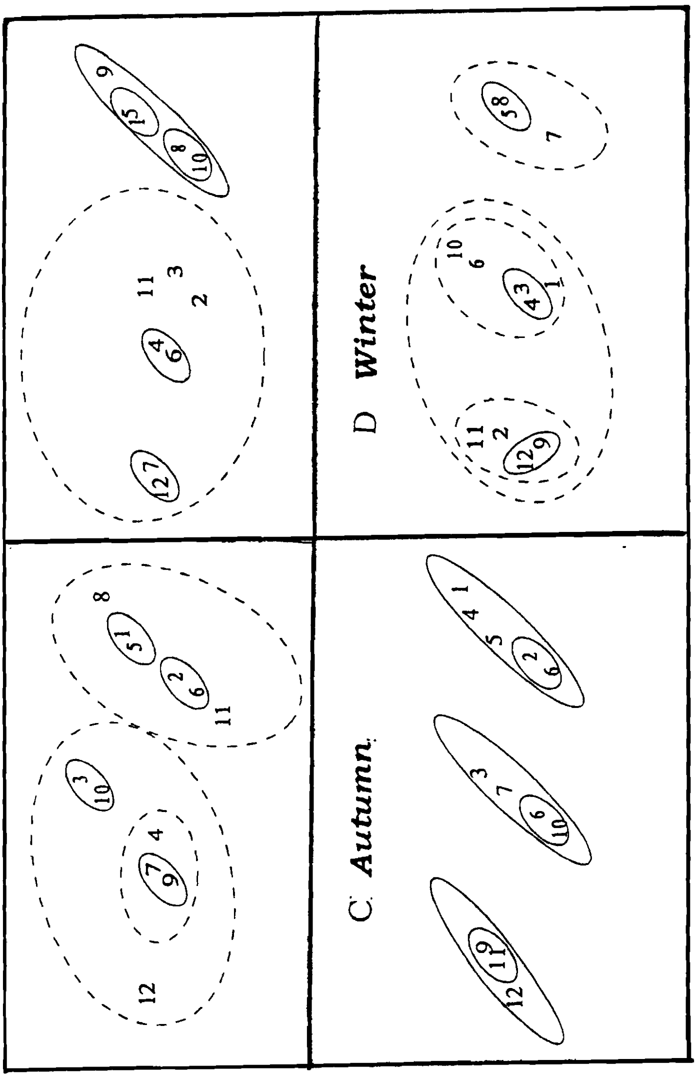


Fig. (7): Multidimensional scaling (MDS) ordination mean groups from cluster analysis indicating similarities.

level 62%, stations (5-1) with similarity level 28 % and less so station 9 having the least similarity level of 7%. Figure (7 B) shows the results of MDS using the same similarity matrix as above, delineating groups of stations from the dendrogram (Fig. 6 B). This analysis has essentially the same picture. This period coincided with maximum discharge of drain waters into the lake which amounted to 258 x $10^6$ $m^3$/month.

*Autumn, 1987 (Sep., Oct. & Nov.) :*

The dendrogram classification in autumn, 1987 showing similarity of 13% delineates three groups. The first group was divided into two homogeneous subgroups namely, stations (11-9) with 50% similarity level and station 12 having similarity level 35%. Group 2 comprised stations (10-8), 7 and 3 with similarity levels of 60%, 41% & 22% respectively. The third group was divided into four homogeneous subgroups as follows:- Stations (6-2) having similarity 52%, station 5 with 45% similarity level, station 4 (38 %) and to less extent station 1 with 22% similarity level. Stations of the third group lie arround the Boughaz area. The MDS (Fig. 7 C) analysis gives essentially the same picture as the dendrogram (Fig. 6 C). The amount of drain water in this season amounted to 185.7 x $10^6$ $m^3$/month.

*Winter (Dec., 1987 ; Jan. - Feb., 1988) :*

The dendrogram classification in winter (Fig. 6 D) showed similarity level of 10% delineates three groups. The first group was divided into three homogeneous subgroups such as stations (12-9) with similarity level 62%, station 2 had 39% similarity level while, station 11 showed similarity of 26%. Group 2 was divided into four homogeneous subgroups in which stations (4-3) showed high similarity level of 52% and they closely nearby the Boughaz area. Station 6 had 46% similarity, while station 10 showed similarity at 34%. The fourth subgroup comprised station 1 which showed the least similarity level in this group reached 25%. The last group comprised two subgroups namely; stations (8-5) with similarity level of 18% and station 7 showed the lowest similarity level of 10%. This dendrogram confirms the MDS (Fig. 7 D) and gives the same picture in (Fig. 6 D). The amount of drainage water introduced into the lake in this season ranged to 180.3 x $10^6$ $m^3$/month.

