IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372.Volume 7, Issue 1 Ver. V (Feb. 2014), PP 45-52
www.iosrjournals.org

Relationships of euglenophytes bloom to environmental factors in the fish ponds at Rajshahi, Bangladesh

M. M. Rahman[1*], J. K. Ghosh[2] and M. S. Islam[3]
[1*]*(Assistant Professor, Department of Fisheries, University of Rajshahi, Bangladesh)*
[2]*(Department of Agriculture, Shahmukdhum College, Rajshahi, Bangladesh)*
[3]*(Student, Department of Fisheries, University of Rajshahi, Bangladesh)*

Abstract: *The study was conducted to investigate the relationships of euglenophytes bloom to environmental factors in the fish ponds at Rajshahi, Bangladesh for twelve months from July 2010 to June 2011. Among the study ponds, three ponds with bloom were located at Raighati, Mohanpur Upazila (BP-R), another three ponds with bloom at Yusufpur, Charghat Upazila (BP-Y) and three non-bloom ponds (NBP) at Meherchandi, Motihar Thana. The environmental factors (water temperature, DO, pH, NO_3-N, NH_4-N, PO_4-P, Fe, Zn, Mn and Cu), soil organic matter, and algal community and density were examined monthly by using standard methods. There was no significant difference in water temperature among BP-R, BP-Y and NBP but significantly lower DO and pH, higher concentrations of NO_3-N, NH_4-N, PO_4-P, Fe, Zn, Mn, Cu and soil organic matter and higher density of euglenophytes were recorded in BP-R and BP-Y as compared to NBP ($P<0.05$). The euglenophytes were composed of three genera, Euglena, Phacus and Trachelomonas among which Euglena (E. sanguinea) was highly dominant. The density of euglenophytes in BP-R and BP-Y showed an increasing trend from September (early autumn) and peaked in November (late autumn) and December (early winter). The density of these algae was negatively correlated with water temperature, DO and pH while positively correlated with NO_3-N, NH_4-N, PO_4-P, Fe, Zn, Mn and Cu concentrations ($P<0.05$).*

Key words: *Bloom, Environmental, Euglenophytes, Factors, Fish pond, Relationship*

I. Introduction

Algae are the basic members in the aquatic ecosystem and they form bloom in favourable environmental conditions. In freshwater fish pond, the nutrients enrichment by the addition of fertilizers and supplementary feeding, leads to eutrophication, thereby frequently developing algal bloom [1]. Among different classes of freshwater algae, the members of euglenophytes viz., *Euglena*, *Phacus* and *Trachelomonas* are commonly abundant [2] and these algae formed spectacular red bloom on the surface of the fish ponds in Bangladesh [3].

Although, algal bloom indicates high productivity of the water body concerned [4] but excessive algal bloom causing serious economic losses to aquaculture [5]. Euglenophytes bloom often leads to environmental degradation that hampered growth of fish [6]. Their bloom often create water quality problems, the most severe of which being the oxygen depletion leading to mass mortality of fish [7]. Furthermore, bloom of these algae has a blanketing effect on the fish pond, thereby preventing the entry of sunlight into water that affect the growth of beneficial algae through hampering photosynthesis. The blooms of *Euglena elastica, E. gracilis* and *Trachelomonas charkoweinis* have a significant effect in reducing the number of beneficial algal species in fish pond [8]. Therefore, an understanding of the environmental factors that enhance euglenophytes density in the fish pond is necessary to manage this problematic algal bloom.

The planktonic algal community is largely influenced by the interaction of a number of physico-chemical and biological factors [9]. Moreover, the amount of organic matter in bottom soil of the pond strongly influences water quality and concentration of nutrients available to algae [10]. However, concerning the relations of environmental factors and the growth of euglenophytes, a number of research findings have been reported in different countries of the world [11], [12], [13], [14], [15]. But, the dynamics of the euglenophytes bloom in relations to environmental factors in farmers' fish pond has been poorly understood in Rajshahi, Bangladesh. Therefore, the present study was conducted to investigate the relationships of euglenophytes bloom to environmental factors in the fish ponds with a view to monitor the variation in environmental factors and euglenophytes density.

II. Materials and Methods

2.1 Duration and location of the study

The study was conducted for twelve months from July 2010 to June 2011 in nine fish ponds at three stations of Rajshahi district, north-west part of Bangladesh. Among the ponds, three bloom ponds (BP) were located at Raighati in Mohanpur Upazila (BP-R), another three bloom ponds were at Yusufpur in Charghat Upazila (BP-Y) and three non-bloom ponds (NBP) were at Meherchandi in Motihar Thana.

2.2 Study ponds and their management

The ponds were more or less rectangular in shape with area 2.5 to 3.5 dec. Water levels of the ponds varied between 3.0 and 5.5 feet. Semi-intensive culture system was practiced in the ponds. Initially, the ponds were treated with quick lime (CaO) at the rate of 1kg/dec. Fertilization of the ponds was done with both organic and inorganic fertilizers. The initial and periodic doses of fertilizers are shown in Table.1. The ponds were stocked with fingerlings of *Labeo rohita*, *Catla catla*, *Cirrhina mrigala*, *Hypophthalmichthys molitrix* and *Puntius gonionotus* at the rate of 60-75 fingerlings/dec.

