African Journal of Biotechnology Vol. 8 (9), pp. 1911-1918, 4 May, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Studies on the influence of *Microcystis aeruginosa* on the ecology and fish production of carp culture ponds

P. Padmavathi* and K. Veeraiah

Department of Zoology, Acharya Nagarjuna University, Nagarjuna Nagar - 522 510, A.P., India.

Accepted 26 December, 2008

In many fish ponds, blue-green algae (Cyanobacteria) constitute the greater part of the phytoplankton. Of the blue-green algae common in fish ponds, *Microcystis aeruginosa* is said to be a noxious species. It sometimes forms spectacular water blooms, often with harmful consequences such as depletion of oxygen, poor growth of fish and even mass mortality among the fish. The present study was aimed at investigating the influence of different levels of *M. aeruginosa* on the water quality and fish production of carp culture ponds. For the present study, three carp culture ponds with high, moderate and low levels of *M. aeruginosa* were selected. In the three ponds, physico-chemical parameters of water, phyto- and zooplankton and fish production were studied. The results indicated that the fish yield was low with concomitant fish mortalities in the pond with high levels of *M. aeruginosa* compared to the other two ponds. The influence of the different levels of *M. aeruginosa* on other planktonic groups and in turn their effect on fish production were analyzed and discussed in the light of the existing literature.

Key words: Cyanobacteria, algal blooms, *Microcystis,* phytoplankton, zooplankton, fish production, carp culture ponds.

INTRODUCTION

In fish ponds, the production of fish has often been significantly influenced by the quality and quantity of phytoplankton. Nutrient enrichment by the addition of fertilizers, supplementary feeds and other eutrophication processes are said to cause proliferation of algae, especially blue-greens (cyanobacteria). The plasticity of photosynthetic apparatus (Krogmann, 1973), ability to assimilate a variety of biogenic organic compounds (Smith, 1973) and better adaptability to adjust to different environmental factors (Sevrin-Reyssac and Pletikosic, 1990) are suspected to be responsible for the qualitative and quantitative preponderance of blue green algae over other phytoplanktonic groups. Species of blue-green algae such as *Microcystis, Oscillatoria, Arthrospira, Spirulina, Anabaena* and *Raphidiopsis* are frequently observed as blooms in fish ponds. Though light blooms of these algae may not be harmful to fish life or may even serve as food, a dense bloom may cause changes in water quality which are deleterious to fish populations.

Furthermore, they may be directly toxic to other aquatic organisms (Shilo, 1967; Bernardi and Giussani, 1990; Kaarina and Gary, 1999). Some species liberate compounds (Geosmin, 2-methylisoborneol, hexanal and heptanal) giving a muddy taste and musty odour (off-flavors) to the water and to the flesh of fish (Aschner et al., 1967; Persson, 1980, 1981; Lovell, 1983; Zimba and Grimm, 2003).

Of all the bloom forming species, *Microcystis aeruginosa* proliferates at high magnitude and causes serious harm to the fish (Gorham, 1960). Though a good deal of information on the ecology of freshwater blue-green algae is available, little is known about the ecology of *M. aeruginosa* in fish ponds (Ganapati, 1940, 1960; Prescott, 1948; Singh, 1955; Philipose, 1960, 1969; George, 1962; Sukumaran, 2002; Paerl and Tucker, 2007). Though carp culture has developed at a tremendous pace in the coastal districts of Andhra Pradesh, so far no attempt has been made to study the impact of *M. aeruginosa* on the ecology and fish production in fish ponds. Hence, in the present study, an attempt has been

*Corresponding author. E-mail: padmapin@yahoo.com. Tel: 0863-2337104.

Table 1. Particulars of inputs used during the culture period in the three ponds.

