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Spatial Variation in Primary Productivity of River Damodar at Jharia (Jharkhand) and Raniganj (West Bengal), India

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ABSTRACT

In the present study 16 sampling stations were selected in River Damodar at Jharia and Raniganj. Primary productivity of water was determined by light and dark bottle method. Seasonal variations of gross primary productivity (GPP) net primary productivity (NPP) were determined. Spatial variations in productivity level and dissimilarity coefficient were determined by using chord distance for different seasons. Regression model was determined to estimate role of major phytoplankton groups for the production. Cluster analysis was done for placing similar or statistically related stations into one group.

INTRODUCTION

The factors influencing the abundance and diversity of rivers can be divided into physical, chemical, biological and geographical. The water bodies are continuously subjected to a dynamic state of change. The dynamic balance in the aquatic systems is upset by human activities. Damodar river basin is known for its coal deposits and commonly referred as the storehouse of Indian coal. The presence of active and abundant coal mines, overburden dumps, thermal power plants, coal washeries, coking coal plants and other coal based industries poses serious threats to the quality of available water resources of Damodar river. Coal mining wastes constitute not only an immediate and very serious danger but also cause a long-term disaster to the aquatic ecosystems.

This study endeavours to analyse the upper and downreaches of the Damodar river water by chemical means and to correlate the results with an assay for primary productivity. Specific objectives are to study spatial pattern of variation of different important planktonic groups with the primary productivity of river water. Various workers have studied different aspects of primary productivity for Indian waters (Nasar 1980, Singh 1986, Kumar 1999, Shukla & Pawer 2001), a significant impact of coal mining effluents on primary productivity has also been reported by Kumar (1999) and Saha (2004), but no attempt has yet been made on impact of coal mining on the planktonic productivity of Damodar river in such an elaborate way.

MATERIALS AND METHODS

Damodar river basin lies between latitude 22°45'N to 29°30'N and longitude 84°45'E to 88°30'E covering a length of about 538 km.

Six sampling stations (J_1, J_2, J_3, J_4, J_5, J_6) were selected at Jharia region of Jharkhand state, and 10 (R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{10}) sampling stations at Raniganj area of West Bengal. So a total of 16 sampling stations (SA) covering 10 km in Jharia and 12 km in Raniganj were studied. Jharia

coalfield is 450 km^2 and Raniganj coalfield has an area of about 1550 km^2.

Monthly samples were collected from December 2005 to November 2006 from different stations. Plankton samples were collected by filtering 50 litres of water through plankton net made up of No. 20 bolting silk cloth (mesh size = 0.076 mm) and a total of 50 mL was collected for each sample. For long term preservation, a few drops of Lugol's iodine solution was added. For phytoplankton counting, Lackey's drop method was used. In case of colonies, one colony was considered as one unit. The calculated average values of five samples from each sampling station were pooled for monthly data for each station. From monthly data seasonal average was calculated for each station.

For the study of primary productivity, conventional light and dark bottle method was employed. Productivity data were converted in terms of carbon using conversion factor of 0.375, and values were expressed as mgCm^{-3}/6 hourly (Trivedy & Goel 1990). Chord distance was calculated by the following formula.

$$\text{Chord distance: } CRD_{jk} = \sqrt{2(1 - Ccos_{jk})}$$

$$\text{Chord cosine, } Ccos_{jk} = \frac{\sum_{i=1}^{S} (X_{ij}X_{ik})}{\sqrt{\sum_{i}^{S} X^2_{ij} \sum X^2_{ik}}}$$

X_{ij} represents the abundance of ith parameter in the jth sampling area or sampling unit, and chord distance (CRD) have an upper limit of only $\sqrt{2} = 1.41$.

RESULTS AND DISCUSSION

The occurrence of phytoplankton groups in percent at different stations were estimated. The average NPP/GPP ratio during winter was maximum i.e., 0.80 in the study zone of Damodar river. In the summer the ratio was 0.7. The average minimum value of NPP/GPP was in the rainy season (0.69),

Table 1: The multiple regression model for GPP at different areas in the river in different seasons.

