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Photosynthetic activity in relation to hydrobiological characteristics of a brackishwater tidal ecosystem of Sundarbans in West Bengal, India

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Abstract: Photosynthetic activity of Jagannath canal, an important component of the brackishwater ecosystem of Sundarbans in West Bengal was observed to be highly affected by the attenuation of downwelling radiation. Gross primary production (mg C $m^{-3}h^{-1}$, of the canal was limited at the surface and varied from 5.81-22.16 with an average of 13.45. Respiratory demand (14.24 mg C $m^{-3}h^{-1}$) was higher than production even in the photic zone. Chlorophyll *a* (Chl *a*) concentration ranged from 3.85-6.22 mg m^{-3}. Chl *a* specific photosynthetic production was very low 1.01-4.61 mg C mg chl a^{-1} h^{-1}) and was observed to be a function of attenuation of light, temperature and salinity.

Resumen: Se observó que la actividad fotosintética del canal Jagannath, un componente importante en el ecosistema mareal de agues salobres de Sundarbans, Bengala Occidental, fue grandemente afectada por la atenuación de la radiación que penetra. La producción primaria bruta (mgC m^{-3} h^{-1}) del canal fue limitada en la superficie y varió de 5.81 a 22.16 con un promedio de 13.45. Aun en la zona fótica la demanda respiratoria (14.24 mgC $m^{-3}h^{-1}$) fue más alta que la producción. La concentración de clorofila *a* (Chl *a*) fluctuó en el intervalo de 3.85 a 6.22 mg m^{-3}. La producción fotosintética específica de Chl *a* fue muy baja (1.01 – 4.61 mgC mg chl $a^{-1}h^{-1}$) y se observó que ésta es una función de la atenuación de la luz, la temperatura ya la salinidad.

Resumo: A actividade fotossintética do canal de Jagannath, uma componente importante do ecossistema de águas salobras dos Sundarbans, na Bengala ocidental, foi observado ser fortemente afectada pela atenuação descendente da radiação. A produção primária bruta (mgCm^{-3}.h^{-1}) do canal estava limitada à superfície e variou entre 5,81-22,16 com uma média de 13,45. A exigência respiratória (14,24 mgC.m^{-3}.h^{-1}) foi mais alta do que a produção mesmo na zona iluminada. A concentração da clorofila *a* (Chl *a*) variou no intervalo de 3,85-6,22 mg.m^{-3}. A produção fotossinteticamente específica de Chl *a* foi muito baixa (1,01-4,61mgC.mg Chl.a^{-1}.h^{-1}) e foi observada ser uma função da atenuação da luz, da temperatura e da salinidade.

Key words: Brackishwater, Jagannath canal, photosynthetic activity Sundarbans.

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Introduction

The aquatic network of Sundarbans ecosystem of West Bengal is fabricated by several brackishwater rivers and tidal canals. Among them, the Jagannath canal is one of the most important water body which originates from the Bidyadhari river near Kulti. Depth of the canal varies from 4.21-6.04 m. Brackishwater of the river is mixing with the sewage of metropolitan city of Calcutta at Kulti and flowing through the canal during high tide (Ghosh 1989). Considering this water beneficial for aquaculture, an estimated 3,600 ha brackishwater shrimp/fish culture impoundment (locally called bhery) of varying sizes have developed along the two banks of the canal and its arteries. The shrimp/fish production potential of all these impoundments depend upon the natural productivity of this canal water. Hence, information regarding primary production of such an ecosystem is very important in regard to this aquaculture practice as the natural supporting factor. Materials, transported to the canal through sewage, aquaculture farms' effluent and tidal circulation may affect photosynthetic production by nutrient enrichment. This will also increase the attenuation rate of downwelling light and expose the phytoplankton cell to toxic materials. Individual water body has its individual dynamism in nature. Realizing this fact, primary production potentials of different aquatic ecosystems were studied by workers throughout the world (Dehadrai & Bhargava 1972; Gopinathan *et al.* 1994; Hepher 1962; Melone 1976; Odum 1956; Riemann & Jensen 1991; Williams & Murdoch 1966). The present communication describes seasonal distribution of primary production activity of Jagannath canal of Sundarbans in West Bengal. The environmental factors responsible for variation in chlorophyll specific photosynthetic production have also been documented.

