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Impact of plankton structure on primary productivity in two *beels* of West Bengal, India

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Abstract
Planktonic community in floodplain wetlands embodies the energy transfer through this phase and indicates trophic status of lake. Originally rich bottom coupled with a conducive physico-chemical environment encourages fast colonization of the plankton population. Present investigation was carried out in two floodplain wetlands having characteristics of open (Amda *beel*) and closed (Suguna *beel*) system. The physico-chemical parameters of water and soil of the investigated beels were by and large conducive for planktonic growth. The density of plankton population varied between 1,346 and 2,170 u/l in Suguna *beel* whereas in Amda *beel* it ranged from 1,030 to 1,802 u/l. Seasonal fluctuations in water column were conspicuous and mostly dependent on the replenished resources and volume. A mixed and balanced population of diversified fauna constituted the plankton population of the investigated ecosystems. Mostly the diversity was observed to be maximum during winter seasons with coincidence of favourable temperature, dissolved oxygen and other physico-chemical parameters of water besides optimum solar penetration. Richness of planktonic structure in closed system (Suguna) resulted in higher fish production (1,570.05 kg/ha/yr) than that of open system (Amda) (384.4 kg/ha/yr).

Key words : Primary productivity, Chemical energy, Seasonal influence, *Beel*

Introduction

Apart from promoting aquaculture, the inland fisheries sector must receive adequate and due attention to achieve optimum sustainable yield from the open water systems especially from floodplain wetlands. The management strategy for this vital sector is based on a category-wise approach. Capture fisheries would entail monitoring of recruitment and subsequent growth of the natural population. In closed lakes, stocking is the mainstay of management. A production rate up to 1,000 kg/ha/yr. is attainable from floodplain lakes of West Bengal, India when subjected to scientific management against production of 100 kg/ha/yr under traditional management (Sinha 1998, 2001). Year to year fluctuation in plankton quality is a general phenomenon in freshwater impoundment (Welch 1952) and the factors attributed to it are variation in rainfall, depth of water body, siltation and other chemical factors.

Primary productivity is an important parameter to assess the productivity of a water body. When the nutrient status is poor, the primary productivity and the fish production is also poor (Singh and Desai 1980) indicating that the primary productivity is positively correlated with nutrient concentration. Many investigators have monitored the primary productivity of water bodies at different places and during different seasons of the year and observed only one peak of primary production during summer or early summer in the reservoirs (Singh and Desai 1980). The knowledge of primary production in tropies is still limited except the work by Sreenivasan (1964, 1968), Ganapati and Sreenivasan (1970), Kaliamurthi (1978) and Natarajan and Pathak (1980). Information on biological productivity of swamps, ox-bow lakes and other wetlands is almost scanty (Laal 1981 and Yadav 1988). In this paper an attempt has been made to study relationship of primary production with planktonic structure in two eco-systems having open and closed characteristics.

Materials and methods

The investigation was carried out in two floodplain wetlands, commonly known as *beel*, namely Suguna *beel* and Amda *beel* for two consecutive years during October'97 to September'99. Suguna is a closed type of *beel* (E-1) and the basin is solely dependent on rains for water source. It is almost rectangular in shape with water spread area of 40 hectares lies in between latitude $88^0$4' E and longitude $22^0$6' N, is located at Kalyani, district Nadia, West Bengal. The *beel* was a defunct watercourse, which earlier had connection with the river Hooghly. Presently there is no water flushing from the river Hooghly. The Amda *beel* an open system is a shallow saucer shaped basin of 6 km long (E-2) having total area of 80 hectares. Amda *beel* lies in between latitude 88^0 7' E and longitude $23^0$2' N, is located at Dakshin Bishnupur, district Nadia, West Bengal. The *beel* is connected with the river Ganga and its tributary the Churni through some channels namely the Naba-Ganga, the Kumaler, the Galakata. During monsoon water enters as well as exits from the *beel* through these channels. Different physico-chemical parameters on soil and water were estimated at monthly interval following APHA (1985) and Jackson (1973). Primary production or chemical energy fixed by producers was measured by dark and light bottles technique at six hours incubation period in each *beel* at monthly interval. After the incubation time, dissolved oxygen was fixed and later was estimated by unmodified Winkler's method (Ellis *et al.* 1948). The plankton samples were collected at monthly interval from each *beel* in fixed spots along with water samples. Identification of the planktonic organisms was carried out following the relevant monograph (Philipose 1967, Lackey 1973, Battish 1992, Ward and Whipple 1992). The similarity and species diversity indices of plankton population was calculated in the same manner. Shannon-Weaver Index (H') was measured following the methodology developed by Shannon and Weaver (1964). The data were subjected to statistical analyses following Elhance and Elhance (1992), Fisher and Yates (1974), Snedecor and Cochran (1967).

