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RELATIONSHIP BETWEEN PHYTOPLANKTON, ZOOPLANKTON AND FISH CULTURE IN A FRESHWATER FISH FARM

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ABSTRACT

This study was carried out at the Barrage Fish Farm during 2001 farming season. It was performed to evaluate the plankton communities and the effect of fish ponds on their standing crop and species composition.

The data revealed that the phytoplankton communities are represented by five classes namely Chlorophyceae, Bacillariophyceae, Cyanophyceae, Dinophyceae and Euglenophyceae. Their major peak was observed at Pond 6 while the minor one was found at Pond 5. With regard to the monthly variations, phytoplankton communities flourished in July while their minimum occurrence occurred in September and August. The zooplankton species belonged to rotifers, cladocerans, and copepods in addition to the meroplanktonic forms. Rotifers were most common in all ponds. It constituted 94.64% of total zooplankton in the ponds. Copepoda occupied the second predominant position and contributed 4.23% of total zooplankton crop. Cladocera was dominated by *Moina micrura*. The average zooplankton number at the ponds was 258.4 org l^{-1}, their major peak of 1073 org.l^{-1} was observed at Pond 3 in April, while the minor one of 20 org.l^{-1} occurred at Pond 5.

Fish culture had obviously influenced the intraplanktonic dynamics. Chlorophyceae occupied the first predominant position at the fishponds and constituted about 60% of the total crop followed by Bacillariophyceae (25.8%) and Cyanophyceae (14%). Diatoms replaced green algal position at the River Nile water and contributed about 70% of the total numerical density. The small rotifers and nauplius larvae of copepods were the most dominant in fishponds in spite of the large forms in the main feeder.

Trace metal contents recorded at the sediment of fish ponds were much higher than the corresponding values determined at the River Nile (main feeder). Iron concentrations were substantially higher at the edible muscle tissues of fishes caught from the fish farm compared to River Nile specimens. Its contents were much higher in comparison with Mn and Ni levels.

INTRODUCTION

Predation by fish determines the abundance of herbivorous zooplankton, which in turn regulates the level of phytoplankton (Carpenter *et al.*1985). A recent study (Sarvala *et al.*1998) revealed that changes in the abundance of planktivorous fish do affect both the phytoplankton and zooplanktoin. However, most of the avalabile information comes from experimental enclosures and much less is known about trophic interactins in large ponds (Brett and Goldman, 1996). Exploitation of fisheries resources in Egypt, as well as elsewhere in Africa, has been carried out in the absence of adequate ecological knowledge of the fish food organisms (Mavuti, 1990. The high percentage of the global fish species found in fresh water and the ability of some species to produce very high fish yields indicate that natural feeding strategies used by freshwater fishes are highly successful (Fernando, 1994). Understanding these strategies will assist in fish culture and management of freshwater fisheries. In the recent years, attention has been turned toward fish farming for increasing fish yield. The Nile tilapia are considered the most important fish species in Egypt. It occupied more than 70% of the Egyptian fish landing (Ishak *et al.* 1985). Planktivorous fish have a major influence on the structure of the whole plankton where they modify the density and size structure of communities (Carpenter *et al.*1985).

Phytoplankton and zooplankton are considered the main natural food for fish culture especially during the early stages. Semour (1980) stated that the carrying capacity and production of fishponds could be increased by fertilization that encourages growth of phytoplankton and in turn zooplankton that is required as natural food for fish. Touliabah (1992) evaluated the impacts of fish production and fertilization on managing phytoplankton in Serw Fish Farm. Shehata *et al.* (1994) conducted two experiments for six months in the barrage fish farm to determine the optimum fertilizer doses (urea and super-phosphate) which increase phytoplankton and zooplankton populations for tilapia culture in addition to the artificial food. Sweilum (2001) studied the culture of *Oreochromis niloticus* in mono-, di-, and poly-culture systems in the Barrage fish farm during the season of study. He reported that the highest growth rate of Nile tilapia was in polyculture system than the mono- and di-culture

The relationship between phytoplankton, zooplankton and fish culture is of paramount importance in determining the water quality on one hand and the natural productivity and the fish production on the other. This point hadn't been studied before in the farm. The aim of the present study is to determine these relations in the Barrage fish farm as a freshwater fish farm.

MATERIAL AND METHODS

This study was carried out at the freshwater fish farm of Fish Culture Research Station at El Kanater El Khyria, about 30 km north of Cairo. Fishes (*Oreochromis niloticus*, *Sarotherodon galilaeus*, and *Clarias gariepinus*) were distributed at three different combinations of mono-, di-, and polyculture systems, stocked on 8 April 2000 and harvested in 14 November 2000.

The farm includes seven earthen ponds supported by calcareous stones from sides with a water level of about 1m (Table 1). River Nile water via Menofi Branch is the main feeder of the fish farm (MF). The fresh water discharges to the ponds through feeder canal (F1) and the drainage water inflow to another one (F2).

Sampling was carried out on monthly basis from the two banks of each pond. Water temperature and pH were measured in ponds by portable pH - meter (Jenway 3250). The nutrient salts were measured colorimetrically using Spectronic 20 D and expressed as $\mu g\ l^{-1}$. Nitrite-N was determined according to Bornes and Follcard (1975), nitrate-N was measured using cadmium column technique according to Nydahi (1976), ammonium-N was measured as reported by Booth and Lobring (1973) and phosphate-P was determined as described by Strickland and Parsons (1965).

