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Primary productivity of the phytoplankton in two perennial ponds of Madhepura district, North Bihar

***Avinash Kumar[1], Jai Nandan Prasad Yadav[1] & Arun Kumar[2]**
[1]Department of Zoology, K.P. College, B.N. Mandal University, Murliganj, Bihar, India
[2]University Department of Zoology, B.N. Mandal University, Madhepura, Bihar, India

ABSTRACT

The present study has been carried out to evaluate the status of phytoplankton primary productivity in two perennial ponds, namely Puraini (Pond-1) and Baghmara (Pond-2) of Madhepura district, North Bihar. The experiment was conducted monthly from March, 2019 to February, 2020. The rate of primary productivity was determined *in situ* using light and dark bottle oxygen method. The rate of gross primary production varied between 2.475 g C/m^2/day and 6.615 g C/m^2/day in Pond-1 and between 2.385 g C/m^2/day and 5.935 g C/m^2/day in Pond-2 with mean of value 4.35±0.36 g C/m^{-2}/day and 4.0±0.34. The gross production was relatively higher in Pond-1 than in Pond-2. The rate of production was maximum in summer may be due to penetration of more light into water column, longer sunshine hours and increased phytoplankton density facilitates higher rate of photosynthesis, while minimum during monsoon season probably due to dilution effects of rainwater on phytoplankton density might bring about lower productivity value. Seasonal variations of primary productions showed a bimodal pattern of increase with major peak in summer and second during winter. The rate of net primary production varied from 0.900 g C/m^2/day to 4.450 g C/m^2/day in Pond-1 and from 1.175 g C/m^2/day to 3.949 g C/m^2/day in Pond-2 with mean of 2.91±0.32 g C/m^2/day and 2.51±0.27 g C/m^2/day. The rate of community respiration varied from 0.926 g C/m^{-2}/day to 2.216 g C/m^{-2}/day and from 0.573 g C/m^{-2}/day to 2.693 g C/m^{-2}/day in Pond-1 and Pond-2, respectively with mean value of 1.44±0.12 g C/m^2/day and 1.49±0.18 g C/m^2/day. Net and gross ratio ranged between 0.364 and 0.789 in Pond-1 and between 0.424 and 0.821 in Pond-2 with mean of value 0.65±0.04 and 0.62±0.04. Respiration as percent of the gross production ranged from 21.10% to 63.64% in Pond-1 and from 17.90% to 57.57% in Pond-2 with mean of 35.12±3.66 and 38.12±3.89. The results indicate that ponds studied were highly productive.

Key Words - Primary productivity, perennial ponds, GPP, NPP, CR, environmental factors.

***Corresponding author :** prf.arunkumar@gmail.com

INTRODUCTION

The primary productivity or its major components, net and gross primary production of water body is a manipulation of its biological production. The solar energy required for biological activities is first converted to chemical energy by the process of photosynthesis mainly executed by the primary producers. Thus, primary productivity forms base of the ecosystem functioning (Odum, 1971). The primary productivity is ultimate source of organic production and energy input in an aquatic ecosystem which is available to entire biological community (Ahmed *et al.* 1971). The estimation of primary productivity is predicted on the relationship between oxygen evolution and carbon fixation (Dash *et al.* 2011). The primary productivity is basically dependent upon the photosynthetic activity of autotrophic organisms. Rate of primary productivity varies from lentic to lotic water and from lotic to marine water.

Phytoplankton is a major part of primary producers in aquatic ecosystems. Photosynthesis is fundamental process involved in primary production. Primary productivity is the root of all the food chains and food webs as the organic matter produced by the phytoplankton are utilized by consumers (Singh & Singh 1999). The primary productivity helps to determine the trophic level of various aquatic systems. Its measurement is necessary to evaluate fish production potential of water bodies (McConnell *et al.* 1988). Impacts of solar radiation on aquatic ecosystem and primary productivity has been discussed and worked out by various workers. Despite the effect of basic controlling factors light and nutrients, primary production can be influenced by environmental parameters like duration of sunshine hours, clouds, rainfall, air temperature and relative humidity which influence the quality of water thus influencing primary productivity through phytoplankton growth. Primary productivity is greatly influenced by collective action of all these factors.

Studies on primary productivity of phytoplankton in Indian freshwaters have been carried out in several limnological studies during the past few decades (Screenivasan, 1964, 1965, 1976; Ganpati & Screenivasan, 1970; Ganapati & Screenivasan, 1970; Vijayraghavan, 1971; Khan, 1980; Basheer *et al.* 1996). Recently, the primary productivity of freshwater ponds has received much attention by various researches (Paul *et al.* 2006; Verma & Srivastava, 2015; Deka, 2017). Impacts that alter the rate of primary production can affect transformations of energy to higher trophic levels thus changing the productive capacity of aquatic ecosystem, however, information on primary productivity of freshwaters of North Bihar do not exist. Therefore, in the present study, an attempt has been made to evaluate primary productivity of phytoplankton in two perennial ponds of Madhepura district, North Bihar.

