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Microalgal community structure in experimental carp - pangasiid catfish polyculture ponds

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Abstract
Microalgal community structure in experimental carp-pangasiid catfish polyculture ponds under four different stocking rates (treatments) each with three replications in the Field Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh was studied. A total of 38 microalgal genera were identified under four major groups: 18 genera belong to Chlorophyceae, 9 to Cyanophyceae, 8 to Bacillariophyceae and 3 to Euglenophyceae. Chlorophyceae was abundant in all treatments followed by Cyanophyceae, Bacillariophyceae and Euglenophyceae throughout the study period. The cell densities of total microalgal population varied between 51.66×10^3 cells/L in June in T_1 and 126.4×10^3 cells/L in August in T_2. The appearance of *Microcystis, Oscillatoria, Gomphospheria, Hildenbrandia, Chlorella, Scenedesmus, Cyclotella, Navicula, Nitzschia, Euglena* and *Phacus* as dominant genera throughout the study period may be related to sufficient nutrient availability, good light conditions and high growth rate of these genera. Water quality parameters of the experimental ponds were within suitable range for microalgal production and fish culture though the nutrient (NO_3-N and PO_4-P) concentrations were high. The factors involved in structuring a phytoplankton community arise from the relationship generated by physical, chemical and biological conditions especially the stocked planktivorous carps. Microalgal bloom formation is very common in pangasiid catfish monoculture ponds but in the present study bloom was not formed and the algal species diversity was found to be slightly increased with the study period. The introduction of carps in the experimental ponds might have helped in controlling the microalgal bloom formation and maintenance of the species diversity.

Key words : Microalgae, Community structure, Carp, Pangasiid catfish, Polyculture

Introduction

Microalgae play an important role as primary producer in the aquatic ecosystem (Nozaki 1999) and have been the major nutritional source available to the fish from nature. It is well recognized that the water quality plays an important role on the survival, growth and production of fish. A pond with good water quality produces more healthy fish than a pond with poor water quality. Microalgal blooms (cyanobacterial and euglenophycean

bloom) have become increasingly common and causing water quality problems in ponds and lakes in many countries of the world. Toxic blooms of cyanobacteria have been detected in freshwater lakes all over the world and these toxic cyanobacteria cause death of animals and wildlife when they are consumed with water (Repavich *et al.* 1990, Carbis *et al.* 1995, Negri *et al.* 1995).

The mortality of fishes and irritative bad odour from decayed algae in the fish culture ponds are very common in Bangladesh. A critical time during bloom condition occurs when dense cell masses decompose naturally and this decomposed products plus toxic cellular materials released into the water when the cells lyse may cause death or illness of animals, birds and fishes and may also reduce water quality for animal (including human) and recreational purposes (Collins 1978).

Larger cyanobacteria including *Anabaena, Aphanizomenon, Microcystis, Oscillatoria* and others produce common off-flavour and form surface scum that often lead to algal die-off and water quality deterioration (Perschbacher 1995). It is well known that in aquatic environment, there is a succession or periodicity of algae, which corresponds to the various seasons of the year. Though the seasons of the year in Bangladesh are not so marked as those of temperate countries, yet considerable variations in density of microalgal population are found. In a water body, there is a seasonal progression in the microalgae, such that first one species is dominant and then another, at rather frequent intervals during the year.

The species that is common in one month, very often the same species may become rare in the following months. In tropical eutrophic lakes, algal diversity tends to increase in summer and decline in winter (Moss 1973). However, when the relationship between species diversity and seasons is examined closely, one can find considerable variability among them (Hallegraeff and Ringelberg 1978).

Limnological knowledge is a prerequisite for sustainable aquaculture practice. Culture of fish and other aquatic organisms of commercial importance depend almost completely on different environmental factors of aquatic environment. In turn, the quality of aquatic environment depends on the abundance of phytoplankton, which has been well established as a measure of the degree of organic enrichment of water. Production of phytoplankton can be increased by fertilization but naturally when a water body becomes hypernutrified then blooms occur.