Materials and methods

Monthly sampling was made from March 1995 to February 1997. Three stations were selected for intensive study of primary production of the canal and the average data of these three stations are presented here. As the high spring tidal water is being used to feed the aquaculture impoundments (0.7-0.9 m), the study was conducted under similar tidal condition. Primary production was measured by light and dark bottle technique by incubating the bottles *in situ* for four hours. Dissolved oxygen concentration was estimated by modified Winkler's method. Different physico-chemical characteristics of water and chlorophyll were determined following the methods outlined by Strickland & Parsons (1968). Quantitative estimation of phytoplankton was done by "Direct census method" (Jhingran *et al.* 1969) and planktonic groups were identified by following Desikachary (1959), Ward & Whipple (1959), Hendey (1964) and Philipose (1967). Incident solar radiation for the particular station was calculated from the solar radiation data of Kimbal (1935).

Results and discussion

Environmental characteristics

Temperature of water of Jagannath canal followed seasonal cycle with postmonsoon (November-February) low of 19.6°C and monsoon (July-October) high of 33.47°C (Fig. 1). The temporal variations in temperature of the canal was very conspicuous ($F = 187.97$; $p < 0.01$). Salinity ranged from 0.26 to 9.54‰ with the lowest value during early postmonsoon season. The value of extinction coefficient of light (K_t), calculated from the formula, $K_t = 1.44$/Secchi depth in meter (Holmes

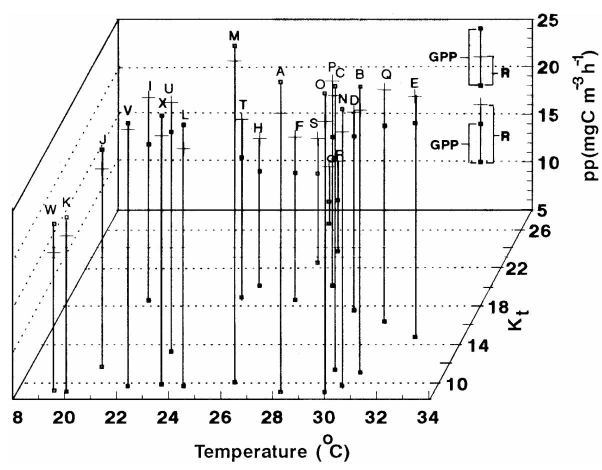

Fig. 1. Three dimensional graph depicting monthly rates of photosynthetic production (PP) in relation to water temperature and light extinction (K_t) in Jagannath canal. Each bar represents one month starting from bar 'A' (March 1995) to bar `X' (February 1997). GPP, gross primary production; R, respiration.

1970) was 8.76-26.52 (Fig. 1), which was a function of suspended particulate matter in this canal (Saha, Bhattacharyya, Pandey & Choudhury unpublished). The corresponding euphotic depth of the canal was very less and varied from 0.075 to 0.228 m. pH of water was alkaline (7.26-8.77) throughout the study period. Variation of dissolved oxygen concentration was 3.41 to 5.66 mg l^{-1}. The concentrations of dissolved inorganic nitrogen, phosphorus and silicon were 36.94-93.67, 4.79-10.33 and 82.85-180.67 μg-at l^{-1}, respectively. The calculated radiant energy varied from 1384.03 to 2395.00 kcal $m^{-2}d^{-1}$.

Standing crop

As depicted in Fig. 2, phytoplankton population of the canal varied from 48.30 to 85.22 x $10^5 m^{-3}$ with an average of 68.77 x 10^5 m^{-3}. The population of Chlorophyta (45.23%) was observed to be highest followed by Bacillariophyta (31.45%) and Cyanophyta (23.32%). Species diversity of different phytoplankton genera of Jagannath canal has been published elsewhere Saha, Bhattacharyya & Choudhury 2000). The chlorophyll *a* (Chl *a*) concentration of the canal varied from 3.85 to 6.22 mg m^{-3} with an average of 4.80 mg m^{-3}. The highest concentration of chl *a* was observed during monsoon months, when rate of discharge of effluent water was high. Also during this period the phytoplankton concentration from the shrimp culture impoundments was highest. Low correlation between chl *a* and phytoplankton counts suggests that chl a estimates may have included significant amount of detrital pigments.

