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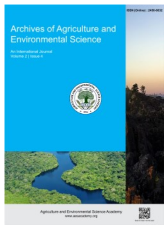

ORIGINAL RESEARCH ARTICLE

CrossMark

Plankton dynamics and physico-chemical parameters: A longitudinal investigation in carp and catfish culture ponds

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ABSTRACT

An experiment was aimed to discover the overall scenario of physico-chemical parameters along with the qualitative and quantitative analysis of plankton in two different fish culture systems as carp mixed culture and catfish (Pangus) monoculture from September 2021 to February 2022 using conventional techniques. The mean values of transparency and dissolved oxygen (DO) noted at the catfish culture pond were lower than those at the mixed carp culture pond while pH mean values were observed to be higher in the catfish culture pond than in the mixed carp culture pond. A total of 21 genera of phytoplankton were found in both ponds under the groups of euglenophyceae (4), cyanophyceae (4), bacillariophyceae (5) and chlorophyceae (8). Among zooplankton, 13 genera were identified including Rotifera (7), copepoda (2), cladocera (3) and crustacean larvae (1) were recorded in mixed culture ponds whereas in catfish culture ponds, 11 zooplankton genera were recorded including Rotifera (5), copepoda (2), cladocera (3) and crustacean larvae (1). Planktonic abundances were statistically significantly different between the different levels (phytoplankton abundance in CCP, phytoplankton abundance in MCP, zooplankton abundance in CCP, zooplankton abundance in MCP), χ^2 (3) = 220.46, $p < 0.001$. Mixed culture pond cyanophyceae, bacillariophyceae, and euglenophyceae are positively associated with water temperature and pH but negatively correlated with DO. Rotifera is negatively associated with catfish culture pond water temperature, whereas chlorophyceae and cyanophyceae are favorably. Catfish monoculture ponds had higher phytoplankton abundance, so phytoplankton grazing fish species could be included with pangus culture to maintain a better water quality.

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INTRODUCTION

Polyculture of carp species is a profitable venture because this aquaculture system requires less feed since cultured species are very keen to take natural feed, particularly they prefer feeding on plankton (Alam *et al*., 2019). Monoculture of pangasiid catfish (*P. hypophthalmus*) has been accepted in Bangladesh because of its high growth and within a short growing cycle. Now a days, the annual production of cultured pangas was 1.55 lakh tonnes in 2010-11 and it rose by two and a half times to 3.95 lakh tonnes in the 2021-22 fiscal year, according to the Department of Fisheries (DoF, 2021-22). However, Pangus monoculture ponds have a tendency of becoming hypernutrified because of unused natural food and excessive supplementary feeds and water quality deterioration can trigger stress and increase diseases (Haque *et al*., 2016). Fish health is threatened by conditions like low oxygen levels, pH swings, and nutrient imbalances, so it's imperative to maintain ideal water quality. In order to avoid issues related to overfeeding or the use of subpar meals, feed management is crucial. The industry's sustainability is impacted by environmental issues, such as habitat degradation and water pollution, which calls for ethical agricultural methods. The complicated world of pangasius farming is further compounded by variations in market demand, compliance with regulations, and challenges associated with breeding. To maintain the long-term viability of pangasius culture, addressing these issues entails putting best management practices into practice are needed. Pond habitats can easily be manipulated by controlling the water characteristics for creating an optimum environment yielding high level fish production (Munni *et al*., 2015). A slight variation in water parameters like temperature, pH, DO etc. can have detrimental impact on the health and production of fish. It also serves as an important technique to enhance the fish production by increasing the primary production in the water body (Abedin *et al*., 2017). Aquatic organisms can also be a factor to determine the degree of pollution associated with physico-chemical parameters (Dirican *et al*., 2009) whereas the planktons are recognized as bio-indicator for monitoring of water quality in aquatic ecosystem. Phytoplanktons are the integral components of freshwater wetlands that significantly contribute towards succession and dynamics of zooplankton and fish. They are producers of any aquatic food chain (Prajapati *et al*., 2019). Thus, the knowledge of water quality parameters of the water bodies provides an important tool for successful production of aquatic organisms in aquaculture. Both the phytoplankton and zooplankton communities influence the water quality characteristics and are important elements in the production of standing waters (Sarkar *et al*., 2020). Therefore, the present study was an attempt to address the interrelationship among the physico-chemical parameters and plankton abundance as well as the influence of culture system on plankton distribution.