Table 1: Doses of fertilizers applied in the study ponds

Fertilizers	Initial dose (/dec.)	Periodic dose (/dec. /15 days)
Cow-dung	6-7 kg	2-3 kg
Poultry manure	2-4 kg	---
Urea	100-200 g	50-100 g
TSP	100-200 g	50-100 g

2.3 Monitoring of environmental factors

The environmental factors viz., water temperature, pH, dissolved oxygen (DO), nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), phosphate-phosphorus (PO_4-P), iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) concentrations were monitored monthly. Some environmental factors were monitored on the spot. For laboratory analysis, water samples were collected from different points of each pond. Water temperature, DO and pH were determined by Celsius thermometer, HACH kit (HANNA, HI-9142) and pH meter (Jenway, 3020 UK), respectively. The concentrations of NO_3-N, NH_4-N and PO_4-P were determined by using HACH kit (DR/2010). The concentrations of Fe, Zn, Mn and Cu were determined by Atomic Absorption Spectrophotometer (Model-3310).

2.4 Determination of soil organic matter

The soil samples were collected using standard method. Determination of soil organic carbon was made by the Walkley-Black method. Organic matter of soil was determined by multiplying the % of organic carbon with conventional Van-Bemmelen's factor of 1.724 [16].

2.5 Study of planktonic algae

For studying of planktonic algae, water samples (10 L) were collected in a plastic bucket from different depth of each pond and passed through plankton net (25 µm mesh size). The concentrated samples were preserved with 5% buffered formalin. For identification and enumeration of algae, the samples were examined using Sedgewick-Rafter counting cell (S-R cell) under compound microscope (NOVEX). Identification of algae was performed according to APHA [17] and Bellinger [18]. The enumeration was done according to Stirling [19].

2.6 Statistical analysis

For statistical analysis of the data, one way analysis of variance (ANOVA) was performed using software SPSS (Statistical Package for Social Science, version 16.0). The mean values were compared to see the significant difference from the DMRT (Duncan Multiple Range Test). Correlation analyses were performed to determine relationships between euglenophytes density and environmental factors by using software SPSS. Significance was assigned at the 0.05 level.

III. Results

3.1 Environmental factors

The environmental factors (except water temperature) in the bloom ponds (BP-R and BP-Y) showed significant difference from the non-bloom ponds (NBP) but, between BP-R and BP-Y, these factors did not show any significant difference (Table 2). The water temperature showed a seasonal trend and it was over 32.0 ºC in the summer and below 17.5 ºC in the winter. The mean values of DO and pH were significantly low in BP-R and BP-Y as compared to NBP (Table 2). The maximum value of DO (5.98 mg/l) was recorded in NBP in April and the minimum (4.06 mg/l) in BP-Y in November whereas the maximum value of pH (8.03) was recorded in NBP in September and the minimum (5.94) in BP-R in December.

During the study period, the concentrations of NO_3-N, NH_4-N and PO_4-P in BP-R and BP-Y were almost over 1.0 mg/l, 0.65 mg/l and 0.81 mg/l whereas in NBP, these nutrients were below 0.55 mg/l, 0.30 mg/l and 0.50 mg/l, respectively. The concentrations of NO_3-N and NH_4-N were increased up to 1.81 mg/l and 1.49 mg/l in BP-Y whereas the concentrations of PO_4-P were increased up to 1.86 mg/l in BP-R. The mean concentrations of these nutrients were significantly higher in BP-R and BP-Y as compared to NBP (Table 2).

Like major nutrients, the mean concentrations of Fe, Zn, Mn and Cu were significantly higher in BP-R and BP-Y as compared to NBP (Table 2). The maximum concentrations of Fe and Mn (0.78 mg/l and 0.36 mg/l) were recorded in BP-R in November and the minimum (0.11 mg/l and 0.06 mg/l) in NBP in July whereas the maximum concentrations of Zn and Cu (0.42 mg/l and 0.37 mg/l) were recorded in BP-Y in November and the minimum (0.04 mg/l and 0.07 mg/l) in NBP in August.

Table 2: Mean values (±SD) of environmental factors in the study ponds

Parameters	Study ponds		
	BP-R	BP-Y	NBP
Temperature (^{0}C)	26.29±4.47^a	26.37±4.42^a	26.39±4.52^a
DO (mg/l)	4.96±0.47^b	4.99±0.44^b	5.72±0.38^a
pH	6.30±0.39^b	6.34±0.41^b	7.84±0.39^a
NO_3-N (mg/l)	1.22±0.28^a	1.24±0.29^a	0.48±0.11^b
NH_4-N (mg/l)	1.05±0.26^a	1.08±0.27^a	0.23±0.07^b
PO_4-P (mg/l))	1.17±0.35^a	1.19±0.32^a	0.41±0.10^b
Fe (mg/l)	0.50±0.15^a	0.53±0.13^a	0.18±0.05^b
Zn (mg/l)	0.25±0.09^a	0.28±0.10^a	0.09±0.03^b
Mn (mg/l))	0.26±0.07^a	0.24±0.07^a	0.11±0.03^b
Cu (mg/l)	0.25±0.05^a	0.26±0.07^a	0.10±0.03^b

***** BP-R: Bloom ponds at Raighati, Mohanpur; BP-Y: Bloom ponds at Yusufpur, Charghat; and NBP: Non-bloom ponds at Meherchandi, Motihar.

***** Values of environmental factors are mean of triplicate determination. Values in the same row with different superscripts are significantly different (P<0.05).

3.2 Soil organic matter

Significantly higher soil organic matter was recorded in BP-R and BP-Y as compared to NBP and the values were found to vary from 5.06 to 7.98, 5.26 to 7.64 and 2.88 to 3.55% in BP-R, BP-Y and NBP, respectively.

