STUDIES ON ALGAL BLOOM DISASTERS IN CARP CULTURE PONDS

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ABSTRACT

Algal blooms are often disastrous in aquaculture ponds. In fish ponds, the nutrient enrichment by the addition of fertilizers and supplementary feeding, leads to eutrophication, thereby frequently developing dense algal blooms. Among different classes of freshwater algae, Cyanophyceae (blue-green algae) members form spectacular water blooms in fish production ponds. These blooms affect the water quality, the most severe of which being the oxygen depletion leading to mass fish mortality. They also release toxic substances which are hazardous to the cultured fish. Further, these blooms have a blanketing effect on the pond, thereby preventing the entry of sunlight into the water. All these factors may affect the pond productivity. The present study was aimed to research the effect of different algal blooms on the water quality, plankton diversity and density and fish production of carp culture ponds. For the present study, three carp culture ponds located in the West Godavari district, Andhra Pradesh, India, were selected with Microcystis, Oscillatoria and Anabaena blooms respectively. In the three ponds, physico-chemical parameters of water, phyto- and zooplankton and fish productions were studied. The results indicated that the fish yield was lower with concomitant fish mortalities in a pond with Microcystis bloom followed by the ponds with Anabaena and Oscillatoria blooms. The disastrous effects of algal blooms with regard to the ecology of pond water, the diversity and density of plankton and fish production were analyzed and discussed.

Key words: Algal blooms, water quality, phytoplankton, zooplankton, carp culture.

INTRODUCTION

Algae represent the important nutritive base and have a significant effect on the biological productivity of a water body. However, they are considered to be disastrous when in bloom. The ponds used for carp culture often develop dense algae blooms. Among different algae, blue-green algae (Cyanobacteria) form spectacular water blooms in fish production ponds. Nutrient enrichment by the addition of fertilizers, supplementary feeding and other eutrophication processes may cause proliferation of these algae. The factors which are responsible for the preponderance of blue-green algae over other algal groups are their ability to assimilate a variety of biogenic organic compounds [30], being better adaptable to different environmental factors [27] and the plasticity of their photosynthetic apparatus [15]. In India, species of blue-green algae such as Microcystis, Oscillatoria, Arthrospira, Spirulina, Anabaena and Raphidiopsis are frequently observed as blooms in fish ponds. These surface water blooms can be very fleeting or they can last several days with harmful consequences such as poor growth and even mass fish mortality, mainly by the deteriorated water quality especially of dissolved oxygen depletion. Furthermore, dense blooms are directly toxic to other aquatic organisms [5,28]. Some species liberate compounds (Geosmin, 2 methylisoborneol, hexanal and heptanal) giv-

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ing an earthy-musty odor and taste (off-flavors) to the water and fish [4,17,19,20].

Though a good deal of information on the ecology of freshwater blue-green algae is available, little is known about the ecology and their disastrous effects in fish ponds in India. 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 blue-green algal blooms on the ecology and fish production of carp ponds. Therefore, in this work, an attempt has been made to study the factors that influence the proliferation of blue-green algae (Microcystis aeruginosa, Oscillatoria sp. and Anabaena sp.) and their effect on the water quality, plankton and fish production in carp culture ponds of the West Godavari district, Andhra Pradesh, India.

MATERIAL AND METHODS

Three carp culture ponds located in the villages Gundugolanu ($81^{o}12'$ E and 16o45’ N), Sreeparru ($81^{o}08'$ E and $16^{o}38'$ N) and Agadallanka ($81^{o}13'$ E and $16^{o}44'$ N), West Godavari district, Andhra Pradesh, India were chosen for this study. They are designated as pond A, B and C and were selected mainly based on the occurrence of *Microcystis aeruginosa, Oscillatoria sp. and Anabaena sp.* as dominant species for most of the culture period respectively. The extent (water spread area) of ponds and duration of the culture period in each pond is given in Table 1.

