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Investigation of Phytoplankton and Physico-chemical Parameters in Nursery, Growout and Broodstock Ponds

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Abstract

The study measures the relationship between physico-chemical variables with the cell density of phytoplankton in nursery, growout and broodstock ponds of fish. This study was conducted at Natore Government Fish Farm in Bangladesh from January to June, 2012. The observed physico-chemical variables like water temperature, transparency, dissolved oxygen, pH, ammonia-nitrogen, total alkalinity and total hardness were found within the standard ranges. Phytoplankton belonging to bacillariophyceae, chlorophyceae, cyanophyceae and euglenophyceae were found among the ponds but euglenophyceae with highest abundance was recorded in almost all the ponds. Total abundance of different groups of phytoplankton was recorded as mean (±SD) cell density (cell/l) $(62.77\pm2.16)\times10^4$, $(47.22\pm0.69)\times10^4$, and $(77.12\pm3.42)\times10^4$ in nursery pond, growout pond and broodstock pond, respectively. Overall phytoplankton abundance was more in broodstock pond than in others. Total phytoplankton density has exhibited significantly positive correlation with dissolved oxygen (DO) and inverse relation with water temperature, pH, ammonia-nitrogen and total alkalinity in case of nursery pond. For growout pond, total phytoplankton density has exhibited significantly positive correlation with temperature and transparency, and significantly negative correlation with other physico-chemical characteristics. In case of broodstock pond, total phytoplankton density has no significant relationship with any physico-chemical variables of water.

Keywords: Nursery pond; Growout pond; Broodstock pond; Phytoplankton; Water quality, physico-chemical parameters

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1. Introduction

Water body is the habitat as well as the supplier of food for fish. Fish production of a water body is directly dependent on the quality and quantity of the food organisms

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available there. Live organisms of the water consist of three major groups of organisms namely plankton, nekton and benthos [1]. Among these, plankton is very important for fish production. Phytoplankton is the basic of primary production of all types of water bodies and is used as food by fish directly or indirectly.

The aquatic organisms are directly or indirectly depend on phytoplankton population. The knowledge of planktonic biomass available in an ecosystem is of fundamental importance for fish culture. The value of phytoplankton in a water body forming the basic link of food chain of fishes is well recognized. Although phytoplankton is an essential component of an aquatic ecosystem it should be in an optimum range to ensure proper productivity. The qualitative and quantitative abundance of plankton and its relation to environmental condition has become a prerequisite for fish production. Therefore, a thorough knowledge of phytoplankton abundance and its quality in relation to environmental condition is essential for fish culture. Environmental parameters exert an immense influence on the maintenance of a healthy aquatic environment and productions on which the fish subsist are immensely influenced by the inherent water quality parameters of the habitat. So, the factors controlling aquatic fertility need to be understood in order to perform adequate management of the water bodies to enhance fish production.

Water quality determines the species optimal for culture under different environments [2]. The overall productivity of a water body can easily be deduced from its primary productivity, which forms the backbone of the aquatic food chains [3]. The plankton community is comprised of the primary produces or phytoplankton and zooplankton; the secondary producers [4]. The phytoplankton population represents the biological wealth of a water body, constituting a vital link in the food chain. Both the qualitative and quantitative abundance of phytoplankton in a fish pond are of great importance for managing the successful aquaculture operations, as they vary from location to location and pond to pond within the same location even within similar ecological conditions [5]. Phytoplankton not only serves as food for aquatic animals, but also plays an important role in maintaining the biological balance and quality of water [6]. They have a short life span and responds quickly to environmental changes [7-8].

The productivity of freshwater community that determines the fish growth is regulated by the dynamics of its physico-chemical and biotic environment [9]. The physico-chemical and biological characteristics of water also play a big role in plankton productivity as well as the biology of the cultured organisms and final yields. The pH, dissolved oxygen, alkalinity and the dissolved nutrients are important for the phytoplankton production [10]. Plankton diversity responds rapidly to changes in the aquatic environment particularly in relation to nutrients. Physico-chemical attributes of a water body are principle determinants of fish growth rates and developments [11]. Climate has a major influence on water quality and consequently, the biodiversity within the water bodies [12].

The microscopic plankton algae of the ponds are critical food for planktivorous fish species (carps) as well as the larvae of commercially important crustaceans and fin fishes. In most cases, the proliferation of planktonic algae is beneficial for aquaculture, fish

production and wild fisheries operations. However, in some situations algal blooms can have a negative effect, causing severe economic losses to aquaculture, fisheries operations and having major environmental and human health impacts. So, the monitoring programmes of plankton are very important because they may provide information on possible new introductions and may serve as early warning systems to detect the onset of potentially hazardous blooms and may suggest predicative factors for blooms. Species diversity indices when correlated with physical and chemical parameters provide one of the best ways to detect and evaluate the impact of pollution on aquatic communities [13].

Development and scientific fish culture is dependent on various information about limnological factors such as water quality, microorganism, plankton, benthos etc., where aquatic animals largely dependent on planktonic organism. Therefore, knowledge regarding plankton and their culture in the laboratory and use of cultured plankton are very important and can contribute significantly for the development of fisheries and fish production. Considering the importance of nutrient transformation and recycling process in the aquatic systems, the present study tries to understand the situation in Bangladesh. Instead of having a wide scope for fish farming in Bangladesh, the farming system is not so developed scientifically. Therefore, the findings of the study will help to improve the productivity of fish culture in Bangladesh.

2. Materials and Methods

Study sites

The study ponds were situated at the Government fish seed production farm, Natore Sadar Upazila under Natore district in Bangladesh (Fig. 1).

Fig. 1. Geographical location of the study area – Natore Sadar Upazila, Bangladesh.

Sample selection

The study was conducted for a period of six months from January to June, 2012 to measure the present status of physico-chemical characteristics and plankton population. The water quality characteristics and plankton population were collected from nine ponds- 3 nursery ponds (T_1), 3 growout ponds (T_2), and 3 broodstock ponds (T_3). Area of the ponds was between 30 decimal to 60 decimal. Each pond has inlet for watering but no outlet. The ponds were dependable on rainfall and deep tube well water. The depths of different broodstock ponds were ranged from 1.5 to 2 meter.