3.3 Planktonic algal community

A total of 28 genera of algae belonging to euglenophytes, cyanophytes, chlorophytes and bacillariophytes were recorded. The number of planktonic algal genera varied from 13 to 22, 12 to 23 and 21 to 27 in BP-R, BP-Y and NBP, respectively. Relatively higher number of algal genera was recorded in NBP as compared to BP-R and BP-Y. Among four groups of planktonic algae, chlorophytes had the maximum number of genera (11) and euglenophytes had the minimum number of genera (3) which are *Euglena*, *Phacus* and *Trachelomonas*.

3.4 Density of euglenophytes

The density of euglenophytes was found to be ranged from 8.36 to 31.88, 8.12 to 38.79 and 2.24 to 3.67 x 10^4 cells/l in BP-R, BP-Y and NBP, respectively. Significantly higher mean density of these algae was recorded in BP-R and BP-Y as compared to NBP (Table 3). The average percent contributions were 68.03, 69.79 and 17.69% in BP-R, BP-Y and NBP, respectively. In BP-R and BP-Y, these algae occupied the most dominant group in respect of density. Their density was relatively low in July-August but started to increase in September and formed its peak density in November and December with the maximum density (38.79 x 10^4 cells/l) in BP-Y. The density was started to decrease from January and it was quietly low in February, March and June, although a light increase was observed in May (Fig. 1)). But in NBP, the density of these algae showed no significant variation in monthly observations and it was quietly low throughout the study period as compared to BP-R and BP-Y (Fig. 1).

Among three genera of euglenophytes, *Euglena* (*E. sanguinea*) was the most dominant and *Trachelomonas* was the least dominant based on their density. Significantly higher mean density of these three genera was recorded in BP-R and BP-Y as compared to NBP (Table 3). In the total euglenophytes, average percent contribution of *Euglena* was 83.21, 83.50 and 95.52%; *Phacus* was 13.53, 13.37 and 3.07%; and *Trachelomonas* was 3.27, 3.13 and 1.41% in BP-R, BP-Y and NBP, respectively.

3.5 Density of cyanophytes, chlorophytes and bacillariophytes

Cyanophytes was the second abundant group of algae in BP-R and BP-Y but in NBP, it was the most abundant group. Bacillariophytes was the least abundant group of algae. Significantly higher mean density of cyanophytes, chlorophytes and bacillariophytes was recorded in NBP as compared to BP-R and BP-Y (Table 3).

3.6 Correlations between euglenophytes density and environmental factors

In correlation analysis, it was observed that euglenophytes density in the blooms ponds (BP-R and BP-Y) was negatively correlated with water temperature (r = -0.407 and -0.432; P<0.05), DO (r = -0.807 and -0.806; P<0.05) and pH (r = -0.905 and -0.868; P<0.05) whereas the density of these algae was positively correlated with NO_3-N (r = 0.949 and 0.914; P<0.05), NH_4-N (r = 0.793 and 0.815; P<0.05) and PO_4-P (r = 0.793 and 815; P<0.05). The density of these algae was also positively correlated with Fe (r = 0.886 and 0.868; P<0.05), Zn (r = 0.902 and 0.895; P<0.05), Mn (r = 0.809 and 0.813; P<0.05) and Cu (r = 0.782 and 0.824; P<0.05). From the results, it was observed that euglenophytes density was increased with decreasing water temperature, DO and pH, and with increasing nutrients and heavy metal concentrations whereas the density showed a declining trend with increasing temperature, DO, pH, and with decreasing nutrients and heavy metals concentrations.

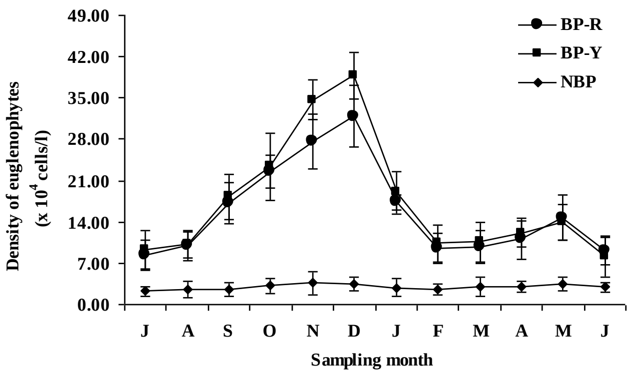

Figure 1: Monthly variations in density of euglenophytes in BP-R, BP-Y and NBP

Table 3: Mean density (± SD) of planktonic algae in the study ponds

Group/genera of algae (x 10^4 cells/l)	Study ponds		
	BP-R	BP-Y	NBP
Euglenophytes	15.76±8.11[a]	17.39±10.30[a]	2.95±1.12[b]
Euglena	13.11±6.93[a]	14.52±9.07[a]	2.82±0.48[b]
Phacus	2.13±0.98[a]	2.32±1.16[a]	0.09±0.04[b]
Trachelomonas	0.52±0.17[a]	0.54±0.19[a]	0.04±0.03[b]
Cyanophytes	4.53±2.06[b]	4.52±2.20[b]	9.45±2.25[a]
Chlorophytes	2.65±0.76[b]	2.76±0.85[b]	3.60±0.63[a]
Bacillariophytes	0.23±0.11[b]	0.25±0.10[b]	0.67±0.13[a]

***** BP-R: Bloom ponds at Raighati, Mohanpur; BP-Y: Bloom ponds at Yusufpur, Charghat; and NBP: Non-bloom ponds at Meherchandi, Motihar.