Fish species for metal analysis were selected so that a range of size was available for each species. In the laboratory, specimens were rinsed in distilled water and fillets removed from both sides. The fish samples were frozen and kept at -20°C prior to analysis. The dry homogenized samples were digested for 3 hours with concentrated nitric acid (Hornung & Kress, 1991). The samples of sediment were collected, digested and analyzed according to the standered techniques as reported in Messiha-Hanna (1992). The concentrations of Fe, Ni, and Mn were measured by Atomic Absorption (Perkin Elmer-Model 3110) according to APHA *et al.* (1992). The data were discussed in terms of $\mu g\ g^{-1}$ wet wt.

For preparation and examination of phytoplankton the water samples were preserved in situ with Lugol's Iodine solution. A known volume of the samples was allowed to stand on a graded cylinder for five days untill the algal species had settled and then siphoned off the supernatant with plastic tube ended with plankton cloth of 5 um mesh diameter. A drop method was applied for counting and identification of different phytoplankton species. Examination of diatoms requried drying a few drops of the concentrated samples in coverglass for 20 minutes on a hot plate. This treatment drives off most of the organic matter present leaving only siliceous diatom cells wall. If the organic matter was not completely removed, the material was boilied in about ten times its volume of commercial hydrochloric acid for 20 minutes, then commercial nitric acid was then added to the boiling solution to bring about the rapid oxidation of the organic matter. The samples was then rinsed with distilled water. The main references used for identification of phytoplankton organisms were: Weber (1971), Kimor & Pollingher (1965), Vinyard (1975), Stansbery (1971) and Dillard (1989).

Standing crop and species composition of zooplankton were determined by filtration of 20 litres from two banks of each pond, through a 55 μ mesh net and fixed with a final concentration 4% neutral formaline . .. The following references were used for identification of zooplankton species: Yamamato (1960), Edmandson (1966), Ruttner-Kolisko (1974), Pennak (1978) and Verheye & Dumont (1984). The mean values of organisms were estimated for each sample and expressed as a number of organisms/liter.

Correlation coefficient was done by Microsoft Excel Program 5.0/7.0 (1997).

RESULTS

Physico-chemical parameters:

The average values of the measured physicochemical parameters are presented in Table (2). Regional average value of water temperature varied within a narrow range. Its values varied from 28.3°C at Pond 7 to 31.48°C at Pond 1. Its monthly variations showed that, the minimum temperature 23.4°C was recorded in October while the maximum temperature of 37.2°C occurred in August.

The regional average pH values ranged from 7.61 at Pond 5 to 8.03 at Pond 6. The monthly pH values showed a sharp decline in July (6.88), while its maximum value of 8.33 was recorded in April.

The present data of nutrients revealed that, NH_4-N levels at the Ponds were much higher than NO_2-N and NO_3-N concentrations. NO_2-N values ranged from 6.18 $\mu g\ l^{-1}$ at Pond 4 to 25.34 $\mu g\ l^{-1}$ at Pond 1. Its monthly concentrations varied between 6.8 $\mu g\ l^{-1}$ in October and 21.01 $\mu g\ l^{-1}$ in August. NO_3-N contents increased from 60.8 $\mu g\ l^{-1}$ at Pond 6 to 219.2 $\mu g\ l^{-1}$ at Pond 3. Its monthly variations revealed an obvious increase in April when the highest value of 187.2 $\mu g\ l^{-1}$ was observed. On the other hand, NO_3-N reached its lowest concentrations of 57.6 $\mu g\ l^{-1}$ in August and October. NH_4-N levels revealed a wide fluctuation, where its minimum value being 179.5 $\mu g\ l^{-1}$ at Pond 7, while its maximum concentration was 717.4 $\mu g\ l^{-1}$ at Pond 5. Its monthly variations showed a distinct increase in April and July (420.3 $\mu g\ l^{-1}$ and 450.67 $\mu g\ l^{-1}$), while the minimum value of 124.44 $\mu g\ l^{-1}$ was observed in August.

PO_4-P levels recorded at fishponds showed a remarkable increase compared to the main feeder (MF). Its maximum concentrations of 21.26 and 20.63 $\mu g\ l^{-1}$ were detected at Ponds 4 and 7 respectively, while its minimum value of 14.38 $\mu g\ l^{-1}$ was recorded at Pond 1. With regard to the monthly PO4-P values, its concentrations fluctuated between a minimum of 14.38 $\mu g\ l^{-1}$ in August and 23.13 $\mu g\ l^{-1}$ in April.

Trace metals:

Trace metal contents recorded at the sediment of fish ponds were much higher than the corresponding values determined at the River Nile (main feeder). The concentrations of trace metals in edible muscle tissue of each species are summarized in table (3). Iron levels in the muscle fish tissues were consistently high at the fish farm in comparison with Ni and Mn contents. Levels of iron in the fish farm fishes ranged from 61.19 to 76.12 $\mu g\ g^{-1}$, while in River Nile fishes varied from 51.22 to 68.7 $\mu g\ g^{-1}$, Ni from 1.56 to 13.32 $\mu g\ g^{-1}$ at fish farm and from 1.71 to 14.99 $\mu g\ g^{-1}$ at River Nile, Mn from 0.46 to 0.83 $\mu g\ g^{-1}$ at fish farm and 0.57 to 0.64 $\mu g\ g^{-1}$ at River Nile.