MATERIALS AND METHODS

Study site

Two freshwater perennial ponds, namely Puraini (Pond-1) and Baghmara (Pond-2) of Madhepura district of North Bihar were selected for primary productivity studies. Pond-1 is rectangular in shape covers an area of 2.79 acre and located at 25^{o}35'53" N latitude and 86^{o}59'31"E longitude. Fishery of this pond is being managed by local fishers. Pond-2 is surrounded by the farming lands, irregular in shape, covers an area of 2.2 acre and lies at latitude 25^o 34'26'' N and longitude 87^{o}0' 34'' E. No organized fishing activity is being carried out in this pond.

Analysis of primary productivity

Experiments on primary productivity of phytoplankton in two perennial ponds were carried out monthly from March 2019 to February 2020 using classical light and dark bottles oxygen technique (Gaarder & Gran, 1927). Samples were collected to measure primary production. Three replicates of each type of initial, light and dark bottles were immediately filled with water of respective pond. The dark bottle was painted black and wrapped with black cellulose tape to stop photosynthesis and thus only respiration occurs in this bottle. Oxygen in initial bottle was fixed immediately by adding Winkler's reagent. Light and dark bottles were incubated at surface level (0.5 meter depth) for 6 hours from 9.00 AM and 3.00 PM. Oxygen in initial, light and dark bottle were determined by modified Winkler's method (APHA *et al.* 1998). Gross photosynthesis was calculated from differences in oxygen in light and dark bottles and net production from differences in oxygen concentration in light and initial bottles and community respiration from differences between initial oxygen and final oxygen in dark bottle. Obtained data were computed per unit time and volume of water. To obtain carbon values, the oxygen values were multiplied by a factor 0.375 and expressed as g C/m^2/day taking photoperiod of the region as a day (Sreenivasan, 1976).

Table-1: Monthly variations in primary productivity of Puraini pond (Pond-1)

Parameters/ Months	GPP (g C/m^2/day)	NPP (g C/m^2/day)	CR (g C/m^2/day)	NPP/GPP	R as % of GPP
March, 2020	4.829	3.150	1.679	0.652	34.77
April	5.515	3.299	2.216	0.598	40.18
May	6.615	4.450	2.165	0.673	32.73
June	5.189	3.896	1.293	0.751	24.99
July	3.269	1.946	1.323	0.595	40.47
August	2.475	0.900	1.575	0.364	63.64
September	2.573	1.215	1.358	0.472	52.78
October	3.331	2.213	1.118	0.664	33.56
November	4.517	3.564	0.953	0.789	21.10
December	4.951	3.735	1.216	0.754	24.56
January, 2021	5.019	3.578	1.441	0.713	28.71
February	3.869	2.943	0.926	0.761	23.93

Table-2: Monthly variations in primary productivity of Baghmara pond (Pond-2)

Parameters/ Months	GPP (g C/m^2/day)	NPP (g C/m^2/day)	CR (g C/m^2/day)	NPP/GPP	R as % of GPP
March, 2020	4.126	2.815	1.311	0.682	31.77
April	4.930	2.714	2.216	0.551	44.95
May	5.869	3.176	2.693	0.541	45.86
June	5.935	3.949	1.986	0.665	33.46
July	2.769	1.175	1.594	0.424	57.57
August	2.385	1.229	1.154	0.515	48.39
September	2.655	1.379	1.275	0.519	48.02
October	3.949	1.815	2.134	0.460	54.03
November	4.215	3.149	1.066	0.747	25.29
December	4.619	3.792	0.827	0.821	17.90
January, 2021	3.085	2.512	0.573	0.814	18.57
February	3.495	2.391	1.104	0.684	31.59

Table-3: Primary productivity parameters of ponds with range and mean ± SE.