It is obvious that there is an immense need to develop a polyculture system of Thai-pangasiid catfish and carps for getting higher production of fish and maintaining better water quality for sustainable aquaculture development. Microalgae that are produced in pangasiid catfish ponds can be eaten by silver carp that may help to prevent algal mat formation. The ultimate goal of which is to keep aquatic environment suitable for pangasiid catfish culture and to get an extra crop of carps without additional cost, making aquaculture more profitable to the farmers.

With an aim to establish a better management technique in carp - pangasiid catfish farming, the present study was planned to observe the microalgal community structure in experimental carp - pangasiid catfish polyculture ponds.

Materials and methods

The study was conducted for a period of 112 days from 17 June to 6 October 2004 in 12 equal sized (each 200 m^2), adjacent, rain-fed, rectangular experimental carp - pangasiid catfish polyculture ponds in the Field Laboratory of the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. The ponds were dried during the end of May 2004, limed with CaO at the rate of 250 kg/ha and left exposed to sunlight for about two weeks and then filled with water pumped from an adjacent large pond. The fish fingerlings were stocked on 17 June and harvested on 6 October 2004. The ponds were arranged in four treatments (T) each with three replications. The fish stocking density was 30,000/ ha in all the treatments (15,000 pangasiid catfish and 15,000 silver carp in T_1, 15,000 pangasiid catfish and 15,000 catla in T_2, 15,000 pangasiid catfish, 7,500 silver carp and 7,500 catla in T_3 and 15,000 pangasiid catfish, 10,000 silver carp and 5,000 catla in T_4). Commercial pelleted feed (Quality Fish Feed Ltd., Bangladesh) was fed only to pangasiid catfish at the rates of 8% of fish biomass per day during the first six weeks, 6% during the second six weeks and 4% thereafter.

On each sampling day the collection of plankton and water samples and measurement of some other water quality factors were made between 0900 to 1100 hrs at a fixed site of each pond. Dissolved oxygen (mg/L) and pH were measured on the spot by using a digital DO meter (HANNA instruments, HI-9142 Portugal) and a pH meter (HANNA instruments, HI-9142, Portugal) respectively at the depths of 0.00 m, 0.65 m and 1.30 m (pond depth 1.10-1.50 m). Surface water temperature was measured by using an ordinary Celsius thermometer and a Secchi disc was used to measure the transparency of water.

Water samples were collected from the selected sites by using a 1 meter long plastic tube (4 cm diameter) and kept into separate bottles of 250 ml capacity and were then labeled properly. The water was filtered in the laboratory through GF/C filter paper (Whatman) and the concentration of nitrate-nitrogen and phosphate-phosphorus in the filtrate were determined by a data logging spectrophotometer (Odyssey-2500 HACH, USA) using Nitra Ver 5 and Phos Ver 3 powder pillows respectively. The chlorophyll-*a* content of the water was determined spectrophotometrically after acetone extraction (Beveridge 1985). To study microalgae, a known volume of water from each pond was collected and concentrated to about 200 ml by passing through a plankton net (mesh 15μm). The collected samples were then stored in plastic bottles and preserved in 5% buffered formalin for laboratory analysis. For the qualitative and quantitative study of plankton 1 ml sample was taken by a dropper and drained on a S-R (Sedgwick- Rafter) counting cell. The plankton in 20 randomly selected squares was identified and counted under a compound microscope. The mean number of microalgae were recorded and expressed numerically per liter of water (cells/L) for each pond. The qualitative study of microalgae was made following Prescott (1964), and Bellinger (1992). The microalgae per liter of original water were estimated following Rahman (1992).

Results

Microalgal community

A total of 38 microalgal genera were identified under four major groups: 18 genera belong to Chlorophyceae, 9 to Cyanophyceae, 8 to Bacillariophyceae and 3 to Euglenophyceae (Table 1). The percent composition of different groups of microalgae is shown in Fig. 1. The variations in the number of genera in different groups of microalgae occurred during the study period is shown in Table 2. The cell densities of total microalgal population varied between 51.66×10^3 cells/L in June in T_1 and 126.4×10^3 cells/L in August in T_2. The occurrence, abundance and distribution of different groups of microalgae did not show any uniform pattern during the study period. The cell density of different microalgal genera was found to vary in the ponds of different treatments (Table 1).

