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Original Research Paper

Study of Factors Affecting Phytoplankton Primary Productivity in a Pond of Patna, Bihar, India

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ABSTRACT

The rate of carbon fixation at the primary level currently provides the best assessment of the result of physical, chemical and biological interactions determining the actual fertility of any environment. Phytoplankton primary productivity and its regulating factors were studied in a pond in Patna, Bihar, India month-wise periodically from April 2011 to March 2013. Primary productivity was determined by light and dark bottle method. Physicochemical factors, i.e. water temperature, light penetration depth, pH, DO, alkalinity, hardness, TSS, TDS, nitrate, phosphate and phytoplankton density were determined following standard methods. Phytoplankton primary productivity (gross primary productivity) was estimated as 5.496 gC/m^2/day to 9.964 gC/m^2/day with mean value of 7.73 gC/m^2/day. It indicates eutrophic nature of the pond. Higher values of primary productivity were found in the post monsoon season and monsoon season. Mean value of primary productivity was lower in summer and winter season. Phosphate, TSS and phytoplankton density were found to be highly correlated positively with phytoplankton primary productivity while light penetration depth, alkalinity and hardness were highly correlated negatively. Phytoplankton primary productivity was found to be moderately correlated with temperature.

INTRODUCTION

The primary productivity is the first fundamental step of ecosystem function and it makes the chemical energy and organic matter available to consuming organisms. The importance of the study of primary productivity and its regulating factors is of practical value in the fish culture program (Sivakumar & Karuppasamy 2008). The rate of carbon fixation at the primary level currently provides the best assessment of the result of physical, chemical and biological interactions determining the actual fertility of any environment (Goldman & Wetzel 1963). The primary productivity of an ecological system, community or any part thereof, is defined as the rate at which radiant energy is stored by photosynthetic and chemosynthetic activities of the producer organisms (chiefly green plants) in the form of organic substances which can be used as food materials. Primary production refers to the quantity of new organic matter produced by photosynthesis. Photosynthetic fixation of carbon in the inland aquatic system occurs in various plant communities such as phytoplankton, periphytic algae, benthic algae and macrophytes. Production by the phytoplankton, the primary synthesis, is the most important phenomenon and reflects the nature and the degree of productivity in the aquatic ecosystem. Primary productivity is further distinguished as gross primary productivity (GPP) and net primary productivity (NPP). GPP is the total rate of photosynthesis, including the organic matter used up in respiration during the measurement period. NPP is the rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants during the measurement period. This is thus the rate of increase of biomass and is also known as apparent photosynthesis or net assimilation. Recently, increased importance has been given to the phytoplankton productivity in relation to physical and chemical parameters of aquatic systems. It has been measured by several workers in various aquatic ecosystems of the world.

MATERIALS AND METHODS

The pond under study is situated in Patna, the capital city of Bihar state of India. Patna is located at the south bank of river Ganga. The pond studied is located in the Saidpur Campus of Patna University (approximate latitude 25° 36.50' N, longitude 85° 9.89' E and altitude about 55 m above sea level). Area of the pond is about 2.1 acres and average depth is 1.5 meters. This pond is surrounded by human habitations. The pond was found affected by various anthropogenic activities mainly by domestic and municipal sewage, domestic waste disposal, bathing of domestic animals, washing of clothes, etc. Few cow sheds and vacant land are also present in the vicinity of pond. From these places, the monsoon run off also mixes with the pond water. This pond is also used in

aquaculture i.e., fish culture and *Trapa* culture. A preview of available literatures has revealed that no other scientific study has been carried out with respect to ecological characteristics of this pond. With this background, it was proposed for the study.

Sampling and analysis were carried out periodically on a monthly basis for 24 months from April 2011 to March 2013 from a fixed station in an undisturbed area of the pond. Sampling and analysis of physicochemical parameters of water was done following the standard methods (CPCB 2011, APHA 2005, Trivedy & Goel 1986). Primary production was measured using the light-dark bottle technique with 3 hours incubation during midday (10:00 a.m.-1:00 p.m.). Calculations of gross and net photosynthetic rates and respiration rates were done based on the change in oxygen concentration between initial (IB), light (LB) and dark (dB). The carbon values were obtained from the O_2 values by multiplying with 0.375 (Sreenivasan 1964). The gross and net productions were calculated with the following equations outlined in Britton & Greeson (1987):

G.P.P.(O_2mg/L/hr) = (L.B – D.B)/T × 0.375 = gC/m^2/ hr

N.P.P.(O_2mg/L/hr) = (L.B – I.B)/T × 0.375= gC /m^2/ hr

Respiration rate (O2mg/L/hr) = (I.B – D.B)/T × 0.375 = gC/ m^2/hr

Where, L.B. = DO of light bottle sample, D.B. = DO of dark bottle sample and I.B. = DO of the initial bottle sample.

