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Primary productivity of Kharasrota river (India)

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Abstract : *The primary productivity of the river River Kharashrota (Orissa) has been analysed both spatially and seasonally. The maximum GPP was noted during summer season and minimum in rainy season at all the six stations. The annual average GPP varied from 0.075±0.009 gC.m^{-3}.h^{-1} to 0.938±0.103 gC.m^{-3}.h^{-1}.The NPP value varied from 0.012±0.001 gC.m^{-3}.h^{-1} to 0.832±0.081 gC.m^{-3}.h^{-1} and exhibited an increasing trend from the month of September to February. The community respiration (CR) ranged from 0.026±0.002 gC.m^{-3}.h^{-1} to 0.496±0.043 gC.m^{-3}.h^{-1} and exhibited a systematic seasonal pattern with maximum and minimum value during summer and winter respectively at all the stations. The correlation of NPP, GPP and CR with some of the physico-chemical parameters has also been established.*

Keywords: Primary productivity, Gross primary productivity, Net primary productivity, Community respiration, Kharashrota.

Introduction

The rate of production of organic matters per unit time is termed as productivity. Measurement of primary productivity gives information regarding the photosynthetic production of organic matter in an area per unit time and the functional aspects of ecosystem (Odum, 1971). The primary productivity of a water body is the manifestation of its biological production. It forms the basis of the ecosystem functioning. It plays an important role in any ecosystem as it makes the chemical energy and organic matters available to the entire biological community (Ahmed *et al.*, 2005). Production at each level can be distinguished further into gross production, i.e. the total amount of organic matters produced and net production or the amount of organic matter produced at a particular level. In favourable conditions, the organic matters produced and the net primary productivity has a positive value, but when conditions are unfavourable, the rate of net primary productivity may fall to zero or even become negative if respiratory losses exceed photosynthetic gains (Yeragi and Shaikh, 2003). The estimation of primary productivity is predicted on the relationship between oxygen evolution and carbon fixation. Primary productivity varies from stream to stream on the stretch of a river due to increase in oxygen demanding pollutants or photosynthetic inhibiting pollutants, particularly more in the downstream (Sahu *et al.,1995).* Most of the organic matters of an aquatic ecosystem are produced within the water by phytoplankton which is utilized by the consumer.

The area under study is river Kharasrota which originates from river Bramhani at Jenapur (20° 52' 4.82"N latitude and 86° 04' 21.45"E longitude) in the district of Jajpur and again joins with river Brahmani in Kendrapara district of Orissa. The Kharasrota river basin, located in Jajpur district of Orissa, drains an area of 1011 sq kms. The Kalinga Nagar industrial area,

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Chromite mines in the Sukinda valley as well as the Rourkela and Angul-Talcher industrial area are in the upper stretch of the study area. The catchment of the Kharasrota river is one of the richest chromite producing area in India (Som *et al.*, 1999). The drastic reduction in ichtyofaunal density and diversity along the various fishing centers of Kharasrota river calls for immediate analysis and intervention.

Materials and Methods

For primary productivity analysis, “Light and Dark bottle” method of Gaarder and Gran, (1927), as recommended by Vollenweider, (1969), was followed. Gaarder and Gran in 1927 first proposed the technique of using light and dark bottles and Winkler’s titration to measure the production and consumption of Oxygen.

Water samples were collected in triplicate in the middle of each month between 10.00 am to 12.00 noon. The samples in the first bottle were used immediately to determine the initial level of dissolved oxygen content following modified Winkler’s volumetric method (APHA, 1998). All O_2 values obtained in the present study were converted to Carbon values by multiplying with the factor 0.375 (Odum, 1956). The second bottle was painted with black color (dark bottle) to prevent light and hence serve as control to measure respiration. The third bottle (light) was treated as a test to measure the net production. These two bottles were incubated under water in the euphotic zone for a period of two hours by suspending it in water after which, dissolved Oxygen content of each bottle was estimated.

Gross primary production (GPP) and the net primary production (NPP) were calculated in the following manner:

Gross Primary Productivity (GPP) O_2 mg/L/h = (D1-Di)/h

Net Primary Productivity (NPP) O_2 mg/L/h = (D1-Dd)/h

Community Respiration O_2 mg/L/h =(Di-Dd)/h

Where:

D_1 = DO (mg/L/h) in the light bottle.

