Primary Production and Fish Yield Estimation in the Meghna River System, Bangladesh

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Abstract

This study was carried out in four selected stations (Mohonpur, Kaligonj, Charludua and Daulatkhan) in the Meghna river system, Bangladesh between the latitude 22°35.494Ñ N - 23°23.987 N and longitude 90°35.793 E - 90°49.061Ñ E. Average net primary production (NPP) and gross primary production (GPP) ($gC \cdot m^3 \cdot h$) in the euphotic zone of the Meghna river were 0.089 ± 0.021 and 0.161 ± 0.025 respectively. The rate of conversion of GPP into NPP ranged between 48.17 and 62.63% with an average of 54.72%. The mean ratio of NPP to GPP (NPP:GPP), NPP:Respiration and average percent respiration rate to GPP were 0.549 ± 0.060, 1.251 ± 0.320 and $45.04 \pm 6.02\%$ respectively. The mean photosynthetic production for the day ($gC \cdot m^3 \cdot day$) and year ($gC \cdot m^3 \cdot yr$) were 1.930 and 704.45 respectively. Annual computed fish yield in relation to gross carbon synthesis was 7.0 kg $fish \cdot m^3 \cdot year$. The actual production of fish from the Meghna river is accounted about 0.21% of the estimated production. The gross energy production ($Kcal\ energy \cdot m^3 \cdot day$) by the producers was estimated about 18.0. The NPP of phytoplankton established a high significant negative correlation ($r = -0.975$; $p < 0.01$) with water temperature and low, but a definite negative correlation existed ($r = -0.767$) between GPP and water temperature.

Introduction

Bangladesh lies in the delta of the world's three great river systems the Ganges-Padma, the Brahmmaputra-Jamuna and the Meghna river system and a complex network of 230 rivers. These three river basins drain

a catchment area of 1,720,000 km^2 of which only seven per cent lies in Bangladesh (UN 1995). About 2.4 billion tons of sediments are carried yearly by the river system in Bangladesh (Holemen 1986).

The Barak, head stream of the Meghna, rises in the hills of Manipur in India. The Meghna flows in south-west direction to meet the Padma at Chandpur. Below Chandpur, the combined flow is known as lower Meghna. The length of the river is 902 km, of which 403 km flows through Bangladesh. The total catchment area of the Barak-Meghna is 82,000 km^2, out of which 47,000 km^2 and 35,000 km^2 lie in India and Bangladesh, respectively (UN 1995). The recorded maxiumum discharge of the Meghna at Bhairab, Bangladesh upstream of its confluence with the Padma, is 19,800 m^3 per second. Average annual sediment discharge is 1.3 x 10^5 tons. The confluence of Padma-Meghna is a very significant water body, the major nursery grounds of hilsa (*Tenualosa ilisha*) and many other commercially important riverine fishes of Bangladesh.

The primary productivity of a water body is the manifestation of its biological production. It is an ultimate outcome of photosynthesis that forms the basis of ecosystem functioning since it makes the chemical energy and organic matter available to the entire biological community. The chlorophyll bearing organisms utilize solar energy and convert it into chemical energy in the form of carbohydrate molecules by taking carbon dioxide and water from the environment (Mishra and Saksena 1992). In comparison to work done on the productivity of stagnant waters very little information is available on free flowing waters (Rajyalakshmi and Premswarup 1975, Ramarao et al. 1979, Anand 1982, Saha et al. 1985, Patra 1985, Kar et al. 1987, Jhingran and Pathak 1988, Shukla et al. 1989). Factors such as water level, meteorological factors like light intensity, photoperiod, rainfall, wind velocity, etc., and hydrological cycle (inflow and outflow) have great influence on the rate of primary production in lacustrine and flowing waters (Gupta 1982, Verma and Datta Munshi 1989). In Bangladesh a little research work has been done so far on the primary productivity of the lentic waters of Bangladesh (Hussain et al. 1978, ARG 1986, Haldar and Ahmed 1991, Haldar et al. 1992, Ahmed 1994) and no work has yet been reported from any lotic water. In this paper, an attempt has been made for the Meghna river ecosystem where a limnological study has been done so far (Shafi et al. 1978).