Water bodies/ Parameters	Pond-1		Pond-2	
	Range	Mean ±SE	Range	Mean ±SE
Gross Primary Production	2.475-6.615	4.35±0.36	2.385-5.935	4.0±0.34
Net Primary Production	0.900-4.450	2.91±0.32	1.175-3.949	2.51±0.27
Community Respiration	0.926-2.216	1.44±0.12	0.573-2.693	1.49±0.18
NPP/GPP ratio	0.364-0.789	0.65±0.04	0.424-0.821	0.62±0.04
Respiration as % of gross	21.10-63.64	35.12±3.66	17.90-57.57	38.12±3.89

*GPP, NPP and CR value in g $C/m^2/day$

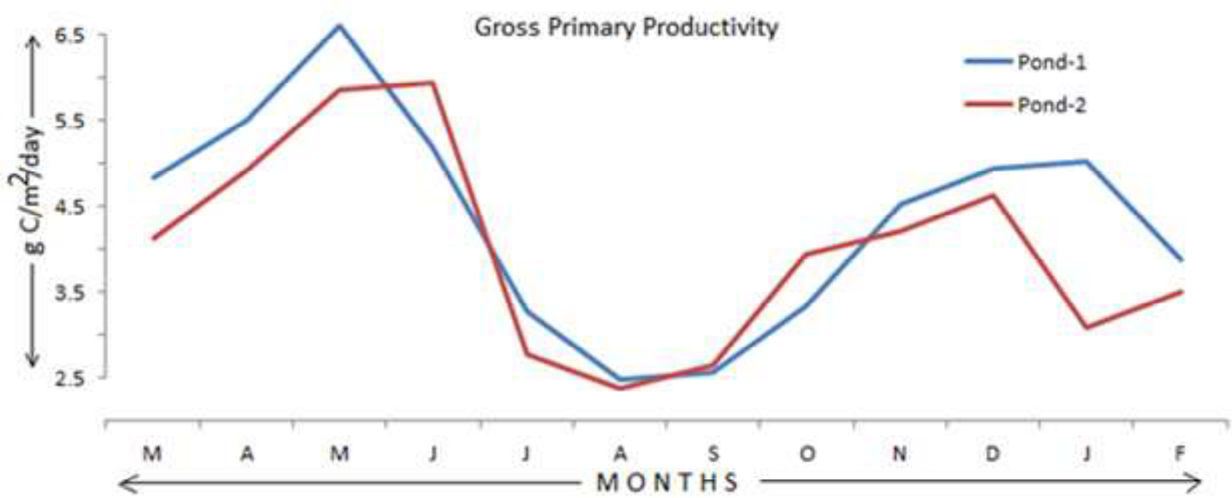

Figure-1: Monthly variations in gross primary productivity at Pond-1 and Pond-2

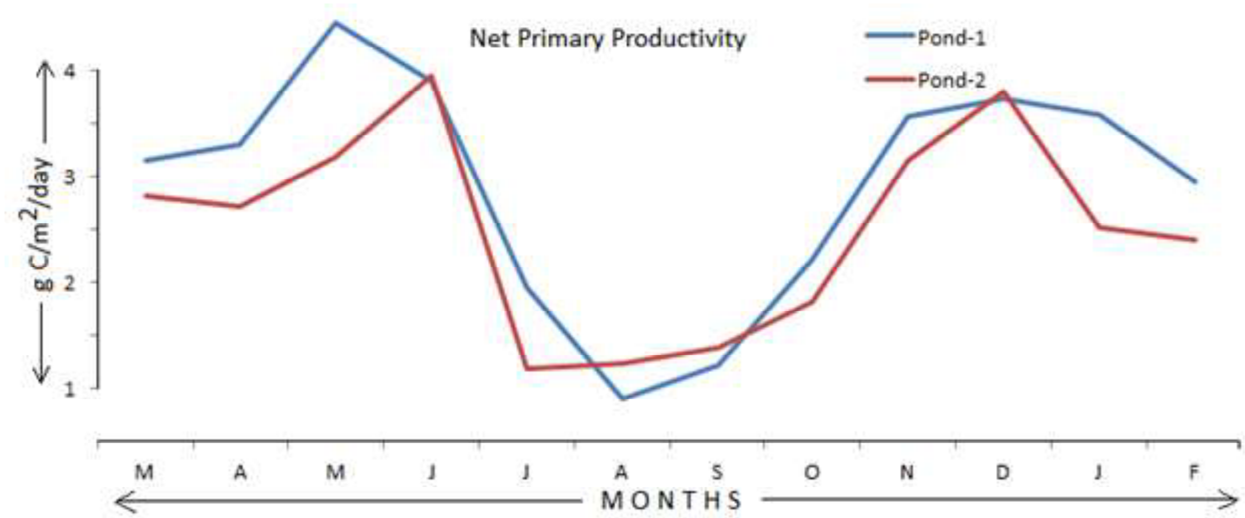

Figure-2: Monthly variations in net primary productivity at Pond-1 and Pond-2.

