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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 7 (11): 1870-1875, 2004
ISSN 1028-8880

Ecological Studies of the River Padma at Mawa Ghat, Munshiganj II. Primary Productivity, Phytoplankton Standing Crops and Diversity

[1]Ashfaque Ahmed and [2]Md. Almujaddade Alfasane
[1]Ecology and Environment Laboratory, [2]Phycology and Limnology Laboratory,
Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh

Abstract: Net primary productivity of the Padma river, studied during February to December 2002, ranged between 0.13 and 0.54 mg O_2 L^{-1} h^{-1} and community respiration rate was 0.15 to 1.04 mg O_2L^{-1} h^{-1}. In some occasions, community respiration exceeds the net primary productivity. Phytoplankton community was represented by 29 genera belonging to 6 families. Greatest crops of phytoplankton occurred in February where 26 genera of 5 families were recorded among which Chlorophyceae was abundant (38.46%) in terms of number of genera. *Melosira* sp., *Synedra* sp. and *Fragilaria* sp. (897.9×10^3, 129.1×10^3 and 117.1×10^3 ind. L^{-1}, respectively) of Bacillariophyceae and *Actinastrum* sp., *Schroederia* sp. (378.7×10^3 and 204.1×10^3 ind. L^{-1}, respectively) of Chlorophyceae were the most abundant genera. In June only 2 genera of 2 families were recorded. Although the common river alga, *Melosira* sp. was found most common in February and April, it was totally absent in June. Two pollution indicator algae viz., *Arthrospira* sp. and *Oscillatoria* sp. were found during the sampling period. Four different most commonly used diversity indices were calculated which were interrelated. The values of Shannon and Wiener Index of Diversity were 0.81 (minimum) in June and 5.1 in February (maximum). Species diversity (Shannon and Wiener index) increased with higher net production.

Key words: Community respiration, indices of diversity, pollution indicator, productivity

INTRODUCTION

The results of observations taken on the physiochemical aspects on the river Padma at Mawa ghat, Munshiganj, during February 2002 to December 2002 were discussed in the earlier paper[1], but yielded no information about the seasonal growth of the algae and the population fluctuations in relation to habitat factors and the primary productivity. Phytoplankton primary productivity in association with limno-chemical qualities could be fruitfully utilized as indices of trophic status of water bodies[2,3]. Many workers have discussed the principles, mechanisms, techniques of measurements and limiting factors involved in the primary productions[4-7].

Reinhard[8] has discussed the influence of physical, chemical and biotic factors in the adaptation and distribution of plankton of Upper Mississippi. Effects of water quality on the diatom flora of Lesotho were described by Schoeman[9]. Phytoplankton in two English rivers was illustrated by Swale[10]. Crayton and Sommerfield[11] have investigated phytoplankton distribution and abundance in eleven tributaries of the Colorado River within the Grand Canyon. In the aquatic environment, the phytoplankton community is recognised as one of the most sensitive indicators of change and perturbations[12] and the present study will thus provide important baseline data in assessing the impact of any future exploitation.

MATERIALS AND METHODS

Primary production was estimated at the surface (depth: 0.1 m) by *in situ* incubation of water samples for 1.5 h in 100 mL light and dark bottles[13-15]. Dissolved oxygen was determined by the methods described in APHA[15] and the values were converted into carbon, using a factor of 0.375[16]. Gross and net primary production and respiration values and percentage of net production and respiration were calculated.

For the collection of phytoplankton sample plastic bottles of 100 mL capacity were used. Water samples were collected from 4 sites from each of the 3 zones. These samples were collected with a closing bottle from a depth of 0.5 m and the samples were preserved with Lugol's iodine[17]. Then the bottles were closed and brought to the laboratory for phytoplankton counting. The genera of

Corresponding Author: Ashfaque Ahmed, Ecology and Environment Laboratory, Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh Tel: 88 02 9661900 59/6047 (O), 88 02 8312748 (R) Fax: 88 02 8615583
E-mail: ashfaque@bdmail.net; smuslema@dhaka.net

planktonic organisms were identified with the help of standard Bangladeshi and other literatures[15,18-23].