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

POND	A	B	C
AREA (ha)	2.2	3.2	1.6
DURATION OF CULTURE PERIOD (Days)	191 Jun 20 to Dec 27, 2001	240 Dec15,2001 to Aug 11,2002	252 Jan 9 to Sep 17, 2002
A. FERTILIZERS			
1. ORGANIC (t/ha)	15.75	15.00	10.00
Cowdung	5.50	4.50	10.00
Poultry manure	10.25	10.50	---
2. INORGANIC (kg/ha)			
Single Superphosphate	100	450	380
N.P: K (28:28:0)	--	150	25
Urea	120	260	--
Di-ammonium phosphate	120	100	200
B. LIME (kg/ha)	250	500	600
C. FISH STOCKED (no./ha)	13144	8710	7540
D. SUPPLEMENTARY FEEDING			
a) Percentage body wt.of fish/day	2-9	2-7	2-8
b) Percentage composition:			
Deoiled rice bran	77	78	84
Groundnut cake	20	20	16
Common Salt	2	2	--
Mineral Mix	1	--	--
E. $CuS0_4$+Citric acid (kg/ha)	5+10	10+0	5+10

In the three ponds, fortnight samples were collected to study physico-chemical parameters of water and plankton during the culture period 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 APHA [2], Golterman and Clymo [11] and Welch [36]. Plankton samples were collected by filtering 100 l of water through a plankton net made up of silk bolting cloth No.25 and the plankton obtained was fixed in 5% formalin. The individual plankters were enumerated along the lines recommended by Wetzel and Likens [37]. 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. Fish were fed daily with supplementary food (Table 1) at the rate of 2-9% of body weight of the fish, the maximum being given during the initial periods and the minimum at the end of the culture period. The particulars of inputs used during the culture period in the three ponds are given in Table 1. To control the algal blooms, a mixture of copper sulfate and citric acid 0.5 and 1.0 ppm respectively was used in the ponds. Also during the period of heavy algal bloom, the water was aerated at night-time to prevent fish mortality due to dissolved oxygen depletion.

RESULTS

1. PHYSICO-CHEMICAL WATER PARAMETERS:

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

2. PLANKTON:

The total number of genera recorded in pond A, B and C was 35, 44 and 40 respectively. Their monthly abundance was also recorded.

A. Phytoplankton: Phytoplankton was numerically more abundant than zooplankton. Phytoplankton was represented by 17, 23 and 21 genera in pond A, B and C respectively. They belonged to four classes viz., Cyanophyceae, Chlorophyceae, Bacillariophyceae and Eugleninae. The genera recorded in the three ponds are summarized in Table 3. All three ponds were dominated by blue-green algae (Cyanophyceae). Pond A was dominated by Microcystis aeruginosa, pond B by Oscillatoria sp. and pond C by Anabaena sp. The monthly numerical abundance of different phytoplankters was studied. The range and mean + SEM values and the dominant genera during the culture period are given in Table 4.

B. 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 pond A, B and C was 23 (14, 3 and 6), 28(15, 5 and 8) and 26 (16, 3 and 7) 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 abundance of different zooplankters was studied. The range and mean + SEM values and the dominant species during the culture period are given in Table 4.

3. FISH: In pond A, three Indian major carps namely catla, rohu and mrigal, were stocked whereas in pond B and C, only catla and rohu were stocked. The number of fish stocked and harvested with their average weights and gross and net yields are given in Table 5.

DISCUSSION

An efficient and economical means of increasing production in fish culture ponds under semi-intensive methods is the use of fertilizers. The fish ponds receiving fertilizers become eutrophic in the course of time and quite often dominated by blue-green algae. At times, they proliferate at higher magnitude forming blooms and cause disastrous effects on the environment and on aquatic organisms.

In the ponds under study, the temperature was ranged from 26 to 34^{o}C and dense algal blooms occurred (October, May and July in ponds A, B and C respectively) when the temperature was at its maximum. Fogg et al. [8] and Roberts and Zohary [25] reported that 25 to 35^{o}C is the temperature for optimal growth of Anabaena, Aphanizomenon, Oscillatoria and Microcystis. Thus high temperatures form an important factor conditioning the formation of blooms. In fish ponds, secchi disc transparency provides a rough estimate of plankton abundance. Water transparency showed an inverse correlation to plankton abundance ($P<0.05$). Dissolved oxygen is the most important factor in influencing the productivity of ponds as was remarkably seen