* Values of algal density are mean of triplicate determination. Density values in the same row with different superscripts are significantly different (P<0.05).

IV. Discussion

4.1 Planktonic algal community

Planktonic algal community structure is regulated by environmental factors, growth rate of algal species and specific rate of loss attributed to grazing, sedimentation and dilution [20]. In the present study, a total of 28 genera of planktonic algae were recorded belonging to euglenophytes, cyanophytes, chlorophytes and bacillariophytes. The total numbers of planktonic algal genera recorded in the present study are close to the findings of Wahab *et al*. [21] and Affan *et al*. [22] who recorded 26 and 27 genera of planktonic algae in the fish ponds of Bangladesh. Rahman and Khan [3] recorded 34 genera of algae belonging to euglenophytes, cyanophytes, chlorophytes and bacillariophytes from the fish ponds in Bangladesh which are diverged from the present study.

The result of the present study showed that the number of algal genera in the bloom ponds were low as compared to the non-bloom ponds. This might be due to the variations in the environmental condition as confirmed by the values of environmental factors in the study ponds. This assumption is consistent with the findings of previous report that aquatic environments are subject to high temporal variation with frequent reorganization of algal communities, as a result of interaction among physical, chemical and biological factors [9]. In the present study, euglenophytes algae were occurred with three genera viz., *Euglena*, *Phacus* and *Trachelomonas*. Previous phycological studies have been reported that euglenophytes algae were occurred by three genera, *Euglena*, *Phacus* and *Trachelomonas* among which *Euglena* was the most dominant in the fish ponds of Bangladesh [3], [6], [7], [22]. These reports are fairly well supportive to the present study.

4.2 Variation in euglenophytes density

Euglenophytes algae are cosmopolitan, inhabiting very wide range of water environments [23] and often predominant in eutrophic waters including high organic and inorganic contents [24], [25]. In the present study, euglenophytes was the most abundant group of algae on the basis of density followed by cyanophytes, chlorophytes and bacillariophytes in the bloom ponds. This finding is agreed with the report of Mishra and Saksena [26] who stated that euglenophytes density is higher than other group of algae in eutrophic water bodies. Higher concentration of soil organic matter and inorganic nutrients in the bloom ponds indicated that these ponds were highly eutrophic which might be enhanced the density of euglenophytes. The present results accord with the previous reports that euglenophytes are abundant in locations rich in organic and inorganic matter [27], [28], [29].

Physico-chemical parameters of water may account for algal proliferation resulting in algal bloom and influence algal succession [30]. During the present study, the density of euglenophytes showed an increasing trend from autumn to winter and peaked in late autumn (November) and early winter (December) with *Euglena* as the dominant genus whereas in summer, monsoon and spring season, the density of these algae was dropped. The present results are in conformity with the report of Dewan [31] who stated that plentiful growth of euglenophytes occurred in the fish pond from September to December. Present finding is accord with the report of Affan *et al*. [22] who recorded late autumn (November) dominance of euglenophytes in aquaculture ponds with *Euglena* as the dominant genus. The present findings are also agreed fairly well with the opinion of Park and Chung [32] who stated that euglenophytes density increased in winter. Kim and Boo [2] reported bimodal pattern of euglenophytes density, being maximal in the winter and in the early summer. This report is partially supportive to the present study.

4.3 Correlations between euglenophytes density and environmental factors

The results of the present study showed that the variation in density of euglenophytes in the study ponds were related to some environmental factors viz., water temperature, dissolved oxygen, pH, nutrients and heavy metal concentrations. During the study tenure, bloom of euglenophytes with maximum density was recorded in November and December when water temperature was relatively low whereas the density was relatively low when temperature was relatively high. In correlation analysis, it was observed that euglenophytes density showed negative correlation with water temperature. This result is consistent with the previous report that some euglenoids showed positive relation to low temperature those are abundant in winter [2]. The present result is also agreed with the report of Park and Chung [32] who stated that the euglenophytes proliferate its' peak at low temperature. Rahman *et al*. [6] observed thick bloom of euglenophytes in experimental fish ponds at relatively higher water temperature. This finding is contrasting to the present study which might be due to the variation in responses of algal species to temperature changes or variation in geographical position or variation in other specific environmental factors.

The density of euglenophytes showed negative correlation with DO concentration and the maximum density was recorded at lower DO concentration. This result is consistent with the previous reports that euglenophytes proliferate in the environment poor in DO concentration [6], [11]. The oxygen deficits condition can be helpful to trigger the oxygen-iron-phosphate complex, releasing larger quantities of phosphorus and iron which might be enhaned the proliferaion of euglenophytes [24].

During the present study, it was observed that euglenophytes density negatively correlated to pH values and the density increased at acidic pH (less than 6.5) and showed a declining trend with increasing pH values. This finding is supported by the earlier report that algal abundance increased when the pH of water lowered from 6.6 to 5.0 [33]. The result showed that pH value <6.5 was conducive for increasing density of euglenophytes. Zakrys and Walne [12] stated that *Euglena gracilis* grow well at acidic pH. *Euglena mutabilis* and *Euglena gracilis* are acid tolerant, growing optimally at pH 2.5 to 7.0 [34]. The findings aforementioned are consistent to the present result. Nonetheless, it is obvious that euglenophytes can grow quietly less in number at alkaline pH (>7.5) but pH value less than 6.5 is suitable for their bloom formation.