D_i = DO (mg/L/h) in the initial bottle.

D_d = DO (mg/L/h) in the dark bottle.

h = Duration of exposure in hours.

The hourly rate can be converted to daily rates by multiplying with duration of sunshine on that day. Oxygen values (mg/L) were converted to carbon value by applying the equation suggested by Thomas *et al.,* (1980).

Production (gC) = (O_2 (mg/L) x 0.375)/PQ

Where PQ = 1.25

PQ represents respiratory quotient = Respiration/Photosynthesis and a comprised value of 1.25 was used which represents metabolism of sugar, fat, and proteins. The value 0.375 represents a constant to convert Oxygen value to Carbon value (Thomas *et al.*, 1980).

Results and Discussion

The seasonal variation of gross primary productivity (GPP), net primary productivity (NPP) and community respiration (CR) of river Kharasrota is given in Table-1. The average and standard deviation of GPP, NPP and CR of 12 different months in six different stations are presented in Table-2, 3 and 4 respectively.

Seasonally, the minimum GPP was recorded in rainy season and maximum was recorded during summer season in all the six stations. Almost all the stations showed minimum value during August and maximum value during March. The variation reflects a well defined seasonal pattern.

The minimum value of NPP was recorded

Table 1. Seasonal GPP, NPP and Respiration (mean±SD) in gcm³/h at different stations of river Kharasrota during the study period.

	GPP			RES			NPP		
	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter
ST1	0.789± 0.138	0.184± 0.076	0.559± 0.131	0.228± 0.05	0.049± 0.02	0.036± 0.012	0.561± 0.169	0.086± 0.062	0.581± 0.232
ST2	0.581± 0.059	0.269± 0.05	0.481± 0.083	0.366± 0.043	0.187± 0.032	0.054± 0.016	0.165± 0.135	0.088± 0.06	0.294± 0.054
ST3	0.825± 0.077	0.211± 0.035	0.534± 0.159	0.209± 0.008	0.116± 0.021	0.051± 0.028	0.616± 0.068	0.087± 0.037	0.418± 0.141
ST4	0.639± 0.058	0.249± 0.092	0.495± 0.158	0.264± 0.035	0.187± 0.057	0.054± 0.022	0.375± 0.073	0.096± 0.109	0.309± 0.106
ST5	0.582± 0.058	0.257± 0.069	0.476± 0.114	0.363± 0.114	0.076± 0.013	0.051± 0.035	0.194± 0.178	0.093± 0.1	0.39± 0.125
ST6	0.606± 0.089	0.296± 0.072	0.465± 0.103	0.433± 0.072	0.199± 0.065	0.062± 0.054	0.121± 0.108	0.108± 0.113	0.266± 0.066

Table 2. Monthly Average GPP values in gcm³/h (mean±SD) at different stations during the period of the study.

Month	ST1	ST2	ST3	ST4	ST5	ST6
January	0.64±0.052	0.532±0.059	0.532±0.044	0.47±0.052	0.53±0.07	0.485±0.053
February	0.687±0.067	0.55±0.061	0.71±0.069	0.723±0.08	0.596±0.046	0.562±0.051
March	0.938±0.103	0.628±0.057	0.881±0.116	0.722±0.065	0.66±0.079	0.71±0.078
April	0.862±0.138	0.63±0.052	0.894±0.102	0.63±0.052	0.532±0.064	0.633±0.057
May	0.724±0.065	0.51±0.049	0.791±0.071	0.612±0.059	0.59±0.055	0.584±0.077
June	0.63±0.052	0.556±0.073	0.732±0.081	0.59±0.07	0.545±0.048	0.498±0.045
Jully	0.211±0.02	0.225±0.025	0.259±0.023	0.191±0.016	0.215±0.019	0.286±0.034
August	0.198±0.026	0.24±0.022	0.176±0.023	0.181±0.021	0.194±0.022	0.22±0.024
September	0.075±0.009	0.274±0.022	0.198±0.023	0.244±0.027	0.271±0.027	0.287±0.026
October	0.251±0.028	0.337±0.04	0.213±0.023	0.38±0.034	0.348±0.024	0.393±0.032
November	0.396±0.063	0.365±0.04	0.325±0.052	0.366±0.048	0.332±0.02	0.492±0.043
December	0.512±0.046	0.477±0.076	0.57±0.063	0.421±0.05	0.446±0.033	0.32±0.038

Table 3. Monthly Average NPP values in gcm³/h (mean±SD) at different stations during the period of the study.