Among different groups of microalgae, Chlorophyceae ranked top in respect of both abundance and number of genera throughout the study period. The most dominant genera of Chlorophyceae were *Chlorella, Scenedesmus* and *Pleurococcus*, and they maintained their dominancy until the end of the study. *Gonatozygon, Hildenbrandia, Pediastrum, Stichococcus, Tetraedon* and *Ankistrodesmus* were the sub-dominant and *Actinastrum, Coelastrum, Chlosterium, Cosmerium, Ankyra, Micractinium, Botryococcus, Ulothrix* and *Volvox* were the rare genera. The highest cell density of Chlorophyceae was found in T_1. The cell density of this group of plankton started to increase in July with the increase of nitrate-nitrogen and phosphate-phosphorus and reached its peak abundance in September (52.66×10^3 cells/L) (Figs. 2 and 3). The second largest group of phytoplankton in all the treatments was Cyanophyceae. The most dominant genera of this group were *Microcystis* and *Oscillatoria. Anabaena* and *Gomphosphaeria* were the sub-dominant and the rare genera were *Aphanizomenon, Aphanocapsa, Chroococcus, Merismopedia* and *Gloeocapsa.* Cyanophyceae reached a maximum cell density of 40.24×10^3 cells/L in T_2 in August and then there was a decreasing trend in September with the increase of nitrate-nitrogen and phosphate-phosphorus. In T_2, the cell density of Cyanophyceae had again a slight increasing trend in October. In T_3 and T_4 Cyanophyceae showed its highest cell density in September and then a slight decreasing trend was found in October.

Bacillariophyceae was found to be as a minor group in all the treatments where *Nitzschia, Cyclotella* and *Navicula* were the dominant genera. The cell density of Bacillariophyceae was found to be highest in September (24.16×10^3 cells/L) in T_2 and lowest in June (0.63×10^3 cells/L) in T_3. Euglenophyceae was found only in small quantities where the dominant genera were *Euglena* followed by *Phacus* and *Trachelomonas.* This group of phytoplankton ranked third in T_3 and T_4 but fourth in T_1 and T_2 in respect of abundance.

Table 1. Cell densities ($\times 10^3$ cells/L) (mean ± SE; n = 15) of different genera of microalgae in ponds of different treatments

Microalgal genera	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Chlorophyceae				
Chlorella	4.10±0.64	9.42±0.44	7.27±0.61	4.31±0.32
Scenedesmus	8.31±0.84	2.86±0.29	6.41±0.70	5.69±0.53
Pleurococcus	6.34±0.74	3.39±0.27	5.49±0.18	5.64±0.43
Gonatozygon	6.58±0.38	3.06±0.38	4.65±0.45	5.07±0.17
Hildenbrandia	3.93±0.39	3.60±0.54	5.76±0.29	4.64±0.37
Ankistrodesmus	3.78±0.40	1.0±0.22	2.55±0.18	2.70±0.42
Stichococcus	2.54±0.41	2.77±0.67	2.28±0.34	1.82±0.21
Tetraedon	2.89±0.37	1.26±0.06	1.88±0.13	2.07±0.14
Pediastrum	1.87±0.23	1.15±0.15	2.21±0.22	2.15±0.32
Volvox	1.34±0.49	1.09±0.50	1.15±0.34	1.25±0.39
Cosmerium	0.65±0.30	1.60±0.35	0.99±0.27	0.55±0.14
Ulothrix	0.10±0.06	0.31±0.11	0.36±0.07	2.71±0.78
Actinastrum	0.64±0.12	0.48±0.06	0.90±0.13	1.08±0.25
Botryococcus	0.16±0.09	0.34±0.20	0.71±0.28	1.82±0.21
Coelastrum	0.49±0.14	0.61±0.20	0.73±0.14	0.79±0.19
Micractinium	-	-	-	0.44±0.16
Ankyra	-	-	-	0.30±0.17
Chlosterium	-	0.07±0.04	0.13±0.07	-
Cyanophyceae				
Microcystis	19.23±1.71	18.28±2.10	17.80±1.56	15.62±2.22
Oscillatoria	5.27±0.58	5.61±0.50	2.99±0.59	5.98±0.89
Gomphospheria	3.14±0.71	6.05±1.32	3.72±0.43	2.09±0.37
Anabaena	0.61±0.27	6.94±1.17	3.37±0.84	0.60±0.16
Aphanizonenon	0.31±0.11	2.03±0.32	0.89±0.27	5.65±2.27
Merismopedia	-	1.12±0.31	-	-
Aphanocapsa	-	0.93±0.20	-	-
Chroococcus	-	0.44±0.19	-	0.25±0.14
Gloeocapsa	-	-	0.43±0.16	-
Bacillariophyceae				
Nitzschia	4.88±0.68	4.39±0.88	3.43±0.59	4.42±0.48
Cyclotella	1.59±.20	3.33±0.48	2.0±0.42	1.72±0.29
Navicula	2.54±0.25	2.34±0.41	1.64±0.46	1.45±0.25
Tabellaria	0.50±0.12	5.24±1.22	1.49±0.47	0.66±0.18
Uroglena	0.03±0.01	1.23±0.49	0.72±0.23	0.38±0.12
Surinella	0.23±0.04	0.66±0.15	0.39±0.06	0.21±0.07
Fragilaria	0.28±0.08	0.39±0.12	0.29±0.06	0.51±0.14
Melosira	0.38±0.14	-	-	-
Euglenophyceae				
Euglena	5.29±0.59	6.11±0.84	9.09±0.87	8.56±1.27
Phacus	2.54±0.26	4.45±0.47	4.43±0.21	3.78±0.52
Trachelomonas	-	0.66±0.25	0.31±0.12	0.48±0.17

