Journal of

Fisheries and Aquatic Science

ISSN 1816-4927

Academic
Journals Inc.

www.academicjournals.com

Journal of Fisheries and Aquatic Science 3 (3): 176-183, 2008
ISSN 1816-4927

Comparison Studies on Water Quality and Plankton Production Between Perennial and Non-Perennial Ponds in Bangladesh

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Abstract: The present study was conducted to compare the water quality and plankton availability between perennial and non-perennial ponds in Bangladesh for a period of six months during October 2004 to March 2005. All water quality parameters in perennial ponds were statistically different ($p<0.05$) than that of non-perennial ponds except temperature. Free CO_2, total alkalinity, pH and transparency were greater in the perennial ponds than that of non-perennial ponds, whereas an opposite result was observed in case of DO concentration. In general, water quality in the perennial ponds was more suitable for aquaculture than that of non-perennial ponds. Total phytoplankton and zooplankton availability were also greater in perennial ponds than that of non-perennial ponds. Absence or presence of aquatic macrophytes was the main cause of the water quality and plankton availability variation between perennial and non-perennial ponds. The present study suggests that non-perennial ponds will be suitable for aquaculture if aquatic macrophytes are removed.

Key words: Water quality, phytoplankton, zooplankton, perennial, non-perennial, Bangladesh

INTRODUCTION

Bangladesh is one of the world's leading fish producing country. In 2005, it was the sixth largest aquaculture producing country in the world, supplying 12% of global aquaculture production, excluding China (FAO, 2007). The country has an extensive pond water resource comprising 198.179 ha (65% of the total pond area) of perennial and 106.846 ha (35% of total pond area) of non-perennial ponds (DOF, 2005). The non-perennial ponds are derelict with no aquaculture activity. The total fish production in 2003 was about 2 million metric tones (MT) of which 43% came from aquaculture (FAO, 2005), pond aquaculture contributed 89% to the total aquaculture (DOF, 2005). However, in principle, pond aquaculture production can be increased at least 35% if all non-perennial come under aquaculture activity.

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A successful pond aquaculture largely depends on overall aquatic environment. Scientific management of a water body is closely related to the acquisition of knowledge of the environment factors specially physico-chemical and biological factors that largely affect the aquatic productivity (Hossain *et al*., 2007; Rahman *et al*., 2007). Water quality determines the species optimal for culture under different environments (Jhingran, 1991; Dhawan and Karu, 2002). Moreover, a suitable water quality enhance primary production, which in turn enhances secondary and tertiary production. The phytoplankton population represents a vital link in the food chain. The zooplankton forms the principal source of food for most of the fish (Prasad and Singh, 2003). However, information on physico-chemical and biological conditions of an water body has a great importance on the management of successful aquaculture (Boyd, 1982).

To the best of the author's knowledge, there is a little information on water quality and plankton production in different parts of Bangladesh (e.g., Wahab *et al*., 1995; Begum *et al*., 2003; Hossain *et al*., 2006). However, information on the water quality and plankton production in non-perennial ponds is still lacking. Moreover, water quality in perennial pond of Rajshahi region in Bangladesh is still poorly understood. Therefore, the aim of this study was to compare the basic water quality and plankton availability between perennial and non-perennial ponds in Rajshahi region in Bangladesh to check whether non-perennial ponds are suitable for aquaculture.

MATERIALS AND METHODS

The six months experiment was carried out in four earthen ponds (two were perennial and another two were non-perennial) between October 2004 and March 2005 in the Rajshahi University, Rajshahi, Bangladesh. Perennial pond indicates the pond with aquaculture activity while on-perennial pond indicates the pond without aquaculture activity. Each of the perennial ponds had a surface area of 0.48 ha and a depth of 1.2 m. The surface area and depth of non-perennial ponds were 0.64 ha and 1.4 m, respectively. The perennial ponds were under aquaculture activity with some exotic (common carp *Cyprinus carpio* and silver carp *Hypophthalmichthys molitrix*) and indigenous fish (rohu *Labeo rohita*, catla *Catla catla* and mrigal *Cirrhinus cirrhosus*) and were regularly (monthly interval) supplied with fertilizers (1 kg urea per 40 m^2) and supplimentary feeds (2-3% of fish body weight). Non-perennial ponds were partially covered by *Eicchornia* sp., whereas perennial ponds were free from *Eicchornia* sp.