Input	Pond		
	A	B	C
Area (ha)	2.2	2.2	1.6
Duration of culture	191	220	278
period (days)	Jun 20, 2003 to Dec 27, 2003	Jun15, 2003 to Jan 20, 2004	Jul 15, 2003 to Apr 18, 2004
Fertilizers			
Organic (t/ha)			
Cow dung	5.50	8.5	7.5
Poultry manure	10.25	--	--
Inorganic (kg/ha)			
Single Superphosphate	100	--	210
N.P: K (20:20:0)	--	--	218
N:P:K (28:28:0)	--	--	31
Urea	120	40	--
Di-ammonium phosphate	120	40	--
Potash	--	--	100
Lime (kg/ha)	250	250	1330
Fish stocked (no./ha)	13,144	8,680	5,540
Supplementary feeding			
Percentage body wt. of fish/day	2-9	2-8	2-10
Percentage composition:			
Deoiled rice bran	77	78	83
Groundnut cake	20	20	17
Common Salt	2	2	--
Mineral Mix	1	--	--
$CuS0_4$+Citric acid (kg/ha)	5.0 + 10.0	--	--

made to study the factors influencing the proliferation of *M. aeruginosa* and the different levels of *M. aeruginosa* on water quality, plankton and fish production in carp culture ponds.

MATERIALS AND METHODS

Three carp culture ponds located in the village Gundugolanu (81°12' E and 16°45' N), West Godavari district, Andhra Pradesh were chosen for the present study. They are designated as ponds A, B and C. The ponds were selected mainly based on the relative levels of the blue-green alga, *M. aeruginosa* such as high, moderate and low levels in Ponds A, B and C, respectively. The extent (water spread area) of ponds A, B and C is 2.2, 2.2 and 1.6 ha, respectively. The depth of water in the ponds was maintained between 1.2 and 1.5 m. The duration of the culture period in each pond is given in Table 1.

In the three ponds, monthly samples were collected for studying physico-chemical parameters of water and plankton during the culture period in between 9 and 10 a.m. The physico-chemical parameters studied in the ponds are given in Table 2. The estimation of various parameters was followed by the standard methods suggested by Welch (1948), Golterman and Clymo (1969) and APHA (1985). Plankton samples were collected by filtering 100 l of water through plankton net made up of silk bolting cloth No.25 and the plankton obtained was fixed in 5% formalin. Enumeration of the individual plankters was done on the lines recommended by Wetzel and Likens (1979). Indian major carps namely *Catla catla* (catla) *Labeo rohita* (rohu) and *Cirrhinus mrigala* (mrigal) were stocked in the ponds. The number of fish stocked and harvested with their average weights, and gross and net yields are given in Table 5. The ponds were treated with organic and inorganic fertilizers before and after the release of carps during the culture period. The particulars of inputs used during the culture period in the three ponds are given in Table 1. However, the detailed pond fertilization schedule is as follows: Pond A - June 14th – cow dung 5.5 t/ha, single super phosphate 100 kg/ha, urea and DAP, each 60 kg/ha; July 28th - poultry manure 10.25 t/ha, urea and DAP, each 60 kg/ha; Pond B - June 10th – cow dung 4.5 t/ha, urea and DAP, each 20 kg./ha; Aug.13th – cow dung 4.0 t/ha, urea and DAP, each 20 kg/ha; and Pond C - July 11th – cow dung 3 t/ha, super phosphate 100 kg/ha, NPK (28:28:0) 31 kg/ha, potash 25 kg/ha; Sept. 12th – cow dung 2 t/ha, NPK (20:20:0) 100 kg/ha, Potash 25 kg/ha Nov. 5th - NPK (20:20:0) 118 kg/ha and potash 25 kg/ha Feb. 25th – cow dung 2.5 t/ha, super phosphate 110 kg/ha and potash 25 kg/ha. Fish were fed daily with supplementary food (Table 1) at the rate of 2-10% of body weight of the fish, the maximum being given during the initial periods and the minimum at the end of the culture period, and also during the periods of dissolved oxygen depletion in pond A. In pond A, in order to control the *M. aeruginosa* bloom, a mixture of copper sulphate and citric acid (0.5 and 1.0 ppm, respectively) was used in October. Also during the period of heavy algal bloom, water was aerated at nighttime to prevent fish mortality due to dissolved oxygen depletion.

Table 2. Physico-chemical parameters of water in the three ponds (MEAN ± SD).