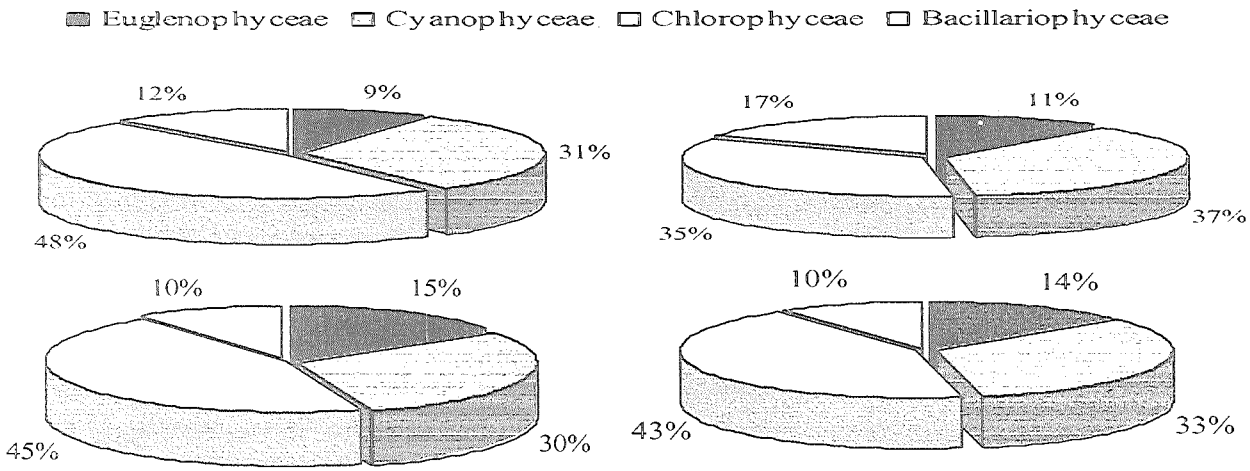

Fig. 1. Percent composition of different groups of microalgae in ponds of different treatments.