Standing crop and species composition of plankton:

Phytoplankton:

The phytoplankton community was represented by five classes namely: Chlorophyceae, Bacillariophyceae, Cyanophyceae, Dinophyceae and Euglenophyceae (Table 4 and Fig. 1a). Concerning the total phytoplankton crops, their major peak of 624 cell x 10^4 l^{-1} was observed at Pond 1 in July, while the minor one of 34x 10^4 l^{-1} was recorded at Pond 3 in August. With regard to feeders, their numerical density showed two peaks at MF in October (698 cell x 10^4 l^{-1}) and F1 in April (674 cell x 10^4 l^{-1}) as shown in figures 2a and 3a.

Chlorophyceae occupied the first predominant position at the ponds and feeders with the exception of MF, where Bacillariophyceae predominated over Chlorophyceae and Cyanophyceae, as shown in table (6). The green algae were dominated by *Scenedesmus quadricauda*, *Tetraedron minimum*, *Oocystis parva*, and *Crucigenia quadrata* (Fig. 4a).

Bacillariophyceae occupied the second predominant position forming 23.8% of the total phytoplankton crop. Diatoms occupied 70.4 % of the total phytoplankton crop at MF. *Melosira granulata*, *Synedra ulna* and *Cyclotella ocellata* were the most common diatom species flourished at the ponds (Fig. 5a) and feeders.

Cyanophyceae occupied the third predominant position and constituted 14% of the total phytoplankton crop at fishponds as shown in table (6). *Microcystis* and *Merismopedia* were the most abundant species recorded at the ponds (Fig. 6a) and feeders.

Zooplankton:

The zooplankton species found in the ponds were all, common in the Nile system especially at Menofi Canal. A total of 52 zooplankton species of which 39 were rotifers, 9 were cladocerans, and 4 were copepods in addition to the other meroplanktonic forms as shown in Table 5 and Figure 1b. Menofi Canal and Feeder 1 harbored the highest species number (33 and 34 respectively), whereas the lowest species number was recorded at Pond 5.

The average zooplankton number in the ponds was 258.4 org l^{-1}, its major peak of 1073 org l^{-1} was observed at Pond 3 in April, while the minor one of 20 org l^{-1} occurred at Pond 5 in August. With regard to feeders, their numerical density showed two peaks at MF and F1 in April (845.6 and 746.2 org l^{-1} respectively) and in August (532 and 328 org l^{-1} respectively) as shown in figures 2b and 3b. Generally, the maximum count was recorded at Ponds 3 followed by Pond 6.

Rotifers were most common in all ponds. It represented 94.64% in the ponds and 90.25% of total zooplankton number in the main feeder (Table 8). Among the thirty-nine species of rotifers found, only few species developed adequate pulses to form sufficient bulk in the samples, whereas the rest of them were found rarely. *B. caudatus*, *Polyarthra vulgaris*, *K. cochlearis*, and *B. angularis* were the most abundant, while *A. fissa*, *B. calyciflorus*, *F. longiseta*, and *T. pusilli* occurred at intermediate densities (Fig. 4b).

The maximum number of the total rotifers was recorded in MF, F 1 and F 2 during April; while in the fish farm, the maximum number was observed at Ponds 3, 6, and 7. The highest number of *B. caudatus* was recorded in F1 during October, Pond 3 during August, and Pond 6 during July. *K. cochlearis* was dominated in MF, followed by Pond 3 during April. For *B. angularis*, the maximum number was observed in F 1 and F 2 followed by Pond 3.

Copepods belonged to the families Cyclopoidae, Calanoidae, and Harpacticoidae. They were the second most common group among the metazoan zooplankton and constituted 4.23% of total zooplankton number at the fishponds. Four species were recorded. the adult and copepodite stages were not abundant, while their nauplius larvae were the most dominant stage (Fig. 5b). The maximum number of nauplius larvae was recorded in the fishponds where they represented 93.99% of total copepod numbers and 75.16% in the main feeder as in table 7. The highest numbers of nauplius larvae were recorded at F 2 during April, and at Pond 2 during June.

Cladocera was dominated by *Moina micrura*. The maximum number of total cladoceran organisms was observed at F1, Ponds 1,3, 6, and 7 with a peak during April. *M. micrura* constituted 76.50 % of total cladoceran numbers in the fishponds (Fig. 6b). It was dominated during April with maximum number in the last two ponds.

Meroplankton groups were mostly concentrated in Pond 7 and were represented mainly by insect larvae that flourished during April and October.

DISCUSSION

Phytoplankton and zooplankton communities in fishponds are subjected to wide variations in environmental conditions in addition to the fish predation. The phytoplankton and zooplankton communities developed in rearing ponds are influenced by interactions between temperature, water quality, nutrient availability, and fish predation (Lynch and Shapiro, 1981).