Parameter	Pond		
	A	B	C
Water temperature (^{0}C)	29.4 ± 2.16 (26.0 - 32.0)	29.2 ± 1.42 (27.0-31.2)	29.61 ± 1.35 (27-31.8)
Transparency (cm)	21.0 ± 6.95 (9-29)	34.15 ± 5.36 (25-41)	30.22 ± 5.35 (22-39)
Dissolved oxygen (mg/l)	4.24 ± 1.25 (2.2 - 6.0)	5.42 ± 0.76 (4.2 - 6.2)	6.06 ± 0.86 (4.8-7.4)
pH	8.68 ± 0.47 (8.1-9.3)	8.15 ± 0.12 (8.0-8.4)	8.6 ± 0.45 (8.1-9.1)
Total alkalinity (mg/l as $CaCO_3$)	124.85 ± 8.31 (112-138)	120.8 ± 13.6 (98-138)	110.22 ± 22.39 (84-146)
Total hardness (mg/l as $CaCO_3$)	162.5 ± 43.5 (125-255)	159.14 ± 30.2 (135-220)	155.55 ± 40.65 (100-220)
Conductivity (µmhos/cm)	609.2 ± 74.7 (520-700)	586.4 ± 39.4 (520-645)	340 ± 86.27 (260-490)
Chlorides (mg/l)	120.11 ±12.42 (104.9-135.9)	118.3 ± 10.8 (105.9-132.9)	47.31 ± 13.96 (29.98-63.98)
Nitrate - N (mg/l)	0.18 ± 0.11 (0.07-0.39)	0.23 ± 0.12 (0.09-0.41)	0.73 ± 0.22 (0.42-1.04)
Nitrite - N (mg/l)	.03 ± 0.016 (0.011-0.064)	0.036 ± 0.014 (0.012-0.055)	0.034 ± 0.01 (0.021-0.052)
Ammonia - N (mg/l)	1.03 ± 0.54 (0.34-1.84)	0.41 ± 0.12 (0.26-0.59)	0.45 ± 0.14 (0.24-0.68)
Orthophosphate (mg/l)	0.93 ± 0.19 (0.52-1.78)	0.90 ± 0.20 (0.33-1.42)	0.77 ± 0.45 (0.141-1.49)
Iron (mg/l)	0.59 ± 0.22 (0.35-0.97)	0.46 ± 0.10 (0..32-0.61)	0.47 ± 0.18 (0.24-0.86)

Values in parentheses are the ranges.

RESULTS

Physico-chemical parameters of water

The parameters studied and their mean ± SD values (n = 7, 7 and 9 for ponds A, B and C, respectively) observed during the culture period in the three ponds are given in Table 2.

Plankton

The total number of genera recorded in ponds A, B and Cwere 35, 44 and 51, respectively. Their monthly levels was also recorded.

Phytoplankton

Phytoplankton was numerically abundant than zooplankton. Phytoplankton was represented by 17, 23 and 31 genera in ponds A, B and C, respectively. They belonged to five classes; Cyanophyceae, Chlorophyceae, Bacillariophyceae, Eugleninae and Dinophyceae. The genera recorded in the three ponds are summarized in Table 3. The monthly numerical levels of different phytoplankters was studied. The range and mean ± SEvalues and the dominant genera during the culture period are given in Table 4.

Zooplankton

Zooplankton was represented by Rotifera, Copepoda and Cladocera in the order of dominance whereas the other zooplanktonic forms were almost negligible. Zooplankton was identified up to species level. The total number of species recorded in ponds A, B and C was 23 (14, 3 and 6), 28 (15, 5 and 8) and 31 (16, 6 and 9), respectively. The numbers in parentheses represent the number of species of rotifers, cladocerans and copepods, respectively. The species recorded in the three ponds are summarized in Table 3. The monthly numerical levels of different zooplankters was studied. The range and mean ± SE values and the dominant species during the culture period are given in Table 4.

Fish

In the three ponds, Indian major carps namely catla, rohu and mrigal were stocked. The number of fish stocked and harvested with their average weights, and gross and net yields are given in Table 5.

DISCUSSION

The carrying capacity and production of fish ponds can be increased by fertilization which encourages the growth of phytoplankton and in turn the amount of food available to the fish. The fish ponds receiving fertilizers become eutrophic in course of time and quite often dominated by blue-green algae. These algae play a major role in fish ponds, not only because of their prolific development but also due to their effects on the environment and on zooplankton and fish. In the ponds under study, the temperature was ranged from 26 to 31.8°C. Roberts and Zohary (1987) reported that 25 to 35°C is the temperature for optimal growth of *Microcystis*. Thus high temperatures form an important factor conditioning the formation of blooms. In fish ponds, secchi disc transpa-

Table 3. Plankton composition in the three fish ponds.