Materials and Methods

This study was carried out in four selected stations viz., Mohonpur, Kaligonj, Charludua and Daulatkhan in the Meghna river system between the latitude 22°35.494Ñ N - 23°23.987 N and longitude 90°35.793 E -

90°49.061Ñ E (Fig. 1). Samplings were conducted during winter and summer seasons, during July 2002 to June 2003.

Collection of samples and necessary preservation for various physico-chemical parameters and their estimation were carried out following Standard Methods (APHA 1995). Temperature (Air and water), transparency, dissolved oxygen (DO), free carbon dioxide (CO_2), total water hardness, total alkalinity, total dissolved solids (TDS) and chemical oxygen demand (COD) were determined following APHA (1995). Ammonia and nitrite were estimated using a HACH water test kit. Conductivity and pH meter were used to determine water pH and specific conductance respectively.

The euphotic zone was measured by a Secchi disc. Primary production was estimated by the oxygen measurment method and the rate of changes in oxygen level were determined by the classical "Light and dark
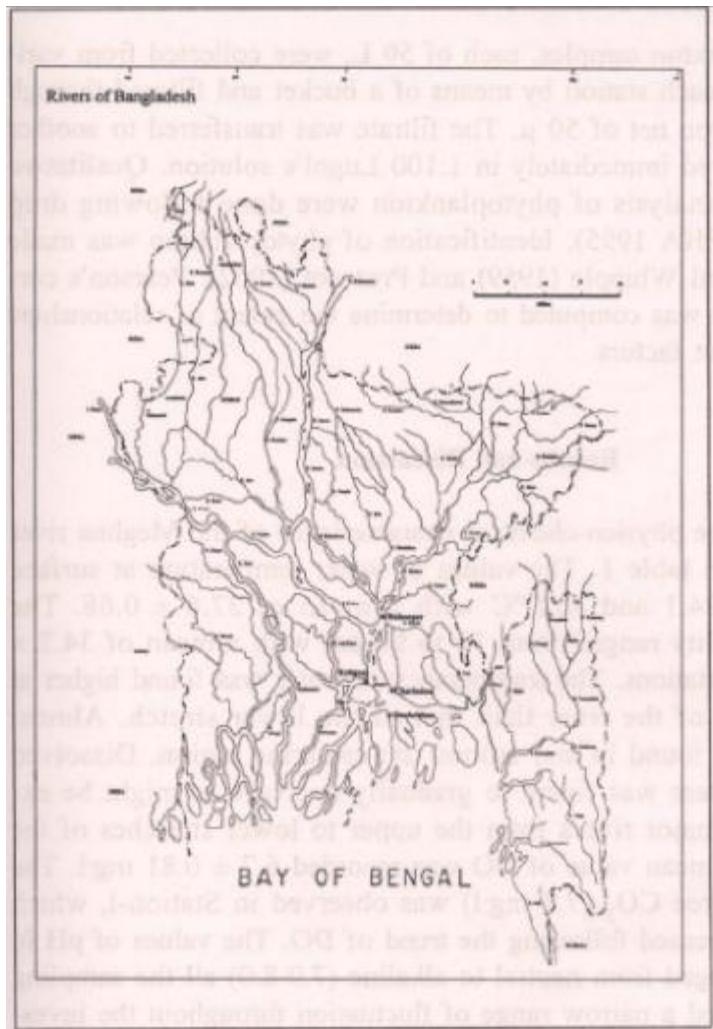

Fig. 1. Map showing the sampling stations in the Meghna river system of Bangladesh

bottle" technique (Gaarder and Gran 1927). To determine of primary production, representative water samples of the euphotic zone were collected at the onset of sunrise from the mid-euphotic level with the help of a Kemmerer water sampler and both light and dark bottles were hung immediately in duplicate in the water at the same depth and incubated for half the period of the day length. The data was extrapolated in different forms using standard coefficient. The following conversion factors were used in this work:

Carbon = gO_2 x 0.375 (g) (Laevastu 1957)
Organic matter = g O_2 x 0.69 (g) (Winberg 1960)
Plankton biomass = gO_2 x 3.3 (g) (Winberg 1960)
Energy production = gO_2 x 3.51 (Kcal) (Winberg 1960)
1 g of C = 10 g of fish wet weight (Rodhe 1958)
1 g wet fish = 1200 cal (Srenivasan 1972)