Monsoon:	
GPP = 90.24 + –0.093 (Chloro) + –0.434 (Bacil) + –0.074 (Cyano)	at Jharia
GPP = –5903.49 + 59.527 (Chloro) + 60.737 (Bacil) + 58.715 (Cyano)	at Raniganj
Winter:	
GPP = –3665.03 + 37.512 (Chloro) + 38.051 (Bacil) + 36.838 (Cyano)	at Jharia
GPP = –7522.48 + 75.861 (Chloro) + 75.793 (Bacil) + 76.181 (Cyano)	at Raniganj
Summer:	
GPP = –93.25 + 21.186 (Chloro) + 2.029 (Bacil) + 1.453 (Cyano)	at Jharia
GPP = 14.80 + –0.144 (Chloro) + 0.244 (Bacil) + 3.425 (Cyano)	at Raniganj

Table 2: Percentage contribution of different plankton groups in the river water for GPP.

Group	% contribution of Jharia region			% contribution of Raniganj region		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
	$R^2 = 0.652$	$R^2 = 0.353$	$R^2 = 0.499$	$R^2 = 0.646$	$R^2 = 0.137$	$R^2 = 0.616$
Chlorophyceae	18.6	33.7	34	46.5	49.8	2.2
Bacillariophyceae	80.3	17.4	25.3	50.6	24.9	2.6
Cyanophyceae	1.1	48.9	40.7	3	25.3	95.2

which is probably due to high concentration of suspended and insoluble material in the water causing reduction of transparency of water (Fig.1).

Considering plankton groups, Chlorophyceae, Bacillariophyceae and Cyanophyceae as composite environmental factors, both for Jharia and Raniganj, multiple linear regression equations for GPP have been deduced in different seasons. The values of coefficient of multiple determination (R^2) are given in Table 1 and 2 along with percent contribution of various algal groups to GPP in different seasons. Seasonal variations in the primary productivity are very common for Indian waters. Many workers have shown maximum values of GPP during summer, and minimum values during winter. In the present study average maximum value was also reported in the summer months, but the minimum average value in monsoon.

In the study, the coefficient of determination between GPP and phytoplankton groups was deduced. At Jharia region values were 0.652 (F ratio = 1.246), 0.353 (F ratio = 0.364) and 0.499 (F ratio = 0.664) in monsoon, winter and summer seasons respectively. This indicates that nearly 35% to 65% of variations in GPP in the Jharia region of Damodar river is due to variations of phytoplankton productivity. Similarly for Damodar river in Raniganj area the coefficient of multiple determination (R^2) between GPP and phytoplankton groups was 0.646 (F ratio = 3.653), 0.137 (F ratio = 0.317) and 0.616 (F ratio = 3.203) in monsoon, winter and summer seasons respectively, i.e., about 13% to 64% of GPP variation in the Raniganj area is due to the variations of the studied plankton groups.

From the Table 2, it can be said that during monsoon GPP of Damodar river was contributed by the Bacillariophyceae, in winter it is difficult to ascertain the major contributory phytoplankton group for GPP, but in summer in both the regions the group Cyanophyceae was the maximum contributor in terms of percentage for the GPP.

If we assume that plankton groups are not independent, then regression tests are also not independent, so a multidirectional test is required. Distance coefficient applying chord distance measuring dissimilarity values on the basis of GPP and NPP abundance data put greater importance on the relative proportion of GPP and NPP at the sampling areas and correspondingly less important on their absolute quantities (Pielou 1984). In the present study dissimilarity values between sampling

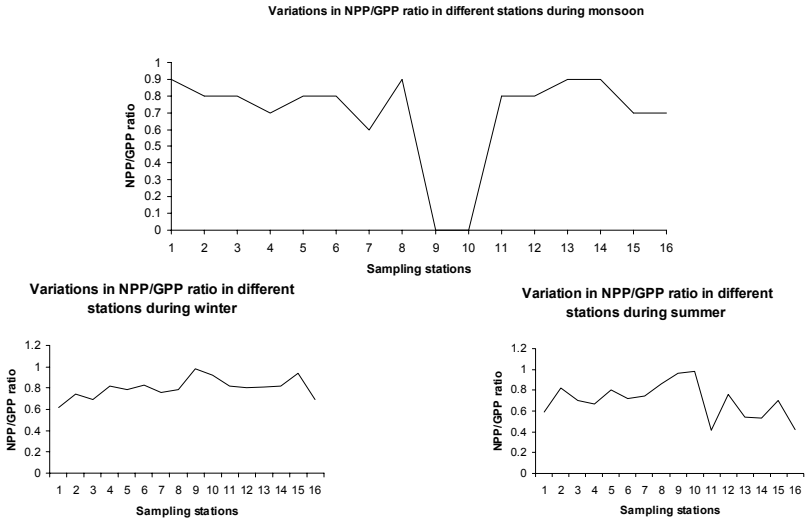

Fig.1. Variations in NPP/GPP ratio in different stations during different seasons.