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

POND	A	B	C
1. Water temperature (^{0}C)	29.4±2.16 (26.0 – 32.0)	29.63±3.23 (24.8-33.9)	30.6±2.76 (26.8-34.0)
2. Transparency (cm)	21.0±6.95 (8-29)	26.2±8.04 (7-35)	24.22±6.82 (10-32)
3. Dissolved oxygen (mg/l)	4.24±1.25 (2.0 – 6.0)	4.54±1.30 (2.2 - 6.2)	4.63±1.36 (2.3-6.4)
4. pH	8.68±0.47 (8.1-9.3)	8.94±0.24 (8.6-9.4)	8.58±0.42 (7.8-9.2)
5. Total alkalinity(mg/l as $CaC0_{3)}$	124.85±8.31 (112-138)	218.8±18.05 (188-254)	97.33±10.91 (82-116)
6. Total hardness (mg/l as $CaC0_{3)}$	162.5±43.5 (125-255)	217.22±30.73 (175-265)	148.33±25.98 (110-185)
7. Conductivity (µmhos/cm)	609.2±74.7 (520-700)	641.1±55.7 (580-730)	329.4±58.6 (260-410)
8. Chlorides (mg/l)	120.11±12.42 (104.9-135.9)	139.85±9.27 (126.9-155.9)	49.09±13.15 (29.9-63.9)
9. Nitrate – N (mg/l)	0.18±0.11 (0.07-0.39)	0.39±0.26 (0.09-1.12)	0.11±0.0.05 (0.04-0.21)
10. Nitrite – N (mg/l)	0.03±0.016 (0.011-0.064)	0.049±0.015 (0.032-0.072)	0.021±0.011 (0.009-0.044)
11. Ammonia – N (mg/l)	1.03±0.54 (0.34-1.84)	0.91±0.42 (0.28-1.64)	0.43±0.15 (0.24-0.68)
12. Orthophosphate (mg/l)	0.93±0.19 (0.52-1.78)	2.73±1.05 (1.21-4.18)	1.69±0.74 (0.73-2.92)
13. N/P	1.54±0.96 (0.26-0.98)	0.55±0.21 (0.26-0.98)	0.38±0.18 (0.19-0.78)
14. Iron (mg/l)	0.59±0.22 (0.35-0.97)	0.49±0.11 (0.34-0.66)	0.37±0.09 (0.21-0.51)

Values in parentheses are the ranges

Table 3. Plankton composition in the three fish ponds.

I. PHYTOPLANKTON	
Cyanophyceae	: Microcystis aeruginosa, Merismopedia, Gomphosphaeria, Anabaena, Oscillatoria and Lyngbya.
Chlorophyceae	: Eudorina, Pandorina, Actinastrum, Pediastrum, Tetraedon,Scenedesmus, Ankistrodesmus, Crucigenia and Coelastrum
Bacillariophyceae	: Synedra, Navicula, Fragilaria, Nitzschia, Amphora, Cymbella,Gomphonema , Melosira and Cyclotella
Euglenineae	: Euglena, Phacus and Trachelomonas
II. ZOOPLANKTON	
Rotifera	: Brachionus calyciflorus, B. angularis, B. caudatus, B. falcatus, B. forficula, B. diversicornis, B. rubens, B.budapestinensis, B. patulus, 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 abundance in the three fish ponds (mean ± sem)

POND	A	B	C
I. PHYTOPLANKTON (Ind./l)			
Cyanophyceae	173083±151776 a (1924-1084020)	139617±133604 b (1892-1208400)	52256±45333 c (4588-414572)
Chlorophyceae	376±97 de (0-692)	459±88 df (2-948)	1375±449 de (46-4482)
Bacillariophyceae	2077±1093 g (151-8500)	360±53 gh (176-644)	345±76 g (110-814)
Euglenineae	28±17 i (0-122)	39±10 ij (0-94)	214±160 I (0-1486)
Total	175565±151596 (2952-1085194)	140476±133519 (2569-1208582)	54190±45100 (4078-414728)
II. ZOOPLANKTON (Ind./l)			
Rotifera	272±112 kmno (12-826)	519±137 nol (156-1522)	917±496 op (72-4688)
Cladocera	36±22 q (0-172)	30±11 qr (2-112)	23 ±5 q (2-44)
Copepoda	73±16 s (16-134)	46±7 t (22-92)	40±10 t (2-92)
Copepod larvae	334±103 (126-882)	153±31 (42-276)	343±159 (96-1560)
Total	717±195 (184-1504)	748±155 (222-1812)	1323±648 (186-6326)
III. TOTAL PLANKTON (Ind./l)	176282±152181 (3664-1086022)	141225±133454 (3323-1208804)	55513±44952 (5004-414914)