Results and discussion

Maintenance of a healthy aquatic environment and production of sufficient fish food organisms in the water bodies are two basic factors of primary importance for boosting fish production.

Physico-chemical parameters of water

In the present study, the *beels* by virtue of differences in topography, hydromechanics, contour, age and catchment characteristics showed ecological and production variation. In E-2 the riverine ingress served as water filler apart from water from catchment area during monsoon season. The E-1 was dependent solely on catchment run-off for the depth replenishment. Mukhopadhyay (1997) indicated that majority of the beels in West Bengal is vulnerable to high water level fluctuations. Low rainfall causes seasonal water balance problems for the closed *beels*. Sugunan *et al.* (2000) reports in shallow *beels*, the whole water body gets heated up rapidly, thereby increasing the spread of chemical and bio-chemical reactions. Kumar (1985) recorded stratified temperature in a *beel* eco-system of Nadia district in West Bengal. In the investigated *beel* ecosystems, the water temperature closely followed the atmosphere temperature. Bhowmik (1988) reported that maximum and minimum temperature in *beels* and *baors* of West Bengal varied from 17.5 to 32.0 ^{0}C, which is in conformity with the present study. The pH of the both investigated *beels* (E-1 & E-2) fluctuated between 7.9 and 8.1 indicating alkanotrophic. The surface water contained more oxygen than the bottom and the difference in oxygen concentrations between the surface and bottom was maximum in E-1, which was a closed and comparatively deeper *beel*. The DO values in the bottom layer of the *beels* indicate depletion of oxygen depicting the eutrophic characteristics; reading as low as 0.2 ppm, which were recorded during early morning of summer in both the *beels*. Kumar (1985) also reported similar observation. In the present investigation, alkalinity of the *beel* waters was observed to be within the productive range. Out of the two ecosystems, E-1 (100-163 ppm) possessed higher alkalinity, while E-2 showed lesser value (89-156 ppm) throughout the investigated period. The high alkalinity of the *beel* water was due to presence of salts generated through the death and decay of the macrophytes, benthic organisms and also the plankton. Further, the system like E-1 that receives the run-off from human habitations was rich in alkalinity by virtue of allochthonus inputs as also reported by Sugunan *et al.* (2000). In the present study, free CO_2 content in surface water of the beels was always below detection levels and the gas was examined to be present at the bottom layers in moderate to low concentration (E-1, 0.4-0.6 & E-2, 0.55-0.92 ppm). Both the ecosystems under investigation maintained moderate to high specific conductivity of water and the values (E-1, 221-762 μmhos/cm & E-2, 224-463 μmhos/cm) were, by and large, higher during dry seasons, summer and winter, whereas comparatively lower in monsoon spell of the year. The level of the nutrient was observed to be by and large same (E-1: 0.12 - 0.48 ppm, E-2 : 0.09 to 0.24 ppm). The nitrate content in the studied *beels* were within the productive range and optimal for the growth of plankton, which is in agreement with the study of Banerjea (1967), Chu (1943). The phosphate values were much lower compared to the nitrate values in both the *beel* ecosystems. The level of phosphate was 0.02 - 0.08 ppm in E-1 where as in E-2, which is an open system, recorded lower level of phosphate (0.03 to 0.05 ppm). The concentration of the silicate was almost same in both *beels* being 10.84-19.06 ppm in E-1 and 10.88 -18.08 ppm in E-2.