Plankton	Species
I. Phytoplankton	
Cyanophyceae	*Microcystis aeruginosa, Merismopedia, Gomphosphaeria, Anabaena*, *Oscillatoria* and *Lyngbya.*
Chlorophyceae	*Eudorina, Pandorina, Actinastrum, Pediastrum, Cosmarium, Closterium, Tetraedon, Scenedesmus, Ankistrodesmus, Crucigenia* and *Coelastrum*
Bacillariophyceae	*Synedra, Navicula, Fragilaria, Nitzschia, Amphora, Cymbella,Gomphonema , Melosira* and *Cyclotella*
Euglenineae	*Euglena, Phacus* and *Trachelomonas*
Dinophyceae	*Peridinium* and *Gymnodinium.*
II. Zooplankton	
Rotifera	*Brachionus calyciflorus, B. angularis, B. caudatus, B. falcatus B. forficula, B. diversicornis, B. rubens, B.budapestinensis, Keratella tropica Asplanchna* sp., *Filinia longiseta, Lecane* sp., *Monostyla bulla, Hexarthra* sp. and *Polyarthra* sp.
Cladocera	*Diaphanosoma excisum, Moina micrura, Ceriodaphnia cornuta, Bosminopsis dietersi, Alona pulchella* and *Chydorus ventricosus*.
Copepoda	*Heliodiaptomus viduus, Allodiaptomus raoi, Neodiaptomus strigilipes, Pseudodiaptomus binghami, Mesocyclops thermocyclopoides, M. aspericornis, Thermocyclops crassus, Microcyclops varicans, Eucyclops serrulatus* and *Tropocyclops prasinus*.

Table 4. Plankton levels (Ind./l) in the three fish ponds (mean ± SE).

Plankton	Pond		
	A	B	C
Phytoplankton			
Cyanophyceae	173083±151776 ab (1924-1084020)	3088±1224 ab (416-9300)	1514±777 ab (46-7200)
Chlorophyceae	376±97 cd (0-692)	1936±1370 ce (268-10148)	11032±6220 ecf (48-58320)
Bacillariophyceae	2077±1093 g (151-8500)	366±70 gh (76-644)	345±76 gh (110-816)
Euglenineae	28±17 l (0-122)	202±115 ij (0-864)	262±161 ij (0-1488)
Dinophyceae	--	--	481±435 k (0-3956)
Total	175565±151596 (2952-1085194)	5593±2511 (1769-20188)	15888±7675 (300-58640)
Zooplankton			
Rotifera	272±112 lmno (12-826)	634±72 no (80-1487)	972±489 op (72-4688)
Cladocera	36±22 q (0-172)	50±13 qr (18-112)	115±61 qs (6-594)
Copepoda	73±16 t (16-134)	57±8 u (32-94)	77±11 u (2-99)
Copepod larvae	334±103 (126-882)	187±36 (88-324)	402±192 (96-1560)
Total	717±195 (184-1504)	1234±279 (386-2616)	1528±447 (420-4886)
Total plankton	176282±152181 (3664-1086022)	6828±2428 (3085-21092)	17417±6675 (720-59522)

Values in parentheses are the ranges. "a" to "u" indicate the dominant genera/species. a, *Microcystis aeruginosa;* b, *Oscillatoria;* c, *Pediastrum;* d, *Scenedesmus;* e, *Eudorina;* f, *Pandorina;* g, *Synedra;* h, *Melosira;* i, *Phacus;* j, *Euglena;* k, *Peridinium;* l, *Brachionus forficula;* m, *Filinia longiseta;* n, *Keratella tropica;* o, *Polyarthra* sp. ; p, *B. caudatus*; q, *Moina micrura;* r, *Diaphanosoma excisum;* s, *Ceriodaphnia cornuta;* t, *Microcyclops varicans*; and u, *Mesocyclops* sp.

rency provides a rough estimate of plankton levels. Transparency of water showed an inverse correlation to plankton levels ($P<0.05$). Among the three ponds, low transparency is seen in pond A indicating an abundant plankton followed by pond C and B (Figure 1).

