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Research Note

Phytoplankton Composition, Community Structure and Regional Climatic Variations in Two Tropical Model Ponds in India

Sunita Kumari, Chirashree Ghosh* and Girija Jayaraman[1]

Centre for Environmental Management of Degraded Ecosystem
School of Environmental Studies, University of Delhi, Delhi-110 007
[1]Centre for Atmospheric Sciences, Indian Institute of Technology, New Delhi-110 016
✉ chirashreeghosh@hotmail.com

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Abstract: Simulated freshwater model ponds have been used as ideal natural laboratories for the comparative assessment of physicochemical and biological parameters. The study was conducted simultaneously at two places, one in Northern India (Delhi) and the other in Eastern India (West Bengal) carrying similar trophic structure and eutrophication dose during non-monsoon season (October 2003 to March 2004). The study emphasizes the local and regional climatic influence on plankton's species composition, diversity and density variation in freshwater pond ecosystem along with dispersal and grazing pressure.

Key words: Phytoplankton, zooplankton, density, diversity, pond 1 (P1) and pond 2 (P2).

Introduction

Phytoplankton and zooplankton are the principal components of the water bodies; the tolerance limit of these organisms to diverse stresses assumes tremendous relevance from the ecological standpoint. For aquatic ecosystem, most of the evidence of trophic cascade is based on experiments concerning three trophic levels: Phytoplankton, Zooplankton and Planktonivorous fish (Carpenter, 1968; Strong, 1992). The interannual variability in phytoplankton dynamics is being controlled by several factors ranging from meteorological, climatic fluctuations (Arhonditisis et al., 2004), to quick recovery of nutrients by the system (Wang et al., 2006). Individually or in combination, all these factors affect the primary productivity of the phytoplankton population.

India has wide variation in climatic factors in different months in different regions. Climate of a region determines its agriculture, aquaculture as well as its ecology. But very few information is available in the freshwater ponds in the Northern region of this country. According to Ramakrishnan et al. (2002), 97.8% of the variations in phytoplankton density of the freshwater pond were influenced by physico-chemical factors. Goswami (1984, 1992) reported in detail about the seasonal variability in the zooplankton standing stock community structure from the fringing mangroves of Goa. Zooplankton biomass tends to be positively correlated with temperature and phytoplankton (chlorophyll-a) biomass.

Comparative study of water chemistry and biology of two model ponds have been conducted to understand the major interferences controlling the production of the freshwater pond system having similar trophic level (with three-level food chain—primary producer, herbivore and predator), nutrient dose, grazing pressure and time period in two different states of India with slightly varying geological setup.

* Corresponding Author

Materials and Methods

System Layout

Similar pattern of experiment was conducted in one of the simulated model pond (P1) located in the field station of the Centre for Atmospheric Sciences, Indian Institute of Technology, Delhi and another model pond (P2) at Village Hatserandi, about 8 km northeast of Sriniketan, West Bengal. Water depths of the pond were varied between 105 and 180 cm. Both the ponds were treated with organic fertilizer (raw cow dung) at the rate of 3000 kg $ha^{-1}month^{-1}$ and time-to-time with inorganic fertilizer with standard combination of the Urea (670 kg $ha^{-1}yr^{-1}$) and super phosphate (750 kg $ha^{-1}yr^{-1}$).

Chemical and Biological Analysis

pH was measured with a field pH meter. Water temperature was recorded regularly by digital thermometer and water transparency by using Secchi Disc method. Dissolved Oxygen (DO) was estimated by Winkler's Method. For nutrient analysis, nitrate nitrogen (NO_3) and phosphate (PO_4) were measured colorimetrically using standard methods (APHA, 1995). Alkalinity was measured titrametically using phenolphthalein and methyl orange as an indicator. Counting and identification of phytoplankton population was done by Haemocytometer method using Lugol's Solution as a preservative. Plankton density was estimated by Lackey's drop method. Zooplankton samples were collected at different levels of the pond. Organisms were identified and counted microscopically. The correlation studies and significance tests were performed using SPSS statistical package.

Results

Meteorological Data

Experiment was conducted for a period of six months from October 2003 to March 2004 (post-monsoon period). Average meteorological variables at two places were collected from the India Meteorological Department (Figure 1).