According to the present study, the nutrients viz., nitrate, ammonium and phosphate concentrations were significantly abundant in the bloom ponds as compared to the non-bloom ponds. In correlation analysis, it was observed that euglenophytes density positively correlated to nitrate, ammonium and phosphate concentrations. The present results indicated that euglenophytes favoured to a combination of higher concentrations of nitrate, ammonium and phosphate nutrients. The present findings are conformity with the previous studies which reported that euglenophytes become abundant in higher concentrations of nitrate-nitrogen [6], [35], [36], ammonium-nitrogen [2], [36] and phosphate-phosphorus [3], [13], [37].

In correlation analysis, it was also observed that euglenophytes density was positively correlated to heavy metal concentrations (Fe, Zn, Mn and Cu) and the density showed its peak at higher concentrations of these heavy metals. The present finding is agreement with the report of Duttagupta *et al*. [36] who stated that euglenophytes bloom found to be induced by higher concentrations of Fe, Mg, Cu and Zn, and whereby their concentrations declined leading to a collapse of the bloom. The present result is also consistent to the report of Hutchinson and Nakatsu [38] who stated that *Euglena* density increased at higher concentrations of Fe, Zn, Mn, Al and Cu.

In relation to the role of the nutrients and heavy metals on euglenophytes density, it seems to be clear that the major nutrients (nitrate, ammonium and phosphate) and heavy metals (Fe, Zn, Mn and Cu) constitute the important regulatory factors for their bloom formation, since the concentrations of these nutrients and heavy metals were quietly low in the ponds where the bloom did not occur.

V. Conclusion

The overall study revealed that euglenophytes density in the fish ponds showed a seasonal variation with the higher density in autumn to winter and the lower density in summer, monsoon and spring season. Temperature, DO, pH, nutrients (nitrate, ammonium and phosphate) and heavy metals (Fe, Zn, Mn and Cu) contributed to the variation in density of these algae. Higher concentrations of nutrients and heavy metals under lower water temperature, DO and pH (acidic) enhance their density attributed by the active growth of *Euglena* (*E. sanguinea*). Further study at the sampling frequency of several days in a month for several years would allow more accurate correlation of changes in the density of euglenophytes and environmental factors.

Acknowledgement

Authors are thankful to the Department of Fisheries, University of Rajshahi, Bangladesh and to the Soil Resource Development Institute (SRDI), Rajshahi, Bangladesh for providing the laboratory facilities.

References

[1] Padmavathi, P. and M.K.D Prasad, Studies on algal bloom disasters in carp culture ponds. *Braz. J. Morphol. Sci. 24 (2).* 2007, 32-43

[2] Kim, J.T. and S.M. Boo, Relationship of green euglenoid to environmental variables in Jeonjucheon, Korea. *Korean J. Limnol. 34(2).* 2001, 81-89.

[3] Rahman, M.M. and S. Khan, Noxious euglenophytes bloom in fertilized fish ponds. *Bangladesh J. Fish. Res. 11(1).* 2007, 7-18.

[4] Boyd, C.E. and C.S. Tucker, *Pond aquaculture water quality management*. Kluwer Academic Publishers, London, 1998.

[5] Hallegraeff, G.M, A review of harmful algal blooms and their apparent global increase. *Phycologia 32(2).* 1993, 79-99.

[6] Rahman, M.M., M.A.S. Jewel, S. Khan and M.M. Haque, Study of euglenophytes bloom and its impact on fish growth in Bangladesh. *Algae 22(3).* 2007, 185-192.

[7] Rahman, M.M., K.A. Habib and M.I.A. Bhuiyan, Fish mortality associated with euglenophytes bloom in a polyculture pond at Bangladesh Agricultural University campus. *Bangladesh J. Prog. Sci. Tech. 3(2).* 2005, 205-208.

[8] Hosmani, S.P., Seasonal changes in phytoplankton communities in a freshwater pond at Dharwar, Karnatak State, India. *Phykos. 27(1-2).* 1988, 82-87.

[9] Reynolds, C.S., M. Dokulil and J. Padisak, Understanding the assembly of phytoplankton in relation to the trophic spectrum: where are we now. *In*: Reynolds, C.S., M. Dokulil and J. Padisak (Eds.), The trophic spectrum revised: The influence of trophic state on the assembly of phytoplankton communities. *Development in hydrobiolog*y, Academic Publishers, London, 2000, 147-152.

[10] Boyd, C.E., *Bottom soils, sediment and pond aquaculture*. Chapman and Hall, New York, 1995.

[11] Xavier, M.B, C.S.R. Mainardes-Pinto and M. Takino, *Euglena sanguinea*, bloom in a fish-breeding tank (Pindamonhangaba, Sao Paulo, Brazil). *Algological Studies 62.* 1991, 133-142.

[12] Zakrys, B. and P.L. Walne, Floristic, taxonomic and phytogeographic studies of green Euglenophyta from the Southeastern United States, with emphasis on new and rare species. *Arch. Hydrobiol. Suppl. 102.* 1994, 71-114.

[13] Kim, J.T. and S.M. Boo, Morphological variation and density of the *Euglena viridis* cells related to environmental factors in the urban drainage. *Korean J. Limnol. 34(3).* 2001, 185-191.

[14] Olaveson, M.M. and P.M. Stokes, Responses of the acidophilic alga *Euglena mutabilis* (Euglenophyceae) to carbon enrichment at pH 3. *J. Phycol. 25(3).*1989, 529-539.

