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Studies on Monthly and Seasonal Variations in Primary Productivity of Glacial fed Mountainous Goriganga River in Kumaun Himalaya, Uttarakhand, India

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Abstract

The primary productivity of Glacial fed Mountainous Goriganga River in Kumaun Himalaya, Uttarakhand India has been estimated for two years from July-2006 to June-2008. Monthly and seasonal variations in Gross Primary Productivity (GPP), Net Primary Productivity (NPP) and Community Respiration (CR) were studied at three selected spots (spot-1, Jauljibi-600msl; spot-2, Baram- 900msl and spot-3, Madkot-1300msl). GPP values ranged between 0.024 gC/m^2/day to 0.198 gC/m^2/day, NPP values ranged between 0.012 gC/m^2/day to 0.124 gC/m^2/day and Community Respiration (CR) values ranged between 0.008 gC/m^2/day to 0.086 gC/m^2/day. Monthly, seasonal, yearly and selected spot wise variations in primary productivity including coefficient correlations have also been recorded and discussed in detail in the present paper.

Keywords: Monthly, seasonal, productivity, GPP, NPP, CR, Goriganga, Kumaun, Himalaya.

Introduction

Introduction: With ever increasing load on aquatic ecosystems, studies on riverine ecology have become necessary to the quality of life for mankind. Primary productivity is the most important biological phenomenon in nature on which the entire diverse array of life depends, either directly or indirectly. It involves trapping of radiant energy of the sun and its transformation in to high potential of biochemical energy by photosynthetic apparatus, using inorganic materials of low potential energy. It is being the driving force for all metabolic activities in the biosphere, it also helps in measuring the ability of an area to support a biological population and sustain a level of growth and respiration. Primary productivity can be defined as the weight of new organic matter created through carbon assimilation by plants or the energy it represents. Primary production in aquatic ecosystems has certain features distinct from that in terrestrial systems. The flow of energy through an ecosystem is an unidirectional process in contrast to nutrients which may be cycled many times. The biotic communities of an aquatic ecosystem are interlinked with one another. The knowledge of complex relationship of food chain and the flow of energy and nutrient in community metabolism is of great importance for the correct understanding of the bioenergetics and trophic dynamics of the aquatic ecosystem. The primary productivity is the root of all food chains and food webs of any ecosystem generating 70% atmospheric oxygen of the world[1]. It is important to note that the study of productivity now receiving so much attention in ecology and the ecologists interested in ecoenergetics are primarily concerned with the quality of incident solar energy per unit area of the ecosystem and the efficiency with which energy is converted by organisms in to other forms (chemical energy). For estimating the available energy at the lowest trophic level (producer level) to be used by heterotrophs, the source of energy entering the system must be considered.

In India very few attempts have been made to study energy transformation in various processes. Sreenivasan[2] and Ganapathi and Sreenivasan[3] have studied the energy flow in some aquatic ecosystems. The energy fixed by producers can be measured from the oxygen produced during photosynthesis as it is known that to liberate one milligram of energy through photosynthesis, 3.68 calories of energy is expanded[4]. The chemical energy assimilated by plants flows to the higher trophic levels and dynamics equilibrium exist between the producer energy and the energy assimilated by the heterotrophs. Heterotrophs get their nutritional energy from the breakdown (oxidation) of organic material stored by the producers. All the energy consumed by the heterotrophs is not assimilated by them and a part of energy is lost as faecal matters. The assimilated energy varies from species to species and also with the quality of the available food. The storage of energy in heterotroph's tissue is termed as secondary production. In the present study our interest lies in what happens to the energy after it enters in the system and before it leaves the system. The effective running of the aquatic ecosystem depends on the energy transfer from organism to organism.

In lotic aquatic ecosystems with little known fishery structure, both the energy input and energy output by each species are easy to calculate but in controlled aquatic ecosystems (reservoirs) there are large number of fishes with different feeding habits and the energy calculations are extremely difficult. Various workers have presented the trophic dynamics models to explain the productivity in aquatic ecosystems. The first attempt to draw an energy budget for the whole biological system was that of Juday[5]. He referred to photosynthesis as the primary accumulation of energy and the heterophic organisms as the secondary stage in the storage of energy accumulated by aquatic plants. Lindeman[6] proposed that organisms should be finally grouped according to their mode of obtaining energy as primary producers, herbivores, predators on herbivores and so on, each he called a trophic level and pointed out that the energy content of a trohphic level is in a state of flux, receiving energy from the previous level and loosing it by passing it to the next trophic level or dissipating it as metabolism or decomposition. Primary productivity is considered to be the system's capacity for the formation of the potential energy and the subsequent reconversion to kinetic energy, such studies provides the opportunity to evaluate the efficiency of available energy within the system for better understanding of the first level of aquatic food chain. Various fresh water communities such as phytoplankton and macrophytes are responsible for the photosynthetic fixation of carbon[7]. Record on primary productivity studies in Indian lotic waters are meagre[8-13].

The main aim of productivity measurement of aquatic systems, which started in the second half of the twentieth century was to get a better understanding of the food chain relationships and of the functioning of the ecosystem[14-17]. Primary productivity is being the important sources of energy input in aquatic ecosystem, it is directly related to temperature[18] and the available nutrients in the water and soil in relation to other physico-chemical factors[19]. Biological production can be used as an index of trophic status, fisheries potential, productivity and biodiversity of water body[20-21]. The object of the present study was to obtain quantitative information about the amount of energy available to support the bioactivity besides the seasonal variations in primary productivity of Goriganga river. Studies on primary productivity and energy flow in different aquatic ecosystems have been made by several workers[22-34].

Though, recently Upadhyay[35] and Pathani and Mahar[36] have given the excellent works on productivity in spring fed rivers Suyal and Ramganga (W) of Kumaun Himalayas, but there is no reports on productivity of gacial fed mountainous Gorigang river. Therefore, the present study is an endeavour to elucidate the seasonal and monthly variations in primary productivity of the Goriganga river for the first time.

Material and Methods

The study was conducted from July-2006 to June-2008 on monthly basis at three selected spots (spot-1, Jauljibi-600msl; spot-2, Baram- 900msl and spot-3, Madkot-1300msl) which are extended in a river stretch of 44km. Primary productivity was measured by Gaarder and Gran's Light and Dark Bottle method. In this method two bottles of one liter capacity was filled with sample from the known depth containing phytoplankton and zooplankton. One of the two bottles was completely darkened to prevent photosynthesis but allow respiration activity of the organisms and the other bottle was light transmitting bottle which allows photosynthesis to occur. After filling, both (light and dark) bottles were immediately suspended at the desired depth of the selected sites and incubated for a given period of time (24 hours). At the beginning and at the end of the experiment, dissolved oxygen content was measured by Winkler's modified method.

Methods described by Adoni[37] were employed to analyse primary productivity and Statistical calculations like mean, standard deviation and correlation.

$$\text{Net primary productivity (NPP) } O_2\text{mg/l/hr} = \frac{DL - Di}{h}$$

$$\text{Gross primary productivity (GPP) } O_2\text{mg/l/hr} = \frac{DL - Dd}{h}$$

$$\text{Community respiration } R^2 = \frac{Di - Dd}{h}$$

Where DL = dissolved oxygen in the light bottle in mg/l., Di = dissolved oxygen in the initial bottle in mg/l., Dd = dissolved oxygen in the dark bottle in mg/l., h = Duration of exposure in hours. The values can be converted to carbon by multiplying with factor 0.375.