Table 2. Monthly variation in number of microalgal genera in ponds of different treatments

Family	June	July	August	September	October
Treatment 1					
Chlorophyceae	11	12	11	12	12
Bacillariophyceae	4	6	6	8	7
Cyanophyceae	3	3	4	4	4
Euglenophyceae	2	2	2	2	2
Treatment 2					
Chlorophyceae	9	13	13	14	14
Bacillariophyceae	6	5	5	7	7
Cyanophyceae	3	6	6	6	6
Euglenophyceae	2	2	2	3	3
Treatment 3					
Chlorophyceae	11	12	16	14	14
Bacillariophyceae	6	5	7	7	7
Cyanophyceae	3	4	5	6	5
Euglenophyceae	2	3	2	3	3
Treatment 4					
Chlorophyceae	10	12	15	15	12
Bacillariophyceae	3	4	7	7	7
Cyanophyceae	5	5	5	5	5
Euglenophyceae	2	2	2	3	3

Water quality parameters

The observed values of different water quality parameters are shown in Table 3. Water temperature in different treatments was found to be more or less similar. The maximum temperature (32.12 °C) was found in August in T_2 and the minimum (27.02

°C) was found in October in T_3. The highest dissolved oxygen concentration was recorded in T_2 (5.21 mg/L) but it was not significantly higher than the value of dissolved oxygen found in T_1 (5.15 mg/L), T_3 (5.18 mg/L) and T_4 (5.20 mg/L). The pH value varied from 6.56 to 7.22, 6.84 to 7.30, 6.65 to 7.42 and 6.66 to 7.31 in T_1, T_2, T_3 and T_4 respectively. Water transparency was found to vary from one treatment to another and also one month to another month during the study period. No significant difference of transparency was found among different treatments when ANOVA was performed. Nitrate-nitrogen concentration in water of the ponds under T_1, T_2, T_3 and T_4 was found to be ranged from 0.52 mg/L to 1.21 mg/L, 0.49 mg/L to 1.22 mg/L, 0.38 mg/L to 1.28 mg/L and 0.56 mg/L to 1.15 mg/L respectively. Though the concentration of NO_3-N was apparently found to be different but it was not statistically significant. The highest concentration of PO_4-P was recorded in T_2 (0.83 mg/L) while the lowest was found in T_1 (0.79mg/L). Chlorophyll-*a* content was significantly ($P<0.05$) different among the treatments. Significantly higher value of chlorophyll-*a* was recorded in T_2 (191.52 μg/L) than the other treatments