Replicate plankton samples, each of 50 L, were collected from various spots around each station by means of a bucket and filtered through bolting silk plankton net of 50 μ. The filtrate was transferred to another bottle and preserved immediately in 1:100 Lugol's solution. Qualitative and quantitative analysis of phytoplankton were done following drop count method (APHA 1995). Identification of phytoplankton was made following Ward and Whipple (1959) and Presecot (1962). Pearson's correlation coefficient was computed to determine the extent of relationships among the different factors.

Results and Discussion

The data of the physico-chemical characteristics of the Meghna river are summarized in table 1. The values of water temperature at surface ranged between 24.1 and 30.5°C with a mean of 27.6 ± 0.68. The Secchi disc visibility ranged from 12 to 90 cm with a mean of 34.2 ± 18.08 at different stations. The transperancy of water was found higher at the upper stretch of the river than that of the lower stretch. Almost muddy water was found in and around the estuarine region. Dissolved oxygen (DO) content was found to gradually decrease as might be expected for many major rivers from the upper to lower stretches of the river system. The mean value of DO was recorded 6.7 ± 0.81 mg·l. The highest value of free CO_2 (7.7 mg·l) was observed in Station-I, which also gradually decreased following the trend of DO. The values of pH in the river water ranged from neutral to alkaline (7.0-8.0) all the sampling stations. It exhibited a narrow range of fluctuation throughout the investigation period.

Total alkalinity was detected in appreciable quantities (48.0-88.7 mg·l) indicating that the river water is nutrient enriched and of hard type (42.3-95.1 mg·l). Such waters could be considered as good for optimum fish production. The ammonia concentration was found to be elevated and ranged from 0.1 to 0.6 mg·l. It showed a gradually decreasing trend from upward to downward stretches. Except Station-I the concentration of nitrite was found to be zero for the other stations. The values of chemical oxygen demand (COD) were very high in Station-I and Station-IV, which were far above the critical range. The causes of higher values of COD at the aforesaid stations could not be explained. Total dissolved solids (TDS) fluctuated between 0.12 and 0.32 mg·l with a mean of 0.20 ± 0.05. The highest value (220 mS/cm) of conductivity was recorded at Station IV, which is about 2.5 fold higher than those of other recorded values in different stations at the same period. Statistical analysis detected the existence of significant correlation among various physico-chemical and biological variables in few cases in the Meghna river system.

Table 1. Mean physico-chemical characteristics of the Meghna river system, Bangladesh during the period of 2002-03 (figures in the parentheses are ranges).

Parameters	Station-I Mohonpur	Station-II Kaligonj	Station-III Charludua	Station-IV Daulatkhan	Mean±SD
Global position (Latitude/Longitude)	23°23.987 N 90°35.793 E	22°51.252 N 90°39.169N E	22°42.456 N 90°49.061 E	22°35.494 N N90°45.446 E	-
Air temp. (°C)	(25.3-28.7) 27.0	(27.2-31.6) 29.4	(27.8-31.8) 29.8	(28.9-31.5) 30.2	29.1±1.44
Water temp. (°C)	(24.1-29.2) 26.6	(24.8-30.4) 27.6	(26.0-30.5) 28.2	(25.5-30.2) 27.8	27.6±0.68
Secchidisc Transparency (cm)	(26-90) 58.0	(15-62) 38.5	(12-25) 18.5	(14-30) 22.0	34.2±18.08
Dissolved Oxygen (mg·l)	(7.4-8.3) 7.8	(6.8-6.9) 6.8	(5.9-6.6) 6.3	(5.1-6.9) 6.0	6.7±0.81
Free CO_2 (mg·l)	(2.4-7.7) 5.0	(3.4-7.3) 5.3	(4.3-6.4) 5.3	(3.6-4.0) 3.8	4.8±0.74
pH	(7.8-8.0) 7.9	(7-8) 7.5	(7.7-8.0) 7.8	(7.7-8.0) 7.8	7.8±0.18
Total Alkalinity (mg·l)	(48.0-78.1) 63.0	(80.5-81.4) 80.9	(80.6-83.2) 81.9	(73.2-88.7) 79.4	76.3±8.91
Total Hardness (mg·l)	(42.3-84.8) 63.5	(54.9-94.3) 74.6	(60.5-95.1) 77.7	(63.7-84.8) 74.2	72.5±6.21
Ammonia (mg·l)	(0.1-0.8) 0.4	(0.1-0.6) 0.3	(0.1-0.6) 0.3	(0.1-0.4) 0.1	0.35±0.08
Nitrite (mg·l)	(0-0.03) 0.01	0	0	0	0 – 0.01±0
Chemical Oxygen Demand (mg O_2·l)	(33.6-70.7) 52.1	(8.3-53.8) 31.0	(4.2-56.9) 30.5	(53.7-62.4) 58.1	42.9±14.24
Total Dissolved Solids (mg·l)	(0.12-0.26) 0.19	(0.12-0.18) 0.15	(0.22-0.32) 0.27	(0.18-0.21) 0.19	0.20±0.05
Conductivity (mS·cm)	(75-91) 83.0	(98-147) 122.5	(96-150.4) 123.2	(152.2-220) 186.1	128.7±42.63