MATERIALS AND METHODS

Study site

The study was conducted in three carp culture and three catfish monoculture ponds situated in the northern parts of Bangladesh from September 2021 to February 2022 to observe the difference in two types of culture methods as carp polyculture and pangus monoculture (*P. hypophthalmus*) (Figure 1). The catfish ponds were depended on artificial feed where the carp ponds on both natural and artificial ones. In case of carp ponds several species were cultured such as Rui (*Labeo rohita*), Catla (*Catla catla*), Mrigal (*Cirrhinus mrigala*), Silver carp (*Hypophthalmichthys molitrix*), Grass carp (*Ctenopharyngodon idella*), Common carp (*Cyprinus carpio*) Thai sarputi (*Barbodes gonionotus*) etc while in catfish ponds pangus (*Pangasius hypophthalmus*) monoculture was done. Carp mixed culture ponds were considered as MCP whereas catfish monoculture ponds as CCP.

Figure 1. *Map showing the study area.*

Determination of physico-chemical parameters

The water quality parameters were recorded within a certain period of time randomly throughout the experimental period. Water quality measurements and sample collection were made between 8.00 am and 11.00 am, on each sampling day. Water quality parameters such as temperature (°c), depth, transparency (cm), dissolved oxygen (mg/l), pH, ammonia and nitrate were measured by different digital meters and testing kits.

Sampling framework

Most of the physical and chemical parameters were measured at the pond site using different digital meters and kits. But for the qualitative and quantitative study of phytoplankton and zooplankton, water samples were collected every month and preserved for further analysis.

Determination of the qualitative and quantitative abundance of plankton

Water samples were collected using a plankton net (25 µm mesh size) between 8 am to 11 and then the samples were taken to the laboratory and preserved with 5% formalin in a jar. Samples were collected from different layers. Quantitative analysis of plankton was done using a Sedge-wick-Rafter cell under a phase contrast light microscope at EF-N Plan 4×0.10 magnification (Motic Panthera E2 Binocular Microscope) with bright field and phase contrast illumination which involved transfer of 1 mL subsample from each of the samples to the Sedge Wick-Rafter counter and counting of cells within 10 squares of the cells and chosen randomly. Different images of both phytoplankton and zooplankton were kept with the help of the microscope. The phytoplankton and zooplankton were then identified up to the genus level. The cell counts were used for enumerate the cell density using the Striling (1985) formula where the plankton density is determined by:

$$N = (A \times 1000 \times C) / (V \times F \times L)$$

Where, N= No. of plankton cells or units per liter of original water, A=Total no of plankton counted, C=Volume of final concentrate of the sample (ml), V=volume of a field (mm^3), F=No. of fields counted, L=Volume of original water (L).

Identification of plankton

For proper identification of freshwater plankton, different books, literature, and Websites were considered.

Data analysis

The mean number of phytoplankton and zooplankton was recorded and manifested numerically as $\times 10^3$ cell/liter of water of the pond and the information were represented in Microsoft excel simultaneously by different data set formation. An analysis of variance (One Way ANOVA) and Tukey's test was applied to data for determining significance and comparison between means ± SD (standard deviation). A Kruskal-Wallis (1952) test and Two-way ANOVA test was also carried out for comparative observation of phytoplankton and zooplankton in both mixed and catfish culture ponds. The statistical analyses were calculated by using SPSS 25 ver. and PAST software.

RESULTS AND DISCUSSION

The experiment was conducted with a view to explore the differences and their interrelationship in water parameters including physico-chemical and biological in two widely accepted fish culture systems in Bangladesh. The results of water quality acquired from the mixed carp culture pond (MCP) and catfish culture pond (CCP) were categorized under two sections, the physico-chemical section and the biological section which discovered the planktonic population.