Results and Discussion

Gross Primary Productivity (GPP): The gross primary productivity (GPP) of Goriganga river was studied at Jauljibi, Baram and Madkot for two years (from July 2006 to June 2008). The gross primary productivity (GPP) values on three selected spots in the Goriganga river have shown month wise, season wise and year wise fluctuations table 1, 2 and figures 1, 2, 3, 4. The gross primary production ranged from 0.024 gC/m^2/day to 0.198 gC/m^2/day in 2006-07 and from 0.024 gC/m^2/day to 0.186 gC/m^2/day in 2007-08 table-1. The lowest values for gross primary productivity were recorded as 0.036 gC/m^2/day at Jauljibi; 0.024 gC/m^2/day at Baram and 0.030 gC/m^2/day at Madkot during July month in the first year (2006-07) in the Goriganga river table-1. The highest values for gross primary productivity were recorded as 0.198 gC/m^2/day and 0.198 gC/m^2/day at Jauljibi in the month of October and March; 0.132 gC/m^2/day and 0.150 gC/m^2/day at Baram in the months of October and May. While it was 0.142 gC/m^2/day and 0.120 gC/m^2/day at Madkot in the months of September and May during first year (2006-07) table 1. In the subsequent year, 2007-08, the lowest values of gross primary productivity were 0.074 gC/m^2/day at Jauljibi; 0.034 gC/m^2/day at Baram and 0.024 gC/m^2/day at Madkot in July 2007-08 table-1. The highest values were 0.124 gC/m^2/day and 0.186 gC/m^2/day at Jauljibi in the months of October and April; 0.126 gC/m^2/day and 0.120 gC/m^2/day at Baram in the months of September and May table

1. While it was 0.118 gC/m^2/day and 0.120 gC/m^2/day at Madkot in the months of September and March table-1.

It was also noted that few high values of gross primary productivity (GPP) were recorded in winter months and summer months and low values in the month of July in both the years with slight month and station wise variations in the present study table 1. Therefore, it could be generalized that the gross primary productivity values showed two peaks, bimodal in October and March at Jauljibi, in October and May at Baram and in September and May at Madkot during first year (2006-07) table-1, figure-1. Similar trend of bimodal rhythms in gross primary productivity (GPP) values were observed in the second year (2007-08) in the study. During second year (2007-08), two peaks-bimodal, in October and April at Jauljibi, in September and May at Baram and in September and March at Madkot were obtained in the study table-1, figure-2. The present study revealed that there is monthly, seasonally and yearly variations in the productivity values of gross primary production.

The maximum seasonal mean was 0.154 gC/m^2/day at Jauljibi; 0.120gC/m^2/day at Baram in summer and 0.078 gC/m^2/day at Madkot in monsoon recorded in the first year (2006-07) table-2, figure-3. The highest seasonal mean values for gross primary productivity (0.121 gC/m^2/day) at Jauljibi, 0.108 gC/m^2/day at Baram and 0.092 gC/m^2/day at Madkot were obtained in summer season for the second year (2007-08) table 2, Figure 4. While the lowest seasonal mean values for the first year (0.072 gC/m^2/day) at Jauljibi and 0.067 gC/m^2/day at Baram during monsoon season and 0.70 gC/m^2/day at Madkot equally in monsoon and winter seasons were obtained table-2, figure-3.

During second year the lowest seasonal mean values for gross primary productivity (0.086 gC/m^2/day) at Jauljibi, 0.071 gC/m^2/day at Baram and 0.059 gC/m^2/day at Madkot during monsoon season were recorded table 2, figure-4. It was observed that the highest annual mean (0.123 gC/m^2/day and 0.103 gC/m^2/day) was recorded at Jauljibi and the lowest annual mean (0.073 gC/m^2/day and 0.070 gC/m^2/day) was recorded at Madkot in 2006-07 and 2007-08, respectively in the present study table-1.

It was also observed that the higher annual mean value of gross primary productivity (GPP) was recorded during first year (2006-07) than the second year in the study table 1. Altitudinally, gross primary productivity (GPP) values were decreased from downstream to upstream (0.123 gC/m^2/day, 0.102 gC/m^2/day and 0.073 gC/m^2/day) in the first year (2006-07) and (0.103 gC/m^2/day, 0.090 gC/m^2/day and 0.070 gC/m^2/day) in the second year (2007-08) at spot-1, spot-2 and spot-3 respectively in the present study table 1.

It was also observed that gross primary productivity (GPP) showed positive significant correlation with net primary productivity (NPP) (r = 0.737031 and r = 0.980351, figure 5 and 6. Whereas it showed positive insignificant correlation with community respiration (r = 0.385615) during 2006-07 and positive significant correlation with community respiration (r = 0.938173) during 2007-08 figure 7 and 8. Mostly, the values of dissolved oxygen (D.O) and gross primary productivity (GPP) were low in monsoon season and high in summer and winter seasons. But it is also evident that the temperature has significant role in productivity because in winter months when water temperature was low and light penetration high, the productivity is lower in comparison to that in the summer months when temperature was higher and penetration of light was slightly low as compared to the winter months.

Table-1
Monthly data of Gross Primary Productivity (GPP) at three spots in the Goriganga river during 2006-07 and 2007-08

Month	Gross primary productivity (GPP) (gC/m^2/day).					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)
July	0.036	0.024	0.030	0.074	0.034	0.024
Aug	0.066	0.074	0.092	0.086	0.072	0.048
Sept	0.124	0.098	0.142	0.112	0.126	0.118
Oct	0.198	0.132	0.100	0.124	0.116	0.106
Nov	0.168	0.124	0.072	0.104	0.106	0.048
Dec	0.112	0.064	0.062	0.074	0.078	0.048
Jan	0.098	0.154	0.048	0.104	0.074	0.036
Feb	0.126	0.162	0.040	0.098	0.096	0.080
Mar	0.198	0.072	0.048	0.106	0.112	0.120
Apr	0.126	0.098	0.074	0.186	0.104	0.096
May	0.166	0.50	0.120	0.094	0.120	0.072
Jun	0.062	0.074	0.048	0.074	0.052	0.048
Mean	0.123	0.102	0.073	0.103	0.090	0.070
S.D.	0.052	0.042	0.034	0.030	0.028	0.033

Net Primary Productivity (NPP): Spot wise, month wise, season wise, year wise and altitudinal fluctuations in net primary productivity (NPP) values were recorded in the present study table 3 and 4 and figures 9, 10, 11 and 12. In 2006-07, the values of net primary productivity (NPP) ranged from 0.016 $gC/m^2/day$ to 0.124 $gC/m^2/day$ and from 0.012 $gC/m^2/day$ to 0.1 $gC/m^2/day$ in 2007-08 table 3. In the first year (2006-07), net primary productivity values have fluctuated from 0.026 $gC/m^2/day$ to 0.124 $gC/m^2/day$ at spot-1 (Jauljibi), 0.016 $gC/m^2/day$ to 0.116 $gC/m^2/day$ at spot-2 (Baram) and from 0.020 $gC/m^2/day$ to 0.072 $gC/m^2/day$ at spot-3 (Madkot) table 3.