Dissolved oxygen is observed to be the most important factor in influencing the productivity of ponds as was clearly seen in pond A. In this pond, low fish production (Table 5) was mainly due to low oxygen concentrations prevailed by the high stocking densities of fish, heavy organic manuring and the presence of abundant *M. aeruginosa*. The proliferation of *M. aeruginosa* particularly in pond A might be due to low dissolved oxygen concentrations prevailed for long periods (Figure 1). Steward and Pearson (1970) reported that in light, blue-green algae grow more rapidly under microaerophilic than under fully aerobic conditions. Ganf (1974) also stated that the development of blue-green algae may de-

Table 5. Fish production data in the three ponds.

Production data	Pond		
	A	**B**	**C**
A. Ffish stocked (no./ha)	13,144 Mean wt. g	8,680 Mean wt. g	5,540 Mean wt. g
Catla	3,472 (150)	2,480 (200)	1,510 (200)
Rohu	7,440 (125)	4,960 (175)	3,162 (175)
Mrigal	2,232 (125)	1,240 (150)	868 (175)
Fish harvested (no./ha)	7,936	8,184	5,232
Catla	1,488 (630)	2,356 (1145)	1,413 (1820)
Rohu	4,588 (545)	4,712 (1015)	3,026 (1525)
Mrigal	1,860 (485)	1,116 (920)	793 (1345)
Fish yield (t/ha)			
Gross yield	4.34/191 days or 8.29/year	8.50/220 days or 14.10/year	8.25/278 days or 10.83/year
Net yield	2.61/191 days or 4.98/year	6.96/220 days or 11.54/year	7.25/278 days or 9.52/year

pend on the ability of the ponds to maintain low concentrations of dissolved oxygen for long periods. Sevrin-Reyssac and Pletikosic (1990) stated that the substantial quantity of oxidizable substances in fish ponds (excrements of zooplankton and fishes, organic fertilizers added) may be of considerable benefit to cyanobacteria indirectly because it lowers the concentration of dissolved oxygen. In fish ponds, oxygen depletion occurs mainly due to algal blooms during early hours. In pond A, mortality of fish (about 5000/ha) was observed in the month of October during early hours when the bloom persists. The causes have been traced to be due to low oxygen content and also most probably due to high ammonia content of the water which is toxic at high pH (Figure 1 and Table 2). Hence, it can be said that the mortality of fish may not only be due to low dissolved oxygen content but also due to high pH and ammonia levels associated with *M. aeruginosa* bloom. Further, insufficient oxygen and high ammonia levels not only kill fish outright but also promote disease and/or temporarily reduce the feeding and growth rates of fish (Meyer et al., 1973; Shilo and Rimon, 1982). Thus poor growth and production of fish in pond A can be explained.

The pH of water in all the ponds was on the alkaline side. In pond A, the pH at which dense bloom of *M. aeruginosa* observed was 9.3. The moderate levels of this alga was observed at pH ranging between 8.0 and 8.8. Gerloff et al. (1952), who studied *M. aeruginosa* in pure cultures reported that maximum growth was obtained in cultures when the pH was maintained at 9-10 for about ten days, though according to them, in nature where the alga remains longer, heavy growth might occur at pH 8. In the present study, a positive correlation between total alkalinity and blue-green algae has been observed. Conductivity and chlorides are relatively higher in pond A and B than in pond C in which green algae dominated. Nitrate-N, ammonia-N and orthophosphate concentrations were observed to be high in the months before the formation of dense bloom of *M. aeruginosa* (Figure 1). These high levels of nutrients might be due to the addition of fertilizers in the pond. Thus, the increase in concentrations of nitrates and phosphates were reflected in the increased growth of *M. aeruginosa.* However, during the peak levels of *M. aeruginosa*, low levels of nitrates and phosphate, but not ammonia, were recorded (Figure 1). As ammonia is the chief excretory product of fish, its persistence in the water can be explained. Fogg et al. (1973) also stated that cyanobacteria predominant in waters, poor in nutrients, maxima tending to occur some weeks after the nutrient concentrations have decreased. The reason for this may be that they store previously available nitrogen which they use under nitrogen-limiting conditions. However, their levels seems closely linked to the degree of eutroplication of the water. Gerloff et al. (1952) who studied *M. aeruginosa* in pure cultures in inorganic nutrient solutions reported that its nitrogen requirement is high. According to Philipose (1960), the presence of nitrates seems an important source of nitrogen to promote the growth and rapid reproduction of *M. aeruginosa.* In the subsequent months when the bloom disappeared, the levels of nutrients again increased. As the pond A was not fertilized after August, this increase in nutrient levels might be due to the release of stored nitrogen and phosphorus contents during algal decay. Gerloff and Skoog (1954) have shown that *M. aeruginosa* stores large amounts of nitrogen. Even though this alga is not known to fix atmospheric nitrogen, this capacity to store nitrogen has been attributed as one of the reasons for its dominance. Hammer (1964) stated that accumula-tion of orthophosphates by blue-green algae helped in their bloom formation and in the liberation of phosphates into water during their decomposition.