[15] Jahan, R., S. Khan, M.M. Haque and J.K. Choi, Study of harmful algal blooms in a eutrophic pond, Bangladesh. *Environ Monit. Assess. 170.* 2010, 7-21.

[16] Piper, C.S. 1949. *Soil and plant analysis* (Protocol and analytical methodology), Infestation control pesticides discipline, Adelaide Univ. Press, Australia, 1949, 78-92.

[17] American Public Health Association (APHA), *Standard methods for the examinations of water and waste water.* Eighteenth Street, New York, Washington, DC, USA, 1992.

[18] Bellinger, E.G., *A key to common algae*: *Freshwater, estuarine and some coastal species*. The Institute of Water and Environment Management, London, UK, 1992.

[19] Stirling, H.P. *Chemical and biological methods of water analysis for aquaculture*. Univ. Stirling Publ. Stirling, UK, 1985.

[20] Fogg, G.E., *Algal culture and phytoplankton ecology* (2nd Edn.). The University of Wisconsin Press, Wisconsin, 1975.

[21] Wahab, M.A., Z.F. Ahmed, A. Islam and S. M. Rahmatullah, Effect of introduction of common carp, *Cyprinus carpio* (L) on the pond ecology and growth of fish in polyculture. *Aquaculture Research 26.* 1995, 619-628.

[22] Affan, A., M.A.S. Jewel, M. Haque, S. Khan and J.B. Lee, Seasonal cycle of phytoplankton in aquaculture ponds in Bangladesh. *Algae 20(1).* 2005, 43-52.

[23] Kim, J.T., S.M. Boo and B. Zakrys, Floristic and taxonomic accounts of the genus *Euglena* (Euglenophyceae) from Korean fresh waters. *Algae 13(2).* 1998, 173-197.

[24] Munawar, M., Ecological studies of Eugleninae in certain polluted and unpolluted environments. *Hydrobiologia 39(3).* 1972, 307-320.

[25] Kim, J.T. and S.M. Boo, Seasonal changes of the Euglenoid species and biomass in the Kumgang river. *Algae 11(4).* 1996, 375-379.

[26] Mishra, S.R. and D.N. Saksena, Phytoplanktonic composition of sewage polluted Morar (Kalpi) River in Gwalior, Madhya Prades. *Environ. Ecol. 11(3*). 1993, 625-629.

[27] Phang, S.M. and K.C. Ong, Algal biomass production in digested palm oil mill effluent. *Biological Wastes 25(3).* 1988, 177-191.

[28] Nwankwo, D.I., Euglenoids of some polluted storm-water channels in Lagos, Nigeria. *Tropical Freshwater Biology 4.* 1995, 29-39.

[29] Wild, A., J. Lee-Kaden, H. Gimmler and W. Simonis, Phycological and hydro-chemical investigations of two polytrophic ponds near to an urban development. *Limnologia 25(3-4).* 1995, 229-236.

[30] Wirasith, C. and S. Traichaiyaporn, Water quality variation and algal succession in commercial hybrid catfish production ponds. *Maejo Int. J. Sci. Technol. 6(1).* 2012, 105-118.

[31] Dewan, S., *Investigations into the ecology of fishes of a lake*. Ph.D. thesis, Bangladesh Agricultural University, Mymensingh, Bangladesh, 1973.

[32] Park, J.W. and J. Chung, The population variations of Euglenophyceae in the Kumho River. *Korean J. Limnol. 29(2).* 1996, 133-142.

[33] Leavitt, P.R., D.L. Findlay, R.I. Hall and J.P. Smol, Algal responses to dissolved organic carbon loss and pH decline during whole-lake acidification: Evidence from paleolimnology. *Limnol. Ocean. 44(3).* 1999, 757-773.

[34] Olaveson, M.M. and C. Nalewajko, Effects of acidity on the growth of two *Euglena* species. *Hydrobiologia 433(1-3).* 2000, 39-56.

[35] Kim, J.T. and S.M. Boo, Morphology, population size and environmental factors of two morphotypes in *Euglena geniculata* (Euglenophyceae) in Korea. *Arch. Hydrobiol. Suppl. 126*. 1998b, 27-36.

[36] Duttagupta, S., S. Gupta and A. Gupta, Euglenoid blooms in the floodplain wetlands of Barak Valley, Assam, North eastern India. *J. Environ. Biol. 25(3).* 2004, 369-73.

[37] Barone, R. and L.N. Flores, Phytoplankton dynamics in a shallow, hypertrophic reservoir (Lake Arancio, Sicily). *Hydrobiologia 289(1-3).* 1994, 199-214.

[38] Hutchinson, T.C. and C.H. Nakatsu, Mutualism of *Euglena mutabilis* and *Cryptococcus* spp: Increase of growth in high metal concentrations and acid pH's. *Abstract of Paper Scheduled for the Annual Meeting of the Phycological Society of America*. Colorado State University, Fort Collins, 1984, 15.