Daily rate (gC/m^2/day) can be obtained by multiplying the maximum hourly rate obtained during the day (Trivedy & Goel 1986). In the present study, respiration rate refers to only those organisms, which are suspended in water together with phytoplankton. 50 L of surface water was filtered for sampling of phytoplankton through the standard plankton net (mesh 25, diameter of the pore 60µ). Quantitative analysis of phytoplankton was done by using Sedgwick-Rafter cell.

Water samples were named as follows:

Sample of month April, 2011 as A1; sample of May, 2011 as M2; similarly June, 2011as J3; July, 2011 as J4; August,2011 as A5; September 2011 as S6; October 2011 as O7; November 2011 as N8; December 2011as D9, January 2012 as J10; February 2012 as F11; March 2012 as M12; April 2012 as A13; May 2012 as M14; June 2012 as J15; July 2012 as J16; August 2012 as A17; September 2012 as S18; October 2012 as O19; November 2012 as N20; December 2012 as D21, January 2013 as J22; February 2013 as F23 and March 2013 as M24.

RESULTS AND DISCUSSION

Monthly variation of primary productivity with some physicochemical factors is shown in Fig.1 and 2. Fig.3 shows monthly variation of phytoplankton density. Summary statistics of phytoplankton density is given in Table 1. Summary statistics of phytoplankton primary productivity of the pond under study is depicted in Table 2. Monthly variation of primary productivity is given in Table 3. Summary statis-

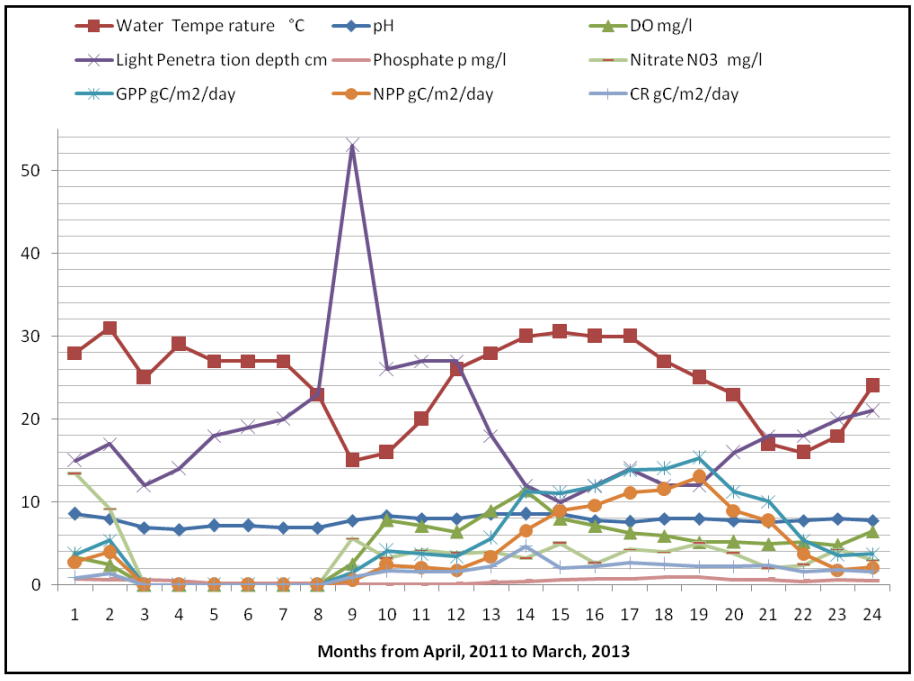

Fig. 1: Monthly variation in primary productivity with some physicochemical factors.

Table 1: Summary of descriptive statistics of phytoplankton density of pond.