Physico-chemical parameters

The recorded monthly variation of physico-chemical parameters of the present study is presented in Table 1. In both the culture ponds temperature was higher in summer months (September) as well as lower in winter (Dey *et al*., 2021). The observed temperature is within the optimal ranges for (18.3-37.8c) for production of plankton (Shah *et al*., 2022). Abedin *et al*. (2017) also investigated the value of temperature ranged from 29 to 33°C where the mean temperature was found 31.14±0.24°C in case of Pangus culture ponds which is slightly different from the present study. In general, the mean values of transparency and dissolved oxygen (DO) noted at the catfish culture pond were lower than those at the mixed carp culture pond. Ali *et al*. (2019) found water transparency in Pangus culture ponds between 15.54cm-53.72cm which is more or less similar to the present study. However, pH mean values and turbidity were observed to be higher in the catfish culture pond than in the mixed carp culture pond. This could happen because of high number of phytoplankton present in catfish culture ponds and foods staying uneaten (Rahman *et al*., 2020). Ferdoushi and Haque (2006) recorded an increase in pH in pangas ponds as 9.10 which is higher than the current finding. Nitrate concentration was found null in all cases of mixed culture ponds possibly due to not using urea fertilizer while in catfish ponds it was within a range between 0-5 mg/L. Haque & Ferdoushi (2006) during their investigation found that nitrate concentration was higher in pangasiid catfish ponds rather than culturing combination with silver carp. Ammonia concentration was found within a range between 0-0.25 mg/l in mixed culture ponds and within a range between from 0.25-1 mg/L in catfish ponds (Abedin *et al*., 2017).

Qualitative study of the plankton community

A total of 21 phytoplankton genera were found in both MCP and CCP that belong to 4 groups such as euglenophyceae consisted of 4 genera, cyanophyceae consisted of 4 genera, bacillariophyceae included 5 genera and chlorophyceae consisted of 8 genera. Jewel *et al*. (2016) found that the phytoplankton population composed of 20 genera of which belong to Chlorophyceae, Cyanophyceae, Bacillariophyceae Euglenophyceae with whereas zooplankton consisted of 11 genera belonged to Rotifer, Copepod, Cladocera and Crustacean larvae in fed pond. Among zooplankton, 13 genera were identified including rotifera (7), copepoda (2), cladocera (3) and crustacean larvae (1) were recorded in mixed culture ponds (Table 2). Whereas in catfish culture ponds, 11 zooplankton genera were recorded including rotifera (5), copepoda (2), cladocera (3) and crustacean larvae (1) (Figure 2).

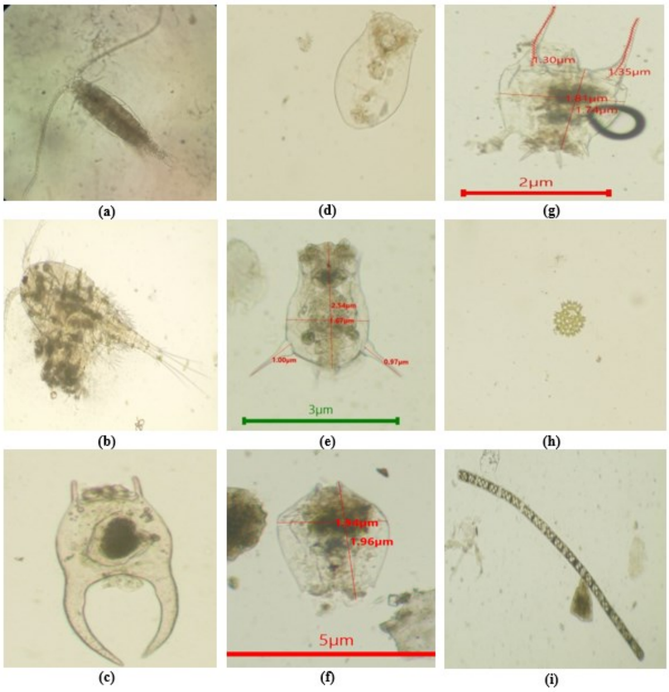

Figure 2. *Some dominant plankton species in fish culture ponds, (a) Diaptomus sp., (b) Cyclops sp., (c) Brachionus forticula, (d) Asplanchna sp., (e). Brachionus calyciflorus, (f) Brachionus plicatilis, (g) Brachionus quadridentus, (h) Pediastrum sp., (i) Spirogyra sp.*

Table 1. Variations (Mean±SD) of physico-chemical parameters in mixed and catfish culture ponds.