Nursery pond is a pond which is prepared for rearing the spawn to fingerling stage, for a period of 50-60 days. In general, the size of nursery pond is small and depth of water is low (1-1.5 m). The growout pond is used to produce table fishes from fingerlings. Whereas, a broodstock pond is used to rear mature male and female fishes in order to produce spawn. The size and depth of growout and broodstock ponds are generally higher than that of nursery pond. Mean size (±SD) of the ponds were- 0.178±0.015 ha (nursery, T_1), 0.227±0.021 ha (growout, T_2) and 0.242±0.031 ha (broodstock, T_3).

In nursery ponds fish seeds of 3-5 days were reared up to a size of 5-7 inches. Mixed carp species (Rohu, *Labeo rohita*; Catla, *Catla catla*; Mrigal, *Cirrhinus chirrosus*; Silver carp, *Hypophthalmichthys molitrix*; Bighead carp, *Aristichthys nobilis*; Common carps, *Cyprinus carpio* and Bata, *Labeo bata*) were reared in all the ponds. Both fertilizers (cow dung, urea and triple super phosphate) and supplementary feeds (rice bran, mustard oil cake and commercial pellet feeds) were applied in growout and broodstock ponds. Only mustard oil cake was applied in nursery ponds and fertilizers were used during preparation of nursery ponds.

Data collection

Among the physico-chemical characteristics, temperature, dissolved oxygen, pH, transparency, alkalinity, hardness and ammonia nitrogen of water in the ponds were considered in the study. Six sampling sites in each pond were selected and data recorded on-the-spot. Samplings were restricted to strategic sites and 10 liters of water were collected from each selected site by a plastic bucket to measure the physico-chemical characteristics. The samples were always collected from the subsurface with minimum disturbance of water. Data were taken monthly basis at 9:00-11:00 in the morning.

For the study of phytoplankton abundance, water samples were collected monthly from nine stations. In every case, twenty liters of water samples were filtered through plankton net of 25µ mesh size. Then the samples were concentrated to a volume of 20 ml and preserved in plastic vials with 5% formalin. For analysis, a sub-sample of 1 ml was quickly drawn with a wide mouthed pipette and poured into a Sedgewick Rafter counting chamber of one ml capacity and organisms were counted as outlined by Boyd [14].

Measurements of variables

The researchers collect data by themselves and compute the data in different ways. The transparency of water was measured with the help of a secchi-disc which value was

expressed in cm. Water temperature was recorded by a centigrade thermometer within the range of 0°C to 120°C. Dissolved oxygen (DO) of water was recorded by dissolved oxygen meter (YSI-85/10 FT), and the concentration of DO was expressed in milligram per liter (mg/l) of water. pH was recorded by pH meter (YS1-60/10 FT). Total alkalinity (mg/l) was measured by bromophenol blue indicator and HI 3811-0 solution by titrimetric method (HI 3811 Alkalinity Test Kit). Total hardness (mg/l) was measured by bromophenol blue indicator and HI 3811-0 solution by titrimetric method (HI 3811 Hardness Test Kit). Ammonia-nitrogen (mg/l) was determined by the help of water quality test kit (HACH, FF2, USA).

There is no single method for this estimation of phytoplankton population per ml/L that can be considered the best under all circumstances and for all purposes. Various kinds of cells are used for phytoplankton counting, such as the haemocytometer, Sedgewick-Rafter etc. In this study, Sedgewick-Rafter counting chambers were used for the purpose. For the qualitative and quantitative study of plankton, 1ml of the concentrated plankton sample was taken by a dropper and then put on the S-R (Sedgewick-Rafter) counting cell. The S-R cell is a special type of slide having a counting chamber of 55 mm in length, 20 mm width and 1 mm depth. The volume of chamber is 1 ml. The counting chamber is equally divided into 1000 fields each having volume of 0.001 ml.

For analyzing the phytoplankton, the S-R counting cell was placed under a binocular microscope (NOVA 950). Phytoplankton was counted from 20 random fields out of total fields of the S-R counting cell. For each pond, mean abundance of phytoplankton were recorded and expressed numerically (cell/l) following Greenberg *et al.* [15]. The qualitative calculation of phytoplankton was done by using the following formula.

$$N = \frac{Ax1000xC}{VxFxL}$$

where, N = number of phytoplankton cells or units per liter of original sample; A = total no. of phytoplankton counted; C = volume of final concentrate of the sample in ml; V = volume of a field; F = number of fields counted; and L = volume of original water in liter.

The mean number of phytoplankton was recorded and expressed numerically per liter of water (cells/l). The phytoplankton was identified up to the genus level following Greenberg *et al.* [15], Prescott [16], Pennak [17], and Bellinger [18].

Data validation and calibration

Data were validated by testing stoical significance of the mean value. Different treatments were further tested by using one way analysis of variance (ANOVA) F-test. To identify significant differences among means, Post Hoc (Tucky) test were conducted. Correlation coefficient was estimated by Pearson's Correlation coefficient method and also tested for statistical significance at 1%, 5%, and 10% level. This statistical analysis was performed with by using SPSS software.

3. Results and Discussion

Physico-chemical status

Water temperature plays a vital role in aquatic production through influencing physical, chemical and biological conditions of a water body. Optimum temperature helps to obtain maximum production. Jhingran [11] quoted that the suitable temperature range for

production of phytoplankton in tropical ponds were between 18.3 to 37.9°C. During the study period water temperature was found to vary from 15.4±0.1°C in January to 32.3±0.26°C in June. The mean (±SD) values of water temperature ranged from 15.4±01 to 32.17±0.15 in T_1, 15.5±0.0 to 32.3±0.26 in T_2, and 15.57±0.06 to 32.3±0.3°C in T_3, and the overall mean values (±SD) were 26.40±0.02°C in T_1, 26.51±0.11°C in T_2 and 26.50±0.09°C T_3.Similar results also reported by other studies, like Affan *et al.* [19] recorded temperature 18.3°C to 35.1°C in fish ponds of BAU and BFRI; Hasan [20] recorded water temperature 18.2°C to 34.2°C in Chalan Beel; Hossain *et al.* [21] recorded temperature 27°C to 33°C in coastal ponds. The statistical test (Tuckey) shows that the temperature does not differ significantly among the ponds except for T_1 and T_3 in January which differs significantly at 5% level (Table 1).