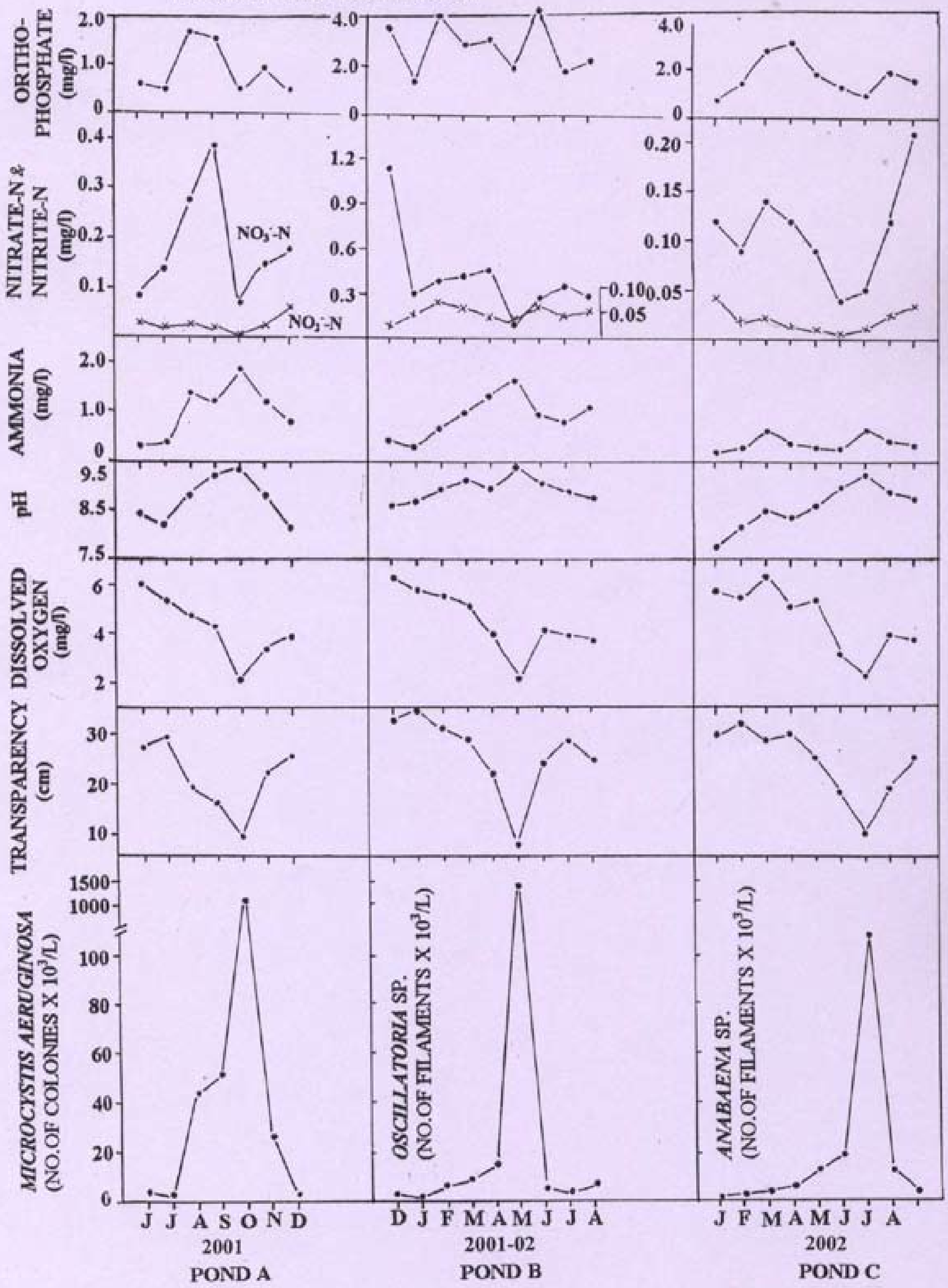
Values in parentheses are the ranges.
“a” to “u” indicate the dominant genera/species

a= *Microcystis aeruginosa*
b= *Oscillatoria*
c= *Anabaena*
d= *Pediastrum*
e= *Scenedesmus*
f= *Eudorina*
g= *Synedra*
h= *Fragilaria*
i= *Phacus*
j= *Euglena*
k= *Brachionus forficula*
l= *B. calyciflorus*
m=*Filinia longiseta*
n= *Keratella tropica*
o= *Polyarthra* sp.
p= *B. caudatus*
q= *Moina micrura*
r= *Diaphanosoma excisum*
s= *Microcyclops varicans*
t= *Mesocyclops* sp.

