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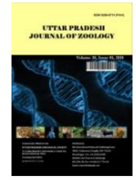

COMPARATIVE STUDY OF FISH PRODUCTION IN RELATION TO PERIPHYTIC STRUCTURE IN FLOODPLAIN WETLAND ECOSYSTEMS

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The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Periphytic communities are a major component of wetland ecosystem which are influenced by several ecological factors like light, temperature, nutrients, and space availability in the water. Immense potential does exist towards increase in fish production about 3 times through aquaculture based on periphyton. Present investigation was carried out in two floodplain wetlands having unique characteristics of both open (Amda beel) as well as close (Suguna beel) system for two consecutive years during October, 2018 to September, 2020. Periphytic community, Soil and water quality and fish production of the beels were estimated and assessed in monthly interval during the study. 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. A mixed population of diversified fauna constitutes the periphytic population of the investigated ecosystems. The values of species diversity clearly indicated that both the *wetlands* were favourable for harbouring balanced population of the periphytic fauna. In this paper an attempt has been made to study comparative status of fish production in relation to periphytic structure in unique ecosystems where flowing and stagnant conditions were compared. From the point of view of fish crop, the Suguna was more productive as indicated by the annual fish yield being 1601.01 - 1688.58 kg $ha^{-1}yr^{-1}$. In this beel the major carp contributed maximum towards production (54.17 - 87.53 %). The per cent contribution of miscellaneous group of fishes in Suguna was 9.59-45.83 during the study. The annual average fish production of the Amda fluctuated between 353.76 – 442.85 kg $ha^{-1}yr^{-1}$. The major contributor to the fish catches were the miscellaneous species (about 62%). The carps contributed 6.64 – 68.95% of the fish production in Amda. The fish production in the open beel was found to be very low in spite of higher biomass of periphytic community was mainly due to higher siltation rate, poor management, weed infestations and nutrient imbalances, and many more issues related with the river connectivity leading to natural fluctuations in the water level in the beel. The situations in these beels are complex and needs the balance to maintain sustainable fish production and associated livelihood in equilibrium with socio-environmental ethics.

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1. INTRODUCTION

In West Bengal, extensive floodplain wetlands covering an area of about 42,000 ha, locally known as *beels*, bear special significance as the inland fisheries resources. In spite of constituting 22% of the entire freshwater area of the state, fish yield is generally much lower i.e. about 100–150 kg/ha annually [1] than their potential. The wetlands vary widely in size, shape, extent of riverine connection and on the course of losing connection with the lotic system. The wetlands usually represent the lentic component of the floodplain, but may retain its connection with the lotic system. The typical complexity of inundation creates habitat mosaics that support a wide range of organisms including aquatic plants, invertebrates, fish and many more [2-3]. Comprehensive assessment of the trophic relationship governing the biological productivity of water bodies is difficult without any knowledge of abiotic and biotic factors. Seasonal fluctuations of the different ecological parameters should therefore, be studied closely in order to understand the process of aquatic productivity. The term *periphyton* was introduced by Behning in 1924 and refers to the entire complex of attached aquatic biota on submerged substrates, including associated non-attached organisms and detritus as bacteria, fungi, protozoa, algae, zooplankton and other invertebrates. Periphyton as a major component of wetland ecosystem is influenced by several ecological factors like light, temperature, nutrients, and space availability in the water. Periphytons are the major contributor to carbon fixation and act as an indicator of environmental change by environmental sensitivity [4]. In India, Philipose [5] made observation on the periphytic forms in the pond. Misra and Singh [6] and Vass et al. [7] also reported the periphytic fauna of freshwater and brackish water impoundment respectively. Several recent studies on periphyton from different parts of India enlighten the role of these communities [8-11]. Immense potential does exist towards increase in fish production through aquaculture based on periphyton which was reported to be about 3 times [12] but scientific fish culture is cost intensive and as such, may be beyond the reach of poor or marginal fish farmers. Further, its intensification is beset with problems of availability of certain required inputs and possible impacts on environment. Thus, total reliance on aquaculture for meeting targeted fish production cannot be placed and it is essential to give due priority to fishery of inland open water resources to achieve environment friendly sustainable production [13]. In this paper an attempt has been made to study comparative status fish production in relation to periphytic structure in a unique eco-system where both flowing and stagnant conditions exit though partition.

2. METHODS AND MATERIALS

The investigation was carried out in two floodplain wetlands commonly known as beels namely Suguna beel and Amda beel for two consecutive years during October, 2018 to September, 2020. Suguna is a closed single basined *beel* with an area of 40 hectares and it is solely dependent on rains for water source. The *beel* was formed as a result of defunct watercourse, which had connection with the river Hooghly earlier. The connection with the river Hooghly was lost now. Suguna beel henceforth is to be known as B-1 lies in between latitude $88^0 4'$ E and longitude $22^0 6'$ N, is located at Kalyani, district Nadia, West Bengal. Amda beel is a shallow basin having total area of 80 hectares. The *beel* is connected with the river Ganga and its tributary the Churni through some channels namely the Naba-Ganga, the Kumaler and the Galakata. During monsoon water enters as well as exits from the *beel* through these channels. Amda the open one henceforth is to be known as B-2 lies in between latitude 88^0 7' E and longitude $23^0 2'$ N, is located at Dakshin Bishnupur, district Nadia, West Bengal (Fig. 1A & B).