The average values of net primary productivity (NPP), gross primary productivity (GPP), and respiration rate have been given in Table 2. It is evident from the table 2 that the average values of NPP, GPP, NP:GP and NP:Respiration were found higher in Station II (Kaligonj). Higher respiration rate and Respiration% of GPP were found in Station III (Charludua). The average NPP (gC·m^3·h) in the euphotic zone of the Meghna river ranged from 0.068 to 0.119 with a mean of 0.089 ± 0.021 during the investigation period. The average GPP (gC·m^3·h) fluctuated between 0.128 and 0.190 at different stations of the aforesaid river system with a mean of 0.161 ± 0.025. The rate of respiration (gC·m^3·h) was very low, it ranged from 0.059 to 0.085. The mean value of respiration during the investigation period was estimated at 0.072 ± 0.010.

The high GPP values indicated the influence of organic pollution. Overall decrease in primary production due to toxic industrial wastes in the river was reported in India. In river Mahanadi, the rates of gross and net primary productivity were adversely affected due to human and animal abuse of water, industrial effluents and sewage disposal (Patra 1985). In the Meghna river, both NPP and GPP were estimated at higher values at the upstreams than those of downstream. Moreover, the primary productivity of the studied river was found low in comparison to many other rivers of India. The plankton biomass was also found relatively low. During the present investigation, 41 genera of phytoplankton belonging to 17 families were recorded. The mean contribution of phytoplankton was about 97.0% of the total planktonic organisms. Phytoplankton density ranged between 7,200 and 51,850/l with a mean of 23,031 ± 9,555 (Table 3). The phytoplankton population was composed of algal flora belonging

Table 2. Mean primary productivity of subsurface water in the Meghna river system, Bangladesh during the period 2002-03 (figures in the parentheses are ranges)

Station	Net Primary Production (gC·m^3·h)	Respiration (gC·m^3·h)	Gross Primary Production (gC·m^3·h)	Net Primary Production: Gross Primary Production	Net Primary Production: Respiration	Respiration% of Gross Primary Production
Station-I (Mohonpur)	0.089 (0.044-0.135)	0.073 (0.008-0.138)	0.162 (0.052-0.273)	0.550	1.226	44.92
Station-II (Kaligonj)	0.119 (0.019-0.220)	0.070 (0.009-0.132)	0.190 (0.028-0.352)	0.628	1.695	37.11
Station-III (Charludua)	0.079 (0.015-0.144)	0.085 (0.008-0.162)	0.164 (0.023-0.306)	0.483	0.935	51.67
Station-IV (Daulatkhan)	0.068 (0.022-0.115)	0.059 (0.009-0.110)	0.128 (0.031-0.225)	0.535	1.151	46.48
Mean ± SD	0.089±0.021	0.072±0.010	0.161±0.025	0.549±0.060	1.251±0.320	45.04±6.02