Table 1. Descriptive statistics of physico-chemical variables.

Parameters	Pond type	Jan	Feb	Mar	Apr	May	Jun	Jan-Jun
Water temperature (°C)	T_1	15.4±0.1$^{c\wedge}$	22.47±0.15	27.17±0.15	30.13±0.15	31.07±0.12	32.17±0.15	26.4±0.02
	T_2	15.5±0	22.3±0.1	27.3±0.26	30.37±0.15	31.27±0.23	32.3±0.26	26.51±0.11
	T_3	15.57±0.06$^{a\wedge}$	22.37±0.15	27.27±0.25	30.27±0.21	31.23±0.25	32.3±0.3	26.5±0.09
Transparency (cm)	T_1	23.33±1.53	23±3.61	19.33±4.04	18.67±2.08	18.33±2.08	17±2.65	19.94±0.98
	T_2	21±4.36	21.67±0.58	19.67±2.52	19±1	19±1	18.67±7.37	19.83±2.64
	T_3	24±2.65	23.67±1.53	22.33±3.06	19.33±2.52	20.33±2.52	18±1	21.28±0.78
Dissolved oxygen (mg/l)	T_1	7.8±0.5	6.2±1.41	5.93±1.23	5.17±0.65	3.93±0.47	3.57±0.8	5.43±0.39
	T_2	7.03±0.23	6.53±0.95	4.9±0.2	5.17±0.96	3.77±0.83	4.03±0.25	5.24±0.38
	T_3	7.17±0.76	6.2±0.36	4.8±1.06	4.7±0.62	4.13±0.76	3.53±0.7	5.09±0.23
pH	T_1	7±0.1	7.5±0.2	7.83±0.5	7.83±0.25	6.77±0.67$^{b\wedge c\wedge}$	8.32±0.75	7.54±0.27
	T_2	7.33±0.15	7.37±0.32	7.97±0.22	7.6±0.36	7.83±0.21$^{a\wedge}$	7.73±0.06	7.64±0.11
	T_3	7.27±0.25	7.63±0.49	7.77±0.36	6.64±0.95	8.15±0.22$^{a\wedge}$	8.17±0.76	7.61±0.29
Ammonia-nitrogen (mg/l)	T_1	0.03±0$^{c\sim}$	0.04±0^{c*}	0.05±0.01^{c*}	0.04±0.01^{c*}	0.05±0$^{c\wedge}$	0.05±0.01^{c*}	0.04±0.01^{c*}
	T_2	0.03±0.01$^{c\wedge}$	0.03±0.01^{c*}	0.03±0.01^{c*}	0.03±0^{c*}	0.03±0^{c*}	0.03±0.01^{c*}	0.03±0^{c*}
	T_3	0.12±0.07$^{a\sim b\wedge}$	0.1±0.02^{a*b*}	0.21±0.08^{a*b*}	0.16±0.06^{a*b*}	0.17±0.07$^{a\wedge b*}$	0.15±0.05^{a*b*}	0.15±0.02^{a*b*}
Total alkalinity (mg/l)	T_1	190.7±44.3	178±39$^{c\wedge}$	208±42.6$^{c\wedge}$	212.7±32.3$^{c\sim}$	248±28.1	209.3±27^{b*}	207.78±7.45$^{b\sim c\wedge}$
	T_2	199.7±29.8	237±29.1	237±15.7	237.7±49.2	246±67.1	279±15.9^{a*c*}	239.39±20.14$^{a\sim}$
	T_3	210±15.5	256.7±29.2$^{a\wedge}$	276.3±16.1$^{a\wedge}$	290±21$^{a\sim}$	305.3±19.9	169.7±17^{b*}	251.33±5.09$^{a\wedge}$
Total hardness (mg/l)	T_1	264.7±25	225.7±38.3	254±11	247.7±36.7	225.7±60.3	232±15.6	241.61±17.99
	T_2	261.7±49.2	242±17.8	242.3±51.3	246.7±24	276±34.4	265.3±30.7	255.67±13.43
	T_3	207.3±45.4	241±38.3	234.7±30.9	267.7±20.1	233±41.3	277.3±45.3	243.5±9.83

Significant at the 1%, 5%, and 10% level, respectively; T_1, T_2, T_3 represents growout ponds, nursery ponds, and broodstock ponds, respectively; a denotes mean data differs significantly with T_1, b denotes mean data differs significantly with T_2, c denotes mean data differs significantly with T_3.

Boyd [4] recommended a transparency between 15 and 40 cm as appropriate for fish culture. During the period of the study the lowest amount of transparency was vary from 17±2.65 cm in June, 2012 to 24±2.65 cm in January. The mean (±SD) values of water transparency ranged from 17±2.65 to 23.33±1.53 cm in T_1, 18.67±7.37 to 21.67±0.58 cm in T_2 and 18±1.0 to 24±2.65 cm in T_3, and the overall mean values (±SD) were 19.94±0.98 cm in T_1, 19.83±2.64 cm in T_2 and 21.28±0.78 cm in T_3. Similar results also reported by

other studies, like Hasan [20] recorded water transparency 12 to 29 cm in Chalan Beel; Kohinoor [22] recorded water transparency 12 to 50 cm. The statistical test (Tuckey) shows that the water transparency does not differ significantly among the ponds (Table 1).