Table-2
Seasonal variations in gross primary productivity (GPP) at three spots in the Goriganga river during 2006-07 and 2007-08

Seasons	Gross Primary Productivity (GPP) ($gC/m^2/day$)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)
Monsoon	0.072	0.067	0.078	0.086	0.071	0.059
Winter	0.144	0.118	0.070	0.100	0.093	0.059
Summer	0.154	0.120	0.070	0.121	0.108	0.092

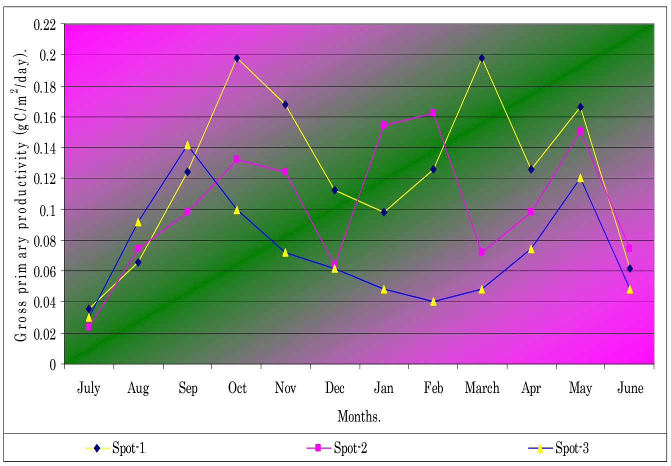

Figure-1
Monthly variations in gross primary productivity (GPP) at three spots in the Goriganga River during 2006-07

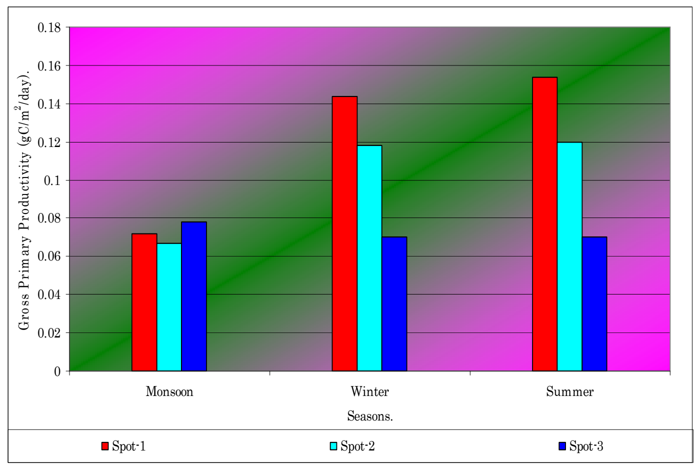

Figure-3
Seasonal variations in gross primary productivity (GPP) at three spots in the Goriganga River during 2006-07

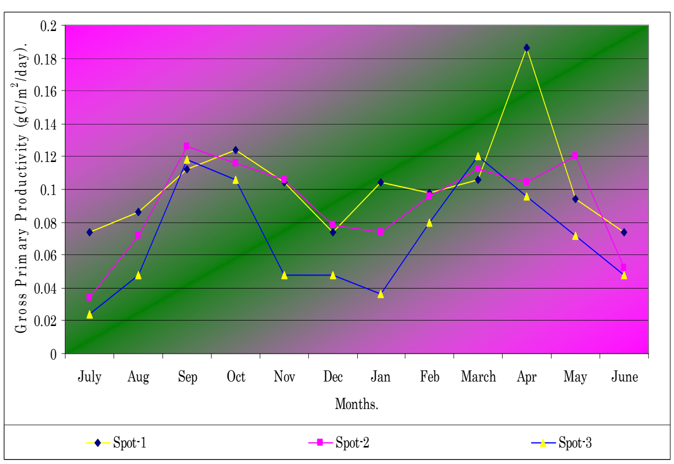

Figure-2
Monthly variations in gross primary productivity (GPP) at three spots in the Goriganga River during 2007-08

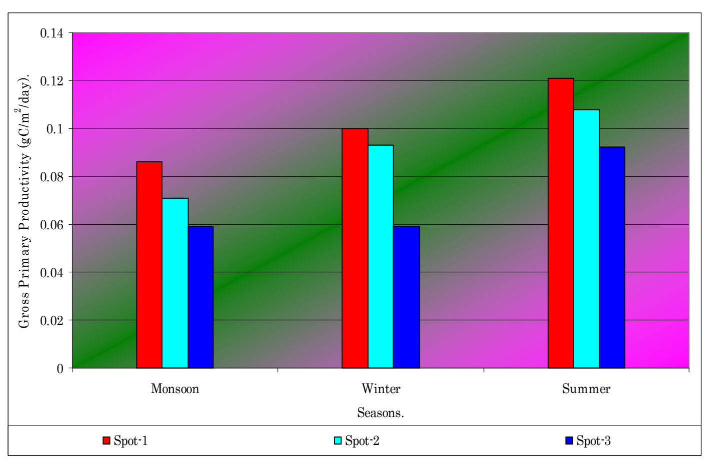

Figure-4
Seasonal variations in gross primary productivity (GPP) at three spots in the Goriganga River during 2006-07

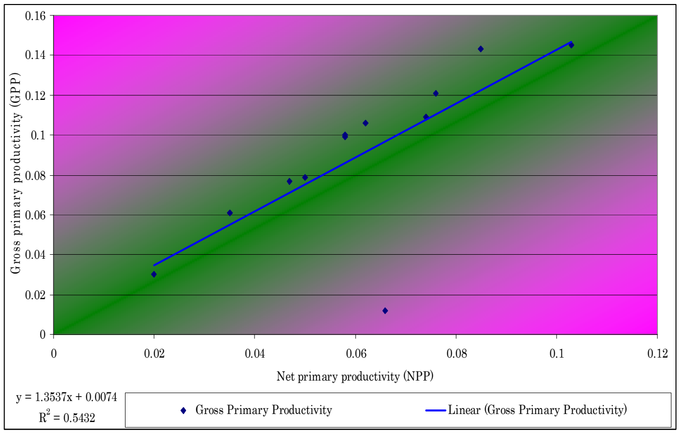

Figure-5
Correlation between gross primary productivity (GPP) and net primary productivity (NPP) in the Goriganga river during 2006-07

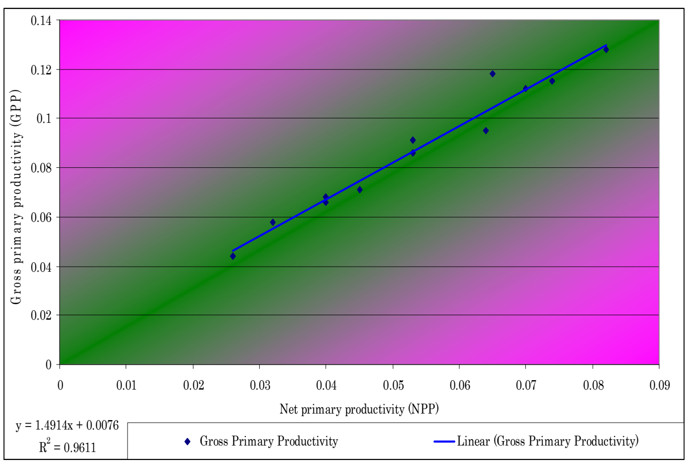

Figure-6
Correlation between gross primary productivity (GPP) and net primary productivity (NPP) in the Goriganga river during 2007-08 (Figure: 6).