Month	ST1	ST2	ST3	ST4	ST5	ST6
January	0.706±0.058	0.32±0.035	0.425±0.039	0.263±0.029	0.467±0.062	0.283±0.031
February	0.832±0.081	0.335±0.037	0.564±0.052	0.465±0.051	0.502±0.039	0.272±0.024
March	0.762±0.069	0.226±0.027	0.667±0.065	0.48±0.047	0.45±0.05	0.268±0.022
April	0.598±0.046	0.326±0.036	0.677±0.061	0.314±0.035	0.177±0.02	0.137±0.016
May	0.53±0.058	0.041±0.003	0.587±0.057	0.366±0.036	0.084±0.008	0.042±0.003
June	0.354±0.042	0.068±0.007	0.533±0.059	0.34±0.037	0.065±0.006	0.038±0.005
July	0.109±0.008	0.096±0.013	0.107±0.008	0.062±0.006	0.063±0.005	0.079±0.009
August	0.049±0.005	0.047±0.005	0.079±0.007	0.012±0.001	0.028±0.003	0.041±0.003
September	0.024±0.003	0.039±0.003	0.039±0.005	0.052±0.006	0.038±0.004	0.037±0.004
October	0.162±0.015	0.17±0.014	0.123±0.011	0.256±0.03	0.241±0.02	0.275±0.03
November	0.317±0.038	0.215±0.026	0.226±0.014	0.234±0.02	0.223±0.019	0.332±0.037
December	0.469±0.042	0.305±0.049	0.458±0.044	0.272±0.032	0.369±0.028	0.175±0.021

Table 4. Monthly Average Community Respiration values in gcm^3/h (mean±SD) at different stations during the period of the study.

Month	ST1	ST2	ST3	ST4	ST5	ST6
January	0.034±0.003	0.041±0.005	0.036±0.003	0.043±0.005	0.032±0.004	0.03±0.003
February	0.031±0.003	0.054±0.006	0.041±0.004	0.036±0.004	0.027±0.002	0.027±0.002
March	0.176±0.016	0.402±0.033	0.214±0.021	0.242±0.022	0.21±0.025	0.442±0.036
April	0.264±0.042	0.304±0.033	0.217±0.024	0.316±0.026	0.355±0.043	0.496±0.043
May	0.194±0.021	0.369±0.03	0.204±0.02	0.246±0.024	0.406±0.038	0.462±0.035
June	0.276±0.033	0.388±0.043	0.199±0.022	0.25±0.029	0.48±0.042	0.33±0.044
July	0.079±0.006	0.15±0.02	0.099±0.008	0.132±0.011	0.069±0.006	0.16±0.012
August	0.043±0.005	0.172±0.019	0.112±0.01	0.149±0.018	0.077±0.009	0.145±0.016
September	0.034±0.004	0.212±0.017	0.107±0.013	0.207±0.023	0.063±0.006	0.202±0.018
October	0.04±0.004	0.215±0.018	0.146±0.014	0.258±0.03	0.094±0.008	0.29±0.034
November	0.053±0.006	0.077±0.009	0.092±0.009	0.085±0.007	0.102±0.009	0.141±0.016
December	0.026±0.002	0.045±0.007	0.033±0.004	0.05±0.006	0.044±0.003	0.051±0.006

Table 5. Total and seasonal ratio between different productivity parameters of river Kharasrota during the study period.