Group	Culture type	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Temperature (^{0}c)	MCP	30.17±0.62 (29.5-31)	27.83±0.62 (27.0-28.5)	27.00±1.47 (25.0-28.5)	22.50±0.71 (22.0-23.5)	18.17±0.85 (17.0-19.0)	22.50±0.71 (22.0-23.5)
	CCP	30.50±0.71 (29.5-31.0)	28.33±1.65 (26.5-30.5)	26.50±0.41 (26.0-27.0)	22.83±0.85 (22.0-24.0)	18.67±0.94 (18.0-20.0)	22.50±0.71 (21.5-23.0)
Transparency (cm)	MCP	37.33±1.03 (36.0-38.5)	35.77±0.61 (35.0-36.5)	34.33±0.62 (33.5-35.0)	32.67±0.62 (32.0-33.5)	31.50±1.08 (30.0-32.5)	29.83±0.62 (29.0-30.5)
	CCP	37.17±0.62 (36.5-38.0)	34.67±0.62 (34.0-35.5)	31.17±1.18 (29.5-32.0)	28.33±0.94 (27.0-29.0)	26.17±0.62 (25.5-27.0)	25.83±1.31 (24.0-27.0)
DO	MCP	3.93±0.29 (3.6-4.3)	4.20±0.29 (3.8-4.5)	5.50±0.50 (4.8-5.9)	4.80±0.29 (4.5-5.2)	5.43±0.49 (4.8-6.0)	6.30±0.16 (6.1-6.5)
	CCP	3.77±0.21 (3.5-4.0)	3.67±0.25 (3.4-4.0)	4.30±0.16 (4.1-4.5)	4.33±0.12 (4.2-4.5)	4.57±0.25 (4.3-4.9)	5.10±0.14 (5.0-5.3)
pH	MCP	7.47±0.19 (7.4-7.8)	7.55±0.18 (7.2-7.6)	7.58±0.17 (7.5-7.9)	7.52±0.25 (7.2-7.8)	7.68±0.18 (7.4-7.8)	7.80±0.14 (7.6-7.9)
	CCP	7.90±0.22 (7.6-8.1)	7.90±0.08 (7.8-8.0)	7.97±0.26 (7.6-8.2)	7.87±0.12 (7.7-8.0)	8.27±0.21 (8.0-8.5)	8.37±0.17 (8.2-8.6)

Table 2. Mean (± SD) values of phytoplankton diversity and density (×10^3cells/L) in mixed and catfish culture pond.

Group	Culture type	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Chlorophyceae	MCP	71.78±3.86	80.00±7.85	68.00±6.19	51.11±4.43	50.44±1.25	61.11±2.51
	CCP	87.78±5.67	74.45±1.57	68.89±5.67	64.44±1.57	55.56±4.15	66.66±0.01
Cyanophyceae	MCP	37.78±3.14	48.22±8.46	39.33±1.96	30.22±6.45	22.89±2.20	39.11±1.26
	CCP	94.44±8.32	85.56±5.66	70.00±7.20	73.33±7.20	61.11±3.14	73.33±2.72
Bacillariophyceae	MCP	27.78±5.66	42.67±3.57	34.44±1.57	22.67±0.94	19.78±1.91	31.56±1.25
	CCP	62.22±3.14	55.55±3.14	51.11±1.57	48.89±1.57	43.33±0.01	53.33±4.71
Euglenophyceae	MCP	30.44±2.79	38.00±1.89	20.45±2.51	16.67±3.57	16.00±2.88	28.67±1.44
	CCP	50.00±0.01	47.78±3.14	50.00±7.20	45.55±6.29	32.22±4.16	45.55±9.56
Total phytoplankton	MCP	167.78±7.43	207.11±10.81	162.22±6.19	120.67±5.68	109.11±4.12	160.44±1.57
	CCP	294.45±14.99	263.33±2.72	239.99±9.81	232.22±6.85	192.22±8.31	238.88±8.74
Rotifera	MCP	4.44±0.71	5.83±0.90	5.83±0.59	5.41±0.34	6.53±0.71	5.13±0.20
	CCP	3.88±0.52	4.52±0.35	5.00±0.59	5.14±0.19	6.39±0.20	6.11±0.52
Copepoda	MCP	2.08±0.01	4.03±0.39	2.64±0.52	2.78±0.71	4.44±0.20	3.19±0.79
	CCP	1.80±0.52	2.50±0.34	3.06±0.52	2.22±0.79	3.61±0.79	2.22±0.40
Cladocera	MCP	1.53±0.20	2.64±0.40	1.95±0.39	2.36±0.71	3.19±0.39	3.05±1.04
	CCP	2.07±0.01	2.92±0.34	3.61±0.19	2.50±0.68	4.59±0.34	2.92±0.01
Crustacea	MCP	0.41±0.01	1.11±0.71	0.83±0.34	1.11±0.20	1.66±0.59	0.55±0.20
	CCP	0.41±0.34	0.14±0.19	0.69±0.52	1.11±0.40	1.39±0.20	1.11±0.40
Total zooplankton	MCP	8.46±0.86	13.61±1.61	11.24±1.59	11.66±1.18	15.82±1.70	11.93±1.68
	CCP	8.17±0.85	10.08±1.03	12.50±1.02	`10.96±1.38	15.98±1.20	12.36±1.10