Annexure 1: Monthly variation in environmental factors in the study ponds

Factors/ Study ponds		Sampling month (2010 -2011)											
		Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Temp. (ºC)	**BP-R**	32.16 (0.10)	31.46 (0.04)	30.01 (0.04)	28.43 (0.15)	24.46 (0.44)	21.66 (0.18)	17.21 (0.12)	22.59 (0.36)	24.14 (0.06)	25.45 (0.09)	26.37 (0.03)	31.50 (0.08)
	BP-Y	32.09 (0.03)	31.58 (0.23)	30.13 (0.26)	28.38 (0.09)	24.59 (0.12)	21.67 (0.09)	17.30 (0.09	23.12 (0.05)	24.22 (0.06)	25.44 (0.04)	26.43 (0.03)	31.51 (0.02)
	NBP	32.29 (0.25)	31.68 (0.14)	30.45 (0.30)	28.26 (0.14)	24.53 (0.19)	21.22 (0.33)	17.27 (0.21)	23.40 (0.10)	24.34 (0.13)	25.27 (0.14)	26.36 (0.21)	31.65 (0.08)
DO	**BP-R**	5.16 (0.15)	5.04 (0.25)	4.75 (0.23)	4.27 (0.14)	4.07 (0.28)	4.65 (0.19)	4.92 (0.29)	5.20 (0.14)	5.23 (0.17)	5.52 (0.25)	5.17 (0.15)	5.50 (0.210
	BP-Y	5.22 (0.07)	5.10 (0.17)	4.76 (0.19)	4.46 (0.18)	4.06 (0.14)	4.73 (0.37)	4.84 (0.18)	5.35 (0.17)	5.42 (0.11)	5.50 (0.16)	5.24 (0.17)	5.19 (0.10)
	NBP	5.66 (0.18)	5.59 (0.24)	5.68 (0.31)	5.64 (0.25)	5.73 (0.29)	5.64 (0.26)	5.52 (0.25)	5.64 (0.22)	5.97 (0.11)	5.98 (0.13)	5.78 (0.15)	5.83 (0.17)
pH	**BP-R**	6.47 (0.16)	6.22 (0.14)	6.18 (0.25)	6.12 (0.18)	6.01 (0.20)	5.94 (0.23)	6.31 (0.30)	6.60 (0.24	6.50 (0.34)	6.35 (0.18)	6.36 (0.24)	6.60 (0.27)
	BP-Y	6.49 (0.18)	6.34 (0.19)	5.99 (0.26)	6.09 (0.23)	5.99 (0.27)	6.06 (0.24)	6.48 (0.30)	6.41 (0.29)	6.62 (0.26)	6.43 (0.21)	6.56 (0.18)	6.65 (0.13)
	NBP	7.92 (0.37)	7.93 (0.31)	8.03 (0.51)	7.81 (0.38)	7.94 (0.31)	7.92 (0.31)	7.67 (0.23)	7.84 (0.43)	7.70 (0.34)	7.78 (0.24)	7.80 (0.13)	7.79 (0.27)
NO_3-N (mg/l)	**BP-R**	0.96 (0.06)	1.03 (0.13)	1.32 (0.15)	1.45 (0.10)	1.68 (0.14)	1.76 (0.08)	1.17 (0.09)	1.13 (0.16)	1.02 (0.12)	0.98 (0.10)	1.03 (0.08)	1.04 (0.16)
	BP-Y	1.02 (0.05)	1.11 (0.10)	1.35 (0.06)	1.46 (0.12)	1.81 (0.13)	1.69 (0.11)	1.25 (0.14)	1.15 (0.09)	1.00 (0.11)	0.95 (0.08)	1.14 (0.10)	0.99 (0.07)
	NBP	0.29 (0.10)	0.43 (0.11)	0.47 (0.07)	0.54 (0.15)	0.49 (0.14)	0.54 (0.14)	0.48 (0.11)	0.49 (0.09)	0.52 (0.08)	0.47 (0.08)	0.53 (0.08)	0.44 (0.09)
NH_4-N (mg/l)	**BP-R**	0.68 (0.14)	0.78 (0.14)	1.12 (0.05)	1.39 (0.06)	1.43 (0.06)	1.40 (0.16)	1.11 (0.12)	1.00 (0.04)	0.97 (0.14)	0.90 (0.11)	0.87 (0.06)	0.92 (0.10)
	BP-Y	0.70 (0.18)	0.83 (0.08)	1.14 (0.13)	1.41 (0.10)	1.49 (0.16)	1.43 (0.14)	1.19 (0.06)	1.01 (0.12)	0.91 (0.06)	0.87 (0.13)	1.04 (0.07)	0.89 (0.13)
	NBP	0.21 (0.08)	0.24 (0.07)	0.28 (0.08)	0.25 (0.06)	0.25 (0.12)	0.21 (0.10)	0.24 (0.08)	0.22 (0.09)	0.24 (0.10)	0.25 (0.05)	0.19 (0.08)	0.23 (0.08)
PO_4-P (mg/l)	**BP-R**	0.96 (0.07)	0.88 (0.16)	1.21 (0.10)	1.44 (0.11)	1.67 (0.13)	1.86 (0.15)	1.30 (0.23)	0.91 (0.19)	0.89 (0.11)	0.81 (0.10)	1.11 (0.16)	1.02 (0.15)
	BP-Y	1.02 (0.11)	1.03 (0.20)	1.21 (0.09)	1.42 (0.13)	1.75 (0.18)	1.80 (0.10)	1.13 (0.17)	1.04 (0.23)	0.96 (0.09)	0.93 (0.09)	1.02 (0.12)	0.95 (0.08)
	NBP	0.27 (0.08)	0.32 (0.07)	0.42 (0.07)	0.38 (0.09)	0.47 (0.12)	0.47 (0.09)	0.48 (0.09	0.45 (0.10)	0.44 (0.09)	0.46 (0.14)	0.41 (0.09)	0.39 (0.10)
Fe (mg/l)	**BP-R**	0.36 (0.04)	0.46 (0.06)	0.49 (0.06)	0.67 (0.04)	0.78 (0.09)	0.69 (0.06)	0.45 (0.07)	0.46 (0.07)	0.36 (0.05)	0.35 (0.07)	0.52 (0.06)	0.40 (0.03)
	BP-Y	0.39 (0.08)	0.49 (0.05)	0.44 (0.04)	0.61 (0.11)	0.74 (0.13)	0.75 (0.07)	0.56 (0.07)	0.49 (0.03)	0.48 (0.08)	0.43 (0.06)	0.55 (0.05)	0.46 (0.09)
	NBP	0.11 (0.03)	0.12 (0.03)	0.16 (0.04)	0.24 (0.05)	0.20 (0.05)	0.2 (0.07)	0.19 (0.06)	0.22 (0.06)	0.18 (0.06)	0.19 (0.03)	0.19 (0.04)	0.14 (0.04)
Zn (mg/l)	**BP-R**	0.18 (0.06)	0.19 (0.05)	0.23 (0.06)	0.34 (0.04)	0.38 (0.05)	0.36 (0.04)	0.32 (0.04)	0.24 (0.06)	0.20 (0.06)	0.22 (0.04)	0.19 (0.05)	0.17 (0.05)
	BP-Y	0.19 (0.07)	0.22 (0.06)	0.27 (0.06)	0.33 (0.08)	0.42 (0.07)	0.40 (0.06)	0.36 (0.06)	0.29 (0.05)	0.24 (0.03)	0.19 (0.04)	0.23 (0.05)	0.18 (0.07)
	NBP	0.07 (0.03)	0.04 (0.03)	0.07 (0.04)	0.10 (0.04)	0.11 (0.02)	0.11 (0.04)	0.10 (0.02)	0.11 (0.02)	0.11 (0.04)	0.09 (0.03)	0.07 (0.04)	0.06 (0.02)