	Total			Seasonal								
	NPP:GPP	NPP:CR	CR % of GPP	NPP:GPP			NPP:CR			CR % of GPP		
				S	R	W	S	R	W	S	R	W
ST1	0.80	3.93	20.41	0.71	0.47	1.04	2.46	1.76	16.14	28.90	26.63	6.44
ST2	0.41	0.90	45.63	0.28	0.33	0.61	0.45	0.47	5.44	62.99	69.52	11.23
ST3	0.71	2.99	23.88	0.75	0.41	0.78	2.95	0.75	8.20	25.33	54.98	9.55
ST4	0.56	1.55	36.42	0.59	0.39	0.62	1.42	0.51	5.72	41.32	75.10	0.91
ST5	0.52	1.38	37.25	0.33	0.36	0.82	0.53	1.22	7.65	62.37	29.57	0.71
ST6	0.36	0.71	50.76	0.20	0.37	0.57	0.28	0.54	4.29	71.45	67.23	3.33

during rainy season for all the stations but the maximum value was associated with summer in station-III and IV and winter in rest of the stations. No particular trend was observed in case of seasonal variation of NPP. On comparison of the monthly variations, an increasing trend was found from the month of September to February.

Decreased value of NPP and GPP during the rainy season might be due to the reason that high suspended solids in the flood water restrict light penetration into the water and thereby results in less photosynthetic activities and productivity. At the same time the phenomenon of organic matter entering the riverine system, through surface run-off, causing increased demand of oxygen for the oxidation of allochthonous organic matter cannot be ruled out.

The higher values of GPP and NPP during the summer season may be due to penetration of more light intensity which facilitates higher rate of photosynthesis and ultimately the productivity of the riverine system

The community respiration (CR) exhibited a systematic seasonal pattern with a maximum value during summer and minimum value during winter for all the six stations. A higher community respiration value during summer is possibly due to increased water temperature which stimulates the growth of microbial

Table 6. Paired Samples Correlations between GPP, NPP and CR with other water quality parametes of river Kharasrota during the study period.

		Summer		Rainy		Winter	
Variables	**N**	**Correlation**	**Sig.**	**Correlation**	**Sig.**	**Correlation**	**Sig.**
GPP, CR	24	-0.619	0.001	0.659	0.000	-0.540	0.006
GPP, NPP	24	0.919	0.000	0.762	0.000	0.812	0.000
GPP, WT	24	-0.378	0.069	-0.322	0.125	-0.499	0.013
GPP, pH	24	-0.264	0.213	-0.399	0.054	0.400	0.053
GPP, EC	24	-0.407	0.048	-0.266	0.209	0.249	0.241
GPP, Transp	24	-0.469	0.021	0.633	0.001	0.391	0.059
GPP, Alkalinity	24	-0.272	0.199	0.457	0.025	-0.482	0.017
GPP, Hardness	24	-0.291	0.167	0.412	0.045	-0.077	0.722
GPP, DO	24	-0.018	0.935	0.299	0.156	-0.105	0.624
GPP, BOD	24	0.428	0.037	-0.029	0.894	0.175	0.413
GPP, NO3	24	-0.162	0.450	0.204	0.339	-0.328	0.118
GPP, PO4	24	-0.179	0.402	-0.174	0.415	-0.120	0.576
GPP, NH4	24	0.121	0.574	0.072	0.738	-0.011	0.960
NPP, WT	24	-0.314	0.135	-0.469	0.021	-0.468	0.021
NPP, pH	24	-0.152	0.479	-0.385	0.063	0.099	0.645
NPP, EC	24	-0.289	0.170	-0.355	0.089	0.097	0.652
NPP, Transp	24	-0.390	0.060	0.717	0.000	0.167	0.437
NPP, Alkalinity	24	-0.257	0.225	0.657	0.000	-0.219	0.305
NPP, Hardness	24	-0.261	0.218	0.636	0.001	0.069	0.749
NPP, DO	24	0.132	0.539	0.429	0.037	-0.239	0.260
NPP, BOD	24	0.549	0.005	-0.058	0.786	0.069	0.748
NPP, BOD	24	0.549	0.005	-0.058	0.786	0.069	0.748
NPP, NO3	24	-0.051	0.812	0.108	0.616	-0.191	0.372
NPP, PO4	24	-0.207	0.331	-0.160	0.456	-0.229	0.282
NPP, NH4	24	-0.081	0.706	-0.009	0.965	-0.159	0.457
CR, WT	24	0.120	0.577	-0.124	0.564	0.525	0.008
CR, pH	24	-0.113	0.600	-0.337	0.107	-0.440	0.031
CR, EC	24	-0.013	0.950	0.061	0.775	-0.131	0.542
CR, Transp	24	0.163	0.448	0.455	0.025	-0.145	0.500
CR, Alkalinity	24	0.098	0.648	0.193	0.367	0.400	0.053
CR, Hardness	24	0.087	0.686	0.176	0.412	-0.042	0.844
CR, DO	24	-0.278	0.188	0.099	0.644	-0.100	0.642
CR, BOD	24	-0.591	0.002	-0.234	0.270	-0.082	0.705
CR, NO3	24	0.018	0.935	-0.165	0.442	0.673	0.000
CR, PO4	24	0.166	0.438	-0.192	0.370	0.267	0.206
CR, NH4	24	0.245	0.249	-0.050	0.818	0.049	0.821