Sediment characteristics

The bottom soil composition of a lake is the resultant contribution of various factors, which indicates great variation. In the present study, available nitrogen in the *beel* sediment varied in concentrations at 21.5-25.5 mg/100g of soil in E-1 and 10.6-23.2 mg/100g of soil in E-2.The nitrogen level in *beels* were within the range of favourable productivity. The systems contained almost similar level of available phosphorus (E-1 : 1.82-2.40, E-2: 1.72-2.20 mg/100 g of soil). Sugunan *et al.* (2000) reported that in contrast to other nutrient parameters, available phosphorus values were lowest in closed and weed choked *beels* (traces to 3.18 mg/100 g of soil), higher in closed but moderately weed infested *beels* (traces to 7.6 mg /100 g of soil), and highest in open one (traces to 10.08 mg/100 g of soil). The summer and winter levels of C/N ratio were almost comparable (E1-14: E2-12) while the same for monsoon was comparatively lower. Singh (1960) observed a significant correlation of C/N ratio with available nitrogen content. Banerjea (1967) opined that the C/N ratio less than 5 as very poorly productive; in the range 5 to 10 as productive and between 10 and 15 ideal for aquatic systems. Thus, in the present case, the observed values of C/N ratio indicated high productivity of the *beel* ecosystems.

Plankton structure

The Amda *beel* (E-2) harboured a moderate range of plankton population (3,188-5,592u/l) exhibiting bimodial peaks falling in winter and summer season of the investigated years. Seasonal influence on population structure was conspicuous in the *beel* ecosystem. Whereas plankton population in the Suguna *beel* (E-1) ranged between 5,548u/l and 13,878u/l. A bimodal peaks during winter and monsoon was observed during the investigated years. The winter peak was maximum followed by the monsoon. Summer population of plankton was much lower compared to the other seasons.

Phytoplankton

Phytoplankton was observed to be the major source contributing 66.92-97.70% of the total plankton population in E-2. The population density of organisms of this group varied with the seasons being 4,684-4,726 u/l, 4,948-5,460 u/l and 2,134-3,380 u/l during winter, summer and monsoon seasons, respectively. The species composition of the phytoplankton population varied with the season and a number of species showed wide fluctuation particularly, the *Chlorophyceae* during the summer season in E-1 (11.0-66.0). Phytoplankton constituted 90-94% of the total plankton population of E-1. The species diversity was maximum during winter. The density of the *Dinophycean* population fluctuated between 24 u/l and 120 u/l showing peak during summer (112-120 u/l) season of the investigated years. The percentage of *Cyanophyceae* population was comparatively higher in E-2 (91.0-93.0%). The percentage contribution by the *Bacillariophyceae* was maximum in E-2. The *Dianophyceae* population were recorded in E-1 (0.5-2.2%).

Zooplankton

The zooplankton population of E-2 consisted of multiple group of organisms with their abundance varying between 132-1,054 u/l. The contribution zooplankton in total plankton ranged from 2.3% to 33.1% with peak during monsoon of 1998. The percentage contribution in total plankton by this group fluctuated between 5.2% and 10% in E-1.

The percentage of *Copepods* among zooplankton was recorded minimum in E-1 (7.69-15.30%) whereas *Cladocerans* were present in E-2 only and the percentage contribution by this group of zooplankton in the respective systems were 0.37 to 4.04. *Ostracods* encountered were more in E-1 (2.25 to 23.07%) than E-2 (2.25 to 5.86%). Dominance of *Rotifers* was in E-2 (52.02-70.97%) followed by E-1 (5.17 to 23.07%). Protozoans were encountered more in E-1 (16.21 to 92.33%) than E-2 (3.04 to 5.17%). Sugunan *et al.* (2000) observed population of phyto- and zooplankton in floodplain wetlands of West Bengal at lower level during the South West monsoon, which increased thereafter when the environment become stable and the plankton population established utilizing inorganic nutrients and organic matter brought in by the incoming flood or run-off water. In the present observation, the plankton population was recorded more during summer in E-1, whereas it was higher during winter in E-2. Bhowmik (1988) also recorded maximum plankton population during summer season predominated by phytoplankton whereas during winter predominated by zooplankton. Jha (1997) recorded higher plankton population in the closed type of floodplain lakes in Bihar, which is in conformity with the present study.