	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation	Skewness	95% Confidence Interval of the Difference	
								Lower	Upper
Density unit/L	24	640	3280	1435.489	11.995	28.774	2.553	1222	1683

Table 2: Summary statistics of phytoplankton primary productivity of the pond.

Unit: gC/m²/day		Gross primary Productivity (GPP)	Net primary productivity (NPP)	Community respiration (CR)
N Valid		18	18	18
N Missing		6	6	6
Mean		7.73	5.695	2.035
Std. Error of Mean		1.059	0.945	0.194
Median		5.535	3.870	1.935
Std. Deviation		4.492	4.008	0.824
Skewness		0.340	0.488	1.874
Minimum		1.530	0.540	0.900
Maximum		15.300	13.050	4.680
Percentiles	25	3.758	2.160	1.620
	50	5.535	3.870	1.935
	75	11.408	9.158	2.273
95% Confidence Interval	Lower	5.496	3.702	1.625
of the Difference	Upper	9.964	7.688	2.445

Table 3: Monthly variation of primary productivity.

Month/ Year	GPP gC/m²/day	NPP gC/m²/day	CR gC/m²/day	Month/ Year	GPP gC/m²/day	NPP gC/m²/day	CR gC/m²/day
A1	3.69	2.79	0.90	A13	5.67	3.42	2.25
M2	5.40	3.96	1.44	M14	11.25	6.57	4.68
J3	0.00	0.00	0.00	J15	11.07	9.00	2.07
J4	0.00	0.00	0.00	J16	11.88	9.63	2.25
A5	0.00	0.00	0.00	A17	13.86	11.16	2.70
S6	0.00	0.00	0.00	S18	14.04	11.52	2.52
O7	0.00	0.00	0.00	O19	15.30	13.05	2.25
N8	0.00	0.00	0.00	N20	11.25	9.00	2.25
D9	1.53	0.54	0.99	D21	10.08	7.74	2.34
J10	4.14	2.43	1.71	J22	5.40	3.78	1.62
F11	3.78	2.16	1.62	F23	3.60	1.80	1.80
M12	3.42	1.80	1.62	M24	3.78	2.16	1.62

tics of physicochemical properties of pond water is given in Table 4. Table 5 gives the Pearson Correlation of GPP with different parameters of the pond.

Minimum and maximum temperature of water was 15°C and 31°C respectively, with mean temperature 24.69°C. The minimum value of light penetration depth was 10 cm and maximum value 53 cm with mean value 18.9 cm. For six months, dissolved oxygen was completely depleted. During this period Water chestnut's floating leaves blanket the water's surface, blocking sunlight and preventing underwater photosynthesis. It might be the main cause of depletion of oxygen. In rest of the months, mean value of DO was 6.07 mg/L. Mean pH was 7.78, minimum 6.7 and maximum 8.6. It shows alkaline nature of water. Mean of total alkalinity was 286.71 mg/L. Minimum alkalinity was 160 mg/L and maximum 484 mg/L. High value of total alkalinity coincides with the high planktonic yield i.e., eutrophication. Mean value of TSS was 95.08 mg/L with minimum 63 mg/L and maximum, 158 mg/L. Mean value of total dissolved solids was 419.33 mg/L with minimum 310 mg/L and maximum, 610 mg/L. The TSS may in fact consist of algal growths and hence be indicative of severely eutrophic conditions. High

Table 4: Summary statistics of physicochemical parameters.

Parameters°% Units °%		WT °C	LPD cm	pH	DO mg/L	Alk mg/L	TDS mg/L	TSS mg/L	Hardness mg/L	nitrate mg/L	PO_4 mg/L
Number of Samples	Valid	24	24	24	18	24	24	24	18	24	24
	Unvalid	0	0	0	6	0	0	0	6	0	0
Mean		24.69	18.92	7.78	6.07	286.71	419.33	95.08	269.88	4.61	0.47
Std. Error Of Mean		1.04	1.79	0.12	0.52	17.58	17.86	5.31	11.86	0.64	0.05
Median		26.50	18.00	7.80	6.14	294.00	387	87.50	282.00	4	0.50
Std. Deviation		5.10	8.76	0.57	2.22	86.11	87.51	26.01	58.09	2.70	0.27
Skewness		-0.71	2.71	-0.33	0.43	0.37	0.68	1.04	-0.23	2.44	-0.08
Minimum		15.00	10.00	6.70	2.44	160.00	310	63	156.00	2.00	0.09
Maximum		31.00	53.00	8.60	11.36	484.00	610	158	380.00	13.40	0.93
Percentiles	25	20.75	12.50	7.30	4.92	351.50	76.50	224.50	3.13	0.19	199.00
	50	26.50	18.00	7.80	6.14	387	87.50	282.00	4	0.50	294.00
	75	28.75	20.75	8.00	7.30	495	111.50	316.50	4.83	0.67	325.50
95% Confidence Interval	Lower	22.53	15.22	7.54	4.97	382.38	84.10	245.35	3.27	0.36	250.35
of the mean Difference	Upper	26.84	22.61	8.02	7.18	456.29	106.07	294.40	5.96	0.59	323.07