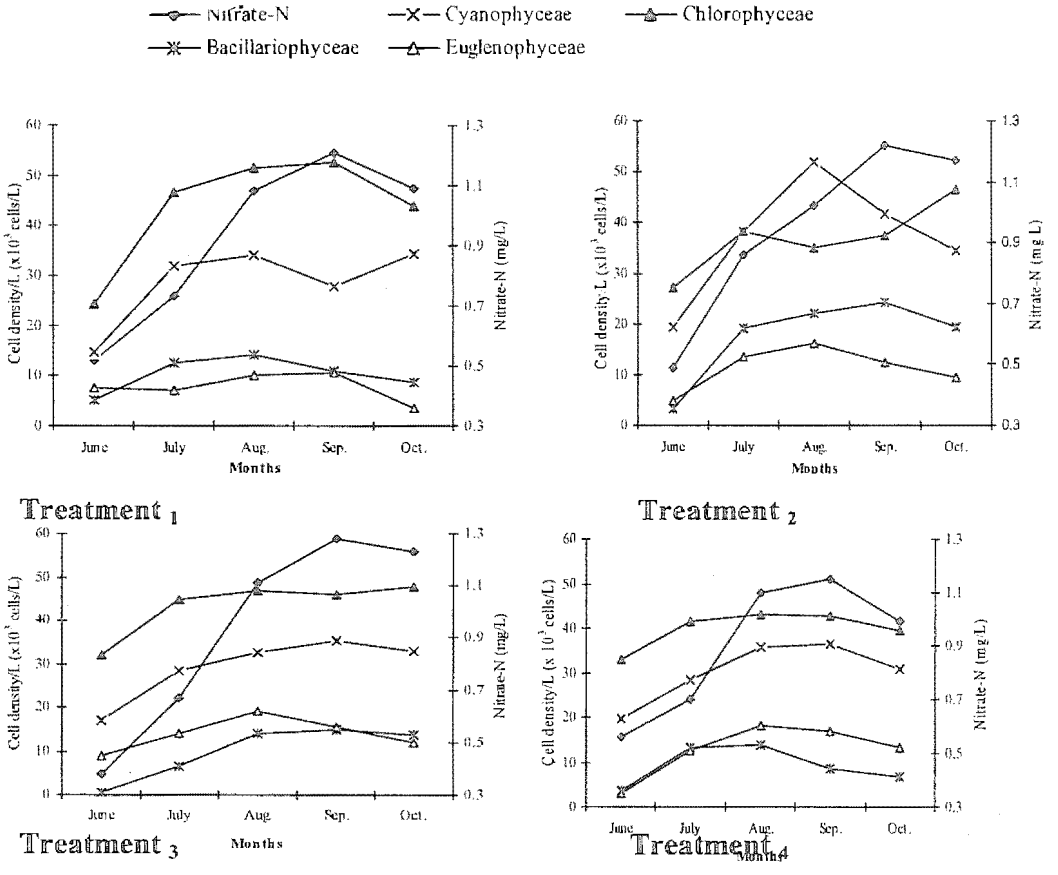

Fig. 2. Relationship between nitrate-nitrogen and abundance of different groups of microalgae in ponds of different treatments.

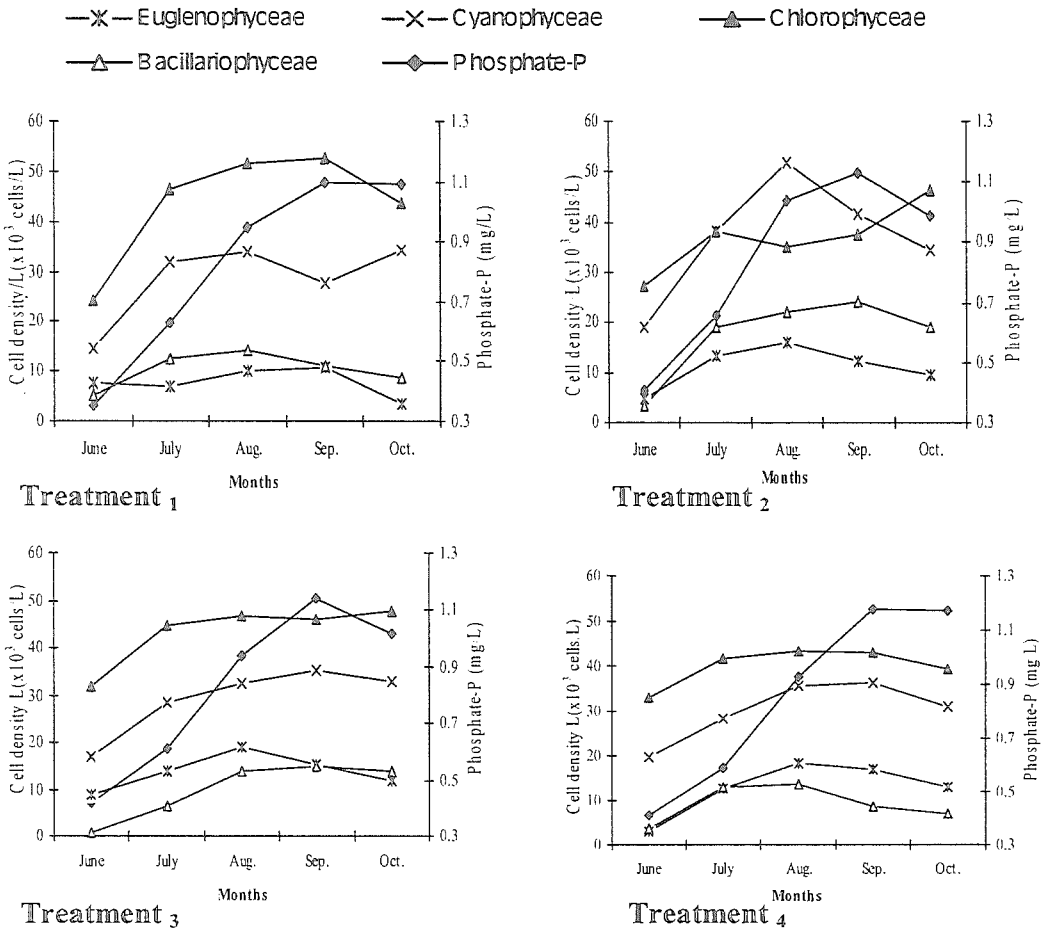

Fig. 3. Relationship between phosphate-phosphorus and different groups of microalgae in ponds of different treatments.