The mean (±SD) values of DO ranged from 3.57±0.8 to 7.8±0.5 (mg/l) in T_1, 3.77±0.83 to 7.03±0.23 (mg/l) in T_2 and 3.53± 0.7 to 7.17± 0.76 (mg/l) in T_3, and the overall mean values (±SD) were 5.43±0.39 (mg/l) in T_1, 5.24±0.38 (mg/l) in T_2 and 5.09±0.23 (mg/l) in T_3. During the period of the study the lowest amount of DO varied from 3.53±0.7 mg/l in June to 7.8±0.5 mg/l in January. Similar results also reported by other studies, like Mumtazuddin *et al.* [23] found DO value of 5 to 10 mg/l in the selected ponds at the Aquaculture Experiment Station, Mymensingh in Bangladesh; Dewan *et al.* [24] studied a Bangladesh Agricultural University (BAU) pond and found DO 2.2-8.8 mg/l; Wahab *et al.* [25] found DO value of 2.2-7.1 mg/l; Kohinoor [22] recorded DO value of 2-7.5 mg/l. The statistical test (Tuckey) shows that the DO value does not differ significantly among the ponds (Table 1).

pH is an important factor in the aquatic environment. It is called the index of water body. The pH value was fluctuated due to fluctuation of water level. The optimum pH range for production of plankton is from 6.5 to 9.0 [11, 26]. The pH value of water during the study period was found to vary from 6.64±0.95 in April to 8.32±0.75 in June. The mean (±SD) value of pH ranged from 6.77±0.67 to 8.32±0.75 in T_1, 7.33±0.15 to 7.97±0.22 in T_2 and 6.64±0.95 to 8.17±0.67 in T_3, and the overall mean values (±SD) were 7.54±0.27 in T_1, 7.64±0.11 in T_2 and 7.61±0.29 in T_3. Similar results also reported by other studies, like Kohinoor [22] and Hossain *et al.* [27]. The statistical test (Tuckey) shows that the temperature does not differ significantly among the ponds except for T_1 with T_2 and T_3 in May, which differs significantly at 5% level (Table 1).

According to BAFRU [28], ammonia should be less than 0.025 mg/l in culture pond. According to Nathan and Hugh [29] the acceptable limit of ammonia-nitrogen is 0-0.4 mg/l. During the study, the maximum value of ammonia nitrogen was found 0.21±0.08 mg/l in March. The mean (±SD) values of ammonia nitrogen ranged from 0.03±0.0 to 0.05±0.01 (mg/l) in T_1, 0.03±0.01 to 0.03±0.0 (mg/l) in T_2 and 0.1±0.02 to 0.21±0.08 (mg/l) in T_3, and the overall mean values (±SD) were 0.04±0.01 (mg/l) in T_1, 0.03±0.0 (mg/l) in T_2 and0.15±0.02 (mg/l) in T_3. Similar results also reported by Amin and Salauddin [30].The statistical test (Tuckey) shows that the ammonia nitrogen of T_3 differs significantly with T_1 and T_2 for overall the study period (Table 1).

Total alkalinity has little direct effect on fishes but indirectly the wellbeing of fish may be affected by total alkalinity, because water of low values of alkalinity are generally biologically less productive than those with high values. According to Alkunhi [31] total alkalinity more than 100 ppm should be present in highly productive water bodies. According to Nathan and Hugh [29] the acceptable limit of total alkalinity as $CaCO_3$ is 20 mg/l to less than 400 mg/l. During the study period total alkalinity was ranged 169.7±17.0 to 305.3±19.9 mg/l. The mean (±SD) values of total alkalinity ranged from 178±39 to 248±28.1 (mg/l) in T_1, 199.7±29.8 to 279±15.9 (mg/l) in T_2 and 169.7±17 to 305.3±19.9 (mg/l) in T_3, and the overall mean values (±SD) were 207.78±7.45 (mg/l) in T_1,

239.39±20.14 (mg/l) in T_2 and 251.33±5.09 (mg/l) in T_3. Similar findings also reported by Alam and Kabir [32] but low alkalinity was reported by Islam [33] (10.68±5.69 mg/l) and Nargis and Pramanik [34] (9.8-12.5 mg/l).The statistical test (Tuckey) shows that total alkalinity of T_1 and T_3 differs significantly in February to April, and T_2 differs significantly with T_1 and T_3 only in June (Table 1).

According to Nathan and Hugh [29] the desirable range of total hardness is 50-150 mg/l and acceptable limit of total hardness is above 10 mg/l less than 400 mg/l as $CaCO_3$. In the period of the study total hardness was found 207.3±45.4 mg/l to 277.3±45.3 mg/l. The mean (±SD) values of total hardness ranged from 225.7±60.3 to 264.7±25 (mg/l) in T_1, 242±17.8 to 276±34.4 (mg/l) in T_2 and 207.3±45.4 to 277.3±45.3 (mg/l) in T_3, and the overall mean values (±SD) were 241.61±17.99 (mg/l) in T_1, 255.67±13.43 (mg/l) in T_2 and 243.50±9.83 (mg/l) in T_3. The present results are much higher than that of the findings of Islam and Bhuiyan [35], Nargis and Pramanik [34] and Shamsad *et al.* [36] who recorded 126.15±10.48 mg/l, 59.1-79.1 mg/l and 16.76-42.28 mg/l total hardness respectively in their study. The statistical test (Tuckey) shows that the total hardness value does not differ significantly among the ponds (Table 1).

Phytoplankton status

During the present study, 23 genera of phytoplankton belonging to bacillariophyceae (4), chlorophyccae (11), cyanophyceae (6) and Euglenophyceae (2) were recorded which agreed with the findings of Wahab *et al.* [25] who observed the phytoplankton population consisted ofc, chlorophyceae, cyanophyceae and euglenophyceae in the ponds of BAU campus. Hossain *et al.* [37] recorded the phytoplankton of bacillariophyceae, chlorophyceae, cyanophyceae and Euglenophyceae. Ahmed *et al.* [38] recorded 27 genera of phytoplankton composed of bacillariophyceae (4), Chlorophyceae (15), Cyanophyceae (6) and euglenophyceae (2). Kohinoor *et al.* [39] recorded 31 genera of phytoplankton belonging to bacillariophyceae (4), chlorophyceae (15), cyanophyceae (8) and euglcnophyccae (3) in the research ponds of BAU campus Mymensingh. The statistical test (Tuckey) shows that the four group of phytoplankton value differs significantly among different ponds ecosystems (Table 2).