Table 3. Kruskal-Wallis Test.

Groups	Mean ±SD
Phytoplankton in CCP	49.4 ±13.0^{a}
Phytoplankton in MCP	38.7 ±17.9^{b}
Zooplankton in CCP	2.92 ±1.77^{c}
Zooplankton in MCP	2.88 ±1.81^{c}

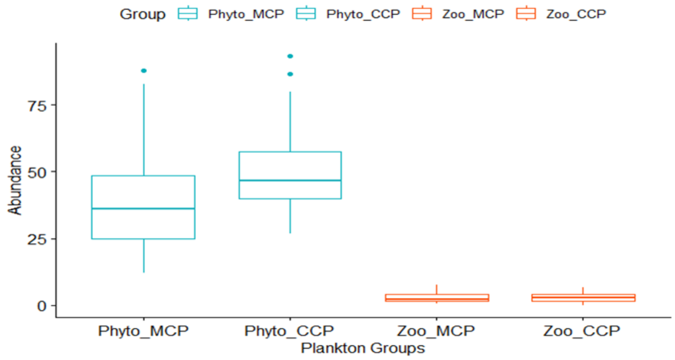

Figure 3. *Comparative scenario of phytoplankton and zooplankton in mixed and catfish culture ponds.*

Quantitative study of the phytoplankton community

Phytoplankton community showed a tendency of gradual decrease in the winter months (Affan *et al.*, 2005). The most thriving group was chlorophyceae and it was dominated by *Chlorella* sp., *Oedogonium* sp., and *Scenedesmus* sp. in mixed culture ponds whereas the dominating group cyanophyceae in catfish culture ponds were ruled by *Anabaena* sp., *Merismopedia* sp., and *Microcystis* sp. (Table 2). Hossain *et al.* (2022) as they also found Chlorophyceae as the dominant one among the other groups.

Quantitative study of the zooplankton community

The most prevalent zooplankton group in mixed culture ponds was Rotifera, which was followed by copepods, cladocerans, and crustacean larvae and in case of catfish ponds rotifera was the most prevalent zooplankton group in the catfish cultivation ponds, followed by cladocera, copepoda, and crustacean larvae. The peak month for the mean abundance of zooplankton was January which can reinforce the findings of Belfiore *et al.* (2021) as they found a decrease in total phytoplankton and cyanobacteria, with the presence of higher zooplankton abundance, especially during the winter months in catfish pond (Figure 3).

Kruskal-Wallis Test

A Kruskal-Wallis test was conducted to determine if there were differences in planktonic abundances that differed in the CCP and MCP. Planktonic abundances were statistically significantly different between the different levels (phytoplankton abundance in CCP (49.4 13.0 ^{a}), phytoplankton abundance in MCP (38.7 17.9 ^{b}), zooplankton abundance in CCP (2.92 1.77 ^{c}), zooplankton abundance in MCP (2.92 1.77 ^{c}), x2(3) = 220.46, $p < 0.001$ (Table 3).