Many indices are available for measuring diversity[24,25]. Some depend on the observation that the number of species (S) found in any one sample tends to be proportional to the logarithm of the number of specimens (N) counted (D_L~ S/logH), some are based on probability theory and others are arbitrary. All are functions of the number of species present, their relative abundances, or both. For the present analysis four indices that are frequently used are chosen[26].

The species diversity is simply the number of species found in a sample: Ds=S[27]

The species dominance is given as $D_D = p_{max}$[28] where, p_{max} is the maximum proportion of any one species in a sample.

The dominance is the simplest of the indices that make use of species proportions to define diversity.

Two other indices making use of species proportions are considered: a modification of Simpson's index and Shannon-Wiener index. These two indices depend on the whole spectrum of species proportions and are here referred to as "compound diversity"[26].

Simson's index[29] can be written as $Dp = 1 - \sum_{1}^{s} p_i^2$ [30,31] in which form it measures the probability that two specimens, picked at random from a sample, belong to different species. This probability may be taken as a measure of diversity of an assemblage.

The Shannon Wiener diversity indices (H) were also calculated: $H = -\sum p_i (\log_2 p_i)$[32]

$$\text{where, } p_i = \frac{\text{number of individuals in ith taxon (genus)}}{\text{Total number of individuals}}$$

In the figure H is designated as D_H.

RESULTS AND DISCUSSION

Primary production or the organic carbon fixed through photosynthetic activity by phytoplankton helps in understanding the productive function of aquatic system[33]. During the present investigation gross primary productivity (GPP or P_g), determined by oxygen method of the river Padma, varied from 0.4 to 1.57 mg O_2 L^{-1} h^{-1} (Table 1). When the values were converted into carbon units (using a factor of 0.375)[16], it ranged between 0.15 and 0.59 mg C L^{-1} h^{-1}. The highest value was noted in February and lowest in December. The variation in the primary production (gross production) in the Padma river could be attributed to the composition and density of phytoplankton and their photosynthetic efficiency which again are functions of the nutrients status and productive potential of the water body. Net primary production (NPP or P_t) values ranged from 0.05 to 0.20 mg C L^{-1} h^{-1}. The gross primary production was higher than net production. The gross: net primary production ratio varied from 1.67 to 4.0. Community respiration (CR) values were 0.06 to 0.39 mg C L^{-1} h^{-1}. The present study showed that CR surpassed NPP in some occasions which may be due to the dominance of zooplankton[34].

The estimates of production and respiration of ecosystem allow judgments as to the stage of ecosystem development and inference as to whether the ecosystem is importing energy[33]. The ratio P_g/P_t is ecologically significant, because values near unity indicate the process of community production and decomposition are nearly balanced (Table 1). Values less than unity generally indicate organic matter is being imported, while values greater than unity indicate a growth-type ecosystem[33]. The caveat in these conclusions is that one or two estimates of P_g/P_t ratio alone are unlikely to reveal much about ecosystem function since local conditions can temporarily alter the ratio on both sides of unity. For example, cloudy weather can depress the ratio below unity. Local upwelling of nutrient can lead to temporarily high values of P_g relative to R_t. etc. However, when P_g and R_t are measured frequently, trends in the value of the ratio provide insight into ecosystem function.

The total volume of plankton varies from season to season in all waters and the seasonal variations in quantity of phytoplankton of the river Padma were not found to be exception. The total algal flora and their density of the river Padma was shown in Table 2. Phytoplankton community was represented by 29 genera belonging to six classes viz., Cyanophyceae, Chlorophyceae, Bacillariophyceae, Cryptophyceae, Euglenophyceae and Dinophyceae. The greatest crops of phytoplankton occurred in winter (February) followed by summer (April) and lowest numbers during the rainy season (June). The diatoms dominated over the other classes of algae during February. Out of the 26 genera of 5 classes found during this period, the dominant phytoplankton recorded were *Melosira* sp., *Synedra* sp. and *Fragilaria* sp. (897.9×10^3, 129.1×10^3 and 117.1×10^3 ind. L^{-1}, respectively) of Bacillariophyceae; *Actinastrum* sp. and *Schroederia* sp. (378.7×10^3 and 204.1×10^3 ind. L^{-1}, respectively) of Chlorophyceae and *Anabaena* sp. (117.1×10^3 ind. L^{-1}) of Cyanophyceae (Table 2). The most abundant species in terms of numbers was *Melosira* sp. which accounted for 31.57%. It is evident from Table 3