In this study, bacillariophyceae was dominated by four genera namely *Cyclotella*, *Navicula*, *Tabellaria* and *Amphora*. The minimum amount of bacillariophyceae was found $(3.33\pm2.89)\times10^4$ cells/l in March and maximum $(58.33\pm16.07)\times10^4$ cells/l in January. The mean (±SD) cell density (cell/l) of bacillariophyceae varied from $(8.33\pm2.89)\times10^4$ to $(58.33\pm16.07)\times10^4$ in T_1, $(3.33\pm1.67)\times10^4$ to $(25\pm5.00)\times10^4$ in T_2, and $(6.67\pm2.89)\times10^4$ to $(28.33\pm7.64)\times10^4$ in T_3, and the overall mean (±SD) cell density (cell/l) were $(21.39\pm4.93)\times10^4$ in T_1, $(11.67\pm2.11)\times10^4$ in T_2, and $(14.17\pm1.78)\times10^4$ in T_3. Other studies also reported similar findings, such as according to Affan *et al.* [40] maximum abundance of bacillariophyceae is 8.67×10^4 cells/l in January and according to Chowdhury *et at.* [41] the minimum abundance of bacillariophyceae is 5×10^4 cells/l in March.

Table 2. Descriptive statistics of phytoplankton.

Phytoplankton groups	Pond type	Jan	Feb	Mar	Apr	May	Jun	Jan-Jun
Bacillariophyceae	T_1	58.33±16.07 $^{b\wedge c\sim}$	28.33±5.77 $^{b\wedge}$	15±5 $^{b\wedge c\sim}$	8.33±2.89 ^{b*}	6.67±2.89 $^{c\sim}$	11.67±7.64	21.39±4.93 ^{b*}
	T_2	25±8.66 $^{a\wedge}$	10±5 $^{a\wedge}$	3.33±2.89 $^{a\wedge}$	20±5 $^{a* c*}$	5±5 $^{c\wedge}$	6.67±2.89 $^{c\sim}$	11.67±2.11 $^{a* c\wedge}$
	T_3	28.33±7.64 $^{a\sim}$	15±5	6.67±2.89 $^{a\sim}$	8.33±5.77 ^{b*}	13.33±5.77 $^{a\sim b\wedge}$	13.33±7.64 $^{b\sim}$	14.17±1.78 $^{b\wedge}$
Chlorophyceae	T_1	8.33±2.89 $^{c\sim}$	23.33±10.41 $^{b\sim}$	8.33±2.89 $^{b\wedge}$	5±0 $^{c\sim}$	6.67±2.89 $^{c\wedge}$	15±5 ^{c*}	11.11±3.52 ^{c*}
	T_2	6.67±2.89 $^{c\sim}$	8.33±2.89 $^{a\sim}$	30±13.23 $^{a\wedge c\wedge}$	8.33±2.89	8.33±5.77 $^{c\sim}$	11.67±5.77 ^{c*}	12.22±4.01 ^{c*}
	T_3	18.33±7.64 $^{a\sim b\sim}$	10±5	10±5 $^{b\wedge}$	25±15 $^{a\sim}$	21.67±7.64 $^{a\wedge b\sim}$	68.33±20.82 $^{a* b*}$	25.56±6.37 $^{a* b*}$
Cyanophyceae	T_1	21.67±2.89 ^{c*}	28.33±10.41 $^{c\wedge}$	10±5 ^{b*}	6.67±2.89 $^{c\wedge}$	8.33±5.77	21.67±2.89 $^{b* c*}$	16.11±2.94
	T_2	6.67±2.89 ^{c*}	18.33±10.41	66.67±20.21 $^{a* c*}$	10±5 $^{c\sim}$	11.67±7.64	6.67±2.89 ^{a*}	20±6.57 $^{c\wedge}$
	T_3	5±0 $^{a* b*}$	6.67±2.89 $^{a\wedge}$	18.33±5.77 ^{b*}	28.33±14.43 $^{a\wedge b\sim}$	6.67±2.89	5±5 ^{a*}	11.67±4.97 $^{b\wedge}$
Euglenophyceae	T_1	5±0 ^{c*}	21.67±2.89 $^{b\wedge c\wedge}$	13.33±7.64	28.33±18.93	18.33±5.77	8.33±2.89 $^{b\sim}$	15.83±6.7
	T_2	8.33±2.89 ^{c*}	10±5 $^{a\wedge}$	15±8.66	5±0 $^{c\sim}$	21.67±16.07 $^{c\wedge}$	25±13.23 $^{a\sim c\sim}$	14.17±6.19 $^{c\sim}$
	T_3	21.67±2.89 $^{a* b*}$	11.67±2.89 $^{a\wedge}$	6.67±2.89	35±10 $^{b\sim}$	65±20 $^{b\wedge}$	6.67±2.89 $^{b\sim}$	24.44±7.01 $^{b\sim}$
Total phytoplankton	T_1	93.33±16.07^{b*}	101.67±18.93$^{b\wedge c\wedge}$	46.67±16.07^{b*}	48.33±18.93	40±5 $^{c\wedge}$	56.67±7.64 ^{c*}	64.44±5.97
	T_2	46.67±2.89 $^{a* c\wedge}$	46.67±20.82 $^{a\wedge}$	115±25.98 $^{a* c*}$	43.33±2.89	46.67±30.55 $^{c\wedge}$	50±15 ^{c*}	58.06±11.65 $^{c\sim}$
	T_3	80±8.66 $^{b\wedge}$	50±13.23 $^{a\wedge}$	41.67±5.77 ^{b*}	93.33±38.19	111.67±24.66 $^{a\wedge}$ $^{b\wedge}$	101.67±14.43 ^{a*} ^{b*}	79.72±12.02 $^{b\sim}$

*, ^, ~ denotes significant at the 1%, 5%, and 10% level, respectively; T_1, T_2, T_3 represents growout ponds, nursery ponds, and broodstock ponds, respectively; a denotes mean data differs significantly with T_1, b denotes mean data differs significantly with T_2, c denotes mean data differs significantly with T_3