# *DISCUSSION*

Results of the present study indicate that Lake Burollus harboured higher zooplankton stocks during the year 1987 ($183 \times 10^3$ organisms.$m^{-3}$) when compared with that previously recorded during 1978, 1979 ($111 \times 10^3$ & $45 \times 10^3$ organisms.$m^{-3}$ respectively) (Aboul Ezz, 1984). This increase in zooplankton density accompanied by diminish in phytoplankton standing crop from $2.7 \times 10^6$ in 1978 and $3.4 \times 10^6$ unit$^{-1}$ during 1979 to 1.4 x 106 unit$^{-1}$ in 1987 (El-Sherif, 1983 & 1993). Also the direct effect of the decreased amount of drain water flowing into the lake, as a result of the decreased annual Nile flood in 1987. The amount of drain water in 1978 and 1979 average to $2.84 \times 10^6$ and $2.46 \times 10^6$ $m^3$/year respectively (Aboul Ezz, 1984).

The zooplankton population in Lake Burollus during 1987-1988 showed relatively decrease in number of species. About 90 spp. had been recorded; 26 Copepoda, 26 Rotifera, 7 Cladocera and 10 protozoa. Other 21 species of different groups appeared rare. While, the previously recorded species during the years 1978 and 1979 were qualitatively rich, they reached 115 species of zooplankton. The annual average numbers and percentage frequency of the main groups changed for the different periods are shown in table (5).

The controlling effect of zooplankton on phytoplankton in Lake Burollus was discussed by El-Sherif and Aboul Ezz (1988). Regionally, the annual average of the two communities showed a linear relationship at the western sector of the lake which harboured highest standing stocks of both phytoplankton and zooplankton where as the consumption rate of phytoplankton by zooplankton is less pronounced which reflect the eutrophic characters of the western sector. Similarly, Makarewicz and Likens (1979) found a linear relation between the net phytoplankton and zooplankton production in various eutrophic lakes. On the other hand, regards the monthly variations, the highest numbers of phytoplankton was always accompanied with drop in zooplankton and vice versa resulting from the direct effect of grazing (El- Sherif & Aboul Ezz, 1988). The number of species of the main groups of zooplankton recorded in the different periods was summarized in table (6).

The distribution of zooplankton generally agreed with the previous data recorded during 1978-1979 where the highest standing stocks attained in the

Table (5): The annual average numbers of different groups of zooplankton (organisms/$m^3$) and their percentage frequencies during 1978, 1979 & 1987-1988.

| Groups | 1978 | | 1979 | | 1987-88 | |
|---|---|---|---|---|---|---|
| | No./$m^3$ | % | No./$m^3$ | % | No./$m^3$ | % |
| **Copepoda** | 76135 | 68.37 | 16670 | 36.84 | 67,000 | 36.6 |
| **Rotifera** | 18.902 | 16.97 | 8513 | 18.81 | 28,300 | 15.5 |
| **Cladocera** | 9808 | 8.81 | 11276 | 24.90 | 40,300 | 21.8 |
| **Protozoa** | 2620 | 2.35 | 520 | 1.15 | 21,000 | 11.5 |
| **Other grousp** | 3889 | 3.50 | 8277 | 18.3 | 26,500 | 14.5 |
| | 111,000 | 100 | 45,000 | 100 | 183,100 | 100 |

Table (6): Numbers of species of the main groups of zooplankton recorded in the different periods.

| Groups of zooplankton | Number of species | | |
|---|---|---|---|
| | 1978 | 1979 | 1987 - 1988 |
| **protozoa** | 3 | 4 | 10 |
| **Rotifera** | 27 | 33 | 26 |
| **Copepoda** | 44 | 34 | 26 |
| **Cladocera** | 9 | 10 | 7 |
| **Ostracoda** | 5 | 5 | 6 |
| **Other groups** | 14 | 14 | 15 |
| **Total number of species year** | 102 | 100 | 90 |

western sector and it decreased gradually towards the east (Table 7). The highest values appeared at stations. 9 and 10 as the result of high abundance of Cladocera and Rotifera where the lake water there, is typically fresh or brackish type. The peaks of copepods were generally observed in late winter and early spring for the three different periods (Table 8) resulting mostly from abundance of the cyclopoid copepods.

Most of the species inhabiting the lake are eurythermic forms and can tolerate a wide range of temperature. They appeared all the year round showing maximum persistence during one season or the other. However, some planktonic groups show seasonal succession in accordance with change of the temperature, similar to the observations of Behrendt (1990) and Sommer ***et al*** (1986). Thus, the dominant Cyclopoida ***Acanthocyclops americanus*** attained its maximum frequency during the winter and spring. This agreed with records of its distribution in Lake Menzalah (Guerguess, 1979) and Lake Mariut, (Abd El-Aziz, 1987). In Lake Edku their peaks occurred in autumn and spring (Samaan, 1976).