WT-water temperature; LPD-light penetration depth; DO-dissolved oxygen; Alk-alkalinity, Cl-chloride; TDS-total dissolved solid; TSS-total suspended solids; PO_4-phosphate

Table 5: Pearson Correlation coefficient values (r) of GPP with other parameters.

Parameters	WT	LPD	pH	DO	Alk	HD	PPD	TDS	TSS	NO_3	PO_4
Value of r	0.471*	-0.678**	-0.116	0.278	-0.837**	-0.807**	0.777**	-0.021	0.664**	-0.251	0.724**

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed), PPD-Phytoplankton density

total dissolved solid may indicate the presence of unsatisfactory sewage effluent discharges. Hardness of water was estimated as 269.88 mg/L (mean value). Minimum value of hardness was 156.0 mg/L and maximum value was 380.0 mg/L. The pond water under study was very hard. Mean value of phosphate was 0.47 mg/L with minimum value 0.09 mg/L and maximum value 0.93 mg/L. The phosphate concentration above 0.5 mg/L indicates pollution. The higher values may be due to the presence of detergents in sewage waste dumped in the pond. Mean value of NO_3 was 4.61 mg/L with minimum value 2 mg/L and maximum value 13.4 mg/L. High nitrate indicates high pollution load. Intrusion of sewage into the natural water increases the level of nitrate.

Phytoplankton primary productivity (gross primary productivity) was estimated 5.496 gC/m^2/day to 9.964 gC/m^2/day (at 95% confidence), in the pond under study. Sreenivasan (1964) has reported primary production rate 6.0 gC/m^2/day to 11.0 gC/m^2/day from a eutrophic tropical pond which is approximately similar to current study. Verduin (1956) also has reported primary production rate of 2 gC/m^2 day^{-1} from a eutrophic western Lake Erie which is much less than the pond under study. Mean value of GPP was 7.73 gC/m^2/day with minimum value 1.530 gC/m^2/day in December 2011 and maximum value of 15.300 gC/m^2/day in October 2012. Minimum value of phytoplankton primary productivity was observed in December 2011 and it is in conformity with the report of Sreenivasan (1964). He has suggested that it is cooler during December than during the other months, and this may be one of the reasons for the lower production. Deterioration of plankton may also be a cause of reduced yields (Sreenivasan 1964). For six months, from the month of June 2011 to November 2011, primary productivity was zero as DO in these months was absent. Density (abundance) of phytoplankton ranged between 1222 unit/L and 1683 unit/L (95% confidence interval). Mean value of phytoplankton density was 1435.489 unit/L with minimum value of 640 unit/L in August 2011, and maximum of 3280 unit/L in August 2012.

Mean value of net primary productivity (NPP) and community respiration (CR) were 5.695 gC/m^2/day and 2.035 gC/m^2/day, which were 73.67 % and 26.33 % of GPP respectively. NPP and CR ranged from 67.36 % to 77.16 % and 29.57 % to 24.54 % of GPP respectively. Difference between mean and median value of productivity shows that frequency distributions of GPP, NPP and CR is asymmetric. Coefficient of variation of GPP, NPP and CR obtained about 58%, 70% and 40% respectively. NPP shows greater variation. Primary productivity was found maximum in the post monsoon season followed by monsoon season, and relatively lower photosynthetic rate in winter season and summer season respectively. Higher values of phytoplankton primary productivity were obtained from M14 (May- 2012) to D21