Photosynthetic production

Primary production pattern of Jagannath canal showed a pronounced seasonal cycle with high values during premonsoon (March-June), followed by postmonsoon and monsoon seasons. The euphotic depth of the canal was so low that primary production was limited to the surface layer only. However, the gross primary production (GPP) of the canal varied from 5.81 to 22.16 mg C $m^{-3}h^{-1}$ with an average of 13.45 mg C $m^{-3}h^{-1}$ which is comparable to those of Mandovi (11.25-45.82 mg C m^{-3} h^{-1}) and Zuari estuary of Goa (12.49-48.40 mg C m^{-3} h^{-1}) (Dehadrai & Bhargava 1972). Qasim (1979) found 11.78-36.99 mg C m^{-3} h^{-1} in Vellar estuary. Higher photosynthetic production of 19.71-40.83 mg C $m^{-3}h^{-1}$ was also observed by De, Ghosh, Jana Ghosh, Jana & Choudhury (1991) in Hugli estuary. Fig. 1 depicts the rate of photosynthetic production in relation to K_t and temperature of water in Jagannath canal. Though regulation of photosynthesis by temperature is a widespread phenomenon at least in locations, where photosynthesis is not limited by shortage of nutrients (Barlow *et al.* 1963; Hepher 1962; Ryther & Yentsch 1957), high values and variations in K_t made the role of temperature less significant in Jagannath canal.

Community respiration in the canal, which varied from 9.51-20.56 mg C m^{-3} h^{-1} (Fig. 1). The percentage of community respiration over GPP was highest during monsoon and varied from 80.8-168% with an average of 112.7%, suggesting that production of energy was insufficient to support the respiratory demand even in the euphotic depth.

The prime source of energy of all ecosystems is the radiant energy from sun, which is attenuated with depth in aquatic systems through absorption and scattering by various agents. Strickland (1958) reported that maximum production of a mixed marine phytoplankton population can be expected where and when the radiation energy has a level near 0.15 ly min^{-1} (=1080 kcal $m^{-2}d^{-1}$). This shows that the solar radiation was not limited in the Jagannath canal area. But the amount of light available to the phytoplankton is more important to organic production (Ryther 1963). Besides solar radiation, primary production is controlled by a combination of various factors, which may be physical (e.g., temperature and salinity), chemical (e.g., nutrients and growth promoting substances) and biological (e.g., species composition and biomass of phytoplankton). GPP of Jagannath canal was strongly correlated with all the major nutrients except silicon, which showed inverse relation-

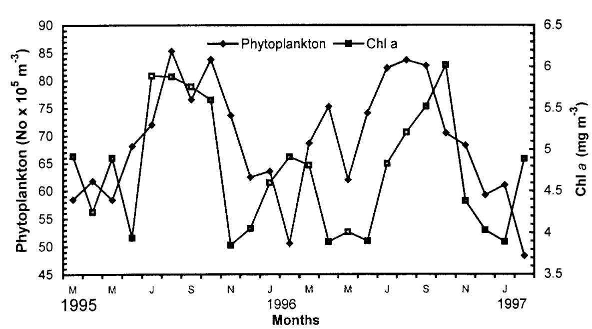

Fig. 2. Standing crop of phytoplankton of Jagannath canal.

Table 1. Correlation coefficients of different nutrients with gross primary production (GPP) and extinction coefficient of light (K_t).