to the groups Chlorophyceae, Myxophyceae, Bascillariophyceae and Euglenophyceae. The members of the group Chlorophyceae represented largely available phytoplanktons and these were found abundant throughout the investigation period. Chlorophyceae on an average consisted of about 95.0% of the total phytoplankton population and represented by various species belonging to genera *Scenedesmus*, *Protococcus*, *Gonatogygon*, *Mougeotia*, *Crucigenia*, *Pediastrum*, *Palmellococcus*, *Ankistrodesmus*, *Microspora*, *Closterium*, *Genecularia*, *Spirogyra*, *Schroederia*, *Hydrodictyon*, *Oocystis*, *Planktosphaeria*, *Pleodorina*, *Dicidium*, *Staurastrum*, *Netrium*, *Mesotenium* and *Zygnema* (Table 4). Myxophyceae contributed more than 3.0% of the mean of total phytoplankton. Myxophyceae included various species belonging to genera *Anacystis*, *Spirulina*, *Microcystis*, *Coelosphaerium*, *Phormidium*, *Anabaena*, *Nostoc*, *Oscillatoria*, *Merismopedia,* and *Aphanocapsa.*

Table 3. Mean abundance of plankton in different stations of the Meghna river system, Bangladesh during the period 2002-03 (figures in the parentheses are ranges)

Station	Phytoplankton (No·l)	Zooplankton (No·l)	Total plankton (No·l)	Phytoplankton (%)	Zooplankton (%)
Station-I (Mohonpur)	9,200 (7,200-11,300)	950 (600-1,300)	10,200	90.69	9.31
Station-II (Kaligonj)	24,000 (15,000-33,000)	350 (300-400)	24,350	98.56	1.44
Station-III (Charludua)	28,750 (17,000-40,500)	500 (500-500)	29,250	98.29	1.71
Station-IV (Daulatkhan)	30,125 (8,400-51,850)	175 (50-300)	30,300	99.42	0.58
Mean ± SD	23,031±9,555	494±332	23,525±9,254	96.74	3.26

Table 4. List of planktonic algae at different sites in the Meghna river systems, Bangladesh during the period 2002-03.

Plankton	Group	Genera
Phytoplankton	Chlorophyceae	*Scenedesmus*, *Protococcus*, *Gonatogygon*, *Mougeotia*, *Crucigenia*, *Pediastrum*, *Palmellococcus*, *Ankistrodesmus*, *Microspora*, *Closterium*, *Genecularia*, *Spirogyra*, *Schroederia*, *Hydrodictyon*, *Oocystis*, *Planktosphaeria*, *Pleodorina*, *Dicidium*, *Staurastrum*, *Netrium*, *Mesotenium*, *Zygnema*
	Myxophyceae	*Anacystis*, *Spirulina*, *Mycrocystis*, *Coelosphaerium*, *Phormidium*, *Anabaena*, *Nostoc*, *Oscillatoria*, *Merismopedia*, *Aphanocapsa*
	Bacillariophyceae	*Melosira*, *Synedra*, *Coscinodiscus*, *Stephanodiscus*, *Diatoma*, *Navicula*, *Gyrosigma*
	Euglenophyceae	*Trachelmona*, *Phacus*
Zooplankton	Rotifers	*Brachionus*, *Trichocerca*, *Kellicottia*, *Keratella*, *Gastropus*, *Polyarthra*
	Cladocera	*Daphnia*, *Bosmina*
	Copepoda	*Calanoid*, *Cyclops*, *Diaptomus*, Nauplius
	Ostracoda	*Cypris*

Bascillariophyceae on an average consisted of only 1.7% of the total phytoplankton population and was represented by various species belonging to genera *Melosira, Synedra, Coscinodiscus, Stephanodiscus, Diatoma, Navicula, Gyrosigma.* Appearance of Euglenophyceae was found at upper stretches and contributed only 0.2%. Euglenophyceae was totally absent in the lower stretches of the river during the study period. This group comprises the genera of *Trachelmonas* and *Phacus.*

It is assumed that plankton density has decreased over time due to the problem of anthropogenic environmental distortion that is continuously affecting the river Meghna. With rapid urbanization in the recent decade this river receives a huge quantum of industrial and domestic effluents of multiple nature. Such industrial pollutant load, metal toxicity and nutrient-gradient play a significant role on the nature of the ecosystem and stressing the biota there in as well. In the winter months, value of water flow reduces and proportionate concentration of pollutant becomes higher which affect the concentration of plankton in the ecosystem and the primary production as well.