Fertilization of ponds as practiced would appear to result in the production of unpredictable mixture of algae. In pond A, relatively higher densities of *M. aeruginosa* can be attributed to the application of more organic manure. In pond C, different pattern of fertilization includ-

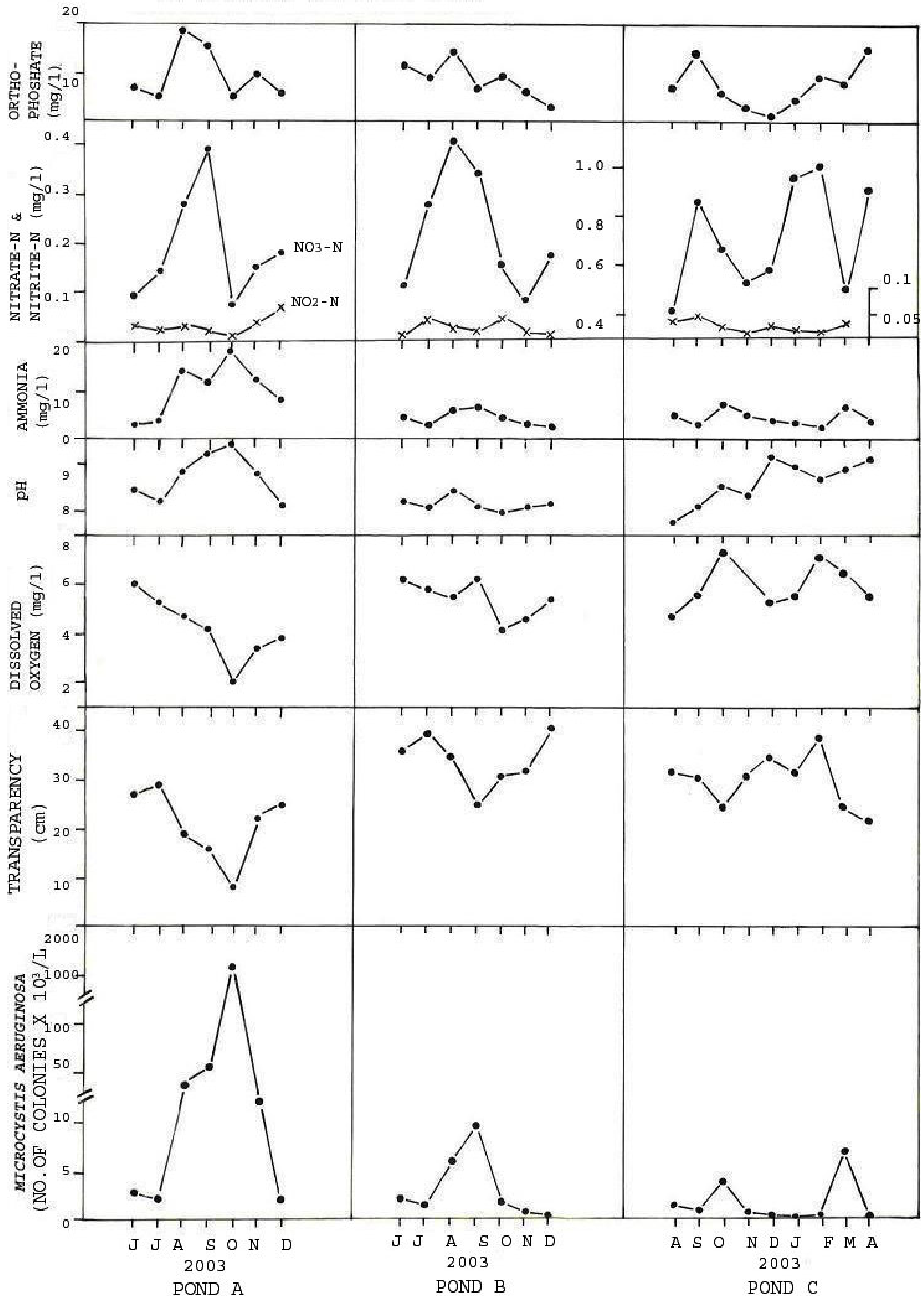

Figure 1. A comparative illustration showing relationships between *Microcystis* levels and some physico-chemical parameters of water in the three ponds.