Chlorophyceae was dominated by eleven genera namely *Chlorella, Pediastrum, Scenedesmuus, Spirogyra, Coelastrum, Ankistrodesmus, Tetraedron, Closterium, Selenastrum, Volvox* and *Ulothrix.* Chlorophyceae was found minimum $(5.0\pm0.0)\times10^4$cells/l in April and maximum was $(68.33\pm20.82)\times10^4$ cells/l in June. The mean (±SD) cell density (cell/l) of chlorophyceae varied from $(5.0\pm0.0)\times10^4$ to $(23.33\pm10.41)\times10^4$ in T_1, $(6.67\pm2.89)\times10^4$ to $(30.0\pm13.23)\times10^4$ in T_2, and $(10.0\pm5.0)\times10^4$ to $(68.33\pm20.82)\times10^4$ in T_3, and the overall mean (±SD) cell density (cell/l) were $(11.11\pm3.52)\times10^4$ in T_1, $(12.22\pm4.01)\times10^4$ in T_2, and $(25.56\pm6.37)\times10^4$ in T_3. Other studies also reported similar types of value, such as Affan *et al.* [40] reported maximum abundance of chlorophyceae is 10.5×10^5 cells/l in June and according to Chowdhury *et al.* [41] the minimum abundance of chlorophyceae is 8.3×10^4 cells/l in April.

Cyanophyceae was dominated by six genera *viz. Microcystis, Anabaena, Gomphoshaeria, Agmenellum, Oscillatoria* and *Nostoc.* The highest and lowest values were found $(66.67\pm20.21)\times10^4$ cells/l (March) and $(5.0\pm5.0)\times10^4$ cells/l (June) respectively. The mean (±SD) cell density (cell/l) varied from $(6.67\pm2.89)\times10^4$ to $(28.33\pm10.41)\times10^4$ in T_1, $(6.67\pm2.89)\times10^4$ to $(66.67\pm20.21)\times10^4$ in T_2, and $(5.0\pm5.0)\times10^4$ to $(28.33\pm14.43)\times10^4$ in T_3, and the overall mean (±SD) cell density (cell/l) were $(16.11\pm2.94)\times10^4$ in T_1, $(20.0\pm6.57)\times10^4$ in T_2, and $(11.67\pm4.97)\times10^4$ in T_3. Other studies reported more values, such as Rahman [42] reported mean abundance (cell/l) of 85.6±59.4, 133.8±108.9, 95.3±72.1 and 101.7±92.8 in four different treatments.

Euglenophyceae was dominated by two genera namely *Euglena*, *Phacus.* In the present study maximum abundance, $(65\pm20)\times10^4$ cells/l of Euglenophyceae in May and minimum abundance, $(5.0\pm0.0)\times10^4$ cells/l in January and April. The mean (±SD) cell density (cell/l) of euglenophyceae was varied from $(5.0\pm0.0)\times10^4$ to $(28.33\pm18.93)\times10^4$ in T_1, $(5.0\pm0.0)\times10^4$ to $(25\pm13.23)\times10^4$ in T_2, and $(6.67\pm2.89)\times10^4$ to $(65\pm20)\times10^4$ in T_3, and the overall mean (±SD) cell density (cell/l) were $(15.83\pm6.7)\times10^4$ in T_1, $(14.17\pm6.19)\times10^4$ in T_2, and $(24.44\pm7.01)\times10^4$ in T_3. Other studies also reported similar types of findings, such as Chowdhury *et at.* [41] reported that maximum abundance $(13.33\times10^5$ cells/l) of Euglenophyceae in November and minimum abundance $(13.3\times10^4$ cells/l) in January.

The mean (±SD) cell density (cell/l) of total Phytoplankton (bacillariophyceae, chlorophyceae, cyanophyceae and euglenophyceae) during the study period were found higher at T_3 than those of T_1 and T_2. Total cell density of different groups of phytoplankton was $(64.44\pm5.97)\times10^4$ in T_1, $(58.06\pm11.65)\times10^4$ in T_2, and $(79.72\pm12.02)\times10^4$ in T_3. Other studies also reported similar types of findings, such as Hossain *et al.* [43] found total number of phytoplankton was $(72.0\pm6.6)\times10^4$ cells/l, $(27.43\pm2.35)\times10^4$ cells/l and $(61.50\pm6.42)\times10^4$ cells/l with treated poultry manure, cow manure and urea and triple super phosphate respectively. Variations in the cell density of different groups of phytoplankton among the three types of pond during the whole experimental period are shown in Fig. 2.

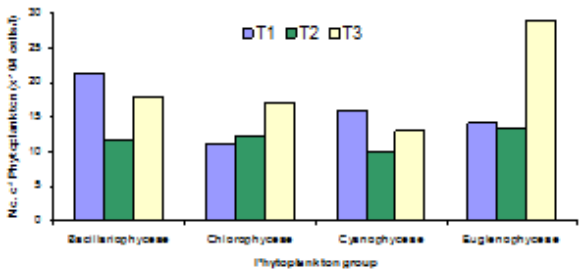

Fig. 2. Mean cell density of different groups of phytoplankton among three types of ponds.

Relationships among the components of phytoplankton

It is also very important to check the interrelationships among phytoplankton groups, because growth of one types of phytoplankton may help to growth of another type of phytoplankton or reduction of other types of phytoplankton. Bacillariophyceae and euglenophyceae show significant negative correlation for T_2 (Table 3). Similarly, cyanophyceae and chlorophyceae shows significant positive relationship for T_1 and T_2. Only chlorophyceae shows negative correlation sign with bacillariophyceae for all types of ponds, but none is statistically significant. It is also statistically found that among all types of phytoplanktons, bacillariophyceae and cyanophyceae dominating significantly in T_1, and cyanophyceae and chlorophyceae both are dominating significantly in T_2.

Table 3. Correlation among the components of phytoplankton.