Mn (mg/l)	**BP-R**	0.16 (0.05)	0.19 (0.08)	0.25 (0.02)	0.34 (0.04)	0.36 (0.04)	0.34 (0.05)	0.31 (0.02)	0.31 (0.04)	0.23 (0.04)	0.22 (0.04)	0.23 (0.01)	0.20 (0.02)
	BP-Y	0.15 (0.02)	0.18 (0.03)	0.23 (0.05)	0.31 (0.04)	0.33 (0.06)	0.31 (0.07)	0.27 (0.07)	0.28 (0.07)	0.22 (0.01)	0.21 (0.02)	0.21 (0.03)	0.19 (0.02)
	NBP	0.06 (0.03)	0.09 (0.04)	0.09 (0.02)	0.11 (0.03)	0.14 (0.04)	0.13 (0.04)	0.11 (0.04)	0.12 (0.03)	0.12 (0.03)	0.11 (0.02)	0.11 (0.03)	0.10 (0.03)
Cu (mg/l)	**BP-R**	0.24 (0.04)	0.26 (0.06)	0.27 (0.07)	0.26 (0.02)	0.31 (0.03)	0.30 (0.03)	0.23 (0.04)	0.25 (0.07)	0.21 (0.05)	0.21 (0.04)	0.22 (0.04)	0.20 (0.04)
	BP-Y	0.26 (0.04)	0.30 (0.04)	0.28 (0.05)	0.33 (0.05)	0.37 (0.05)	0.36 (0.06)	0.25 (0.05)	0.23 (0.02)	0.19 (0.04)	0.18 (0.04)	0.22 (0.02)	0.17 (0.04)
	NBP	0.07 (0.03)	0.09 (0.04)	0.11 (0.03)	0.13 (0.03)	0.11 (0.02)	0.11 (0.04)	0.11 (0.02)	0.12 (0.03)	0.12 (0.03)	0.10 (0.03)	0.10 (0.03)	0.08 (0.02)

Annexure 2: Generic status of planktonic algae in the study ponds

Algal group	Genera under each group
Euglenophytes	*Euglena, Phacus* and *Trachelomonas*
Cyanophytes	*Anabaena, Apanizomenon, Aphanocapsa, Chroococcus, Gomphospheria, Oscillatoria* and *Microcystis*
Chlorophytes	*Botryococcus, Chlorella, Closterium, Pediastrum, Scenedesmus, Spirogyra, Staurastrum, Teraedon, Ulothrix, Volvox* and *Zygnema*
Bacillariophytes	*Asterionella, Cyclotella, Fragilaria, Navicula, Nitzschia, Synedra* and *Tabellaria*

Annexure 3: Monthly variation in euglenophytes density (x 10^4 cells/l) in the study ponds

Study ponds	Sampling month (2010 -2011)											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
BP-R	8.36 (2.50)	9.91 (2.37)	17.25 (3.49)	22.55 (2.78)	27.61 (4.63)	31.88 (5.26)	17.35 (1.25)	9.50 (2.50)	9.78 (2.74)	11.13 (3.39)	14.69 (3.86)	9.08 (2.35)
BP-Y	9.29 (3.23)	10.23 (2.29)	18.24 (3.93)	23.40 (5.74)	34.71 (3.42)	38.79 (4.00)	19.01 (3.57)	10.39 (3.09)	10.58 (3.30)	11.97 (2.27)	13.91 (3.07)	8.12 (3.53)
NBP	2.24 (0.78)	2.53 (1.33)	2.55 (1.13)	3.17 (1.29)	3.67 (1.97)	3.39 (1.18)	2.90 (1.41)	2.50 (0.98)	2.98 (1.63)	3.04 (0.90)	3.47 (1.06)	2.92 (0.83)