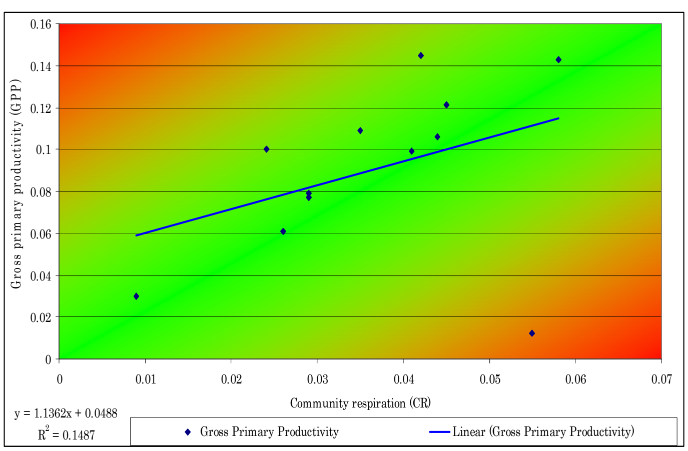

Figure-7
Correlation between gross primary productivity (GPP) and community respiration (CR) in the Goriganga river during 2006-07

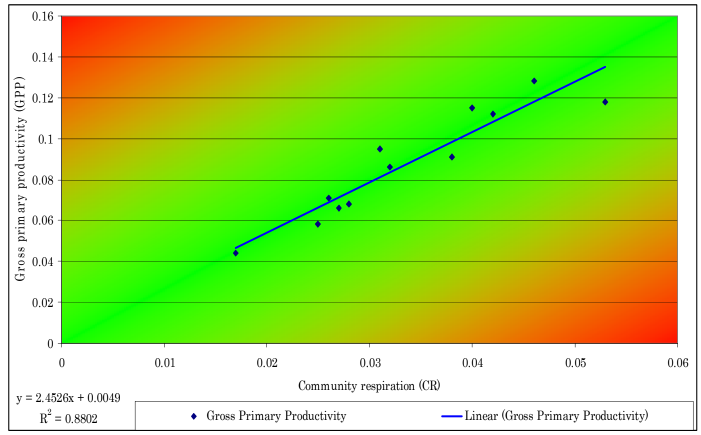

Figure-8
Correlation between gross primary productivity (GPP) and community respiration (CR) in the Goriganga river during 2007-08

The highest values of net primary productivity (NPP) were recorded as 0.124 gC/m^2/day at spot-1 in the month of March; 0.116 gC/m^2/day at spot-2 in the month of May and 0.072 gC/m^2/day in the month of May; and the lowest values 0.026 gC/m^2/day, 0.016 gC/m^2/day and 0.020 gC/m^2/day of net primary production were recorded in the month of July at spot-1, spot-2 and spot-3 respectively in first year table 3 and Figure 9. In the second year (2007-08), net primary productivity values fluctuated from 0.044 gC/m^2/day to 0.1 gC/m^2/day at spot-1, 0.024 gC/m^2/day to 0.076 gC/m^2/day at spot-2 and from 0.012 to 0.88 gC/m^2/day at spot-3 table 3. The highest values of net primary production was recorded as 0.1 gC/m^2/day at spot-1 in the month of April, 0.076 gC/m^2/day at spot-2 in the month of May and 0.088 gC/m^2/day at spot-3 in the month of March; and the lowest values 0.044 gC/m^2/day, 0.024 gC/m^2/day and 0.012 gC/m^2/day at spot-1, spot-2 and spot-3 respectively in the month of July during 2007-08 table 3 and figure 10. Net primary productivity values increases from August to November and February to March at spot-1; August to October and April to May at spot-2; and from August to October and April to May at spot-3 during first year table 3 and figure 9, whereas it increases from September to November and March to April at spot-1; August to October and March to May at spot-2; and August to October and February to March at spot-3 during second year in the present study table 3. The bimodal (two peaks) rhythms of net primary productivity have been recorded in March and November at Jauljibi in May and October at Baram and at Madkot during 2006-07 table 3 and Figure 9. While during second year, the two peaks (bimodal rhythms) of net primary productivity have been recorded in April and November at Jauljibi; in May and October at Baram and in March and October at Madkot during 2007-08 in the study table 3 and figure 10. Like gross primary productivity (GPP), net primary productivity (NPP) values also showed monthly, seasonal, yearly and altitudinal variations. Altitudinally, net primary productivity like gross productivity decreased from downstream to upstream table 3 and figure-9, 10. The annual mean values for net primary productivity were recorded as 0.079 gC/m^2/day, 0.062 gC/m^2/day and0.043 gC/m^2/day and 0.062 gC/m^2/day, 0.055 gC/m^2/day and 0.044 gC/m^2/day at Jauljibi, Baram and Madkot during first and second year, respectively table 3. It was observed that higher annual mean values of net primary productivity were recorded in first year than the second year in the study table 3. The highest seasonal mean values for net primary production was recorded in summer 0.104 gC/m^2/day at spot-1 and 0.077 gC/m^2/day at spot-2. While it was 0.045 gC/m^2/day in monsoon at spot-3 and the lowest seasonal mean values 0.040 gC/m^2/day of net primary productivity were recorded in monsoon at spot-1, Spot-2 and 0.042 gC/m^2/day in winter at spot-3 in first year table 4 and figure-11. During second year (2007-08), the highest seasonal mean values 0.085 gC/m^2/day, 0.071 gC/m^2/day and 0.070 gC/m^2/day of net primary productivity were recorded in summer and the lowest seasonal mean values 0.049 gC/m^2/day, 0.042 gC/m^2/day and 0.032 gC/m^2/day were recorded in monsoon at spot-1, spot-2 and spot-3, respectively in the study table 4 and figure-12. In general, there were summer and winter high values in net primary production and low values in monsoon season in both the years table 4 and figures-11, 12. It was also observed that net primary productivity (NPP) showed positive significant correlation with community respiration r = 0.755314 and r = 0.85249 during 2006-07 and 2007-08 respectively figure-13 and 14.

Community Respiration (CR): The monthly and seasonal community respiration values for three spots (Jauljibi, Baram and Madkot) during 2006-07 and 2007-08 are given in tables 5 and 6. The community respiration values ranged from 0.008 gC/m^2/day to 0.086 gC/m^2/day in first year and from 0.010 gC/m^2/day to 0.086 gC/m^2/day in second year in the study table 5 and figures-15 and 16. During first year (2006-07), the community respiration values fluctuated between 0.010 gC/m^2/day to 0.086 gC/m^2/day at Jauljibi, 0.008 gC/m^2/day to 0.062 at Baram and 0.010 gC/m^2/day to 0.068 gC/m^2/day at Madkot table 5 and figure-15. The highest values of community respiration were recorded as 0.086 gC/m^2/day at Jauljibi in the month of October; 0.062 gC/m^2/day at Baram in the months of January and February; and 0.068 gC/m^2/day at Madkot in the month of September table 5 and figure 15. The lowest values of community respiration were recorded as 0.010 gC/m^2/day, 0.008 gC/m^2/day and 0.010 gC/m^2/day at Jauljibi, Baram and Madkot respectively in the month of July during first year (2006-07) in the study table 5 and figure 15. During second year (2007-08), the community respiration values fluctuated between 0.030 gC/m^2/day to 0.086 gC/m^2/day at Jaulijibi; 0.010 gC/m^2/day to 0.060 gC/m^2/day at Baram and 0.012 gC/m^2/day to 0.050 gC/m^2/day at Madkot table 5.