Nutrients	GPP	K_t
Nitrate-nitrogen	0.7140**	-0.7928**
Ammonium-nitrogen	0.8333**	-0.7951*
Phosphate-phosphorus	0.5319*	-0.2091
Silicate-silicon	-0.7852**	0.8152**

* Significant at 5% level; **Significant at 1% level

ship. As Bacillariophytes require silicon for their growth and the canal water contained 31.45% Bacillariophytes of the total phytoplankton population, this type of relationship cannot be expected. This pattern of relationship between nutrients and GPP was obviously reflection of the correlation pattern between nutrients and extinction coefficient of light (Table 1). However, Saha, Bhattacharyya, Pandey & Choudhury (unpublished) reported that sufficient concentration of different nutrients for the growth of phytoplankton were available in all seasons in the canal. In another investigation, Saha, Bhattacharyya & Choudhury (unpublished) also observed that though the concentration of different trace metals were considerably higher, the ambient levels were not harmful for the primary production of the canal. The seasonal cycle of chl *a* concentration suggested an inverse relationship with GPP. This anomaly was encountered due to the fact that the highest concentration of chl *a* was observed during rainy season when water was highly turbid.

Photosynthetic capacity (PC, 1.01 to 4.61 mg C mg chl $a^{-1}h^{-1}$) also showed same pattern of seasonal variation as GPP. Inspite of availability of sufficient nutrients and radiant energy, average PC (mg C mg chl $a^{-1}h^{-1}$) of the canal was 2.95, which is lower than Hugli estuary (5.22-57.83) as reported by De Jana & Choudhury (1990). Ryther & Yentsch (1957) obtained an average PC of 3.70 mg C mg chl $a^{-1}h^{-1}$ from all sources. Williams & Murdoch (1966) reported that average PC of Beaufort channel was 12.10 mg C mg chl $a^{-1}h^{-1}$ in more productive period and 4.2 mg C mg chl $a^{-1}h^{-1}$ in less productive period. Temperature of water of the channel was 4 to 28°C and depth varied from 4 to 10 m. The entire depth of the channel lay within the eutrophication. The lower PC in Jagannath canal was primarily a function of extinction of

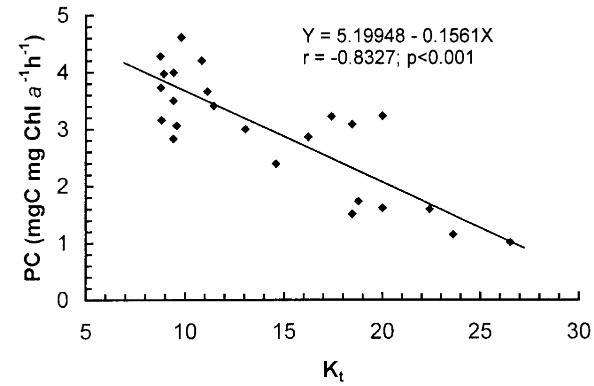

Fig. 3. Photosynthetic capacity (PC) as a function of extinction coefficient of light (K_t) in Jagannath canal.

downwelling radiation (Fig. 3). But the observed lower PC (3.25 mg C mg chl $a^{-1}h^{-1}$ in postmonsoon, in spite of having lower K_t (11.14) than that of premonsoon season (PC, 3.87 mg C mg chl $a^{-1}h^{-1}$; K_t, 12.02) can be explained by the fact that very low temperature during postmonsoon season reduced the photosynthetic activity of the system to some extent. Except temperature, variations in light saturated photosynthesis per unit chl a may also be related to species composition of phytoplankton (Malone 1976). In Jagannath canal, seasonal variation of phytoplankton population was highly significant in case of Bacillariophytes (F = 3.98; p <0.01), which showed significant relationship (r = 0.7162; p <0.001) with salinity. The percentage of Bacillariophytes was also observed to decrease with the decrease in salinity. Hence, the position of seasonal cycle of PC suggested that its value was a function of extinction coefficient of light, temperature and salinity of water. The quantitative relation of PC with K_t, temperature (T°C) and salinity (S‰) was fitted to a multiple regression equation:

$$PC\ [\text{mg C mg chl } a^{-1}h^{-1}] = 5.0679 - 0.1460\ (K_t) - 0.0155\ (T) + 0.0964(S)$$

The value of multiple correlation coefficient (R) was found to be 0.8545. The correlation between calculated and observed estimates of PC was highly significant (r = 0.855; p <0.001).

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