Table 1: Seasonal variations in net-gross primary production ratio and respiration quantum

Dates of collection	GPP mg C/L/h	NPP mg C/L/h	Net: Gross ratio	Respiration mg C/L/h	Respiration as % Gross production
01.02.2002	0.59±0.05	0.20±0.07	0.34	0.39±0.08	66.10
	(1.57±0.15)	(0.54±0.06)	(2.95, P_g: P_t)	(1.04±0.20)	
14.04.2002	0.28±0.03	0.13±0.04	0.46	0.15±0.05	53.57
	(0.76±0.09)	(0.34±0.03)	(2.15)	(0.40±0.04)	
30.06.2002	0.23±0.05	0.12±0.02	0.52	0.11±0.02	47.83
	(0.60±0.10)	(0.31±0.03)	(1.92)	(0.29±0.04)	
15.09.2002	0.20±0.06	0.05±0.01	0.25	0.15±0.03	75.00
	(0.53±0.04)	(0.13±0.03)	(4.0)	(0.40±0.06)	
01.12.2002	0.15±0.05	0.09±0.02	0.60	0.06±0.02	40.00
	(0.40±0.06)	(0.25±0.04)	(1.67)	(0.15±0.30)	

Table 2: Variations in total number of genus and total quantity of blue-greens, greens, diatoms, euglenoids, Cryptophyceae and Dinophyceae through out the sampling periods in the river Padma

Dates of collection		Total No. of genus with total phytoplankton					
		Cyanophyceae	Chlorophyceae	Bacillariophyceae	Cryptophyceae	Euglenophyceae	Dinophyceae
01.02.2002	Total						
	a) Genus	4 (15.38%)	10 (38.46%)	9 (34.61%)	2 (7.69%)	Nil	1 (3.85%)
	b) Phytoplankton	235000	815400	327400	379400	00	87500
14.04.2002	Total						
	a) Genus	4 (26.66%)	4 (26.66%)	3 (20.0%)	1 (6.66%)	2 (13.33%)	1 (6.66%)
	b) Phytoplankton	112500	137500	867000	87500	25000	150000
30.06.2002	Total						
	a) Genus	1(50.0%)	Nil	Nil	Nil	1 (50.0%)	Nil
	b) Phytoplankton	35045	00	00	00	12500	00
15.09.2002	Total						
	a) Genus	Nil	1 (16.67%)	4 (66.66%)	Nil	1 (16.67%)	Nil
	b) Phytoplankton	00	33350	350400	00	16700	00
01.12.2002	Total						
	a) Genus	Nil	Nil	4 (100%)	Nil	Nil	Nil
	b) Phytoplankton	00	00	736200	00	00	00

that, when the groups were considered on the strength of the number of genera present in the phytoplankton, the Chlorophyceae come first represented by 10 genera and that are the most abundant in this time of the study period than in any other study time. Though the green algae exceeded in the number of genera, they did not do so in bulk as compared with diatoms. Algae belonging to the class Euglenophyceae were totally absent during this time.

In April, diatoms, blue-greens, greens, Euglenophyceae, Cryptophyceae and Dinophyceae were all present but total numbers of individuals were less. *Melosira* sp. was also dominant followed by *Peridinium* sp. and *Actinastrum* sp. out of 15 genera belonging to these 6 classes. During June, river reached a higher level which is characterized by swift flow. As a result dilution of the phytoplankton was expected. The observations showed low values or the absence of phytoplankton. Only two genera of Cyanophyceae and Euglenophyceae, one genus from each class, were recorded. Although the *Melosira* sp. was the dominant species during the months of February and April, it was totally absent in June. Seasonal variation in phytoplankton populations as a result of changing environmental conditions has been well documented[35,36]. The dynamics of phytoplankton growth and community structure over a seasonal cycle in temperate latitudes is controlled by a highly complex relationship of environmental factors in which one factor after another gains momentarily greater significance[35].