Trace amount of rainfall was recorded at P1 site (average 0.04 mm), whereas the P2 site receives heavy rainfall in every month (average, 60.85 mm). It received heaviest rainfall (335.1 mm) at the starting of experiment.

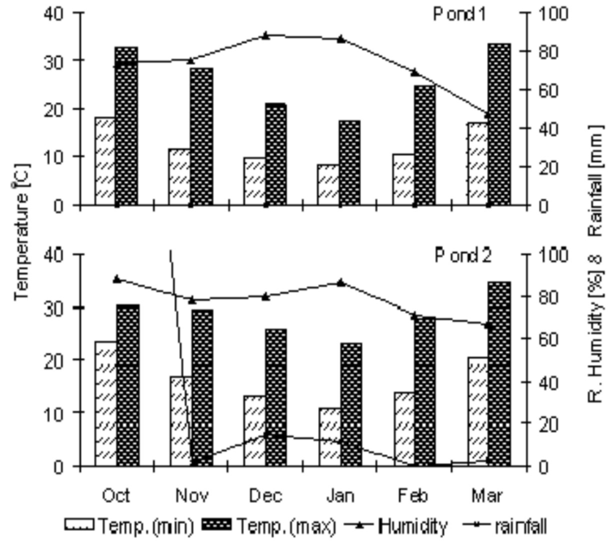

Figure 1: Profile of meteorological variables from October to March in the pond system.

Comparative Assessment of Pond 1 and Pond 2 Dynamics

Nutrient Profile

Nutrient concentration in terms of nitrate and phosphate of P2 pond was much higher (0.41 mg l^{-1} and 0.114 mg l^{-1} respectively) than that of P1 (0.24 mg l^{-1} and 0.03 mg l^{-1} respectively) indicating higher nutrient mineralization process in P2 (Figure 2). Nitrate concentration changes during the period exhibited a major peak (0.525 mg l^{-1}) in October and minor peak (0.264 mg l^{-1}) in February in P2. In P1, nitrate concentration remained essentially constant between November and January followed by gradual increase (0.35 mg l^{-1}) in February. Phosphate concentration also varied at both the places throughout the entire period.

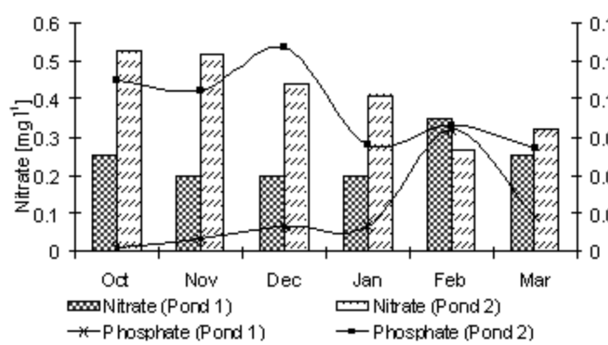

Figure 2: Variation of nutrient concentration.

Temperature and DO Profile

During the experimental period, similar patterns of temperature fluctuations in surface water were observed in both the ponds, with highest peak during October. After that, there was gradual decrease up to January and an upsurge was observed in the profile. The temperature range in surface water varied between 11°C and 29°C in

P1, and 13°C to 31°C in P2 respectively. There was gradual increase in dissolved oxygen in P1 having peak value (13.8 mg l^{-1}) in December; after that it showed declining trend (as shown in Figure 3). The minimum DO value was observed in November (6.9 mg l^{-1}). Comparatively in P2, highest peak was observed in October (8.8 mg l^{-1}).

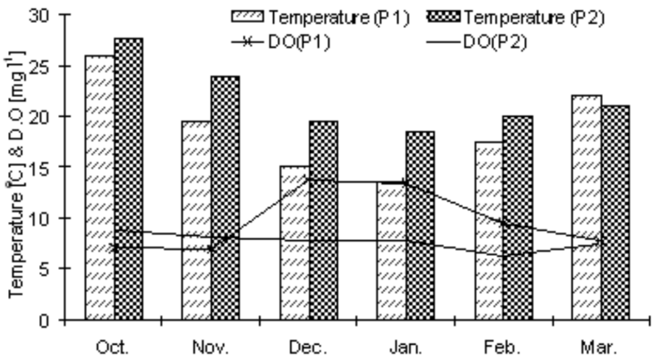

Figure 3: Variation of dissolved oxygen with temperature.