Table-3
Monthly data of net primary productivity (NPP) at three spots in the Goriganga river during 2006-07 and 2007-08

Month	Net primary productivity (NPP) (gC/m^2/day)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)
July	0.026	0.016	0.020	0.044	0.024	0.012
Aug	0.038	0.044	0.062	0.044	0.052	0.024
Sept	0.068	0.056	0.074	0.062	0.066	0.068
Oct	0.112	0.076	0.068	0.074	0.074	0.076
Nov	0.118	0.068	0.042	0.068	0.068	0.024
Dec	0.076	0.038	0.036	0.048	0.048	0.024
Jan	0.060	0.092	0.024	0.068	0.048	0.020
Feb	0.100	0.100	0.022	0.062	0.048	0.050
Mar	0.124	0.038	0.024	0.062	0.062	0.088
Apr	0.070	0.056	0.048	0.100	0.074	0.072
May	0.122	0.116	0.072	0.068	0.076	0.048
Jun	0.034	0.048	0.024	0.048	0.026	0.024
Mean	0.079	0.062	0.043	0.062	0.055	0.044
S.D.	0.035	0.029	0.021	0.015	0.017	0.026

Table-4
Seasonal variations in net primary productivity (NPP) at three spots in the Goriganga river during 2006-07 and 2007-08

Seasons	Net Primary Productivity (NPP) (gC/m^2/day)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)
Monsoon	0.040	0.040	0.045	0.049	0.042	0.032
Winter	0.091	0.068	0.042	0.064	0.059	0.036
Summer	0.104	0.077	0.041	0.085	0.071	0.070

The highest values of community respiration were recorded as 0.086 $gC/m^2/day$ at Jauljibi in the month of April; 0.060 $gC/m^2/day$ at Baram in the month of September; and 0.050 $gC/m^2/day$ at Madkot in the months of September and October table 5 and Figure 16. The lowest values of community respiration were recorded as 0.030 $gC/m^2/day$, 0.010 $gC/m^2/day$ and 0.012 $gC/m^2/day$ at Jauljibi, Baram and Madkot, respectively in the month of July during second year (2007-08) table 5 and Figure 16. Similar to gross primary productivity (GPP) and net primary productivity (NPP), community respiration (CR) values also showed bimodal (two peaks) rhythms at different spots in the study table 5 and Figs 15 and 16. The bimodal (two peaks) rhythms of community respiration have been noticed in October and March at Jauljibi, in October / November and January / February at Baram and in September and May at Madkot in the first year (2006-07) table 5 and Figure 15, whereas, in the second year, the bimodal (two peaks) rhythms of community respiration have been observed in September / October and April at Jauljibi, in September and March at Baram and at Madkot table 5 and figure-16.

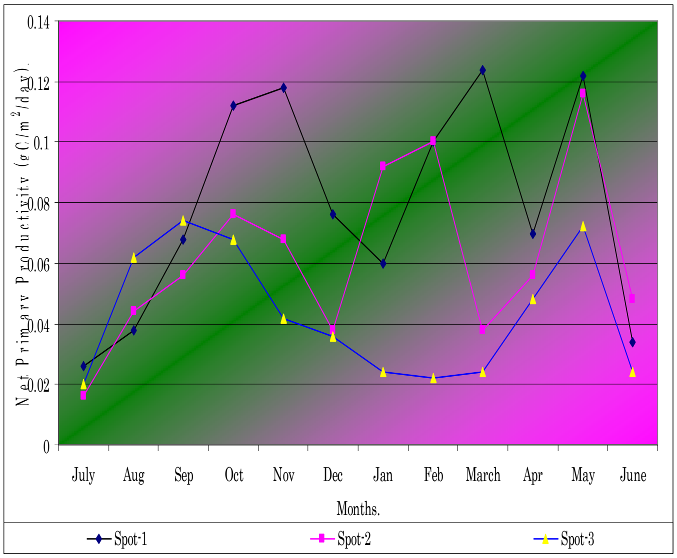

Figure-9
Monthly variations in net primary productivity (NPP) at three spots in the Goriganga river during 2006-07

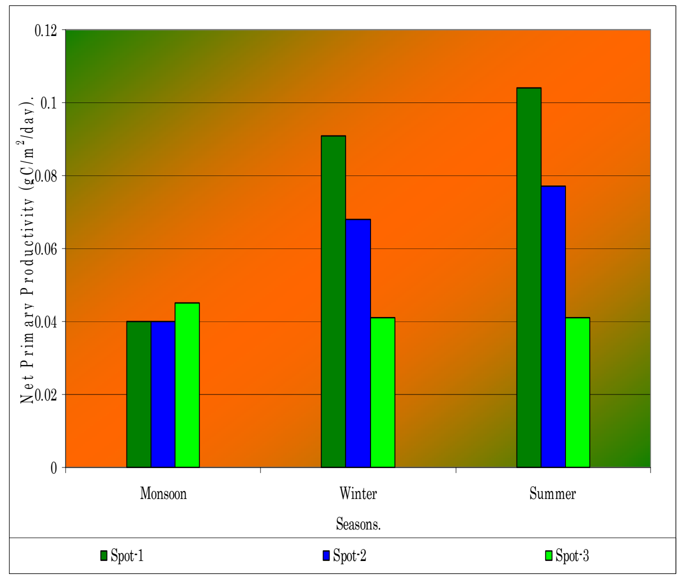

Figure-11
Seasonal variations in net primary productivity (NPP) at three spots in the Goriganga river during 2006-07

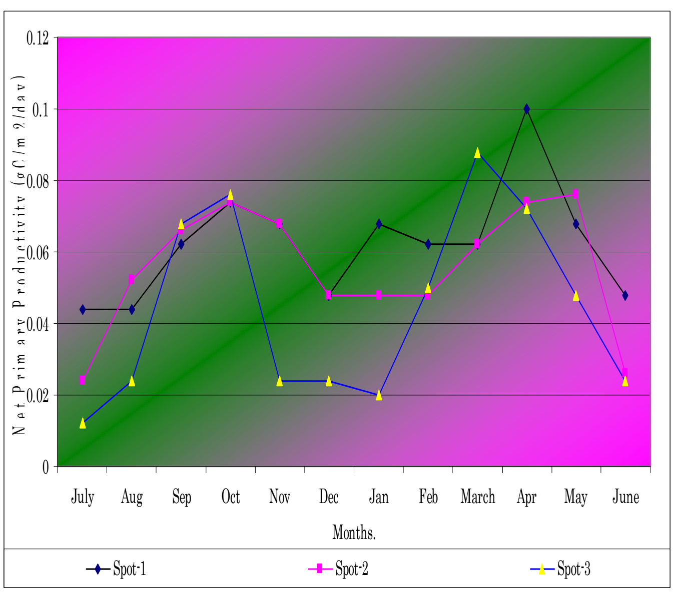

Figure-10
Monthly variations in net primary productivity (NPP) at three spots in the Goriganga river during 2007-08