Diversity indices are often used to monitor the impact of pollutants on aquatic biological communities. Their main advantage is in summarizing large amounts of data which can be easily used by a wide variety of people. Although some authors have expressed their reservations about the use of diversity indices[37-39], there is little doubt that they represent an important tool in water quality studies[40-42]. Various investigators have shown a negative correlation between species diversity and environmental stress[43-45]. Wilhm and Dorris[45] reported that the following values of species diversity are generally with the following description of the water quality: $H<1$-sever pollution; $1<H<3$-moderate pollution; $H>3$-clean water. In the present investigation the Shannon-Wiener diversity values ranged from 0.81 to 5.1 (Fig. 1) which indicate the polluted condition of the river Padma except during February. In February the value was 5.1 and in April it was 2.27. During June it was only 0.81. The various indices are interrelated (Fig. 1). Among the four commonly used indices of diversity, species diversity and compound diversity (Ds-Dp, Ds-DH) and Dp-DH were highly significantly correlated ($p=0.001$).

Table 3: List of phytoplankton and their density (ind L^{-1}) in water of the river Padma river near Mawa Ghat. Values are in thousand (U = Upper reach, M = Middle reach, D = Down reach)

	Dates of collection														
	01.02.2002			14.04.2002			30.06.2002			15.09.2002			01.12.2002		
Groups and genera	U	M	D	U	M	D	U	M	D	U	M	D	U	M	D
(A) Cyanophyceae															
Microcystis sp.	50.5	-	16.6	12.5	-	-	-	-	-	-	-	-	-	-	-
Arthrospira sp.	-	-	33.2	12.5	-	12.5	-	-	-	-	-	-	-	-	-
Anabaena sp.	50.5	16.6	50.0	12.5	12.5	-	12.5	25.5	-	-	-	-	-	-	-
Oscillatoria sp.	-	16.6	-	-	-	-	-	-		-	-	-	-	-	-
Nostoc sp.	-	-	-	-	12.5	37.5	-	-	-	-	-	-	-	-	-
(B) Chlorophyceae															
Westella sp.	-	-	16.6	-	-	-	-	-	-	-	-	-	-	-	-
Schroederia sp.	37.5	83.3	83.3	12.5	-	12.5	-	-	-	-	-	-	-	-	-
Actinastrum sp.	162.5	100.0	116.2	37.5	37.5	-	-	-	-	-	-	-	-	-	-
Ankistrodesmus sp.	-	33.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Pediastrum sp.	-	-	33.2	25.0	-	-	-	-	-	-	-	-	-	-	-
Crucigenia sp.	-	-	33.2	-	-	-	-	-	-	-	-	-	-	-	-
Cosmarium sp.	-	49.8	-	-	-	12.5	-	-	-	-	-	-	-	-	-
Chlorella sp.	-	37.5	-	-	-	-	-	-	-	-	-	-	-	-	-
Ceratium sp	-	12.5	-	-	-	-	-	-	-	-	-	-	-	-	-
Scenedesmus sp	-	16.6	-	-	-	-	-	-	-	-	-	-	-	-	-
Closteriopsis sp.	-	-	-	-	-	-	-	-	-	-	33.35	-	-	-	-
(C) Bacillariophyceae															
Melosira sp.	256.3	300.0	341.6	287.5	216.5	325.0	-	-	-	50.0	83.35	12.5	150.00	218.7	117.5
Gyrosigma sp.	12.5	16.6	-	-	-	12.5	-	-	-	-	-	-	33.35	16.7	-
Nitzschia sp.	-	-	33.2	-	-	-	-	-	-	-	-	-	-	-	-
Synedra sp.	62.5	66.6	-	-	-	-	-	-	-	16.7	16.7	25.5	66.7	50.0	50.0
Cymbella sp.	12.5	-	-	-	-	-	-	-	-	-	-	-	-		-
Fragilaria sp.	50.5	50.0	16.6	-	-	-	-	-	-	-	-	-	-	-	-
Diatoma sp.	-	16.6	16.6	-	-	-	-	-	-	-	-	-	-	-	-
Coscinodiscus sp.	-	33.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula sp.	25.5	16.6	-	-	-	-	-	-	-	-	16.7	-	-	-	-
Cyclotella sp	-	-	-	-	-	25.5	-	-	-	-	16.7	-	-	16.7	16.7
(D) Cryptophyceae															
Cyrptomonas sp.	75.5	116.6	33.2	50.0	37.5	-	-	-	-	-	-	-	-	-	-
Rhodomonas sp.	37.5	66.6	50.0	-	-	-	-	-	-	-	-	-	-	-	-
(E) Euglenophyceae															
Trachelomonas sp.	-	-	-	12.5	-	-	-	12.5	-	16.7	-	-	-	-	-
Euglena sp.	-	-	-	-	12.5	-	-	-	-	-	-	-	-	-	-
(F) Dinophyceae															
Peridinium sp.	37.5	-	50.0		62.5	62.5	25.0	-	-	-	-	-	-	-	-