TABLE 5. FISH PRODUCTION DATA IN THE THREE PONDS

POND	A	B	C
A. FISH STOCKED (no./ha)	12,144 Mean wt g	8,710 Mean wt g	7,540 Mean wt g
Catla	3,122 (150)	2,610 (200)	2,260 (200)
Rohu	7,090 (125)	6,100 (175)	5,280 (175)
Mrigal	1,932 (125)	-----	-----
B. FISH HARVESTED (no./ha)	6,936	6,616	4,530
Catla	1,138 (630)	1,610 (1245)	1,270 (1495)
Rohu	4,238 (545)	5,006 (1120)	3,260 (1195)
Mrigal	1,560 (475)	-----	-----
C. FISH YIELD (t/ha)			
Gross yield	3.77/191 days or 7.20/year	7.61/240 days or 11.57/year	5.80/252 days or 8.40/year
Net yield	2.17/191 days or 4.14/ year	6.01/240 days or 9.14/year	4.43/252 days or 6.42/year

FIG.1. A COMPARATIVE ILLUSTRATION SHOWING RELATIONSHIPS BETWEEN ALGAL ABUNDANCE AND SOME PHYSICO-CHEMICAL PARAMETERS OF WATER IN THE THREE PONDS



in pond A. In this pond, low fish production (Table 5) was mainly due to relatively low oxygen concentrations prevailed by the high stocking densities of fish, heavy organic manuring and the presence of abundant *Microcystis aeruginosa*. Even though the dissolved oxygen concentration was relatively high during the initial culture phase in all the ponds, its concentration was gradually reduced in the subsequent months (Fig.1), probably due to the increasing fish, plankton and organic matter biomass. The prevalence of low dissolved oxygen for a long period might be one of the reasons for the proliferation of algae in the ponds. Stewart and Pearson [33] reported that in light, blue-green algae grow more rapidly under microaerophilic than under fully aerobic conditions. Ganf [9] also stated that the blue-green algae development depends on the ability of the ponds to maintain low concentrations of dissolved oxygen for long periods. Stewart [32] and Sevrin-Reyssac and Pletikosic [27] stated that the substantial quantity of oxidizable substances in fish ponds (excrements of zooplankton and fish, organic fertilizers added) may be of considerable indirect benefit to cyanobacteria because it lowers the concentration of dissolved oxygen and it is known that nitrogen fixation is improved under such conditions.

In fish ponds, oxygen depletion mainly occurs due to algal blooms during early hours and after their collapse. In the ponds under study, fish mortality (5208/ha in pond A, 2094/ha in pond B and 3010/ha in pond C) was observed 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 (Table 2 and Fig.1). Hence, it can be said that fish mortality may not only be due to low dissolved oxygen content but also due to high pH and ammonia levels associated with algal blooms. 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 [18, 29]. Thus, poor growth and production of fish observed after bloom appearance in the ponds can also be explained.

The water pH in all the ponds was on the alkaline side. The pH at which dense algal blooms observed was 9.2-9.4. In this study, Oscillatoria was observed at relatively high total alkalinity whereas Anabaena was noticed at low total water alkalinity (Table 2). 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 Anabaena persists.

Nitrate-N, Nitrite-N and Ammonia-N were relatively lower in pond C than in pond A and B. This indicates that the nitrogen poor waters favor bloom formation of Anabaena compared to Microcystis and Oscillatoria. This might be one of the reasons why Anabaena blooms are rare in fish ponds receiving inorganic nitrogen fertilizers. A survey made in several fish ponds of coastal districts of Andhra Pradesh revealed that Microcystis blooms are common, followed by Oscillatoria, Arthrospira and Spirulina whereas Anabaena blooms are rare. When nitrogen becomes a limiting factor, the most favored species are those assimilating atmospheric nitrogen, this process being associated with the presence of heterocysts (Anabaena, Oscillatoria) [7, 31]. Reynolds [22] also noted the predominance of Anabaena in ponds deficient in inorganic nitrogen in the upper layers receiving light. Nitrogen deficiency can also influence the competitive advantage of other species of cyanobacteria that lack heterocysts but are capable of vertical migration (buoyancy regulation by Microcystis, Oscillatoria and Spirulina)and so can use inorganic nitrogen present close to the water-sediment interface. Thus, the massive development of blue-green algae may be favored by an inorganic nitrogen deficiency in the upper layers of pond water.