Alkalinity and pH Profile

Almost the same seasonal cycle of pH was exhibited in both the systems with highest peak of 10.2 in P1 (January) and 7.5 in P2 (December). Remarkable differences were observed in alkalinity with highest value in February (370 mg l^{-1}) in P1 and in January (140 mg l^{-1}) in P2 respectively (Figure 4).

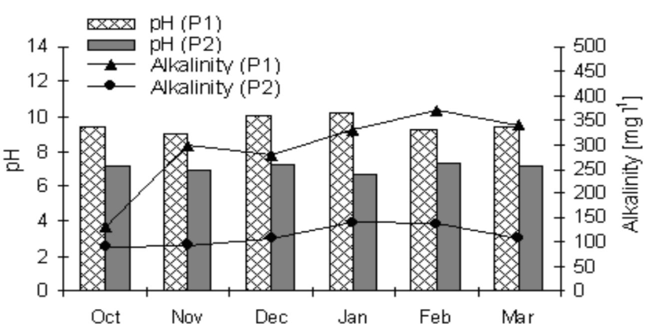

Figure 4: Variation of alkalinity with pH in the pond system.

Comparative Assessment of Plankton Dynamics

Phytoplankton and Community Structure

According to the study of community structure and diversity of the phytoplankton (Figure 5), a total four taxa were distinguished in the P1. Of these taxa, six genera (*Chlorella* sp., *Chlamydomonas* sp., *Chlorococcum* sp., *Coelastrum* sp., *Scenedesmus* sp. and *Cosmarium* sp.) of *Chlorophyceae*, four genera

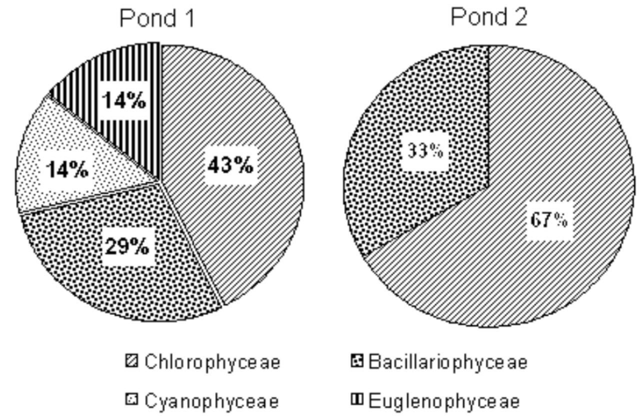

Figure 5: Composition of phytoplankton population.

(*Fragillaria* sp., *Navicula* sp., *Tabellarian* sp. and *Cyclotella* sp.) of *Bacillariophyceae*, two genera (*Euglena* sp. and *Phacus* sp.) of *Euglenophyceae* and two genera (*Merismopedia* sp. and *Coelospherium* sp.) of *Cyanophyceae* were reported. Green algae (*Chlorophyceae*) were more abundant than other taxa (both qualitatively and quantitatively) for entire period except for mid January to February when pinnate diatoms, in terms of cell count, were dominant in P1. Further decline in diatoms were followed by increase in green algae. Blue green algae were found occasionally during the research period.

In the P2, two taxa, *Chlorophyceae* and *Bacillariophyceae* were reported. Among them, four genera (*Volvox* sp., *Pediastrum* sp., *Zygnema* sp. and *Ulothrix* sp.) of *Chlorophyceae* and two genera (*Navicula* sp. and *Cyclotella* sp.) of *Bacillariopjyceae* were observed.

The dominant species like *Chlorophyceae* and *Bacillariophyceae* differ between sites due to different ranges of temperature as well as having light and nutrient limitations (Figure 5). Species diversity within the P1 population was high. May be low N:P ratios favoured *Cyanophytes* (as reported in the P1 as 14%) and higher N:P ratio favoured *Chlorophyceae* (reported in the P2 as 67%).