Phytoplankton groups	Pond types	Chlorophyceae	Cyanophyceae	Euglenophyceae	Total phytoplankton
Bacillariophyceae	T_1	0.16	0.58	-0.55	0.81~
	T_2	-0.56	-0.51	-0.74~	-0.50
	T_3	-0.03	-0.64	0.00	0.13
	All	-0.36	-0.29	-0.42	0.65
Chlorophyceae	T_1		0.86^	-0.03	0.66
	T_2		0.96*	0.18	0.99*
	T_3		-0.24	-0.17	0.60
	All		-0.08	-0.32	0.19
Cyanophyceae	T_1			-0.39	0.87^
	T_2			0.01	0.98*
	T_3			0.05	-0.14
	All			-0.46	-0.13
Euglenophyceae	T_1				-0.44
	T_2				-0.41
	T_3				0.65
	All				0.44

*, ^, ~ denotes significant at the 1%, 5%, and 10% level, respectively; T_1, T_2, T_3 represents growout ponds, nursery ponds, andbroodstock ponds, respectively

Relationships among physico-chemical variables

The interrelationships among the different quality parameters were also analyzed (Table 4). Water temperature and transparency show significant negative correlation for all the treatments *i.e.* T_1, T_2 and T_3. Similarly, dissolved oxygen (DO) and water temperature also show significant negative relationship for all the treatments (T_1-T_3). Water temperature and total alkalinity show significant positive relationship in T_2. Significant positive relationship is also observed in all the treatments among water transparency and dissolved oxygen. Significant negative relationship is observed in T_3 among water transparency and total hardness. Significant negative relationship is found in T_2 and T_1 among DO and pH, and DO and ammonia-nitrogen respectively. Highly positive relationship is observed in T_2 among ammonia-nitrogen and total alkalinity (Table 4).

Table 4. Correlation among physico-chemical variables.

Water quality variables	Pond Type	Transparency (cm)	Dissolved oxygen (mg/l)	pH	Ammonia-nitrogen (mg/l)	Total alkalinity (mg/l)	Total hardness (mg/l)
Water temperature (°C)	T_1	-.943*	-.944*	0.448	0.79	0.68	-0.55
	T_2	-.871*	-.931*	0.74~	0.744~	.852^	0.217
	T_3	-.832^	-.981*	0.316	0.414	0.222	0.778~
	All	-.927*	-.967*	0.649	0.665	0.712	0.588
Transparency (cm)	T_1		.896^	-0.47	0.673	-0.724~	0.32
	T_2		.897^	-0.73~	0.467	-.649	-0.442
	T_3		.898^	-0.165	-0.37	0.108	-.846^
	T_1-T_3		.932*	-0.61	-0.64	-0.52	-.829^

Table 4 (*contd*.)

Dissolved oxygen (mg/l)	T_1	-0.34	-.812^	-0.687	0.698
	T_2	-.839^	-.68	-0.79~	-0.468
	T_3	-0.755	-0.594	-0.079	-0.742~
	All	-.72	-.66	-.647	-.594
pH	T_1		-0.063	-0.262	-0.033
	T_2		0.29	0.53	0.147
	T_3		.18	-0.235	0.010
	All		.55	.151	.38
Ammonia-nitrogen (mg/l)	T_1			.686	-0.73~
	T_2			.906^	.35
	T_3			0.388	0.113
	All			.68	.29
Total alkalinity (mg/l)	T_1				-.28
	T_2				0.202
	T_3				-0.172
	All				.028

*, ^, ~ denotes significant at the 1%, 5%, and 10% level, respectively; T_1, T_2, T_3 represents growout ponds, nursery ponds, and broodstock ponds, respectively

Relationships between phytoplankton and physico-chemical variables

The statistical output shows, bacillariophyceaeis significantly negatively correlated with water temperature of T_1, T_3, and pH of T_2, butpositively correlated with water transparency and dissolved oxygenof T_1 (Table 5). Chlorophyceae shows significantly negative correlation with water transparency of T_3 and total Alkalinity of T_1. Euglenophyceae shows significantly negative correlation with dissolved oxygen of T_2 but positive relationship with Total Alkalinity of T_2. Cyanophyceaehas no statistically significant relationship with any physico-chemical variables of any pond.

The combined value of all four types of phytoplankton shows positive correlation with water transparency of T_1, but negative correlation with water temperature and total alkalinity of T_1.The combined data for all three types of pond shows significant negative correlation between bacillariophyceae and water temperature, bacillariophyceae and ammonia-nitrogen, bacillariophyceae and total alkalinity, chlorophyceae and pH, euglenophyceae and total alkalinity, but significant positive correlation between bacillariophyceae and water transparency, bacillariophyceae and dissolved oxygen.

In the study, chlorophyceae dominated the phytoplankton groups, followed by bacillariophyceae. This is attributed to high temperature and others favourable water quality attributes and high levels of total alkalinity. Similar findings were also reported by Seenayya [44]. Konopka and Brock [45] determined temperature for photosynthesis and natural populations of blue green algae (cyanophyceae) from Lake Mendota in Wisconsin, USA. They recorded that the dominant phytoplankton blue green algae in summer months, the optimum temperature for photosynthesis was usually between 20°C and 30°C,

whereas the average environmental temperatures during the study period were 26.40±2.62℃ in T1, 26.50±2.64℃ in T_2 and 26.57±2.64℃ T_3. So water temperature in all the treatments was suitable for phytoplankton growth.

Table 5. Correlation between phytoplankton and physico-chemical variables.