ing the regular application of potash may lead to the development of green algae as dominant phytoplankton. However, the applicability of potash in developing green algae in other fish ponds requires further study because whether it became a limiting factor in this particular pond or has a stimulating effect on the development of green algae is unknown. The occurrence of *M. aeruginosa* also influenced the diversity and density of plankton. The diversity of plankton was observed to be low as the density of *M. aeruginosa* increased. Hence, the diversity was low in pond A followed by pond B and C. According to Hellebust (1974), blue-green algae can have an inhibiting effect on other species (hetero-antagonism). A blue-green algal species finds optimal conditions in a pond and increases until it becomes dominant, eliminating by its excretions most of the other species, until they are found only sporadically (hetero-antagonism), so that the phytoplankton present is very abundant but not very diversified (Lefevre et al, 1952). The effect of the active substances released by blue-green algae is not only limited to other phytoplanktonic Organisms but also to the zooplankton, e.g. inhibiting nutrition and reproduction among some rotifers (Erman, 1962; Pourriot, 1965) and certain cladocerans (Ryther, 1954; Uhlman, 1961; Arnold, 1971).

The toxicity of *Microcystis* extracts was established by Braginskii (1955) on entomostraca of the genera *Daphnia* and *Cyclops*. Sevrin-Reyssac and Pletikosic (1990) reported that blue-green algae are of poor food value to zooplankton, their large size making them inaccessible to the filter feeding entomostraca. Hence, based on the existing literature on the effect of *Microcystis* on phyto- and zooplankton, the low diversity and density of plankton in pond A can be explained.In the fish ponds, the diversity and density of plankton was also affected by the fish predation as the cultured carps are basically plankton feeders. Among zooplankters, rotifers were dominant followed by copepods and cladocerans throughout the culture period (Table 4). Alikunhi (1957) and Khan and Siddiqui (1973) reported that the cultured carps are planktivorous and especially *Catla catla* feeds preferably on crustacean plankton rather than on rotifers and other planktonic organisms. Thus the low diversity and density of cladocerans and copepods compared to rotifers in the ponds could be explained. Among phytoplankters, green algae are preferably fed upon by the cultured carps, especially by *Labeo rohita* (Khan and Siddiqui, 1973).

Hence, the low diversity and density of phyto-and zooplankton in pond A can be attributed to the cumulative effect of *M. aeruginosa* and the grazing effect of cultured carps.Fish yield data indicated that the yield was higher in pond B followed by pond C and A (Table 5). In pond A, the low yield might be due to the cumulative effect of several interdependent factors such as high levels of *M. aeruginosa,* higher stocking density of fish, low density and diversity of plankton, heavy organic manuring, persistence of low dissolved oxygen and high ammonia contents with concomitant fish mortality. In pond B, higher fish yield might be due to the moderate levels of *M. aeruginosa,* moderate density of fish, optimum levels of dissolved oxygen, ammonia, and phyto-and zooplankton. Ahmed (1966), Sreenivasan (1967) and Swingle (1969) also observed that the carps especially *C. catla* and *Cirrhinus mrigala* were found to utilize *M. aeruginosa* as food and give high yields in ponds and tanks with moderate numbers of *M. aeruginosa*. In pond C, though the stocking density was relatively less, higher growth rate of fish with high yield was obtained. The probable reasons for such yield are the low levels of *M. aeruginosa*, higher densities of green algae and zooplankton which formed preferential food for cultured carp and optimum levels of dissolved oxygen and ammonia. From the present study, it can be said that high stocking densities of fish, large quantities of organic nitrogen in the form of organic manures or leftover fish feeds, and persistence of low dissolved oxygen lead to the formation of *M. aeruginosa* bloom in fish ponds. The formation of such blooms in commercial fish ponds may lead to severe economic losses.

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