Water temperature plays an important role in the activity of aquatic organisms (Reynolds, 1980). It ranged between 23.4°C in October and 37.2°C in August. The average values of water temperature were correlated negatively with Cladocera ($r=-0.78$). Khalifa (2000) indicated that there was an inversely proportional highly significant relation between zooplankton community and its water temperature in the River Nile ($r=-0.75$). The minimum pH values were recorded at pond 5 followed by a distinct increase at pond 6. This observation complies quite well with the fluctuation of phytoplankton especially of green and blue-green algae ($r= 0.53$ & 0.72 respectively). The monthly pH values showed a sharp decline in July, while its maximum value was recorded in April. This fluctuation followed the monthly variations of phytoplankton and zooplankton crops, where their numerical density showed an obvious increase in April and had a remarkable decrease in late summer. This finding clearly illustrates that primary producers play an important role in pH variations at fish farms. These results coincide with of Njoku (1989) and Sweilum (2001) conclusions. Generally, the pH values of the fish farm under investigation were suitable for fish production except mid summer, when pH values were below 6.5 at most fish ponds. In this connection, Stumm and Morgan (1981) reported that pH values below 4 and above 11 are lethal for most fish. In the same time, Boyd (1979) stated that the values of pH ranging between 6.5 to 9 are most suitable for fish production.

Ammonium concentrations at fishponds were much higher than the corresponding values of NO_2-N and NO_3-N. This phenomenon can be related to natural degeneration of nitrogenous organic material of microorganisms yielding ammonia. Fish excretion and decomposition of excess un-consumed feed represented another ammonium sources in ponds (Meade, 1985). Ammonium ions exist at lower pH values, while the more toxic ammonia is present in more alkaline ($pH>9$) conditions (Ellis, 1989).

PO_4-P levels recorded at fishponds showed a remarkable increase compared to the main feeder (MF). This finding could be due to feeding and fertilization of the fish farm during the farming periods. Decomposition of dead organisms represented another source of phosphorus to the aquatic ecosystem (Golachowska, 1986). Stickney *et al.* (1979) reported that fish release sizable amounts of phosphate to water and the rejected phosphorus content sometimes represents from 61 to 87 % of the feed phosphorus. They also stated that when the fish is healthy, a large proportion of phosphorus in the faces is orthophosphate

Iron concentrations were substantially high in edible muscle tissues of the fish caught from the fish farm compared to River Nile specimens. Tilapia species feed mostly on detritus, algae and zooplankton that well flourished at the fishponds. Decomposition of these organisms leads to concentration of these metals on the upper sediment layer of the fishponds, and leaches the metals in the next farming season. Konsowa (2001) stated that the accumulation of metallic ions in the flesh of *O. niloticus* is mainly through their natural food of phytoplankton and zooplankton. In the meantime, Iron levels at the selected species were much higher than the corresponding values of Ni and Mn. This is mainly due to the high concentrations of Fe in River Nile water. In this connection, Hassan (1996) and Sobhy (1999) reported that River Nile water contains high levels of metallic ions, especially Fe which represents the main component of trace metals followed by Zn, Cu, Pb, Ni, Hg, Co, Cd, and Mn.

The phytoplankton densities in the present fishponds were correlated with the densities of zooplankton in the same ponds (r=0.59) as in figure 7. This may be due to two main factors: the regeneration of the nutrients by zooplankton leads to increase the abundance of phytoplankton (Janik, 1989), and the predation of the fishes on large zooplankton leads to the development of phytoplankton (Elhigzi *et al.* 1995).

Planktivorous fish are known to be size-selective predators that prey selectively on largest zooplankton (Zaret, 1980). The present data are concurrent with this observation since the small rotifers and the nauplius larvae of copepods were the most dominant in fishponds. Microzooplankton (rotifers, nauplius larvae, ciliates, and heterotrophic flagellates) develops better when predatory pressure by zooplankton crustaceans is reduced (Richardson *et al.*, 1990). Carpenter and Kitchell (1993) and Brett & Goldman (1996) found that removing large and more conspicuous zooplankton, lefts back small crustaceans and small rotifers. Diana *et al.* (1991) tested the trophic cascade hypothesis in aquaculture ponds containing tilapia at different densities. They detected that fish predations affect not only the prey, but also lower trophic levels. They found that zooplankton densities, particularly small zooplankton were reduced in ponds without fish. In a hypertrophic Florida Lake, Beaver *et al.*(1994) found that the abundance of zooplankters increased dramatically following fish removal (from 22 organisms l^{-1} in the presence of fishes to 151 organisms l^{-1} after fish removal). In the present study, the average number of zooplankton organisms in April (before stocking of fishes) was 2304 organisms/l while they were 706 organisms/l after fish stocking. For phytoplankton, the average number before fish stocking was 318 x 10^4-cell l^{-1}, while it was 231 x 10^4 cell l^{-1} after fish stocking.