Monthly change in the total density of phytoplankton in Pond 1 is shown in Figure 6. The minimum density was observed during December and maximum in January. The diversity of phytoplankton was highest in October. Minimum diversity was obtained in the month of January with only one genera of *Chlorococcum* sp. (green algae). In terms of phytoplankton dynamics, it is clearly observed that there is inverse relationship between density and diversity of the population and an oscillatory pattern is also reported in the growth of phytoplankton and zooplankton populations.

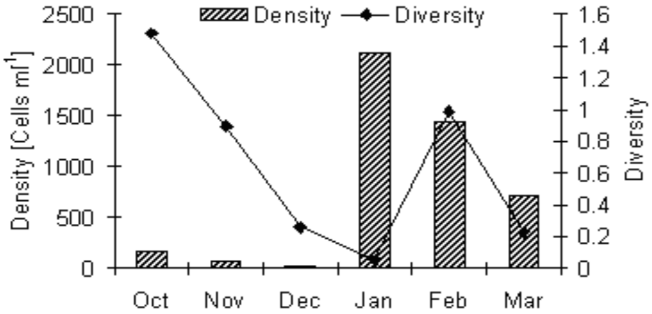

Figure 6: Population dynamics of phytoplankton in the pond 1.

Zooplankton and Fish Species Dynamics

According to Table 1, in P1, the most abundant zooplankton was the filter feeding *Daphnia sp.* (Cladoceran). The filter feeding *Bosmina* sp. (Cladoceran) accounted for a small portion of the biomass throughout the winter season. In P2, zooplankton species diversity was higher because of the effects of higher predator fish composition. It has also been reported that the top predator has a great influence on species abundance, diversity and biomass at lower trophic levels.

Table 1: General composition of zooplankton, zoobenthos and fish species in the pond system

	Zooplankton	*Zoobenthos*	*Fish*
Pond 1	Crustacean (Daphnia, Bosmina)	Tubifex	Labeo rohita, Catla catla, Cirrhina mrigala
Pond 2	Crustacean (Daphnia, Bosmina, Moina, Cyclops, Diaptomus, Eubranchipus) Rotifer (Keratella, Asplancha, Filina, Brachionus)	Chironomid larvae, Tubifex, Gastropods	Labeo rohita, Catla catla, Cirrhina mrigala, Cyprinus carpio

Statistical Analysis

According to the correlation studies (Table 2a), in the P1, dissolved oxygen (DO) was highly affected by the meteorological factors. Although, a highly significant positive correlation ($r = 0.858$) existed between DO and rainfall but correlations between DO and other physicochemical parameters were not statistically

Table 2: Correlation coefficient values (r) between physicochemical and meteorological variables in two ponds

(a) Pond 1

	D.O	*Al*	*pH*	*T*	*N*	*P*	*A. T*	*H*	*R*
W. T	–0.857*	–0.711	–0.637	–0.393	0.219	–0.272	0.972**	–0.601	–0.640
D.O		0.340	0.920**	0.232	–0.293	0.079	–0.858*	0.683	0.858*
Al			0.061	0.401	0.242	0.642	–0.606	–0.065	0.066
pH				0.110	–0.441	–0.200	–0.649	0.586	0.797
T					0.419	0.543	–0.535	0.283	–0.247
N						0.870*	0.184	–0.435	–0.468
P							–0.270	–0.187	–0.169
A. T								–0.724	–0.602
H									0.662

(b) Pond 2

	D.O	*pH*	*N*	*P*	*Al*	*T*	*A. T*	*H*	*R*
W.T	0.541	0.024	0.521	0.091	–0.626	0.579	0.542	.285	0.762
D.O		–0.384	0.937**	0.512	–0.679	0.825*	0.047	.833	0.659
pH			–0.336	0.383	–0.219	0.145	0.160	–.541	0.083
N				0.622	–0.708	0.874*	–0.086	.753	0.458
P					–0.598	0.838*	–0.356	.381	0.241
Al						–0.827*	–0.473	.254	–0.527
T							–0.014	.588	0.617
A.T								–.383	0.399
H									0.531

where W.T = Water temperature, N = nitrate, P = phosphate, AT = air temperature, T = transparency, Al = alkalinity, H = humidity.

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

significant. A negative correlation ($r = -0.858$) was found between DO and temperature. It is already known that increasing temperature increases the diffusion rates of solutes and reduces the solubility of oxygen.