Water quality parameters (temperature, water depth, water transparency, Dissolved Oxygen (DO), pH, total alkalinity, free Carbondyoxide (CO_2) and plankton abundance were determined monthly. For water quality and plankton analysis, water samples were collected from some fixed points of each pond from surface to a depth of 20 cm between 9.00-11.00 am. Water temperature (°C) was recorded with a Celsius thermometer. Transparency (cm) was measured with a secchi disc. DO and pH were measured directly by digital dissolved oxygen meter (Model YSI-58, USA) and pH meter (Jenway Model-3020), respectively. Total alkalinity and CO_2 were determined titrimetrically in the laboratory according to APHA (1992).

For plankton analysis, water samples were collected between 9.00 and 11.00 am, taking 1 L samples at 10 different locations in each pond. Each composite 10 L sample was then passed through a 25 µ mesh plankton net. Each concentrated plankton sample was then transferred to a plastic bottle and diluted to 100 mL with formalin and distilled water to obtain a 5% buffered formalin solution. Plankton numbers were estimated in a Sedge-wick-Rafter (S-R) counting cell. A 1 mL sample was put in the S-R cell and was left 10 min to allow the plankton to settle. The plankton in 10 randomly selected fields in the S-R cell was identified up to genus level and counted. Plankton density was calculated according to Stirling (1985) using the formula:

$$N = \frac{(A \times 1000 \times C)}{(V \times F \times L)}$$

Where:
N = No. of plankton cells or units per litre of original water
A = Total No. of plankton counted
C = Volume of final concentrate samples (mL)
V = Volume of a field (mm^3)
F = No. of fields counted
L = Volume of original water (L)

As determination key used were APHA (1992) and Bellinger (1992). Phytoplankton and zooplankton species diversity (D) were estimated according to Margalef using the formula:

$$D = \frac{(S-1)}{\log_e n'}$$

Where:
S = No. of phytoplankton/zooplankton species
n' = Total No. of individual in the collection

All data were analysed through repeated measure one-way ANOVA (95% probability) using the statistical package SAS, version 8 (SAS Institute, Inc., Cary, NC, USA).

RESULTS

Water Quality Parameters

All water quality parameters in perennial ponds were different ($p<0.05$) than that of non-perennial ponds except water temperature and depth (Fig. 1). The lowest temperature was recorded in January (perennial 18°C, non-perennial 17°C), whereas highest was in October (perennial 30°C, non-perennial 28°C). A significantly higher ($p<0.05$) water transparency was recorded in non-perennial ponds than that of perennial ponds. The fluctuations of water transparency in perennial and non-perennial ponds were 24.75 (February) -29.59 cm (October) and 32.5 (March) -46.2 cm (October), respectively (Fig. 1C). pH was higher ($p<0.05$) in perennial ponds than that of non-perennial ponds. We recorded the variation of pH 6.0 (March) -8.2 (December) in perennial ponds and 5.2 (February) -8.7 (October) in non-perennial ponds (Fig. 1D). DO concentration was higher ($p<0.05$) in perennial ponds than that of non-perennial ponds (Fig. 1E), whereas an opposite result was observed in case of CO_2 concentration (Fig. 1F). The ranges of DO in perennial and non-perennial ponds were 3.0 (October) -6.1 mg L^{-1} (January) and 3.6 (October) -4.3 mg L^{-1} (December), respectively, whereas the ranges of CO_2 in perennial and non-perennial ponds were 5.2 (February) -7.5 mg L^{-1} (November) and 4.5 (March) -8.6 (November), respectively. Greater total alkalinity ($p<0.05$) with a range of 70 (November) -165.0 mg L^{-1} (February) was observed in perennial ponds than that of non-perennial ponds (range: 58 (November) -85.5 mg L^{-1} (March)) (Fig. 1G).