Numerical density of phytoplankton implies that green algae occupied the first predominant position at fishponds, while diatoms were the dominant species of River Nile water (MF). Diatoms can be lost by sedimentation from the lentic water of the fish farm ponds, where sedimentation is affected by species composition. This result is confirmed by Meffert (1989) who stated that the blasted silica wall of diatoms would always have the positive advantage of sinking. In the meantime, planktivorous fish reduce the density of large sized algae. In this connection, Sondergaard *et al.* (1990) found that the removal of about 50% of planktivorous fish was found to alter the plankton community towards an increase in large-sized diatoms in Lake Sobygird, Denmark. These data are consistent with conclusion of Touliabah (1992) that Chlorophyceae always occupied first dominant position, constituting 65% of total phytoplankton crop in Serow Fish Farm (South Western shore of Lake Manzalah). Elhigzi *et al.* (1995) recorded in their experiment with Nile tilapia that the Bacillariophyta dominated in the fishless ponds, while in presence of the Nile tilapia, green algae replaced diatoms. In the same time, Sobhy (1999) reported that diatoms contributed about 55.4% while green algae constituted 25% of the total phytoplankton crop at River Nile.

The Nile tilapia appeared to affect the pond ecosystem in monoculture (pond 4) This result agrees with these of Haider (1993). The present results cleared that the highest growth rate of Nile tilapia was in polyculture system than the mono and di-culture (Sweilum, 2001). This may be due to lack of competition for supplementary or natural food between the reared fishes in polyculture. The mixing stocks of tilapia with *Clarias* usually results in greater fish production in ponds (Gryierek, 1973). For the different phytoplankton and zooplankton groups, no obvius effect was observed in mono, di, and polyculture ponds.

The greater production of fish yield is not only the result of the utilization of food as yet unused components, but is also the result of processes leading to greater productivity of the water body. These processes should be reflected by changes in the phytoplankton and zooplankton as the basic food component of most fishes (Ciborowska, 1972). Balarin and Haller (1983) pointed out that fish production could be increased in presence of natural feeding without adding artificial feeds.

Elhigzi (1995) believed that, Nile tilapia has two different feeding models:(1) size-selective predation, similar to most planktivorous fish species, and (2) a non-selective filter feeding on smaller items like phytoplankton and small zooplankton.

Panov *et al* (1973) calculated the number of zooplankton organisms in carp rearing ponds, and found that 1.5 org ml^{-1} must be in the carp rearing ponds. Houde (1973) and Geiger (1983a and b) evaluated that higher concentration of zooplankton organisms may be required if they consist largely of rotifers. Mageed (1996) calculated zooplankton in ponds of tilapia and mugil at El Fayoum fish farms as 0.2 to 1.5 org ml^{-1}. In the present study, the average of zooplankton organisms ranged between 0.58 org ml^{-1} at pond 3 to only 0.13 org ml^{-1} at pond 5. This means that the secondary production in the fishponds was poor and insufficient to the high fish production.

All freshwater fishes feed on plankton in a broad sense at some stages of their life. It is generally accepted that the first food of the post – larval fish (after disappearence of the Yolk Sac) consists at least partially of plankton (Fernando, 1994). Mavuti (1990) studied the feeding habits of fish fry and found that they feed mainly on zooplankton (60%), Chirnomid larvae (30%), and algae (10%). The fry select larger species as their age and mouth size increase. The contribution of algae increased to more than 50% for the tilapias as the fry increase in size.

In conclusion, pH values dropped to a lesser value during July (below 6.5) at most fish ponds. High temperature and low pH leads to stress on fish life. The fishpond water should be changed during this period or buffering pH values by liming. The total crop of zooplankton in most fish ponds was not adequate to the high fish production. So, fertilization of ponds should be adjusted to decrease the dependance on the artificial food. The concentration of Fe in the flesh of the fish farm fishes was much highr than the River Nile fishes which may be due to its accumulation in the upper sediment layer of the ponds. So, this layer should be replaced at the end of each farming season.

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Table (1): Area (m^2), stocking density (fish/pond), and and stocking rates

	Area m^2	Stocking density			Total (4Fish/m^2)	Stocking Rates
		O. niloticus	*T. galilios*	*C. gariepinus*		
Pond 1	450	900	900	*	1800	1*1*0
Pond 2	900	1800	1200	600	3600	3*2*1
Pond 3	1200	2400	1600	800	4800	3*2*1
Pond 4	300	1200	*	*	1200	1*0*0
Pond 5	750	2250	*	750	3000	3*0*1
Pond 6	800	2400	*	800	3200	3*0*1
Pond 7	525	1050	1050	*	2100	1*1*0

Table (2): Average values of temperature ^{0}C, pH, nitrite (µg/l), nitrate (µg/l), ammonium (µg/l) and phosphate (µg/l).

	Temperature (^{0}C)			PH			Avg. Nitrogen compounds			Avg.
	Min.	Max.	Avg.	Min.	Max.	Avg.	NO_2 µg/l	NO_3 µg/l	NH_4 µg/l	PO_4 µg/l
Main Feeder	23.7	31.7	28.7	6.53	8.27	7.56	8.03	83.2	277.44	11.25
Feeder 1	24.2	33.5	30.2	6.58	8.44	7.75	6.8	233.6	750.71	11.88
Feeder 2	24.7	34.1	30.7	6.19	8.23	7.35	9.27	150.4	479.4	22.6
Pond 1	24.6	37.2	31.5	6.38	8.29	7.7	25.34	62.4	227.8	14.38
Pond 2	23.5	36.6	31.5	6.85	8.4	7.92	10.82	52.8	222.36	16.25
Pond 3	23.8	35.7	31.1	6.53	8.38	7.76	6.8	219.2	595	15
Pond 4	23.4	34.5	30.3	6.82	8.71	7.81	6.18	169.6	414.8	21.26
Pond 5	23.7	33.3	30	6.35	8.36	7.61	7.42	161.6	717.4	18.75
Pond 6	23.8	33.2	29.4	7.63	8.29	8.03	17.3	60.8	274.72	18.75
Pond 7	23.8	30.9	28.3	6.03	8.31	7.39	19.16	67.2	179.52	20.63