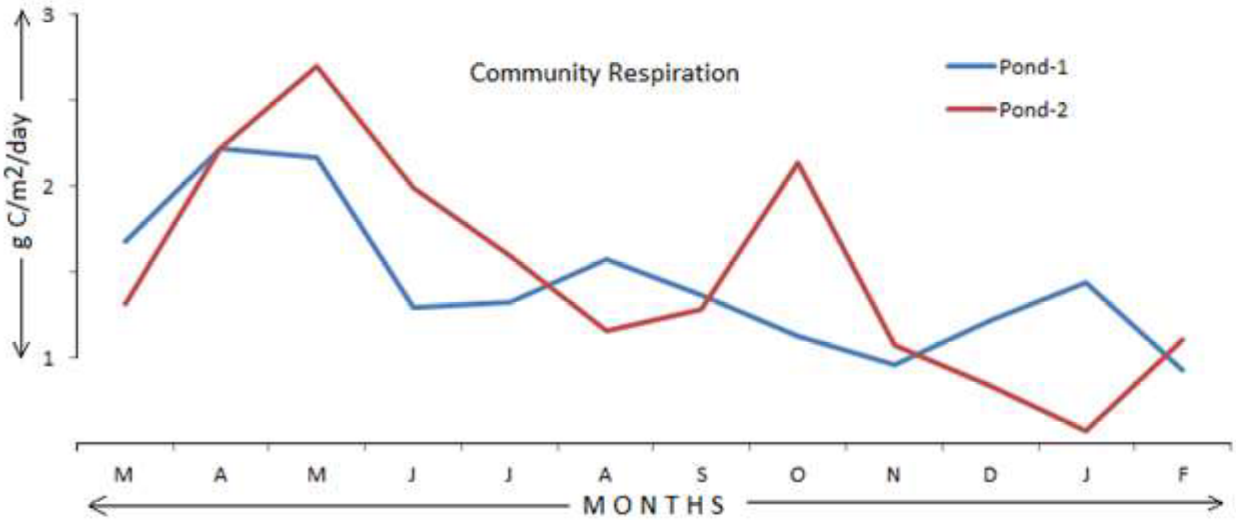

Figure-3: Monthly variations in community respiration at Pond-1 and Pond-2.

RESULTS AND DISCUSSION

Primary productivity is an important biological phenomenon in nature, as it makes the chemical energy and organic matter available to consuming organisms. Primary production study included the net primary productivity (NPP) or the gross primary productivity (GPP), where GPP includes the total amount of fixed carbon(organic matter) plus the rate of respiration, whereas, NPP accounts for the rate of organic matter synthesized through photosynthesis minus the rate lost through respiration and excretion. The community respiration includes rate of loss of the fixed energy in respiration.

The results indicating gross primary productivity (GPP), net primary productivity (NPP) and community respiration (CR), NPP/GPP ratio and respiration as % of gross are given in Table-1 and 2, and mean and standard error is given in Table-3. Seasonal variation of primary productivity is depicted in Figure-1 to 3.

Gross and net primary productivity

Gross primary productivity of phytoplankton was remarkably high in the studied water bodies ranged between 2.475 g C/m^{-2}/day and 6.615 g C/m^{-2}/day in Pond-1 and between 2.385 g C/m^{-2}/day and 5.935 g C/m^{-2}/day in Pond-2 with mean value of 4.35±0.36 g C/m^{-2}/day and 4.0±0.34 g C/m^{-2}/day respectively (Table-3) with minimum and maximum during monsoon and summer (Figure-1). The net primary production provides energy for all heterotrophic activity, varied between 0.900 g C/m^{-2}/day and 4.450 g C/m^{-2}/day in Pond-1 and between 1.175 g C/m^{-2}/day and 3.949 g C/m^{-2}/day in Pond-2 with mean of 2.91±0.32 g C/m^{-2}/day and 2.51±0.27 g C/m^{-2}/day (Table-3), lowest and highest was during monsoon and summer respectively (Figure-2). Higher rates of primary productivity exhibited eutrophic nature of studied water bodies. The rate of primary production was slight higher in Pond-1 than in Pond-2. Definite trend of seasonal variation in the rate of net and gross primary productivity were observed and a bimodal pattern of increased productivity was noticed. The first peak appeared during summer and the second in winter and these peaks were interrupted by heavy rainfall during monsoon when rate of primary production dropped significantly (Figure-1 and 2). Similar trends was recorded by several workers (Khan, 1980; Untoo *et al.*, 2016; Kumari, 2020). The rate of gross productivity was always higher than the net productivity as phytoplankton loses a substantial amount of assimilated carbon in metabolic activities mainly in respiration and excretion (Fogg *et al.* 1973). The rate of gross productivity was lowest during monsoon might be due to decreased light intensity and shorter sunshine hours due to interruption of clouds. Besides these, dilution effect of rainwater on phytoplankton density and increased allochthonous turbidity interrupting light penetration through the water column thus reducing photosynthetic activities (Hujare & Mule, 2007; Kumar & Choudhary, 2007). The rate of primary productivity was high in summer could be attributed to penetration of more light in water facilitating the high rate of planktonic photosynthesis ultimately the higher productivity (Deka, 2017; Untoo *et al.* 2016). Similar trend in seasonal variation of net primary productivity was also noticed (Figure-2). Higher rate of the net and gross productivity indicate greater planktonic activity, though the rate is not controlled by a single factor, but largely governed by various physico-chemical parameters and environmental factors (Singh & Singh, 1999).