Plankton Abundance

A total 17 genera of phytoplankton comprised five major groups (Bacillariophyceae, 3 genera; Chlorophyceae, 5; Cyanophyceae, 5; Dinophyceae, 1 and Euglenophyceae, 3) and 10 genera of zooplankton comprised two groups (Crustacea, 6 and Rotifera, 4) were recorded in both perennial and non-perennial ponds (Table 1, 2). In all ponds the same genera of plankton were found but the quantities were different in perennial and non-perennial ponds. If compare the proportion (% of total phytoplankton or zooplankton) then the different groups of phytoplankton and zooplankton were

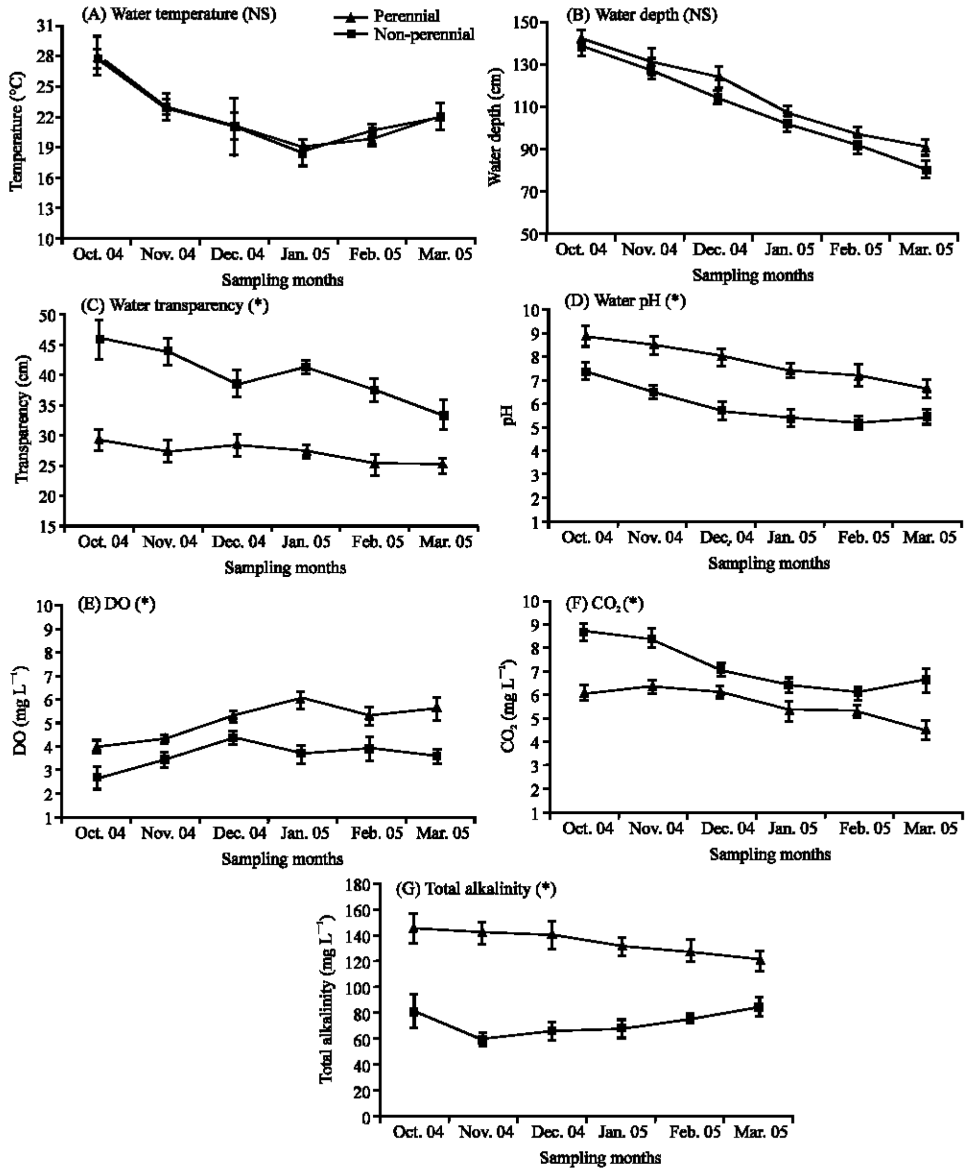

Fig. 1: Monthly fluctuation of water temperature (A), water depth (B), water transparency (C), water pH (D), DO (E), CO_2 (F) and total alkalinity (G) in perennial and non-perennial ponds in Bangladesh from October 2004 to March 2005. NS and * in the parentheses indicate no significant ($p>0.05$) and significant ($p<0.05$) difference, respectively between perennial and non-perennial ponds based on repeated measure one-way ANOVA. Data are mean and standard deviation

almost similar in perennial and non-perennial ponds. The most dominant group of phytoplankton was Chlorophyceae contributing 34.48 and 35.08% of the total phytoplankton in perennial and non-perennial ponds, respectively. The second dominant group of phytoplankton was Cyanophyceae (34.16% in perennial and 30.79% in non-perennial ponds) and followed by Bacollariophyceae (13.87%

Table 1: Monthly abundance phytoplankton and zooplankton ($10^3\times$ cells L^{-1}) in the perennial pond