Species diversity

The diversity indices are based on the concept that the structure of normal communities may be changed by environmental perturbations and extent of change in plankton community structure may be used to assess the intensity of environmental stress. Stability of the ecosystem can be studied by comparing the species diversity of different community (Sugunan 1989).

The study revealed that the maximum species diversity was observed in E-1 which was a closed water body. The system E-2 had comparatively lower species diversity (Table 1). The species diversity in E-1 was more in monsoon and winter while in E-2 during the winter seasons only. This clearly indicates that the winter season with favourable temperature, dissolved oxygen and other physico-chemical parameters besides the solar penetration augmented the species diversity in both the systems irrespective of open or closed system. Similar observations were encountered by Beaver *et al.* (1998) and Welcome (1979). Sugunan *et al.* (2000) reported that diversity indices in respect of zooplankters in different *beels* of South and North Bengal depicted many variations.

Table 1. Species diversity of plankton in investigated *beels* (E-1 &E-2)

Sl no.	Name of *beels*	Winter	Summer	Monsoon	Pooled
1	Suguna(E-1)	1.3000	1.3457	2.20414	1.5253
2	Amda(E-2)	1.9686	2.1567	2.02817	2.2046

Similarity coefficient

The similarity coefficient drawn following Bray and Curtis (1957) among the systems and between the seasons, the individual system indicated the trend in species similarity of plankton in the investigated water bodies. The similarity was most significant between the seasons in E-1 followed E-2. When comparing the relationship of planktonic population between the seasons the correlation was very significant. As a whole the relative values (Table 2) confirmed that the closed system (E-1) was more similar while open system (E-2) differred in planktonic structure depending on the replenishment mechanism and also nutrient supply from autochthonous and allochthonous sources.

The correlation drawn between water and sediment characteristic and plankton population clearly indicated the best of the same between the plankton and dissolved oxygen in E-2, $r= 0.5740$ and silicate in E-1, $r= 0.5328$ ($p<0.01$) (Table 3 & 4). The correlation between the other parameters were also significant with higher *"P"* values. Similar correlation between the plankton and sediment nutrient levels indicated soil nitrate to bear close impact on planktonic growth in E-1, ($r= 0.5080$, $p<0.01$) and E-4, ($r = 0.5198$, $p<0.01$) and phosphorus in E-2, ($r= 0.5010$, $p<0.01$). Banik *et al.* (1994) also made similar attempt to correlate rotifers with the limnological parameters and observed temperature($r= -0.9795$, $p<0.01$), dissolved oxygen ($r= 0.8686$, $p<0.01$), pH ($r= -0.6954$, $p<0.05$), bicarbonate($r= 0.6501$, $p<0.05$) and phosphate phosphorus ($r= 0.9831$, $p<0.01$) showing significant correlation with the occurrence of total rotifers (Tables 3 & 4).

Table 2 Distribution of plankton similarity indices in investigated *beels* (E-1 & E-2)

	E-1S	E-1M	E-1W	E-2S	E-2M	E-2W
E-1S						
E-1M	0.7552					
E-1W	0.6163	0.7528				
E-2S	0.5321	0.4533	0.572			
E-2M	0.448	0.3981	0.4051	0.5915		
E-2W	0.5057	0.4574	0.5964	0.4418	0.6749	

(S = Summer , M = Monsoon and W = Winter)

0.5000 - 0.5999 0.6000- 0.6999 0.7000 - 0.7999 0.8000 - 0.8999

Table 3. Correlation between abiotic and biotic factors in Suguna *beel* (E-2)