Despite of the seasonal variation, the rate of productivity did not fluctuate too much, maximum production recorded 2 times greater than minimum production in Pond-1 and 3 times in Pond-2. The minimum/maximum ratio of primary production reported as 1:10 in Othakadai pond, 4 times in Teppakulum tank and 5 times in Yanamalai pond of South India (Vijayraghavan, 1971). Maximum productivity recorded about 6 times higher than the minimum in a sewage-fed pond at Bhagalpur, Bihar (Nasar & Nasar, 1978). The ratio of two extremes of primary production is reported 1:8 in a sewage-fed impoundment near Kolkata, West Bengal (Dutta & Choudhary, 1984). The magnitude of primary productivity variation is affected by photosynthetic capacity of producers and the direct impact of seasonal variation.

Community respiration

The rate of respiration was relatively much lower than the net and gross primary productivity, ranged between 0.926 g C/m^2/day and 2.216 g C/m^2/day in Pond-1 and varied between 0.573 g C/m^2/day and 2.693 g C/m^2/day in Pond-2, with mean value of 1.44±0.12 g C/m^{-2}/day and 1.49±0.18 g C/m^{-2}/day (Table-3). Highest rate of respiration may be due to greater biotic composition. Respiration rate was higher during summer and in monsoon it gradually decreases and reached lower in winter (Figure-3). Higher rate of respiration during summer might be due to increased water temperature stimulates growth of microbial population in turn utilizes more oxygen in metabolic activities, however lower rate during winter could be due to low temperature and reduced light intensity affect the rate of photosynthetic efficiency (Datta *et al.* 1984; Ahmad & Singh, 1987). The rate of respiration was fairly high in Pond-2 than in Pond-1 (Figure-3) could be due to discharge of sewage and was tested to increased microbial population ultimately accelerated the rate of respiration.

NPP/GPP ratio

The amount of gross production available to consumer organism is evaluated by ratio of net productivity to the gross productivity (Singh & Singh 1999). The NPP/GPP ratio value ranged between 0.364 and 0.789 in Pond-1 and between 0.424 and 0.821 in Pond-2 with mean value of 0.65±0.04 and 0.62±0.04 (Table-3). Minimum and maximum ratio was observed during winter and monsoon respectively. Higher ratio show greater respiration than the production. The ratio of NPP/GPP should approach unity in a healthy population if the respiration is 5-10% of total photosynthesis (Ketchem *et al.*, 1958). If ratio is zero it revealed poor physiological state of producer organisms mainly due to nutrient deficiency. During this study, this ratio was less than one and greater than zero reflecting the ponds studied were productive.

Respiration as % of GPP

Respiration as percent of gross production may be an effective tool to measure eutrophic nature of water bodies (Ganf & Horne, 1975). Respiration accounts for large proportion of gross productivity in productive water bodies. Respiration comprised about 35.12±3.66% of gross production in Pond-1 varied between 21.10% and 63.64%, however, accounted about 38.12±3.89% in Pond-2 ranged between 17.90% and 57.57% (Table-3). The value greater than 40% of respiration as percent of gross production is a characteristic of eutrophication

(Ganf, 1972). Obtained data showed eutrophic nature of studied water bodies.

CONCLUSION

Present investigation on primary productivity has been based on amount of phytoplankton photosynthesis measured for one year in two freshwater perennial ponds of Madhepura district, North Bihar. The water bodies studied were highly productive. Obtained data showed sufficient amount of organic materials synthesized to support aquatic life. Higher rate of primary productivity exhibited eutrophic nature of water bodies. Ratio of the net to gross productivity shows that ponds were productive. Despite the physico-chemical parameters, primary productivity of phytoplankton was affected by various environmental factors, such as air temperature, light intensity, photoperiod, water level and rainfall. Studies on planktonic primary productivity are crucial for aquaculture activities.

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