Plankton groups	2004 October	November	December	2005 January	February	March
Phytoplankton						
Bacillariophyceae	31.20	14.40	18.00	2.90	19.20	19.20
Navicula sp.	22.80	9.00	11.40	1.20	1.20	18.60
Nitzschia sp.	5.40	-	4.20	1.70	9.60	-
Pinnularia sp.	3.00	5.40	2.40	-	8.40	0.60
Chlorophyceae	14.40	42.20	29.40	18.90	81.00	75.00
Chlorella sp.	1.20	1.80	0.60	2.40	-	2.40
Cosmarium sp.	10.20	-	16.80	2.70	27.60	11.40
Spirogyra sp.	2.40	37.40	4.80	3.60	24.60	44.40
Ulothrix sp.	0.60	1.20	4.20	-	27.60	-
Volvox sp.	-	1.80	3.00	10.20	1.20	16.80
Cyanophyceae	36.00	25.76	10.00	43.80	46.20	43.80
Anabaena sp.	6.60	11.40	3.60	17.40	0.00	0.00
Microcystis sp.	-	10.80	4.20	2.40	4.80	14.40
Nostoc sp.	16.80	2.40	-	17.40	4.80	1.20
Oscillatoria sp.	0.60	-	2.20	4.20	16.80	27.60
Rivulatoria sp.	12.00	1.16	-	2.40	19.80	0.60
Dinophyceae	25.20	18.00	-	1.20	0.60	4.20
Peridinium sp.	25.20	18.00	-	1.20	0.60	4.20
Euglenophyceae	19.80	13.20	3.40	5.40	37.20	1.80
Euglena sp.	14.40	7.20	1.60	-	17.40	0.60
Phacus sp.	4.20	5.40	-	3.00	19.80	-
Trachelomonas sp	1.00	0.60	1.80	2.40	-	1.20
Zooplankton						
Crustacea	5.40	7.00	5.26	6.50	4.20	5.16
Daphnia sp.	2.40	1.40	-	1.20	0.60	1.10
Moina sp.	0.60	-	1.40	2.10	1.20	0.80
Cyclops sp.	1.20	2.40	1.40	0.80	0.60	0.96
Diaptomus sp.	-	1.20	0.60	1.40	-	0.90
Diaphonosoma sp.	-	0.80	0.76	1.20	1.20	1.40
Mesocyclops sp.	1.20	1.20	1.10	-	0.60	-
Rotifera	5.40	5.16	2.36	2.40	3.80	3.50
Asplanchna sp.	2.40	0.60	0.80	0.90	-	0.70
Brachionus sp.	1.40	2.10	0.60	-	1.20	0.80
Keratella sp.	-	1.20	0.96	0.60	1.40	1.20
Notholca sp.	1.60	1.26	-	0.90	1.20	0.80