Table 3. Water quality parameters (mean ± SE, n = 15) in ponds of different treatments

Parameters	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Dissolved Oxygen (mg/L)	5.07 ± 0.19	5.21 ± 0.13	5.12 ± 0.17	5.09 ± 0.15
pH	6.56 - 7.22	6.84 - 7.30	6.65 - 7.42	6.66 - 7.31
Temperature (°C)	30.42 ± 0.49	30.47 ± 0.50	30.38 ± 0.50	30.26 ± 0.45
NO_3-N (mg/L)	0.93 ± 0.07	0.95 ± 0.07	0.93 ± 0.09	0.90 ± 0.07
PO_4-P (mg/L)	0.82 ± 0.09	0.85 ± 0.08	0.83 ± 0.08	0.86 ± 0.09
Secchi depth (cm)	28.22 ± 2.34	28.15 ± 2.32	26.54 ± 2.25	28.87 ± 2.66
Chlorophyll-*a* (μg/L)	170.31 ± 19.63	191.52 ± 21.30	183.75 ± 20.15	182.31 ± 21.75

Discussion

Microalgal population indicates the productivity status of a waterbody, because they are the direct and basic sources of food for most of the organisms in an aquatic habitat.

The occurrence and abundance of microalgal population in nature is regulated by a multitude of environmental factors such as temperature, light, dissolved oxygen, pH, nutrient concentration, soil condition etc. In the present study, a total number of 38 genera of microalgae was recorded belonging to Euglenophyceae (3 genera), Cyanophyceae (9 genera), Chlorophyceae (18 genera) and Bacillariophyceae (8 genera). These groups' richness and floristic composition are characteristic for small eutrophic waterbodies. In agreement with the present findings 33-39 genera of microalgae were reported in ponds and lakes in Bangladesh by different authors (Ehshan *et al.* 1997, Rahman *et al.* 1999, Hasanat *et al.* 2000). The microalgal genera in experimental ponds in each month varied from 20 to 30. The species diversity increased with the culture period, which might be due to the availability of sufficient nutrients released through decomposition of unused feed and fish metabolic wastes. As nutrient excretion by fish generally increased with fish biomass, it is suggested that nutrient excretion by fish might stimulate growth of algae (Opuszynski 1979, Starling 1993). Boyd (1973) reported that fish excreta and uneaten portion of feed in catfish ponds supply large quantities of nutrients.

The dynamics of microalgal population structures are a function of many of the environmental processes that affect species diversity (Roelke and Buyukates 2002). Variation in microalgal population may be due to the variation in nutrients and other favourable conditions of water during microalgal production. In polyculture ponds of our present study, variations in mixing conditions, precipitation, nutrient availability as well as light illumination was important for maintaining high diversity. The appearance of *Microcystis, Oscillatoria, Gomphospheria, Hildenbrandia, Chlorella, Scenedesmus, Cyclotella, Navicula, Nitzschia, Euglena* and *Phacus* as dominant genera throughout the study period may be related to sufficient nutrient availability, good light conditions and high growth rate of these genera. Microalgal species diversity in lake ecosystems was influenced by many biotic and abiotic processes that include the magnitude and frequency of inflow events associated with nutrient loading, infection by species-specific pathogens and selective grazing (Sterner 1989). Studies in catfish ponds in Alabama, USA demonstrated close relationships among feeding rates, microalgal abundance and the frequency and severity of low dissolved oxygen concentrations (Tucker *et al.* 1979).