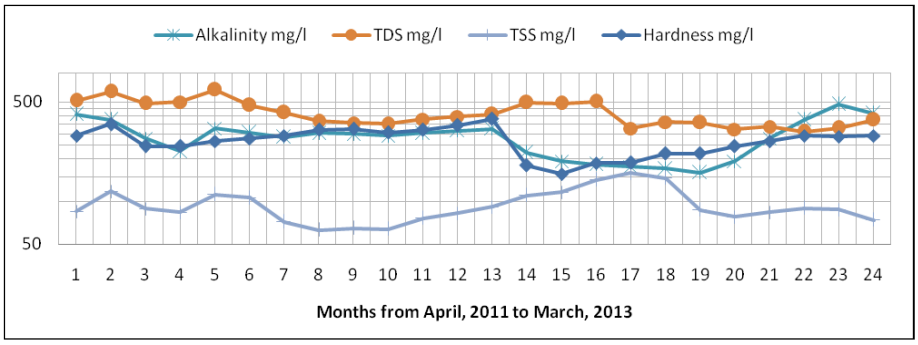

Fig. 2: Monthly variation of alkalinity, hardness, TSS and TDS.

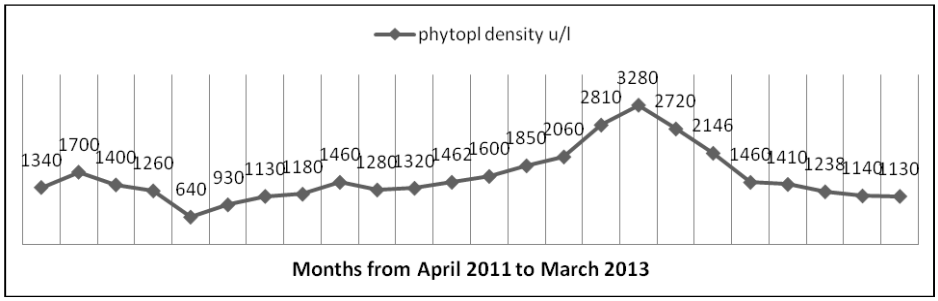

Fig. 3: Phytoplankton density, unit/L.

(December -2012). Phosphate, TSS and phytoplankton density were found highly correlated positively with phytoplankton primary productivity while light penetration depth, alkalinity and hardness were found highly correlated negatively. Higher primary productivity might be the interaction of raised temperature and nutrient enrichment. Higher production rate during summer than during winter has been reported in several tropical freshwater ponds (Hanifa & Pandian 1978). In this study, water temperature showed moderate positive correlation with phytoplankton productivity. Temperature is important in determining seasonal productivity (Goldman & Wetzel 1963, Ichimura & Aruga 1958). They attributed temperature, an important factor, which regulate the biogeochemical activities in the aquatic environment. Probably, high temperature enhances the release of nutrients from sediment through bacterial decomposition. Sultan et al. (2003) reported that temperature, solar radiation and available nutrients may be important limiting factors for primary production and contributing to seasonal variation in any aquatic ecosystem. Algal primary productivity is influenced by the availability of nutrients (Knud-Hansen 1997) and among a large number of nutrients required to stimulate growth, concentrations of nitrogen, phosphorus are commonly responsible for limiting algal growth (Lin et al. 1997). In this study, nitrate was not found correlated with primary productivity significantly. Light penetration is a reliable indicator of productivity (Steeman-Nielsen 1959). In general, transparency of water in an aquatic ecosystem especially in ponds; tanks and lakes are largely influenced by the biotic communities present therein. Community respiration varied from 25-30% of GPP. Respiration as percent of gross production may be as a measure of eutrophic nature of water body (Ganff & Horne 1975). In a productive aquatic ecosystem, respiration accounts for large proportion of gross primary productivity.

CONCLUSION

Higher rate of phytoplankton primary productivity obtained in the present study indicates the eutrophic nature of the pond ecosystem. From month J3 (June 2011) to N8 (November 2011) phytoplankton primary productivity was absent as dissolved oxygen in those months was absent in water. Coefficient of variation of GPP, NPP and CR obtained about 58%, 70% and 40% respectively. Higher values of primary productivity were found in post monsoon and monsoon season. Mean value of primary productivity was lower in summer and winter season. Phosphate, TSS and phytoplankton density were found highly correlated positively with phytoplankton primary productivity, while light penetration depth, alkalinity and hardness were highly correlated negatively. Phytoplankton primary productivity was found moderately correlated with temperature.

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