Table 3a: Chord distances among the sampling areas in matrix form in monsoon. Maximum values of chord distance is $\sqrt{2}$ = 1.41 for maximum dissimilarity.

S.No.	1 J1	2 J2	3 J3	4 J4	5 J5	6 J6	7 R1	8 R2	9 R3	10 R4	11 R5	12 R6	13 R7	14 R8	15 R9	16 R10
J1																
J2	0.06															
J3	0.07	0.02														
J4	0.08	0.02	0													
J5	0.05	0.01	0.03	0.03												
J6	0.04	0.02	0.03	0.04	0.01											
R1	0.14	0.08	0.07	0.06	0.09	0.1										
R2	0.02	0.08	0.1	0.1	0.07	0.06	0.16									
R3	0.73	0.68	0.66	0.66	0.69	0.69	0.6	0.75								
R4	0.73	0.68	0.66	0.66	0.69	0.69	0.6	0.75	0							
R5	0.03	0.02	0.04	0.05	0.02	0.1	0.11	0.05	0.7	0.7						
R6	0.04	0.02	0.04	0.04	0.01	0	0.1	0.06	0.7	0.7	0.01					
R7	0.01	0.06	0.08	0.08	0.05	0.05	0.15	0.02	0.74	0.74	0.04	0.04				
R8	0.03	0.08	0.1	0.11	0.08	0.07	0.17	0.01	0.76	0.76	0.06	0.06	0.02			
R9	0.12	0.07	0.05	0.05	0.08	0.08	0.02	0.15	0.61	0.61	0.09	0.09	0.13	0.15		
R10	0.13	0.08	0.06	0.05	0.08	0.09	0.01	0.15	0.61	0.61	0.1	0.09	0.14	0.16	0.01	

Table 3b: Clustering of 16 sampling areas (SA) of Damodar river by chord distance and flexible strategy with β= –0.25 during monsoon.

Cluster cycle	No. groups	Cluster level	Ref SA	SAs in the group
1	15	0	9	10
2	14	0	6	12
3	13	0	3	4
4	12	0.01	8	14
5	11	0.01	1	13
6	10	0.01	15	16
7	9	0.01	2	5
8	8	0.01	6	11,12
9	7	0.01	7	15,16
10	6	0.02	2	5,6,11,12
11	5	0.03	1	8,13,14
12	4	0.06	2	4,4,5,6,11,12
13	3	0.17	2	3,4,5,6,7,11,12,15,16
14	2	0.26	1	2,3,4,5,6,7,8,11,12,13,14,15,16
15	1	1.82	1	2,3,4,5,6,7,8, 9,10,11,12,13,14,15,16
16	1	1.82	1	All SAs form one group

areas in different seasons are given in the Tables 3a, 4a, 5a. Accordingly, lesser the dissimilarity value, similarity is more. During monsoon, stations R6 and J6 show more similarity in terms of productivity values. In winter J4 and R8 have maximum similarity, and in summer R8 and R7. R9 and J3 have maximum similarity in productivity values. We also can say that in most cases adjacent water bodies have more similarities for productivity values.

These similarity results were further used for cluster-analysis and the results with flexible strategy ($\beta = -0.25$) are given in the Tables 3b, 4b and 5b.

During monsoon, stations 9, 10, 6, 12, 3 and 4 form a cluster distinct from the remaining ten stations. During winter 4, 14 form a distinct cluster, but during summer 3, 15, 13, 14 form a distinct cluster. The clusters show spatial variation and similarity pattern of primary productivity of the river

Table 4a: Chord distances among the sampling areas in matrix form in winter. Maximum values of chord distance are $\sqrt{2}$ = 1.41 for maximum dissimilarity.