Water quality like temperature (^oC), transparency (m), dissolved oxygen (ppm), pH, alkalinity (ppm), specific conductivity(mmhos), nitrate (NO_3) (ppm), phosphate (PO_4) (ppm), Silicate (ppm) and soil quality as pH, organic carbon (mg g^{-1}), available nitrogen (mg 100 g of soil $^{-1}$), available phosphorus (mg 100 g of soil $^{-1}$), C/N ratio of the beels were estimated in monthly interval following the protocols described by American Public Health Association (APHA) [14] and Jackson [15]. For studying the periphyton, sterilized glass slides were firmly suspended by wooden cloth pins with rope and bamboo poles following Newcombe [16]; King and Ball [17]. A set of two such slides were suspended vertically in water. Such a position obviously helps in preventing the deposition of mineral particles on the slides. After the required incubation period of 30 days, the slides were taken out of water with care so as not to disturb the surface growth. The slides were later brought to the laboratory for enumeration of periphytic forms. The periphyton growth from each side of the slides were scraped and preserved in 4% formalin and "*acetic lugol*" for detailed analysis. The numerical estimates of forms have been expressed as unit slide area (cm^{-2}).

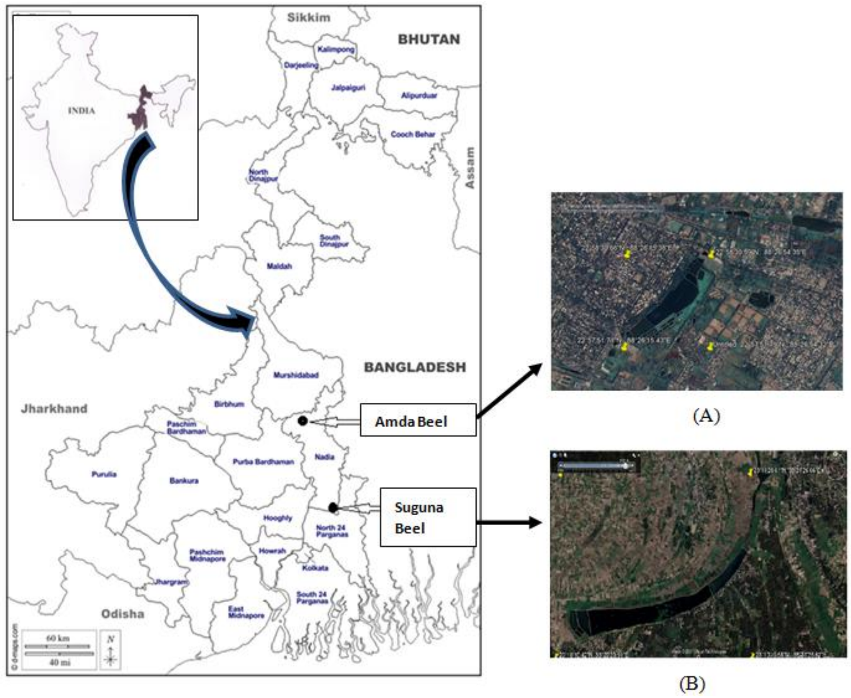

Fig. 1. Map showing the location of study sites of two Beels in Nadia District of West Bengal & Satellite picture of (A) Amda & (B) Suguna beel

Diversity indices like Shannon (H), Evenness (e) and Simpson (D) was calculated for the periphytic flora and fauna throughout the study period.

Shannon Diversity Index (H') = $\sum n_i / N (\log n_i/N)$

In which, n_i =density of the i^{th} species; N=Total density [18]

Evenness Index (e) = H'/(logS)

Where H'= Shannon Diversity Index, S= Total number of Species [19]

Simpson's Index $1\text{-}D = 1 - \sum (n_i/N)^2$

Where n_i=density of the i^{th} species; N=Total density

Dominance Index $D= \sum (n_i/N)^2$ [20-21]

Sorenson's Coefficient (CC) was calculated to assess the community similarities between the periphytic assemblages of two beels using the formula:

Sorenson's Coefficient (CC) =2C/S1+S2

Where C is the number of species the two communities have in common, S1 is the total number of species found in B1, and S2 is the total number of species found in B2 [22].

Statistical analysis was performed among various parameters like pheriphytic community, water and soil parameters and fish production by using SPSS Ver. 18. Differences were considered as statistically significant at a probability value of $P < 0.05$ [23].

3. 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.