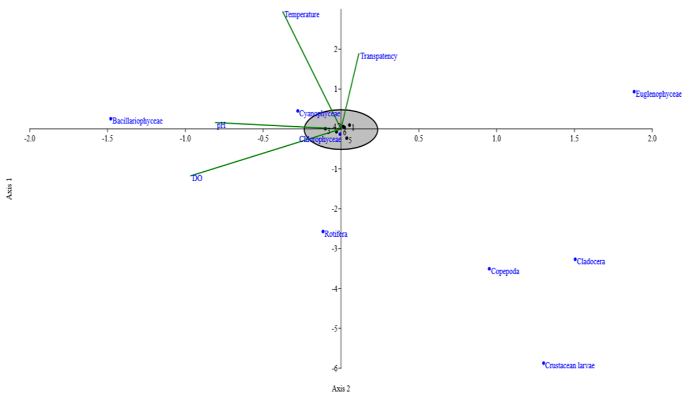

Figure 4. *CCA biplot of plankton and physico-chemical factors at mixed culture ponds.*

Interrelationship between physico-chemical factors and plankton distribution in mixed culture ponds

In mixed culture ponds, several physico-chemical factors affect the distribution of plankton to a different degree. The findings divulge that the distribution of cyanophyceae, bacillariophyceae and euglenophyceae is positively correlated with water temperature and pH but negatively correlated with DO as maximum plankton concentration was observed at a higher temperature (Figure 4). For example, increased temperature and eutrophication promotes Cyanophyceae abundance (Kratina *et al.*, 2012).

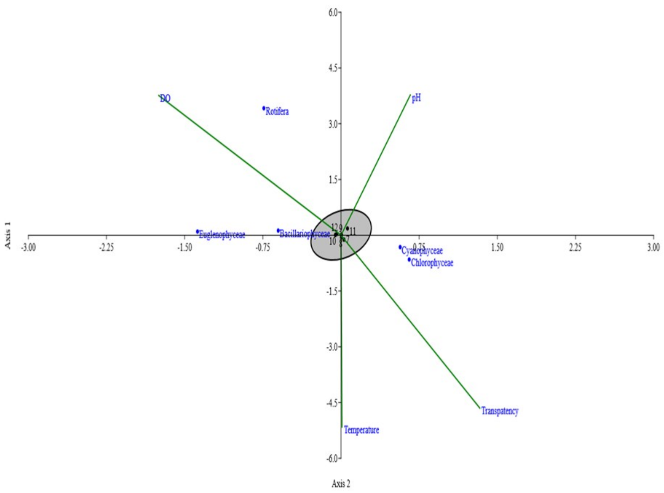

Figure 5. *CCA bioplot of plankton and physico-chemical factors at catfish culture ponds.*

Interrelationship between physico-chemical factors and plankton distribution in catfish culture ponds

Then again, water temperature positively affects the distribution of plankton in catfish culture ponds but its abundance is less dependent on pH and DO. In the CCA bioplot (Figure 5), axis 2 showed that chlorophyceae and cyanophyceae have a highly positive correlation with water temperature but Rotifera is negatively correlated with water temperature. According to Rahman *et al.* (2020) cyanophyceae was correlated well with water temperature.

Conclusion

This study highlights the importance of monitoring water quality for environmental health and sustainability, revealing that regular monitoring of parameters like temperature, pH, DO, and transparency provides valuable insights into aquatic ecosystem health. The physico-chemical characteristics of ponds significantly influence the distribution and abundance of plankton species, highlighting their close relationship with their environment. It is inferred from the current research that the plankton abundance in the catfish culture pond (CCP) was higher than in the mixed carp culture pond (MCP). The water samples from the pond meet the WHO standard and specified range of acceptability based on their physico-chemical properties. As a result, the pond water can be considered to have a good, stable aquatic ecology with higher fish yield. In conclusion, it might be suggested that in order to improve water quality in catfish monoculture pond, phytoplankton grazing fish species could be incorporated in this cultur system.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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