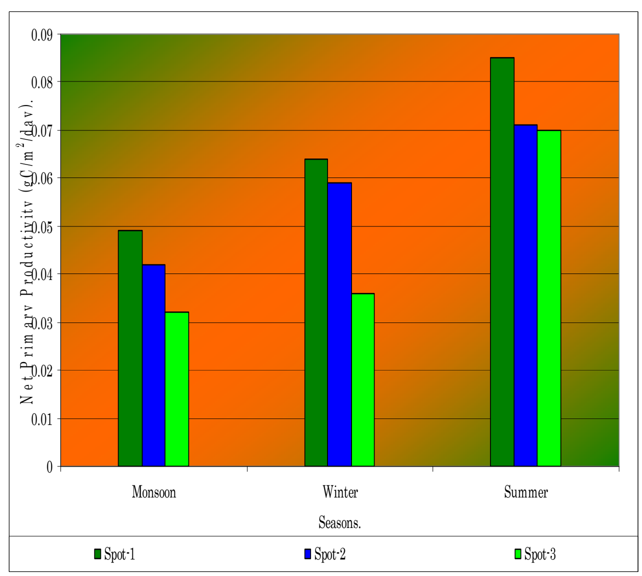

Figure-12
Seasonal variations in net primary productivity (NPP) at three spots in the Goriganga river during 2007-08

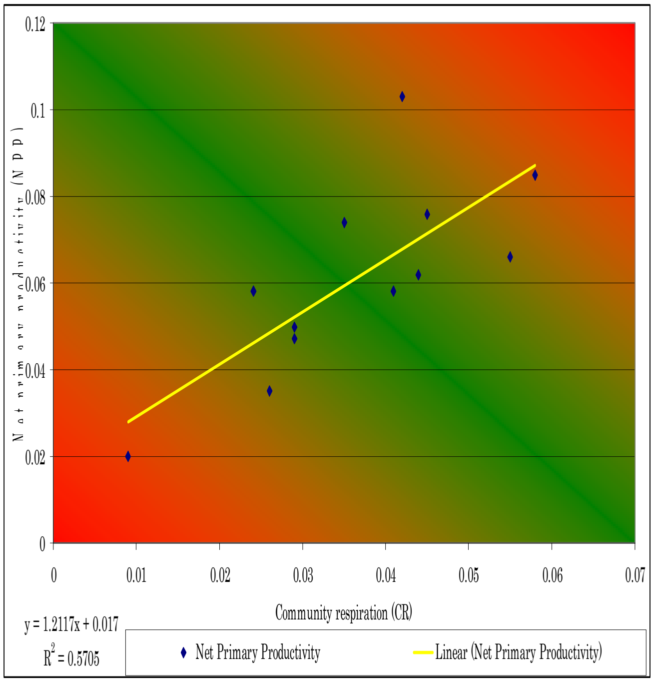

Figure-13
Correlation between net primary productivity (NPP) and community respiration (CR) in the Goriganga river during 2006-07

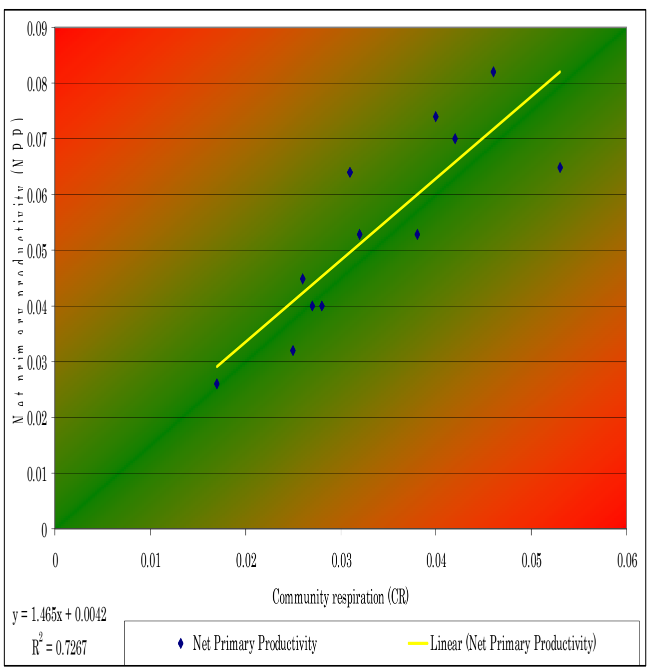

Figure-14
Correlation between net primary productivity (NPP) and community respiration (CR) in the Goriganga river during 2007-08

and altitudinal variation at different spots in the Goriganga river during 2006-07 and 2007-08 Tables 5, 6 and Figs 15 and 16. The highest annual mean values of community respiration were 0.044 gC/m^2/day, 0.039 gC/m^2/day and 0.030 gC/m^2/day and 0.040 gC/m^2/day, 0.035 gC/m^2/day and 0.026 gC/m^2/day at Jauljibi, Baram and Madkot during first and second year, respectively in the study table 5 and Figs 15 and 16. The highest seasonal mean values of community respiration were 0.052 gC/m^2/day at Jauljibi and 0.050 gC/m^2/day at Baram in winter seaon; and 0.033 gC/m^2/day at Madkot in monsoon season table 6.

The lowest seasonal mean values were 0.030 gC/m^2/day at Jauljibi, 0.026 gC/m^2/day at Baram in monsoon season and it was0.028 gC/m^2/day at Madkot in winter season during first year table 6 and Figure 17. In the second year (2007-08), the highest seasonal mean values 0.048 gC/m^2/day, 0.043 gC/m^2/day and 0.027 gC/m^2/day were recorded at Jauljibi, Baram and Madkot, respectively in summer season and the lowest seasonal mean values of community respiration 0.037 gC/m^2/day and 0.029 gC/m^2/day were recorded in monsoon at Jauljibi and Baram and 0.023 gC/m^2/day at Madkot in winter season in the present study table 6 and Fig18. Altitudinally, like gross primary productivity and net primary productivity, downstream community respiration values were higher than upstream (0.044 gC/m^2/day, 0.039 gC/m^2/day and 0.030 gC/m^2/day) in 2006-07 table 5. It is observed that the community respiration (CR) values were higher during 2006-07 (first year) than 2007-08 (second year) in the study table 5 and figsure-15 and 16.

Like gross primary productivity and net primary productivity, community respiration data also showed monthly, seasonal, yearly

Discussion: In the following paragraphs, an attempt is made to discuss the observations made on fluctuations in productivity {Gross Primary Productivity (GPP), Net Pri/mary Productivity (NPP) and Community Respiration (CR)}, prevailing in the Goriganga river of Kumaun Himalaya. From the forgoing account, it is clear that seasonal variations of water quality parameters of Goriganga river at different stations has a marked influence on the productivity, diversity and numerical abundance of plankton and aquatic insects, because different factors coupled with the biological production, interact with each other and thus affects the production.

The primary production of phytoplankton is an integrated manifestation of biotic and abiotic factors which have an important role in the trophic structure through its significant contribution of energy input in water bodies. Production in natural water is dependent on the incident radiation energy and the carbon supply with the nutrient and trace elements. The fluctuations of productivity values in Goriganga river at various spots in different months is well marked.