CR = Community Respiration; WT = Water Temperature; Trnsp = Transparency; N=No of Observations population which in turn utilizes more oxygen for their metabolic activities. The decreased respiration rate during winter was linked with low water temperature and reduced light which affects the rate of photosynthetic efficiency (Nasar and Datta Munshi, 1975; Datta *et al.*,1984; Ahmad and Singh, 1987).

The ratio of net and gross primary production is important for the evaluation of the amount of gross production available to the consumer (Singh and Singh, 1999). Table-5 represents the ratio between the average and seasonal values of NPP, GPP and CR. The GPP-NPP as well as NPP-CR ratio was highest at station-I during winter and lowest at station-VI during summer season while the CR percentage of GPP was found to be highest at station-IV (75.10) during rainy season and lowest at Station-I (6.44) during winter season.

The NPP:CR of value >1 at all the stations during winter could be attributed to clarity of water as well as suitable temperature which favours abundance of phytoplankton and more photosynthetic activities. During the rainy season, this ratio was <1 for most of the stations, which could be on account of less penetration of light into the water due to increased suspended particles resulting in lesser photosynthetic activity and thereby decrease in productivity. At the same time, increase in community respiration, due to the flow of organic detritus along with flood water, cannot be ruled out.

Higher production is not governed by a single factor as stated by Singh and Singh, (1999). There are several environmental factors acting simultaneously which must be taken into consideration while evaluating the production capacity of an aquatic ecosystem. There are some physico chemical and biological factors which control the rate of production in a river ecosystem. The paired sampled correlations among GPP, NPP and CR with other water quality parameters were carried out and the results along with the significance levels are represented in Table-6. The paired correlations between the variables having significant levels less than 0.05 were considered for discussion.

During summer, a strong positive correlation between GPP and NPP ($r=0.919$, $p<0.001$) demonstrated that high GPP is responsible for high NPP. A negative correlation between GPP and EC ($r=-0.407$, $p=0.048$) and GPP and transparency ($r=-0,469$, $p=0,021$) was established. The above findings are well matched with that of Ahmed *et al*., (2005) where they reported a moderate correlation between EC and GPP and NPP. A positive relationship between GPP and BOD ($r=0,428$, $p=0,037$) and NPP with BOD ($r=0,549$, $p=0,005$) indirectly demonstrates that the growth of phytoplankton and their increased productivity is due to organic wastes containing high nutrient values. In this season, BOD plays a major role in controlling GPP, NPP and CR.

During the rainy season positive relationships between GPP with CR ($r=0.659$, $p<0.001$) and GPP with NPP ($r=0.762$ $p<0.001$) were found. High alkalinity and hardness are favourable for increase in GPP and NPP during rainy season. The findings of Goldman and Wetzel (1963), and Singh (1995), support the above finding. Positive correlation between alkalinity and GPP, during rainy season, was also reported by Datta *et al.*,(1984).

During winter a negative relationship between GPP and CR ($r= -0.540$, $p=0.006$) and GPP with water temperature ($r= -0.499$, $p=0.013$) was noted in the current study. An inverse relationship between GPP and alkalinity and NPP with water temperature was recorded. Nitrate being the most essential nutrient for the growth of aquatic organisms supports the positive relation between CR and nitrate during this season.

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