The dominant rotifers ***Keratella quadrata*** reached its maximum occurrence in Lake Burollus during winter of 1978, while ***Brachionus angularis*** was more dominant during winter, 1978 and autumn of 1979 (Aboul Ezz, 1984). Samaan (1976) found the maximum occurrence of ***Brachionus*** spp in Lake Edku during spring.

The dominant cladoceran ***Moina micrura*** reached its maximum persistence in Lake Burollus in summer (Aboul Ezz, 1984). The annual water temperature in the lake ranged between 12.4 and 30.6°C during winter and summer respectively. The transparency of the lake water remained relatively low due to the presence of suspended silt parcticles introduced with the drain water or stirred up from the bottom muds by wind action. The maximum reading of Secchi depth averaged 41 cm were recorded during summer and autumn. The seasonal abundance of Cladocera in the lake coincided with the highest transparency values. This may explain the predominance of Cladocera when the water was more transparent. This is confirmed by the observations of Rylov (1940) who mentioned that the unselective feeding of Cladocera under turbid conditions allows silt to accumulate in their digestive tracts and causes them to

Table (7): Annual average counts (organisms/$m^3$) of the different groups of zooplankton in the three sectors (E) Eastern, (M) Middle and (W) western of Lake Burollus.

| | 1978 | | | 1979 | | | 1987 - 1988 | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Eastern** | **Middle** | **Western** | **Eastern** | **Middle** | **Western** | **Eastern** | **Middle** | **Western** |
| Protozoa | 3,690 | 1,405 | 1,836 | 2,178 | 1,797 | 5,442 | 18,341 | 5,824 | 38,404 |
| Rotifera | 8,981 | 9,964 | 37,761 | 12,666 | 3,263 | 9,610 | 1,156 | 16,188 | 67.583 |
| Copepoda | 43,064 | 60,576 | 124,764 | 12,841 | 14,717 | 22,452 | 22,903 | 45,576 | 132,484 |
| Cladocera | 1,829 | 6,359 | 21,237 | 7,469 | 11,655 | 14,707 | 7,709 | 39,938 | 70,477 |
| Others | 9,248 | 1,866 | 1,484 | 11,956 | 4,632 | 385 | 25,446 | 17,142 | 36,868 |
| Total | 66,812 | 80,170 | 187,082 | 47,110 | 36,064 | 52,596 | 75,555 | 124,668 | 345,816 |

Table (8): Seasonal variations in the differant groups of zooplankton (organisms/$m^3$) in Lake Burollus during (Sp.) spring, (S) summer, (A) autumn and (W) winter.

| | 1978 | | | | 1979 | | | | 1987 - 1988 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sp. | S | A | W | Sp. | S | A | W | Sp. | S | A | W |
| Protozoa | 2,662 | 2584 | 2,876 | 1,117 | 1,338 | 3,370 | 1,703 | 2,238 | 18,414 | 20,244 | 10,211 | 34,174 |
| Rotifera | 20,743 | 6,911 | 3,354 | 44,600 | 212 | 4,389 | 26,051 | 3,400 | 5,593 | 79,976 | 7,680 | 20,548 |
| Copepoda | 197,269 | 18,393 | 13,087 | 75,790 | 16,332 | 10,533 | 21,259 | 18,556 | 34,409 | 22,380 | 57,809 | 155,294 |
| Cladocera | 4,074 | 18,684 | 11,070 | 5,448 | 13,041 | 21,796 | 7,639 | 2,626 | 4,132 | 42,177 | 97,729 | 20,797 |
| Others | 8,119 | 3,662 | 2,550 | 2,426 | 3,603 | 4,724 | 13,246 | 4,965 | 44,991 | 4,880 | 12,868 | 42,652 |
| Total | 232,867 | 50,234 | 32,937 | 129,381 | 34,526 | 44,812 | 69,898 | 31,785 | 107,539 | 169,657 | 186,297 | 273,465 |

sink. Also Sabaneef (1952) indicated that turbidity may acually interfere with their feeding apparatus.

The results also indicate that the dominant zooplankton in Lake Burollus are euryhaline fresh or brackish water forms which showed their maximum distribution in slightly alkaline waters. Some other marine species (Table 1*) were rarely recorded around the Boughaz area. The fresh water plankters appeared more dominant at the southern margins nearby the outlets of the drains.