Parameters	Net production	Dissolved oxygen	Water nitrate	Water phosphate	Silicate	Soil nitrogen	Soil phosphorus	Plankton
Net production	1							
Dissolved oxygen	0.34431	1						
Water nitrate	0.24612	-0.2041	1					
Water phosphate	0.14519	0.0683	0.3656	1				
Silicate	0.54990=	0.1023	-0.0863	0.2010	1			
Soil nitrogen	0.41520	0.4394	0.2213	0.1249	0.1844	1		
Soil phosphorus	0.57664	0.3085	0.02110	-0.1156	0.4412	0.3970	1	
Plankton	0.05632	0.1388	-0.5739	-0.0514	0.5574	-0.0419	0.3610	1

Table 4. Correlation between abiotic and biotic factors in Amda *beel* (E-2)

Parameters	Net production	Dissolved oxygen	Water nitrate	Water phosphate	Silicate	Soil nitrogen	Soil phosphorus	Plankton
Net production	1							
Dissolved oxygen	0.4964	1						
Water nitrate	0.6777	0.6340	1					
Water phosphate	0.3248	0.0700	0.1939	1				
Silicate	0.5129	0.1382	0.4597	0.3713	1			
Soil nitrogen	0.4617	-0.0460	0.1700	-0.1921	-0.0586	1		
Soil phosphorus	0.2265	-0.0916	0.1886	-0.1589	0.2640	0.4297	1	
Plankton	0.6027	-0.0696	0.1477	-0.0193	0.5328	0.5197	0.0337	1

Primary productivity

Table 5 indicated the gross primary production, depending on the plankton structure existed during various seasons, of the investigated systems fluctuated between 0.263 gmC/l/m^3/day and 0.804 gmC/l/m^3/day in Suguna *beel* (E-1) and 0.275 gmC/l/m^3/day and 0.886 gmC/l/m^3/day in Amda *beel* (E-2). Being closed and nutritionally rich, the E-1 system was highly productive with net primary productivity in the range of 0.101 to 0.986 gmC/l/m^3/day whereas in E-2 it ranged from 0.107 to 0.506 gmC/l/m^3/day. However, the average net production in E-1 was maximum during winter and the value ranged between 0.200 gmC/l/m^3/day and 0.566 gmC/l/m^3/day. The least productivity of the system was recorded in monsoon when the values of which ranged from 0.107 gmC/l/m^3/day to 0.406 gmC/l/m^3/day in (E-2). The workers like Croome and Tyler (1975), Khan and Zutshi (1980) have reported high production during higher light intensity and vice-versa. Yadav *et al.* (1987) and Pathak (1997 and 2001) reported moderate primary productivity with little variation in values from tropical waters. The *beels* investigated, by virtue of shallowness and high nutrient content, showed moderate to high productivity throughout the period. The net production values when considered for productivity evaluation of the *beels* indicated fluctuation in the values with the change of season and also of the systems because of variation of plankton population.

Table 5. Productivity of the two different types of *beel* ecosystems

Parameters	Suguna *beel* (E-1)						Amda *beel* (E-2)					
	Summer		Monsoon		Winter		Summer		Monsoon		Winter	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Gross Primary Production	0.263-0.612	0.412 ± 0.111	0.398-0.792	0.607 ± 0.125	0.514-0.804	0.702 ± 0.097	0.418-0.886	0.644 ± 0.141	0.275-0.685	0.430 ± 0.141	0.542-0.752	0.672 ± 0.0721
Net Primary Production	0.101-0.98	0.363 ± 0.355	0.221-0.472	0.297 ± 0.081	0.20-0.566	0.393± 0.130	0.224-0.502	0.317 ± 0.088	0.107-0.406	0.181 ± 0.088	0.218-0.506	0.376 ± 0.106
Assimilation Efficiency	0.25-0.580	0.333 ± 0.111	0.34-0.60	0.492 ± 0.779	0.28-0.81	0.556 ± 0.164	0.33-0.58	0.496 ± 0.076	0.27-0.590	0.372 ± 0.076	0.30-0.73	0.548 ± 0.141
Respiration	0.162-0.294	0.256 ± 0.044	0.177-0.44	0.310 ± 0.082	0.136-0.508	0.308 ± 0.113	0.176-0.461	0.326 ± 0.087	0.168-0.330	0.249 ± 0.087	0.186-0.505	0.319 ± 0.093
Respiration to % of GP	41.83-75.0	63.858 ± 11.39	40.4-66.07	50.922 ± 7.687	19.37-71.18	44.29 ± 16.162	42.11-51.59	47.793 ± 3.563	40.3-72.36	59.918 ± 3.563	26.88-69.75	47.02 ± 13.347