In P2 (Table 2b), DO was positively correlated with humidity ($r = 0.833$) and rainfall ($r = 0.659$), whereas no correlation existed between DO and air temperature. There was high significant positive relation ($r = 0.937$) between DO and nitrate whereas with alkalinity it was negatively correlated. A positive correlation was also established between nitrate and phosphate in both the ponds.

Discussion

The climate regime of North Indian pond falls under the "Semi arid type" and is influenced by the city's inland position and the prevalence of continental air during the major part of the year. It is characterized by extreme dryness with hot summer and cold winter, whereas the climatic zone of Eastern Indian pond falls under "Gangetic plain" which is dominated by frequent rainfall. Consequently, humidity was comparatively higher at this site.

The low values of nutrient in P1 resulted from phytoplankton growth, whereas the higher nutrient trend observed in the P2 was as a consequence of stirring of the pond bottom soil by the bottom dweller fish and drifting of dead algal scum from the surface layer after frequent rainfall. We have noticed that the tolerance levels of phytoplankton determine the dominance of species at different times and seasons. This result is consistent with the report of Wetzel (2001), that in a multi species algal community, the growth among different species is likely to be limited by the resources including different nutrients. The composition biomass of the community varies with location and grazing pressure, which can be supported by the findings of Sommer (1996).

Ponds with lower alkalinities do not usually support high phytoplankton blooms, and do not commonly experience strong pH increase because of intense photosynthesis. A total alkalinity of 20 mg l^{-1} or more is necessary for good pond productivity. A desirable range of total alkalinity for fish culture is between 75 mg l^{-1} and 200 mg l^{-1} as $CaCO_3$ and pH between 6.5 and 9.0. Water of pond P2, with moderate alkalinity and good buffering capacity, does not fluctuate widely which is ideal for fish culture whereas in the P1, the release of carbonate converted from bicarbonate can cause pH to climb above 9.0 (10.2) due to rapid photosynthesis by dense phytoplankton (algal) blooms.

According to Elser et al. (1998), in general higher density and diversity of phytoplankton population were obtained after addition of both nitrogen and phosphorous together, than either nutrient singly. Highest phytoplankton population density was observed in the winter month of January in P1. The widely held assumption that winter productivity is insignificant is not universally valid. We have already reported (Ghosh et al., 2002), GPP (Gross Primary Productivity) values were higher in winter season compared with summer production ranges. As per the explanation of Reid and Wood (1986), cold inhibits respiration and provides the optimum condition for photosynthesis. This observation is of considerable importance in applied aquatic ecology. Higher species diversity of phytoplankton population was reported in the P1. Although ponds with higher diversity generally indicate good quality of water but a low diversity doesn't necessarily indicate poor quality of water. It can be substantiated by the findings of Hawkes (1979), that low diversity index of an aquatic body is not actually due to pollution (as our experiment conducted in the model ponds) but most probably due to the physical conditions prevailing at that experimental site.

According to Carpenter & Kitchell (1993) and Carson & Root (2000), within relatively small homogenous areas predators often reduce the abundance of their prey. Recently Shurin (2001) reported that fish facilitated invasion by more zooplankton species and also enhanced phytoplankton density. This observation suggests that spatial heterogeneity in predator abundance promotes regional coexistence among zooplankton. So, it is very important to determine the impact of local interactions of the aquatic body such as predation on community.

This study suggests that local and regional processes interact to produce patterns of species composition and diversity in freshwater pond ecosystem. Predation and dispersal had interactive effects on the composition of local zooplankton community system (Table 1). In P2, the number of zooplankton species was more higher in the presence of predator fish species (common carp), than in the P1 system. This observation can be supported by the report of Shurin (2001).

Based on the simple trophic cascade model or biomanipulation theory (Perrow et al., 1997), community of an aquatic ecosystem i.e. fish and plankton biomass ratio can be maintained in the optimum range. Increase in the fish production can be obtained by increasing zooplankton productivity, either by manipulating nutrient levels or facilitating decrease of phytoplankton biomass; so in practical terms it will most frequently involve restructuring biological communities. But it is also very important to determine the impact of regional meteorological interactions of the aquatic body such as temperature and rainfall. In future, more regional response of climatic heterogeneity studies are needed to understand the effect more clearly for the better management of freshwater resources in this subcontinent.

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