The results of diversity revealed that the lake has a greater variety of species (high diversity). Its maximum diversity (Shannon & Weaver) 2.683 was recorded in spring at st. 12 (26 species). On the other hand, the lower diversity 0.75 appeared at station 4 in the same season (10 species) (Table 9). This may indicate that the diversity generally increases as the community becomes more stable while severe disturbance usually causes its marked decline (Michael, 1984; Magurran, 1988). This also cleared that the western sector with its eutrophic characters usually harboured high diversity of species beside individuals than the eastern one nearby the Boughaz area.

On the other hand, the annual average of species richness index (Margalef's diversity) reached 1.54 in the lake during this period of investigation, showing its maximum of 2.77 (30 species) at station 3 in summer but harboured low zooplankton standing stock in this season and minimum value of 0.964 (12 species) attained at station 9 in autumn accompanied with high standing stocks (Table 10). Thus in conclusion, the least species richness ( number of species) coincided with the highest standing crops and vice-versa.

The annual average of equitability (0.65) showed the highest value 0.69 in winter, while the lowest 0.623 had been recorded during summer (Table 11). Thus, there is an inverse relation between equilability and the magnitude of standing crop of zooplankton where the least number (6933 organisms.$m^{-3}$) was recorded in December (Table 2).

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 give a picture of the sample variability and the samples were further grouped

Table (9): Seasonal variations of diversity Shannon & Weaver index (averages of stations 1-12) recorded the period April, 1987 - March, 1988.

| Seasons | Range (Maximum - Minimum) | Average of diversity at stations 1-12) |
|---|---|---|
| Spring | 2.683 (St. 12) - 0.75 (St. 4) | 1.7 |
| Summer | 2.536 (St. 11) - 1.22 (St. 8) | 1.95 |
| Autumn | 2.336 (St. 12) - 1.51 (St. 3) | 1.78 |
| Winter | 2.526 (St. 1) - 1.488 (St. 5) | 2.00 |

Table (10): Seasonal variations in the Margalef's diversity index (Richness) recorded during the period April, 1987 - March, 1988.

| Seasons | Range (Maximum - Minimum) | Average of diversity at stations I - XII |
|---|---|---|
| Spring | 2.14 (St. 12) - 1.004 (St. 7) | 1.37 |
| Summer | 2.77 (St. 3) - 1.265 (St. 8) | 1.96 |
| Autumn | 1.89 (St. 12) - 0.964 (St. 9) | 1.34 |
| Winter | 1.83 (St. 6) - 1.076 (St. 9) | 1.49 |

Table (11): Seasonal variations in the (Heip's diversity index) Evenness (equitability) index recorded during the period April, 1987 - March, 1988.

| Seasons | Range (Maximum - Minimum) | Average of diversity at stations I - XII |
|---|---|---|
| Spring | 0.823 (St. 12) - 0.265 (St. 4) | 0.632 |
| Summer | 0.761 (St. 11) - 0.450 (St. 8 & 9) | 0.623 |
| Autumn | 0.804 (St. 2 & 6) - 0.522 (St. 3) | 0.66 |
| Winter | 0.858 (St. 1) - 0.517 (St. 7) | 0.69 |

into four seasons. Multidimensional Scaling (MDS) confirmed the existence 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 (Cluster & MDS) have advantage of great sensitivity and generality of response, but in themselves are indicative only of community changes which can be difficult to interpret in terms either of value judgments or of the possible cause.

In all the zooplankton species recorded in the present study, the results of the multivariate analysis indicate the validity of multivariate analysis to species aggregation at stations 2 and 6 during most seasons due to the effect of sea water introduced into the lake, while the other stations were subjected to different amounts of freshwater flowing into the lake during different seasons resulting from direction of water currents in the lake as shown in figure (6).

In conclusion, Lake Burollus tends to a gradual eutrophic when considering the increase in standing stock of zooplankton during the period 1987-1988. But showed gradual mesotrophic when considering the decrease in phytoplankton standing crop to an average of $1.04 \times 10^6$ Unit$^{-l}$ (El-Sherif, 1993). Besides, the significant changes in the nutrient load of the lake were also traced during the last decade. Thus, the level of nutrients had decreased by about two times since, 1978. (Abd El-Moati ***et al***, 1988 & El-Sherif, 1993). The period 1978-1979 recorded the reverse observations in the annual averages of both phytoplankton and zooplankton. It is noticed that the increase in phytoplankton (average $3.4 \times 10^6$ unit$^{-1}$) in 1979 was accompanied with a sharp decrease in zooplankton average $45 \times 10^3$ organisms.$m^{-3}$. Also during 1978, the phytoplankton standing crop recorded $2.7 \times 10^6$ unit-1 (El-Sherif, 1983) at the same time the zooplankton community reached $111 \times 10^3$ organisms.$m^{-3}$ higher than that recorded in 1979 as mentioned before. All these differences resulting mainly of the variations of hydrographic conditions in the lake.

These 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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