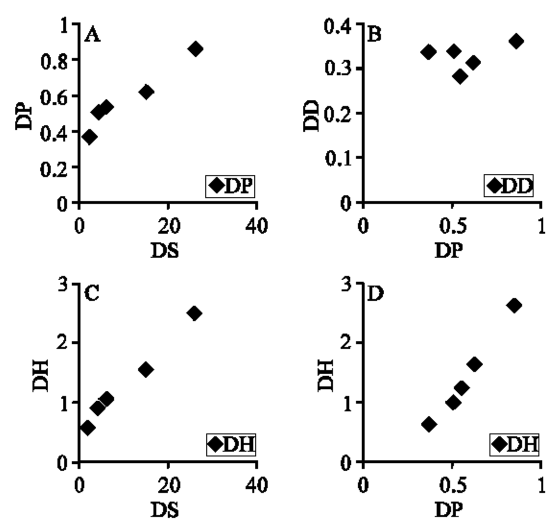

Fig. 1: Relationship between various diversity indices. DP, Ds, DD, DH are defined in text. Ds-Dp, Dp-DH and Dp-DH are highly significantly correlated

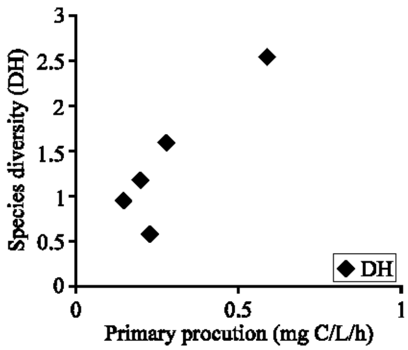

Fig. 2: Species diversity in relation to primary productivity in the river Padma. Species diversity was measured by Shannon-Wiener function. Note high productivity with increase diversity

Connell and Orias[46] stated in their productivity hypothesis that greater production resulted in greater diversity. The present study supported this idea (Fig. 2). The maximum diversity was found when the productivity (GPP) was the highest and diversity decreased in lower production rates. The stability of primary production is a major determinant of the species diversity of a community[47].

Many investigators have tried to relate the presence or absence of specific indicator species to varying degree of water quality[48]. Kolkwitz and Marsoon [49] have included four algae namely *Arthrospira, Oscillatoria, Spirulina* and *Aphanotheca* as indicator types of heavy pollution. In the present study *Arthrospira* (58.2×10^3 ind. L^{-1}), *Oscillatoria* (16.6×10^3 ind. L^{-1}) were found although typical river plankton like *Melosira*[50] was found most abundant. Though the concept of indicator species also offers a fast and efficient means of judging the quality of waters, many biologists have serious doubts about the use of a single species and consequently preferred the concept of indicator communities or assemblages[51,52].

ACKNOWLEDGMENTS

We thank the Delta Study Centre, Dhaka University for financial support of this work and Mr. Zakir Hossain and Mr. Isnain for assistance in the sample collection. The authors are also grateful to the Dean. Faculty of Biological Science, University of Dhaka for his financial help to cover up the printing cost.

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