Table (3): Trace metal concentrations in muscle tissues of *Oreochromis niloticus*, *Tharothrodon galilios*, and *Tilapia zillii* (µg/g wet wt.) and sediment of the Barrage Fish Farm and River Nile

Sites	Fishes µg/g						Sediment µg/g		
	Species	Specimens no.	Size range (mm)	Fe	Mn	Ni	Fe	Mn	Ni
Fish Farm	*O.niloticus*	10	110-150	72.06	13.32	0.83	840	310	15
	S.galilos	8	120-150	76.12	1.56	0.83			
	T.zilli	8	95-110	61.19	2.54	0.46			
River Nile	*O.niloticus*	8	100-140	64.52	14.99	0.64	710	242	10
	S.galilos	6	105-140	68.7	1.71	0.57			
	T.zilli	7	100-110	51.22	1.89	0.62			

Table (4): List of the recorded phytoplankton species at MF, F 1& F 2 and the fishponds.

PHYTOPLANKTON			
Chlorophyceae:-		*Melosira granulata*	(Her.) Ralfs
Scenedesmus quadricauda	(Turpin) Brebisson	*M.granulata var.angustissma*	Muller
S. bicaudatus	Chodat	*Nitzschia palea*	(Kutz.)W.Smith
Oocystis parva	W.et. G.S.West	*N. closterium*	W.Smith
O. solitaria	Wittrock	*N. gracilis*	Hantz
O. gigas	Archer	*Synedra ulna*	(Niyz.)Her
Pediastrum simplex	Meyen	*S. ulna var. biceps*	(Kutz.)
P. simplex var.sturmii	(Reinsch) Wolle	*S. ulna var. danica*	(Kutz.) Grun)
P. clathratum	(Schyoeter)Lemmer	*Pleurosigma elongatum*	W.Smith
P. duplex	Meyen	*Amphora ovalis*	Kutz
Lagerheimia ciliata	(Lagerheim)Chodat	*Rhopalodia gibberula*	(Her.)O.F.Muller
L. citriformis	(Snow)Collins	Cyanophyceae:-	
Kirchneriella obesa	(West)Schmidle	*Microcystis aeruginosa*	Kutz.
Golenkinia radiata	(Chodat)Wille.	*M. flos-aquae*	(Witter.)Elenkin
G. pancispina	West & West	*Gomphosphaeria aponiana*	Kutz.
Coelastrum sp.		*Merismopedia tenuissima*	Lemmer.
Dictyosphaerium pulchellum	Wood	*M. punctata*	Meyen
D. subsolitarium	Van Goor	*Chroococcus turgidus*	(Kutz.)Nageli
Tetraedron minimum	(A.Braun)Hansgirg	*Cylindrospermopsis raciborskii*	Wolosz.
T. trigonum	(Naegeli)Hansgirg	*Phormidium tenue*	(M enegh.)
Straurastrum natator	W.West	*Lyngbya limnetica*	Lemmer.
S. gracile	Ralfs	*Spirulina major*	Kutz
Crucigenia quadrata	Morren	Dinophyceae:-	
C. rectangularia	(A.Br.) Gay	*Peridinium cinctum*	(O.F.Muller)
Chlorella vulgaris	Beijerinck	Phacus pleuronectes	(O.F.Muller)Dujardin
Bacillariophyceae:-		Euglenophyceae:-	
Cyclotella ocellata	Pant	***Euglena acus***	Her.
C. operculata	Kutz	*Euglena varibilis*	Klebs.
C. glomerata	Bachmann		

Table (5): List of the recorded zooplankton species at MF, F 1& F 2 and the fishponds.