Water quality variables	Pond type	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Euglenophyceae	Total phytoplankton
Water Temperature (°C)	T_1	-0.97*	-0.18	-0.54	0.39	-0.83^
	T_2	-0.61	0.19	0.05	0.57	0.07
	T_3	-0.79~	0.51	0.32	0.27	0.46
	All	-0.92*	0.49	-0.03	0.51	-0.60
Transparency (cm)	T_1	0.85^	0.37	0.58	-0.13	0.89^
	T_2	0.34	-0.17	0.03	-0.54	-0.07
	T_3	0.51	-0.79~	-0.25	-0.21	-0.69
	All	0.72~	-0.59	0.18	-0.41	0.39
Dissolved oxygen (mg/l)	T_1	0.87^	0.05	0.33	-0.23	0.70
	T_2	0.69	-0.25	-0.08	-0.77~	-0.15
	T_3	0.71	-0.61	-0.20	-0.20	-0.48
	All	0.86^	-0.58	0.14	-0.51	0.40
pH	T_1	-0.39	0.24	0.09	0.03	-0.19
	T_2	-0.75~	0.71	0.59	0.60	0.65
	T_3	-0.06	0.35	-0.69	-0.01	0.11
	All	-0.68	0.84^	0.29	-0.16	0.04
Ammonia-nitrogen (mg/l)	T_1	-0.82	0.03	-0.36	0.24	-0.65
	T_2	-0.61	-0.21	-0.31	0.70	-0.32
	T_3	-0.63	0.00	0.47	0.17	0.03
	All	-0.73~	0.15	0.44	0.32	-0.26
Total alkalinity (mg/l)	T_1	-0.65	-0.64~	-0.76	0.16	-0.86^
	T_2	-0.68	0.13	-0.05	0.74~	-0.01
	T_3	-0.49	-0.69	0.54	0.62	-0.09
	All	-0.78~	-0.23	0.08	0.83^	-0.73~
Total hardness (mg/l)	T_1	0.57	-0.53	-0.18	-0.38	0.10
	T_2	-0.07	-0.43	-0.54	0.63	-0.43
	T_3	-0.63	0.69	0.35	-0.17	0.32
	All	-0.27	0.64	-0.32	0.06	-0.11

*, ^, ~ denotes significant at the 1%, 5%, and 10% level, respectively; T_1, T_2, T_3 represents growout ponds, nursery ponds, and broodstock ponds, respectively

Pechar [46] reported that grazing pressure of zooplankton and low light condition was suitable for mass development of the small species of cyanophyceae. He also stated that high pH was not necessary to achieve cyanobacterial dominance. These findings are more or less similar with the present study.

Bacillariophyceae was most abundant at a low temperature with the least concentration of nutrients in the winter (December to January). It may be due to least rainfall causing not much run-off, calm weather and less mixing with nutrients rich bottom water. There was a less amount of fish feed as the feeding intensity of fish decreased with decreasing temperature. A similar suggestion was expressed by Havens [47]. These results agree with Talbot and Bate [48] who concluded that blooms of surf diatom species, including *Asterionella* sp. and *Aulacodiscus* sp. appear to be unrelated to nutrient availability.

Euglenophyceae was most abundant in high temperature, low transparency and pH. According to Affan *et at.* [40], moderate temperature and clear sunlight may reasons for the dominance of euglenophytes. Phang and Ong (1988) [49] reported that Euglenoides were dominant at elevated temperature. In addition Wild *et at.* [50] reported that *Euglena* assemblages were widely distributed at elevated temperature. These findings are closely related with the present study.

Influences of phytoplankton and physico-chemical parameters on pond ecosystem

The statistical output of correlation estimations (Table 3) show when temperature increases by 1%, the average number of bacillariophyceae decreases by 0.92% which differs from 0.79% to 0.97% depending on pond types. When transparency increases by 1%, the average number of bacillariophyceae increases significantly by 0.72% which is 0.85% for T_1, and the chlorophyceae decreases by 0.79% only for the case of pond T_3. When DO increases by 1%, the average number of bacillariophyceae increases by 0.86% which is also significant for T_1 at 0.87%, but it leads to decrease of euglenophyceae at 0.77% only for the T_2. A 1% increase of pH leads to 0.75% decrease of bacillariophyceae for T_2 but 0.84% increase of average number of chlorophyceae. A 1% increase of ammonia-nitrogen leads to 0.73% decrease of average number of bacillariophyceae. Total alkalinity shows significant negative relationship with average number of bacillariophyceae in the propensity of 78%. It also shows significant negative relationship with chlorophyceae for T_1 at the propensity of 64%. It also shows significant relationship with average euglenophyceae at the propensity of 83%, and for T_2 only at the propensity of 74%.

It is important to note that different types of pond were influenced by different types of phytoplankton and at different times. Growth of phytoplankton in the Nursery Ponds Ecosystem is more in the starting of the period, and it reduces over the time. As the newly hatched seeds are dependent only on their yolk sac for a short period of time after hatching, grazing pressure on phytoplankton during this time remains almost zero which greatly enhance the production of phytoplankton. Moreover, fertilization also plays a key role in the production of phytoplankton. At that time, bacillariophyceae was dominating over other types of phytoplankton. Growth of phytoplankton in the Growout Ponds Ecosystem is more in the middle of the period, and it constant over the time. This may be due to regular application of fertilizers, both organic and inorganic. At that time, cyanophyceae was dominating over other types of phytoplankton. Growth of phytoplankton in the broodstock Ponds Ecosystem is more in the middle of the period,

and it remains constant over the time. This may be due regular application of fertilizers into the ponds which greatly enhance the phytoplankton production of a water body. Moreover, supplementary feeds were applied to brood fishes which reduce feeding pressure on plankton community resulting in higher abundance of plankton. At that time, chlorophyceae and euglenophyceae were dominating over other types of phytoplankton.

4. Conclusions

A total of 23 genera belonging to four groups of phytoplankton, bacillariophyceae (4), chlorophyceae (11), cyanophyceae (6) and euglenophyceae (2) were encountered in the present experiment. Of which euglenophyceae was the most dominant group contributing 30.19% of the total plankton. Total phytoplankton density exhibited positive relation with DO, water transparency and total hardness, and inverse relation with rest of the parameters in T_1. It showed insignificantly positive relation with temperature and pH and negative relation with rest of the physico-chemical parameters in T_2. In T_3 total phytoplankton density showed negative relation with transparency, DO and total alkalinity and positive relation with rest of the parameters. Broodstock pond (T_3) was found best for the abundant existence of phytoplankton than other types. Further further research is recommended to evaluate the water quality parameters to characterize the long-term variabilities of phytoplankton in nursery, growout and broodstock ponds.

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