The closed system (El) supported by the net production values, has been observed to be more productive compared to the open ones (E-2). Further, the seasonal influence on primary production in the *beels* was pronounced commensurable with availability of plankton. The net production was maximum during winter in both the *beel* systems. While correlating the net production values with the water and sediment nutrients, dissolved oxygen and plankton, exhibited significant influence in both the beels.

Primary production vis a vis fish production

It is evident from the above discussions that the plankton population supported higher primary productivity in the Suguna *beel* (E-1) compared to Amda *beel* (E-2). While comparing the fish productions accordingly reported higher production at 1,570.15 kg/ha/yr in E-1 commensurable with higher plankton population > higher primary productivity in comparison to E-2 where fish production was recorded at 384.4 kg/ha/yr (Fig. 1).

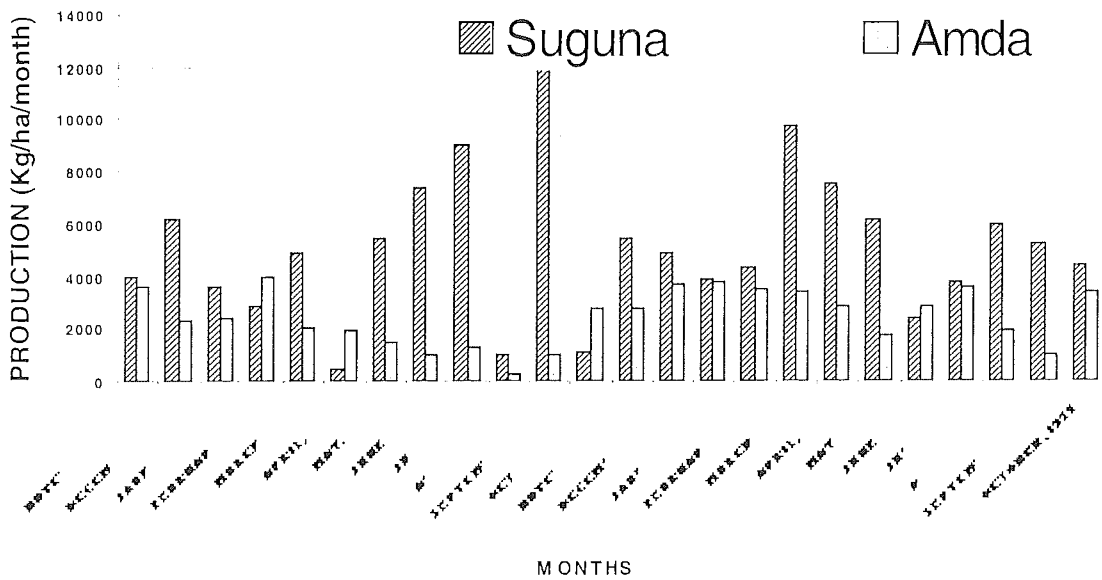

Fig. 1. Comparison of fish production in Suguna and Amda *beels* (E-1 & E-2).

Conclusions

The solar penetration, more transparency and available nutrients influenced planktonic growth in the *beel* ecosystems and as a result, variability in diversity and density of the organisms was observed between the *beels.* The energy fixed by producers flow to consumers at different trophic levels. Therefore, proper understanding of patterns and extent of utilization of this energy in aquatic ecosystems may help in formulating management measures towards enhancement of fish production and conservation of resources. Thus, suitable management options need be formulated to stabilize the available planktonic population and to catalyse higher primary production *vis-a-vis* higher fish production from an ecosystem.

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