Table-5
Monthly data of Community Respiration (CR) at three spots in the Goriganga river during 2006-07 and 2007-08

Month	Community respiration (CR) ($gC/m^2/day$)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)
July	0.010	0.008	0.010	0.030	0.010	0.012
Aug	0.028	0.030	0.030	0.042	0.020	0.024
Sept	0.056	0.042 0.042	0.068	0.050	0.060	0.050
Oct	0.086	0.056	0.032	0.050	0.042	0.030
Nov	0.050	0.056	0.030	0.036	0.038	0.024
Dec	0.036	0.026	0.026	0.026	0.030	0.024
Jan	0.038	0.062	0.024	0.036	0.026	0.016
Feb	0.026	0.062	0.018	0.036	0.048	0.030
Mar	0.074	0.034	0.024	0.044	0.050	0.032
Apr	0.056	0.042	0.026	0.086	0.030	0.024
May	0.044	0.034	0.048	0.026	0.044	0.024
Jun	0.028	0.026	0.024	0.026	0.026	0.024
Mean	0.044	0.039	0.030	0.040	0.035	0.026
S.D.	0.021	0.016	0.014	0.016	0.014	0.009

Table-6
Seasonal variations in community respiration at three spots in the Goriganga river during 2006-07 and 2007-08

Seasons	Community Respiration (CR) ($gC/m^2/day$)					
	July -2006-June- 07			July-2007-June-2008		
	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)	Jauljibi-1 (Spot-1)	Baram-2 (Spot-2)	Madkot-3 (Spot-3)
Monsoon	0.030	0.026	0.033	0.037	0.029	0.027
Winter	0.052	0.050	0.028	0.037	0.034	0.023
Summer	0.050	0.043	0.029	0.048	0.043	0.027

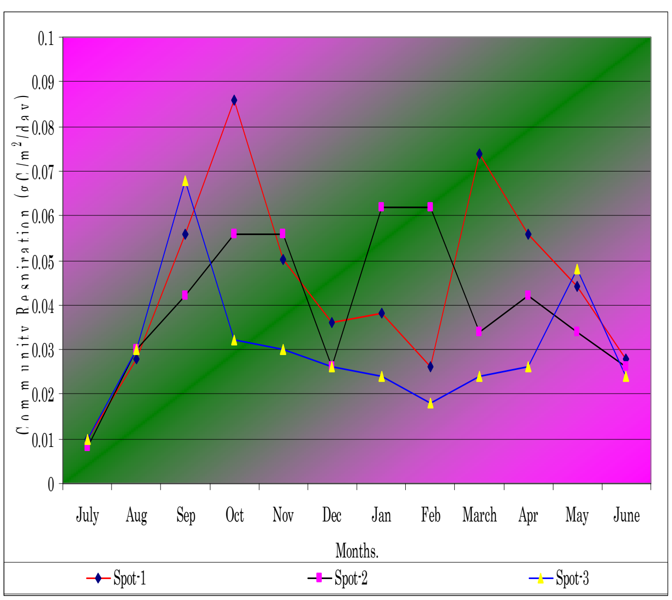

Figure-15
Monthly variations in community (CR) respiration at three spots in the Goriganga river during 2006-07

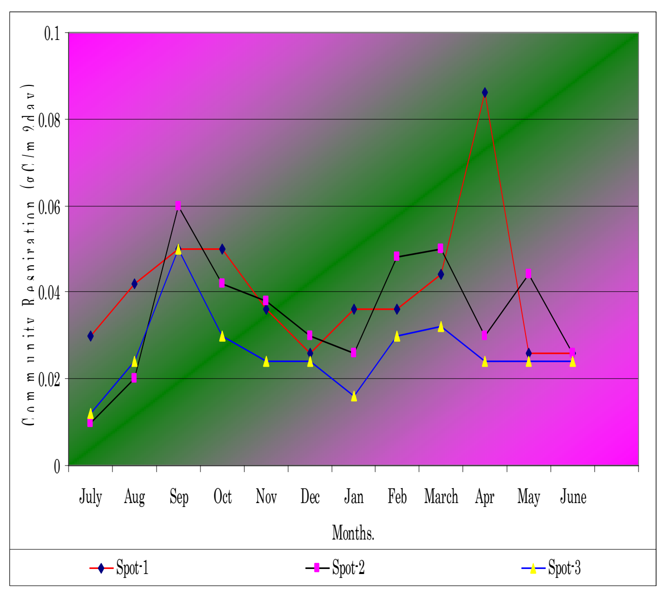

Figure-16
Monthly variations in community (CR) respiration at three spots in the Goriganga river during 2007-08

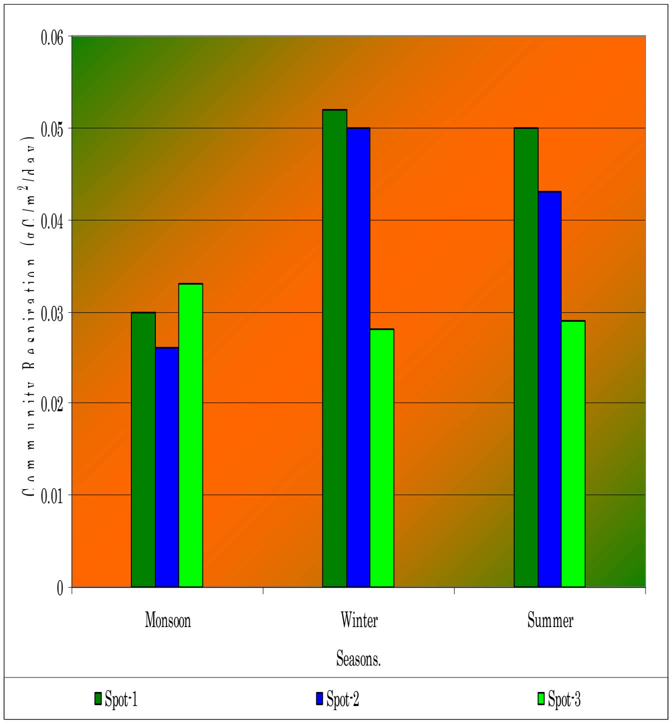

Figure-17
Seasonal variations in community respiration (CR) at three spots in the Goriganga river during 2006-07

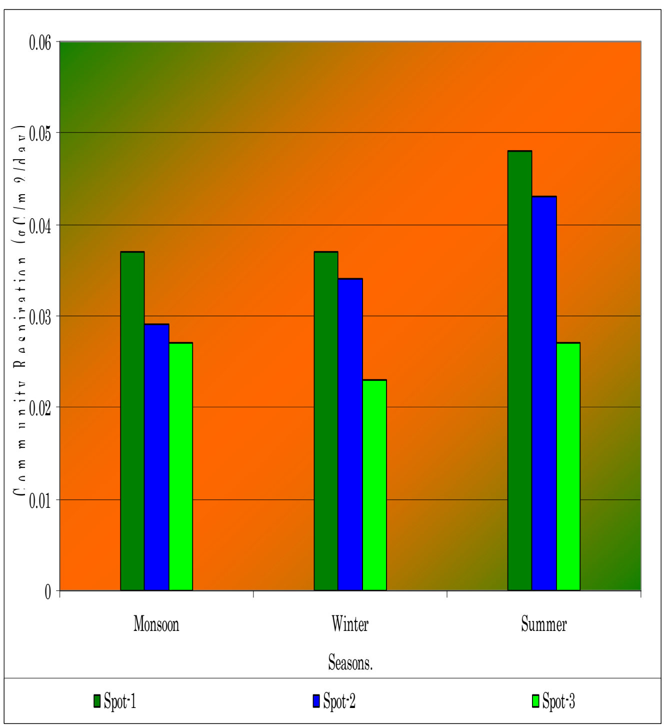

Figure-18
Seasonal variations in community respiration (CR) at three spots in the Goriganga river during during 2007-08

The data collected from different stations exhibit a bimodal profile with two peaks, one in October and other in March at spot-1, one in October and other in May at spot-2 and one in September and other in May at spot-3 during first year and one in October and other in April at spot-1, one in September and other in May at spot-2 and one in September and other in March at spot-3 during second year for gross primary productivity (GPP). For net primary productivity, two peaks were recorded as, one in November and other in March at spot-1 and one in October and other in May at spot-2 and spot-3 during first year and one in November and other in April at spot-1, one in October and other in May at spot-2 and one in October and other in March at spot-3 during second year.