S.No.	1 J1	2 J2	3 J3	4 J4	5 J5	6 J6	7 R1	8 R2	9 R3	10 R4	11 R5	12 R6	13 R7	14 R8	15 R9	16 R10
J1																
J2	0.21															
J3	0.12	0.09														
J4	0.33	0.12	0.21													
J5	0.29	0.07	0.16	0.04												
J6	0.34	0.12	0.21	0.01	0.05											
R1	0.23	0.02	0.11	0.1	0.05	0.1										
R2	0.28	0.07	0.16	0.05	0.01	0.06	0.05									
R3	0.51	0.3	0.39	0.19	0.23	0.18	0.28	0.24								
R4	0.46	0.25	0.34	0.13	0.17	0.12	0.28	0.18	0.06							
R5	0.32	0.11	0.2	0.01	0.04	0.02	0.09	0.04	0.19	0.14						
R6	0.3	0.09	0.18	0.03	0.01	0.04	0.07	0.02	0.22	0.16	0.02					
R7	0.32	0.1	0.19	0.01	0.03	0.02	0.08	0.03	0.2	0.15	0.01	0.02				
R8	0.33	0.12	0.21	0	0.04	0.01	0.1	0.05	0.19	0.13	0.01	0.03	0.02			
R9	0.47	0.26	0.35	0.14	0.19	0.14	0.24	0.19	0.04	0.01	0.15	0.18	0.16	0.14		
R10	0.13	0.08	0.01	0.2	0.16	0.21	0.11	0.15	0.39	0.33	0.19	0.17	0.19	0.2	0.34	

Table 4b: Clustering of 16 sampling areas (SA) of Damodar river by chord distance and flexible strategy with β= –0.25 during winter.

Cluster cycle	No. groups	Cluster level	Ref SA	SAs in the group
1	15	0	4	14
2	14	0.01	3	16
3	13	0.01	5	8
4	12	0.01	11	13
5	11	0.01	4	6,14
6	10	0.01	10	15
7	9	0.02	5	8,12
8	8	0.02	2	7
9	7	0.02	4	6,11,13,14
10	6	0.06	9	10,15
11	5	0.07	4	5,6,8,11,12,13,14
12	4	0.15	*2*	*3,7*,16
13	3	0.23	1	2,3,7,16
14	2	0.43	4	5,6,8,9,10,11,12,13,14,15
15	1	0.67	1	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
16	1	0.67	1	All SAs form one group

water during different seasons. Nutrients play a major role in the metabolism of living beings and some of these have been reported to influence primary productivity (Goldman 1964). In this study, variations in productivity are also found at different stations and this indicates that nutrients in the study zones of the river might have influenced marked variations.

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Table 5a. Chord distances among the sampling areas in matrix form in summer. Maximum value of chord distance is $\sqrt{2}$ = 1.41̄, for maximum dissimilarity.

S.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	J1	J2	J3	J4	J5	J6	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
J1																
J2	0.15															
J3	0.08	0.08														
J4	0.06	0.09	0.02													
J5	0.14	0.01	0.06	0.08												
J6	0.09	0.06	0.01	0.03	0.05											
R1	0.1	0.05	0.02	0.04	0.04	0.01										
R2	0.18	0.02	0.1	0.12	0.04	0.09	0.08									
R3	0.52	0.67	0.6	0.58	0.65	0.61	0.62	0.69								
R4	0.24	0.09	0.16	0.18	0.1	0.15	0.14	0.07	0.75							
R5	0.15	0.3	0.22	0.21	0.28	0.24	0.25	0.32	0.38	0.39						
R6	0.12	0.04	0.04	0.06	0.02	0.03	0.01	0.06	0.63	0.13	0.26					
R7	0.04	0.19	0.12	0.1	0.18	0.13	0.14	0.22	0.48	0.28	0.11	0.16				
R8	0.05	0.2	0.12	0.11	0.18	0.14	0.15	0.22	0.48	0.29	0.1	0.16	0			
R9	0.08	0.07	0	0.02	0.06	0.01	0.02	0.1	0.6	0.16	0.23	0.04	0.12	0.13		
R10	0.13	0.29	0.21	0.19	0.27	0.22	0.24	0.31	0.39	0.38	0.01	0.25	0.09	0.09	0.21	

Table 5b: Clustering of 16 sampling areas (SA)of Damodar river by chord distance and flexible strategy with β= –0.25 during summer.

Cluster cycle	No. groups	Cluster level	Ref SA	SAs in the group
1	15	0	3	15
2	14	0	13	14
3	13	0.01	6	7
4	12	0.01	11	16
5	11	0.01	2	5
6	10	0.02	3	6,7,15
7	9	0.03	2	5,12
8	8	0.04	3	4,6,7,15
9	7	0.05	2	5,8,12
10	6	0.05	1	13,14
11	5	0.12	2	5,8,10,12
12	4	0.19	1	11,13,14,16
13	3	0.22	2	3,4,5,6,7,8,10,12,15
14	2	0.51	1	2,3,4,5,6,7,8,10,11,12,13,14,15,16
15	1	1.04	1	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,
16	1	1.04	1	All SAs form one group

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