Table 2: Monthly abundance phytoplankton and zooplankton ($10^3\times$ cells L^{-1}) in the non-perennial pond

Plankton groups	2004 October	November	December	2005 January	February	March
Phytoplankton						
Bacillariophyceae	17.80	19.40	3.86	2.30	13.65	12.80
Navicula sp.	14.00	16.00	-	0.60	-	12.00
Nitzschia sp.	2.60	-	1.80	1.70	7.60	-
Pinnularia sp.	1.20	3.40	2.06		6.05	0.80
Chlorophyceae	35.20	25.80	5.60	24.06	53.30	50.40
Chlorella sp.	0.80	1.20	-	1.40	1.10	1.80
Cosmarium sp.	21.00	-	1.20	18.00	-	11.40
Spirogyra sp.	1.40	22.00	0.80	3.70	14.00	24.00
Ulothrix sp.	-	1.20	3.60	0.96	28.00	12.00
Volvox sp.	12.00	1.40	-	-	10.20	1.20
Cyanophyceae	24.26	21.16	31.20	50.22	18.20	20.20
Anabaena sp.	3.60	9.96	10.60	22.60	-	4.60
Mycocystis sp.	-	10.60	2.40	12.00	4.80	-
Nostoc sp.	12.06	-	15.60	4.02	-	1.20
Oscillatoria sp.	-	-	2.60	11.60	1.80	12.00
Rivulatoria sp	8.60	0.60	-	-	11.60	2.40

Table 2: Continued

Plankton groups	2004 October	November	December	2005 January	February	March
Dinophyceae	22.00	-	11.00	1.20	-	4.60
Peridinium sp.	22.00	-	11.00	12.00	-	4.60
Euglenophyceae	6.60	12.60	10.20	21.60	16.00	4.50
Euglena sp.	1.40	7.20	10.20	18.00	-	4.50
Phacus sp.	4.00	5.40	-	2.20	16.00	-
Trachelomonas sp.	1.20	-	-	1.40	-	-
Zooplankton						
Crustacea	3.96	4.26	3.31	3.70	4.36	2.56
Daphnia sp.	2.40	0.96	1.80	-	0.60	0.60
Moina sp.	-	0.60	-	1.80	1.40	0.86
Cyclops sp.	0.90	2.10	0.75	0.80	0.96	1.10
Diaptomus sp.	-	0.60	-	-	1.40	-
Diaphonosoma sp.	0.66	-	0.76	1.10	-	-
Rotifera	3.40	2.86	2.26	1.76	2.21	2.53
Asplanchna sp.	1.20	-	0.86	0.90	-	-
Brachionus sp.	0.80	1.40	-	-	1.26	0.60
Keratella sp.	-	0.60	1.40	-	0.95	1.18
Notholca sp.	1.40	0.86	-	0.86	-	0.75

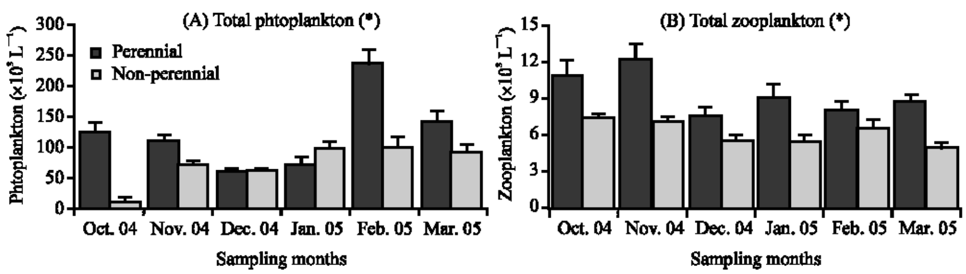

Fig. 2: Monthly total phytoplankton (A) and total zooplankton (B) variations between perennial and non-perennial ponds of Bangladesh from October 2004 to March 2005. * in the parentheses indicate significant difference ($p<0.05$) between perennial and non-perennial ponds based on repeated measure one-way ANOVA. Data are mean and standard deviation