The higher water temperature is usually considered as one of the most important factors in regulating the growth of Chlorophyceae. In the present study, the highest cell densities of Chlorophyceae were found in September when temperature and nutrient concentration were high. Cyanophyceae was found to have a positive relationship with water temperature and nutrient (NO_3-N and PO_4-P) concentrations that are in agreements with the findings of Roelke and Buyukates (2002) and Plinski and Jozwiak (1996). Rao (1953) found much concentration of blue-green algae in brewery ponds with pH near 7 and abundant dissolved organic matter. In the present study, the highest cell density of Cyanophyceae and Bacillariophyceae were found in August and September when temperature, dissolved oxygen and nutrient (NO_3-N and PO_4-P) concentrations were most favourable for the growth of these two groups of phytoplankton. The cell density of Euglenophyceae was found to be highest in August followed by September

and July. Euglenophyceae was found least abundant in ponds of T_1 where Chlorophyceae was most abundant and that might be due to the grazing pressure of silver carp stocked in those ponds. Temperature, pH, nitrate-nitrogen and phosphate-phosphorus were the most important ecological parameters that influenced the growth and biological activity of euglenophytes, which is in agreement with the findings of Lam and Silvester (1979).

In Bangladesh, subsequent culture of pangasiid catfish made the waterbodies hypernutrified leading to microalgal blooms especially by blue-green algae, reduced fish growth, and off flavour in the muscle of catfish, which threatened the industry. So, the main purpose of our present study was to see the effectiveness of silver carp and catla in controlling microalgae. Silver carp is one of the most important aquaculture species in Asia and central-eastern Europe. The fish is commercially cultured, stocked for fisheries enhancement, and used experimentally in aquaculture ponds and managed lakes for water quality control throughout the world (Leventer and Teltsch 1990). Silver carp has been stocked in channel catfish (*Ictalurus punctatus*) aquaculture ponds for water quality enhancement (Green and Smitherman 1984) and to a lessen extent as a biocontrol method for phytoplankton for more than two decades (Opuszynski *et al.* 1991). In our present study, silver carp was found to control blue-green algae in a greater extent but enhanced the production of green algae. In the ponds of T_1 where silver carp was stocked with pangasiid catfish, the cell density of blue-green algae was about two times lower (only 31% of the total phytoplankton) than the pangasiid catfish monoculture ponds (60.63% of the total phytoplankton) found in our previous study (Khan *et al.* unpubl. data). Starling (1993) has also found silver carp to be effective in suppressing cyanobacterial blooms in eutrophic lakes. Smith (1985) has suggested that silver carp is particularly efficient in controlling total phytoplankton biomass when the relative abundance of net phytoplankton is high. However, the use of silver carp as a biomanipulation tool to reduce phytoplankton biomass in lakes and reservoirs remains controversial (Starling *et al.* 1998). While Starling *et al.* (1998) listed 14 successful studies, others found no positive influence of silver carp (Fukushima *et al.* 1999). All of the successful experiments have in common the fact that they were performed under eutrophic or hypertrophic conditions where nuisance algal blooms ought to be suppressed and cyanobateria were the predominant phytoplankton forms.

Catla was not effective in controlling blue-green algae but was able to reduce the total biomass of phytoplankton. Dewan *et al.* (1991) from their studies on food selection, electivity and dietary overlap among planktivorous Chinese and Indian major carp fry and fingerlings, reported that zooplankton was preferred by catla during their fingerlings stages and thereafter switched to phytoplankton gradually. In the present study, catla was found not to prefer blue-green algae. This group of plankton was observed to be higher in the ponds of T_2 where catla was included. There are also some reports on the avoidance of Cyanophyceae from the food items by some species of carps. Wahab *et al.* (1998), while studying the food competition of Thai sharpunti with major carps, observed that catla preferred to graze many species of Chlorophyceae but avoided Cyanophyceae.

Microalgal bloom formation is reported to be one of the important impediments on catfish aquaculture in many countries (Smith 1988) including Bangladesh, but in the present experimental ponds the maximum algal density was 126.4×10^3 cells/L which is very common in aquaculture ponds in summer months in tropical areas. In the present study microalgal bloom was not formed and the algal species diversity was found to be slightly increased with the study period. The introduction of carps in the experimental ponds might have helped in controlling the microalgal bloom formation and maintenance of the species diversity.

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