In this study, the inorganic nitrogen (nitrate+nitrite+ammonia) and phosphorus (orthophosphate) ratio represented as N/P was 1.54 in pond A, 0.55 in pond B and 0.38 in pond C. Rhee [23] and Rhee and Gotham [24] suggested that the N:P ratio of less than 5 is one of the factors that influence the proliferation of cyanobacteria over other algae in pond waters. Nitrate, ammonia and orthophosphate concentrations were observed to be high in the months before the formation of dense algal blooms (Fig.1). These high levels of nutrients may 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 algae. However, during the peak abundance of algae, low levels of nitrates and phosphates, but not ammonia, were recorded (Fig.1). As ammonia is the main excretory product of fish, its persistence in the water can be explained. Fogg et al. [8] 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. Gerloff and Skoog [10] 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. In the subsequent months when the bloom disappeared, the nutrient levels again increased. As the ponds were not fertilized after bloom formation, the increase in nutrient levels may be due to the release of stored nitrogen and phosphorus contents during algal decay. Hammer [12] stated that accumulation of orthophosphates by blue-green algae helped their bloom formation and in the liberation of phosphates into water during their decomposition.

The occurrence of blue-green algae also influenced the diversity and density of plankton. The diversity of plankton was low in pond A followed by pond C and B. It indicates that *Microcystis aeruginosa* has more inhibitory effect on other plankters followed by Anabaena and Oscillatoria. According to Hellebust [13], 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 most of the other species through its excretions, until they are found only sporadically (hetero-antagonism), so that the phytoplankton present is very abundant but not very diversified [16]. 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 [6,21] and certain cladocerans [3,26,34]. Bernardi and Giussani [5] reported that blue-green algae have poor food value for zooplankton and their large size, making them inaccessible to the filter feeding entomostraca. The large filaments of blue-green algae clog up the filtering apparatus of cladocerans and cause high mortality among them. Therefore, based on the existing literature of the effect of blue-green algae on phyto-and zooplankton, the low diversity and density of plankton in the ponds 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 zooplankton, rotifers were dominant followed by copepods and cladocerans throughout the culture period (Table 4). Alikunhi [1] and Khan and Siddiqui [14] reported that the cultured carps are planktivorous and especially Catla catla prefer to feed on crustacean plankton rather than on rotifers and other planktonic organisms. This could therefore explain the low diversity and density of cladocerans and copepods compared to rotifers in the ponds. Among phytoplankton, green algae are preferably fed by the cultured carps, especially by Labeo rohita [14]. Hence, the low diversity and density of phyto- and zooplankton in the ponds can be attributed to the cumulative effect of blue-green algae and the grazing effect of cultured carps.

Fish yield data indicated that the yield was lower in pond A with Microcystis bloom followed by pond C with Anabaena bloom and pond B with Oscillatoria bloom (Table 5). In pond A, the low yield may 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. The fish mortality was high in pond A (5208/ha) followed by pond C (3010/ha) and pond B (2094/ha). In pond C, though the density of bloom and the stocking density of fish were lower than in pond B, fish mortality was high. The fish growth rates during the culture period were also low in pond A followed by pond C and B. This data indicates that *M. aeruginosa* is highly deleterious followed by Anabaena and Oscillatoria in the fish ponds. From this study, it can be said that high stocking densities of fish, large quantities of organic manures, inorganic nitrogen deficiency in upper layers of water, low N/P ratios and persistence of low dissolved oxygen lead to the formation of blue-green algal blooms. They are in turn, directly or indirectly, disastrous to fish by decreasing their growth rate and causing heavy mortality leading to lower fish yields. Thus, the formation of such blooms in commercial fish ponds threatens severe economic losses.

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