ZOOPLANKTON			
Rotifera:-		*Conochilus unicornis*	*Roussiet*
Keratella cochlearis	Gosse	*Scaridum longicaudum*	*Muller*
K. quadrata	Muller	*Ascomorpha ecudis*	*Perty*
Brachionus plicatilis	Muller	*T. similis*	Wierzejski
B. angularis	Gosse	*P. minor*	Voigt
B. caudatus	Battis&Daday	*Hexarthra mira*	*Hudson*
B. calyciflorus	Pallas	**Cladocera:-**	
B. quadridentatus	Hermann	*Diaphanosoma excisum*	Sars
B. falcatus	Zacharias	*Bosmina longirostris*	*Muller*
B. patulis	Muller	*Alona intermedia*	*Sars*
Annuraeopsis fissa	Gosse	*A. rectangula*	*Sars*
Asplanchna priodonta	Gosse	*Macrothrix laticornis*	*Jurine*
A. girodi	De Guerne	*Moina micrura*	*Kruzi*
Monostyla bulla	Gosse	*M. brachiata*	*Jurine*
M. closterocerca	Schmarda	*Ceriodaphnia cornuta*	*Sars*
M. lunaris	Ehrenberg	Copepoda:-	
Lecane luna	Muller	Nauplius larvae	
L. depressa	Gosse	Cyclopoid Copepodites	
Lepadella ovalis	Muller	Calanoid Copepodites	
Fillna opoliensis	Zacharias	*Thermocyclops hyalinus*	*Sars*
F. longiseta	Ehrenberg	*Mesocyclops leuckarti*	*Claus*
Trichocerca pusilli	Jennings	*Thermodiaptomus galebi*	*Barrois*
T. stylata	Gosse	Others:-	
T. collaris	Rousselet	Nematoda	
T. rousselti	Voigt	Insect larvae	
Synchaeta pectinata	Ehrenberg	Tardigrada	
Cephalodella catellina	Muller		
Euchlanis dilatata	Ehrenberg		
Polyarthra vulgaris	Garlin		

Table (6): Distribution of the main groups of the plankton at the fishponds

Stations	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Pond 7
Total phytoplankton (cellsx10^6/l)	292	194	299	260	139	356	196
Chlorophyceae	116	132	163	144	80	256	155
Bacillariophyceae	123	39	74	49	38	56	36
Cyanophyceae	13	22	18	59	21	62	4.2
Others	30	0	30	84	0	0	0.0
Zooplankton (org./l)	150.7	234.4	580	155.6	133.2	301.3	232.5
Rotifera	137.0	182.1	549.5	149.9	120.8	275.9	205.6
Cladocera	3.4	1.7	4	0.75	0.93	8.7	16.2
Copepoda	9.5	50.9	25.7	4.7	11.3	16.4	10.6
Others	0.33	0	0.7	0.17	0	0.37	0.70

Table (7): The percentage abundance of the main groups to the total phytoplankton crop.

Classes	MF	F1	F2	Ponds
Chlorophyceae	13.7	53.7	57	60
Bacillariophyceae	70.4	35.8	34	25.8
Cyanophyceae	15.6	7.5	9	14.05

Table (8): The percentage abundance of the main groups to the total Zooplankton crop.

GROUPS	Main Feeder	Feeder 1	Feeder 2	Ponds
Rotifera	90.25	91.2	84.39	94.64
Copepoda:	5.57	6.47	14.02	4.23
(Nauplii)	(75.16)	(81.66)	(93)	(93.99)
Cladocera	3.33	2.69	0.87	1.01
Others	0.45	0.71	0.74	0.13

Table (9): Correlation coefficient between the different groups of phytoplankton, zooplankton and some physico-chemical characters.

	NO_2 ug/l	NO_3 ug/l	NH_4 ug/l	PO_4 ug/l	Temp.	pH	Rotifera	Cladocera	Copepoda	Chloro.	Bacillario.
Cyanophyta.	0.28	0.08	0.04	0.42	-0.09	0.72	-0.06	-0.26	-0.18	0.57	-0.17
Bacillariophyta.	0.56	0.07	-0.15	0.7	0.55	0.08	0.12	-0.18	-0.22	-0.06	
Chlorophyta.	0.19	0.24	-0.37	0.15	-0.35	0.53	0.43	0.47	0.03		
Copepoda	-0.22	-0.21	-0.16	0.46	0.48	0.43	0.25	-0.21			
Cladocera	0.53	-0.43	-0.52	0.33	-0.78	0.45	0.13				
Rotifera	-0.28	0.50	0.27	0.38	0.12	0.17					

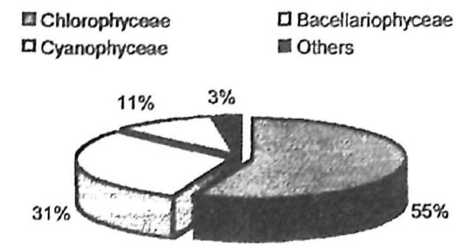

Fig. 1a: Percentage of ocurrence of the different phytoplankton groups

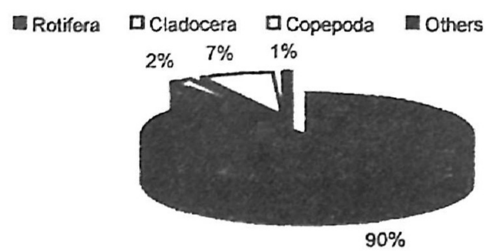

Fig. 1b: Percentage of ocurrence of the different zooplankton groups

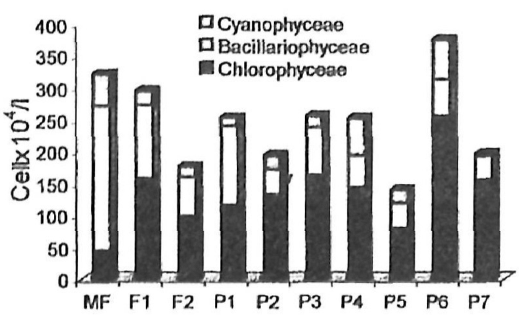

Fig. 2a: Distribution of the main phytoplankton groups.