The rate of conversion of GPP into NPP ranged between 48.17 and 62.63% with an average of 54.72% (Table 2). The conversion of GPP into NPP depends to a great extent on the amount of oxygen consumed by the particulate and dissolved organic matter (Edberg and Hofsten 1973), microbial activity (Stewart et al. 1977) or sediment (Rich 1979). Odum (1957) reported an average of 42.28% conversion of GPP (17,500 $mgC \cdot m^2 \cdot day$). Maximum and average favorable conversion rate of GPP into NPP of the world aquatic system have not yet been standardized. The mean ratio of NPP to GPP (NPP:GPP) was 0.549 ± 0.060. The ratio of NPP to GPP in Morar (Kalpi) river of Madhya Pradesh, India never exceeded 0.52 (Mishra and Saksena 1992), which is very close to the values obtained in the present study. The average ratio of NPP to respiration (NPP:Respiration) was 1.251 ± 0.320. The ratio of the same in the Morar river was greater than 1.0 (Mishra and Saksena 1992). The percentage of respiration rate to GPP was $45.04 \pm 6.02\%$ during the study period (Table 2). The average percent respiration rate to GPP always remained below 50% throughout the investigation period. The values below 50% of the said ratio might be an indicator of polluted water that has been suggested by Ramarao et al. (1979). Ramakrishnaiah and Sarkar (1982) and Verma and Datta Munshi (1989) have focused on the influencing role of light intensity on primary production.

The NPP of phytoplankton at Meghna river had a high significant negative correlation ($r = -0.975$; $p < 0.01$) with the water temperature (Table 5). Establishment of similar correlation was found in the Morar (Kalpi) river of Madhya Pradesh, India (Mishra and Saksena 1992). Low,

but a definite negative correlation existed (r = -0.767) between GPP and water temperature, while moderate negative correlation (r = -0.897) existed between conductivity and GPP. The oxygen also influenced the GPP positively (r = 0.868).

The mean photosynthetic production for the day (gC·m^3·day) and year (gC·m^3·yr) in the Meghna river was 1.930 and 704.45 respectively (Table 6). Lower conversion efficiency of sunlight to photosynthesis in the Meghna river system, which might be due to very poor light penetration for most of the year caused by inert suspended matter, high flow through water, and low nutrient status are responsible for the poor utilization of solar energy. It has been found that the gross energy production (Kcal energy·m^3·day) by the producers was estimated to be 18.0. Based on the conversion of gross carbon production into fish production, the annual yield of fish from the Meghna river was estimated to be 7.0 kg fish·m^3·year. The actual production of fish from the Meghna river system for the year 2001-02 was 1.5 gC·m^3·year (0.015 kg fish·m^3·year), which is about 0.213% of the estimated production. Based on the gross oxygen production the daily production of organic matter (g·m^3·day) and plankton biomass (g·m^3·day) in the Meghna river was estimated as 3.552 and 16.99 respectively. The value of fish as energy was worked out to be about 8453 Kcal energy·m^3·year.

Table 5. Coefficient of correlation (r) between the primary production and factors in the Meghna river system, Bangladesh during the period 2002-03.

Characteristics			Coefficient of correlation (r)
Net production	Vs	Water temp.	- 0.975*
Gross production	Vs	Water temp.	- 0.767
Gross production	Vs	DO	- 0.868
Gross production	Vs	Conductivity	- 0.897

Table 6. Photosynthetic productivity and energy conversion in the Meghna river system, Bangladesh during the period of 2002-03

Parameters	Values
Photosynthetic production (gC·m^3·day)	1.930
Photosynthetic energy (Kcal energy·m^3·day)	18.07
Fish yield (kg fish·m^3·year)	7.04
Fish as energy (Kcal energy·m^3·year)	8453.40
Organic matter (g·m^3·day)	3.55
Plankton biomass (g·m^3·day)	16.99
Photosynthesis (gC·m^3·yr)	704.45
Annual fish yield (gC·m^3·yr)	1.5
Conversion (%)	0.213

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