While for community respiration, the recorded data exhibited bimodal profile with two peaks, one in October and other in March at spot-1, one in October, November and other in January, February at spot-2 and one in September and other in May at spot-3 during first year and one in September and onther in April at spot-1, one in September and ther in March at spot-2 and spot-3 during second year.

Bimodal profile (two peaks) values for primary production have also been reported by Basheer et.al.[38] and Mahar[39]. Gross primary productivity values ranged from 0.024 $gC/m^2/day$ to 0.198 $gC/m^2/day$, net primary productivity ranged from 0.012 $gC/m^2/day$ to 0.124 $gC/m^2/day$ and community respiration values ranged from 0.008 $gC/m^2/day$ to 0.086 $gC/m^2/day$ in the present study.

The forgoing results if compared with those of Joshi et.al.[40] for Ganga canal at Hardwar, who reported that the GPP value ranged between 23.6 $mgC/m^3/hr$ to 144.2 $mgC/m^3/hr$, NPP between 18.9 $mgC/m^3/hr$ to 126.2 $mgC/m^3/hr$ and CR value ranged from 22.0 $mgC/m^3/hr$ to 170.0 $mgC/m^3/hr$, the values for GPP, NPP and CR in the present study are far less and if compared with the studies made on productivity in river Ganga between Mirzapur to Ballia by Shukla et.al.[41], the values for GPP, NPP and CR are slightly less. Both GPP and NPP rates in lotic waters were far below the rates recorded from the lentic conditions. Baduni[42] and Pathani et.al.[43] also recorded low rates of productivity in Alaknanda river in Garhwal Himalaya and in the river Ramganga west in Kumaun Himalaya, respectively. It has been reported that high and low productivity values of water bodies might be due to high and low nutrient status of water.

Vollenwieder[44] classified the fresh water bodies on their trophic nature as oligotrophic (GPP- 0.065 $gC/m^2/day$ to 0.3 $gC/m^2/day$), mesotrophic (GPP- 0.25 $gC/m^2/day$ to 1.0 $gC/m^2/day$) and eutrophic (GPP- 1.0 $gC/m^2/day$ to 8.0 $gC/m^2/day$). The present data on GPP has indicated the oligotrophic nature of Goriganga river as per the classification of Vollenweider[44].

In aquatic ecosystems, the photosynthetic rates of phytoplankton vary in response to physical, chemical and biological factors.

The lower rates of productivity in the Goriganga river was due to the low water temperature, less phytoplanktonic growth and available nutrients. Although present study reveals that there were monthly, seasonally, yearly, altitudinally and spot wise variations in the productivity values.

Generally, higher values of primary production were recorded in summer, moderate in winter and low in monsoon, except at spot-3, where higher values of gross primary productivity and net primary productivity were recorded in monsoon and low in winter and summer during 2006-07, while highest values of community respiration during 2006-07 were recorded in winter at spot-1 and spot-2 and in monsoon at spot-2 whereas the lowest values were in monsoon at spot-1 and spot-2 and in winter at spot-3 in the study. High values of productivity during summer may be due to maximum hours of sunshine, temperature and nutrients available from the organic matter was also explained by Mukhopadhyay et.al.[45] in different water bodies of Santhal (Bihar). Nasar et.al.[46] reported that the highest value of productivity in April and the lowest in the November. Ali and Khan[47] have reported high values of production in spring and low in winter and summer. Dash et.al.[48] have reported high GPP values in winter and minimum in summer in the Hirakund reservoir, which is just reverse to the present findings.

These productivity variations may also be due to various interacting abiotic and biotic factors including sunlight and turbidity especially in high altitude rivers of Garhwal by Nautiyal[49], Singh et.al.[50] and in lotic waters of Darjeeling by Mukdopadhyay[51].

Water velocity is another important factor (limiting factor), which although has no direct impact on productivity, but indirectly influences the productivity through phytoplankton population. The high velocity of water during monsoon might be responsible for the low phytoplankton production. Statistically, productivity in Goriganga river was found to be directly correlated with water temperature and corroborated with the findings of several authors[52-54]. Goldman and Wetzel[55] have suggested that the temperature has the maximum impact on aquatic productivity.

The data on productivity in Goriganga river indicated that the concerned river is less productive and ologotrophic (nutrient poor and oxygen rich) in nature, as the photosynthetic rates always remained below the range of oligotrohpic catagory despite the absence of any point source of water pollution. The data on phytoplankton also confirmed the oligotrophic nature of Goriganga river.

Conclusion

Thus the fluctuations of productivity values in Goriganga river at various spots in different months is well marked. The data collected from different stations exhibit a bimodal profile with two peaks, one in October and other in March at spot-1, one in October and other in May at spot-2 and one in September and other in May at spot-3 during first year (2006-07) and one in October and other in April at spot-1, one in September and other in May at spot-2 and one in September and other in March at spot-3 during second year (2007-08) for gross primary productivity (GPP).

For net primary productivity, two peaks were recorded as, one in November and other in March at spot-1 and one in October and other in May at spot-2 and spot-3 during first year (2006-07) and one in November and other in April at spot-1, one in October and other in May at spot-2 and one in October and other in March at spot-3 during second year (2007-08). While for community respiration, the recorded data exhibited bimodal profile with two peaks, one in October and other in March at spot-1, one in October, November and other in January, February at spot-2 and one in September and other in May at spot-3 during first year (2006-07) and one in September and other in April at spot-1, one in September and other in March at spot-2 and spot-3 during second year (2007-08). The present data on GPP has indicated the oligotrophic nature of Goriganga river. Generally, higher values of primary production were recorded in summer, moderate in winter and low in monsoon, except at spot-3, where higher values of gross primary productivity and net primary productivity were recorded in monsoon and low in winter and summer during 2006-07, while highest values of community respiration during 200-607 were recorded in winter at spot-1 and spot-2 and in monsoon at spot-2 whereas the lowest values were in monsoon at spot-1 and spot-2 and in winter at spot-3 in the study.

At last but not least, the data on productivity in Goriganga river indicated that the concerned river is less productive and ologotrophic (nutrient poor and oxygen rich) in nature, as the photosynthetic rates always remained below the range of oligotrohpic catagory despite the absence of any point source of water pollution. The data on phytoplankton also confirmed the oligotrophic nature of Goriganga river.

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