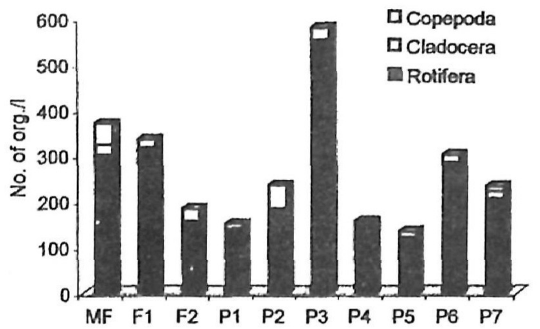

Fig. 2b: Distribution of the main zooplankton groups.

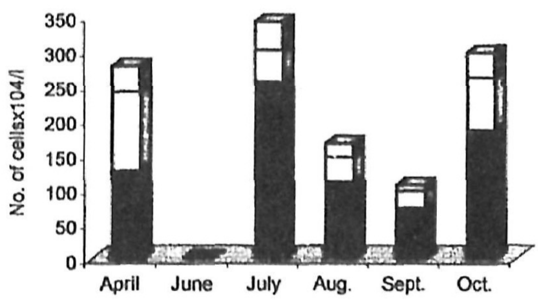

Fig. 3a: Monthly variations of the main phytoplankton groups at the fish ponds

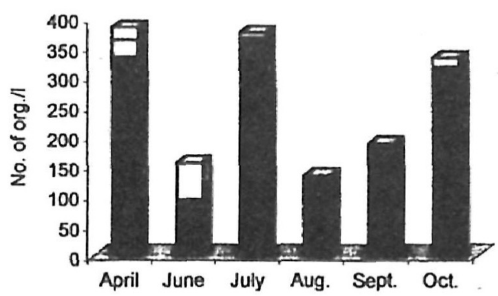

Fig. 3b: Monthly variations of the main zooplankton groups at the fish ponds

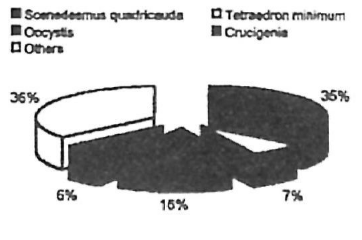

Fig. 4a: Percentage of ocurrence of the dominant Chlorophyceae species

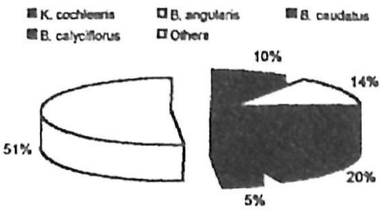

Fig.4b: Percentage of ocurrence of the dominant rotiferan species

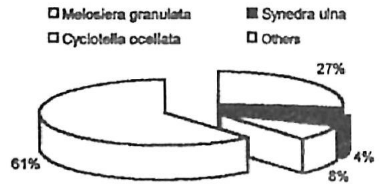

Fig. 5a: Percentage of ocurrence of the dominant Bacellariophyceae species

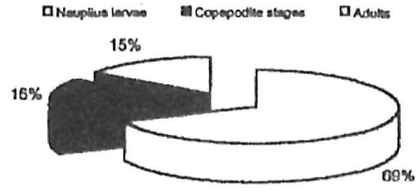

Fig. 5b: Percentage of ocurrence of the different copepod stages

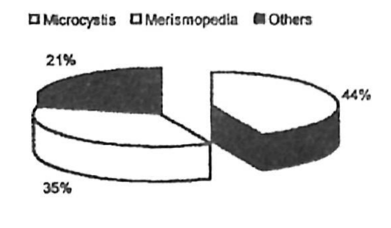

Fig. 6a: Percentage of ocurrence of the dominant Cyanophyceae species

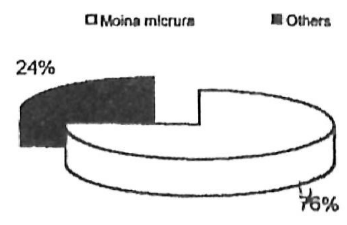

Fig. 6b: Percentage of ocurrence of the donminant Cladoceran species

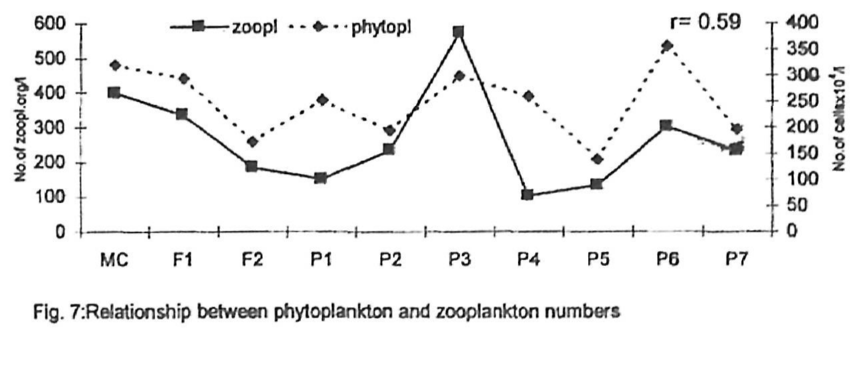

Fig. 7:Relationship between phytoplankton and zooplankton numbers