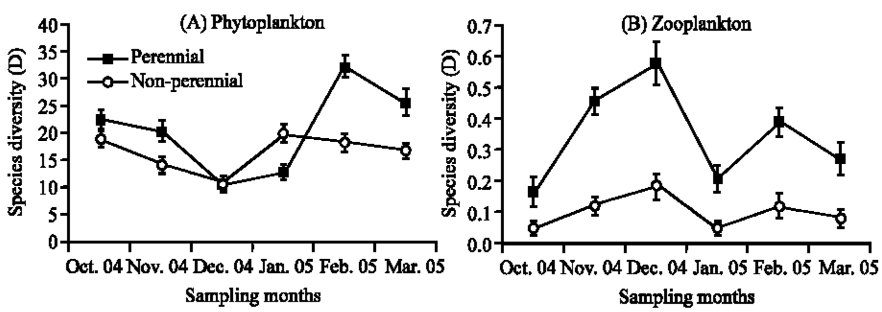

Fig. 3: Monthly variations in phytoplankton species diversity (A) and zooplankton species diversity (B) in perennial and non-perennial ponds of Bangladesh from October 2004 to March 2005. Data are mean and standard deviation

in perennial and 13.27% in non-perennial ponds), Eulenophyceae (10.68% in perennial and 13.40% in non-perennial ponds) and Dinophyceae (6.50% in perennial and 7.27% in non-perennial ponds).

The most dominant group of zooplankton was Crustacea contributing 59.87% of total zooplankton in perennial and 59.59% in non-perennial ponds. Rotifera contributed 40.13 and 40.41% in perennial and non-perennial ponds. The total phytoplankton and zooplankton were significantly higher ($p<0.05$) in perennial ponds than that of non-perennial ponds (Fig. 2). Monthly variations in both phytoplankton and zooplankton species diversity were higher ($p<0.05$) in perennial than non-perennial ponds (Fig. 3).

DISCUSSION

In general, perennial ponds were more suitable for aquaculture with higher pH, alkalinity, DO concentration, plankton abundance and lower free CO_2 concentration. In the present study, temperature was the most critical factor for aquaculture during the observation period except October and November. In October and November the temperature were 23 and 28°C, respectively, which can be considered as the suitable temperatures for higher fish growth. The higher growth rate of the majority of the warm water fishes ranges between 23-32°C (Colt *et al*., 1979; Aston, 1981). The lower DO concentration in non-perennial ponds might be due to the presence aquatic macrophyte (*Eicchornia* sp.) on the surface that might not be allowed oxygen mixing from air to water. Another possible reason of lower DO in non-perennial ponds might be due to higher decomposition, which can be explained by higher free CO_2 concentration and lower pH and alkalinity value. According to Moriarty (1997), biochemical pathway of organic matter decomposition requires oxygen. Carbon dioxide is produced by this process makes the water more acidic, which resulted in lower pH and lower alkalinity value. Perennial ponds were free from aquatic macrophytes, which allowed greater photosynthesis in the water column. This higher photosynthesis might be resulted in higher DO and lower free CO_2 concentration in the water column.

Absence of aquatic macrophytes in perennial ponds not only changed the chemical parameter but also changed biological condition of the ponds. Absence of aquatic macrophytes resulted in greater photosynthesis, which in turn increased total phytoplankton and zooplankton biomass in perennial ponds than that of non-perennial ponds.

However, the present study indicated that water quality and plankton availability variations in perennial and non-perennial ponds were mostly due to absence or presence of aquatic macrophytes on the water surface. In Bangladesh, most of the non-perennial ponds have aquatic macrophytes on the surface of the pond. This study indicates that if aquatic macrophytes are removed from the non-perennial ponds then the physico-chemical and biological conditions (water quality and plankton availability) of pond might be suitable for aquaculture.

ACKNOWLEDGMENTS

The authors wish to acknowledge A.H.M. Ibrahim, University of Rajshahi, Bangladesh for earlier data and P.M. Leunda, University of Navarra, Spain for proof reading the draft.

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