3.1 Periphytic Structure

The periphyton comprised mixed population of both floristic and faunistic organisms. And the density of periphytic population ranged between 1346 - 1950 $u.cm^{-2}$ in closed beel (B-1) and 1047-2274 $u.cm^{-2}$ in open beel (B-2). The seasonal influence on the growth of periphytic organisms was pronounced and showed maximum abundance in winter season (1918-1923 $u.cm^{-2}$ in B1 and 2102-2274 $u.cm^{-2}$ in B2) followed by summer (1880-1950 $u.cm^{-2}$ in B1 and 1471-1876 $u.cm^{-2}$ in B2) & monsoon (1,346-1,352 $u.cm^{-2}$ in B1 and 1047 - 1571 u.cm^{-2} in B2). The density of periphytic biomass was higher in the open beel may be due to the fact of complex relationship between water flow and nutrient enrichment in the system [24]. Periphytic organisms are affected by several physical factors as water level, water flow, temperature, rainfall, substrate type [25-28] which supports the maximum abundance of these organisms during winter season in both open and closed type of flood plain wetlands.

Among the organisms the blue green algae contributed about 36-44 %, green algae about 27-38 % and diatoms 20 - 23% of the total periphytic population and zoo-organisms constituted of rotifers, ciliophors and copepods in B-1. The percentage contribution by the different groups of organisms fluctuated with the season. The variability in percentage contribution by the different groups was conspicuous- diatoms constituted about 17-40%, blue green algae about 23–39%, green algae about 26-30% of the periphytic population. The diatoms were the richest in no. of Taxa and dominant group accounting for 34% of total density in a similar study by Dunck et al. [28]. Among the zoo organisms rotifers and copepods contributed about 2-4%, while ciliophores about 5-9 % of the total periphyton in B-2. The maximum growth of green algae and rotifer population was in summer, while that of blue green algae and ciliophore in monsoon and diatoms and copepods in the winter season (Fig. 2) in both the beels. Diatoms, presented the highest number of representing genera (9 Genera) in B2 and at all the seasons investigated, may be due to the fact that diatoms are rapid and efficient colonizers, have specialized structures like short or long mucilaginous peduncles (e.g. *Gomphonema)*, mucilaginous matrices (e.g.*Cymbella*, *Frustulia*, *Navicula)* etc for fixation to substratum which gives them a competitive advantage in more stressful environment [29] and may be *Synedra, Achnanthes, Navicula acted* as indicator species for environmental gradients in the B2 [30]. Numerically, desmids i.e. Green algae were significantly represented which may be related with the presence of macrophytes as also low water current in these two types of beels [31].

The littoral characteristic was favourable for the growth of periphytonic organisms in the investigated beels. A good growth of submerged vegetation supported periphytic growth consisting of various groups of phyto and zoo planktonic organisms providing adequate substrate required for the purpose. The biomass production of periphyton varies greatly in the two beels in two different ecological conditions. Higher Periphyton growth was observed in B2 may be due to the fact that the periphyton grows better in wetlands with higher water flow on artificial substrate [32]. The dominance of bacillarophycaea among different periphyton classes in terms of diversity and density in B2 showed much similarities with the observations of Rashid et al. [33]; Rashid and Pandit [34] & Albay and Aykulu [35] on wetlands with higher water flow. The solar penetration, more transparency and available nutrients influenced periphytic growth in the beel ecosystems and as a result, variability in diversity and density of the organisms was observed among the beels [36].

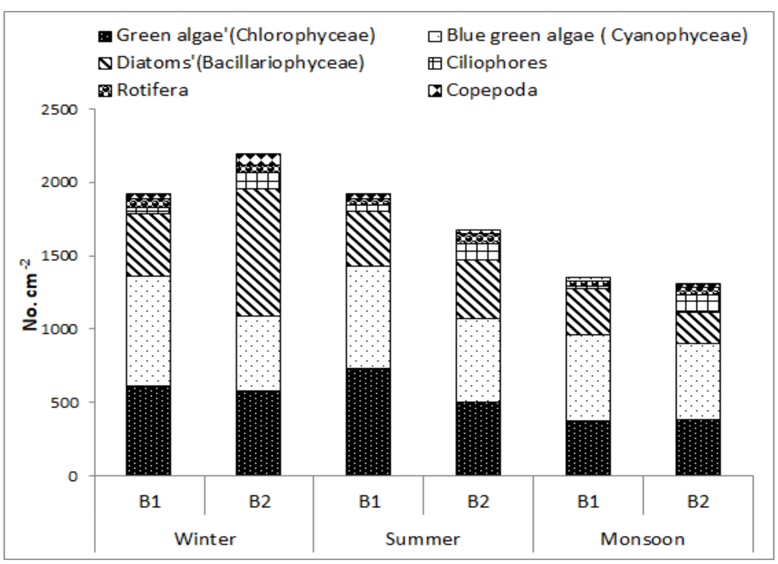

Fig. 2. Seasonal variation of periphytic abundance both qualitative and quantitative (No.cm^{-2}) in the two beels studied (B1 & B2)

The Shannon index in B1 varied between 2.098-2.225 for periphytic flora and 1.752-1.888 for periphytic fauna. In B2 the index ranged from 2.156-2.487 for periphytic flora and 1.766-1.925 for periphytic fauna which indicated a more or less good situation for richness and had good quality in biodiversity in both the beels studied (Table 1). The Shannon indices are generally used in the studies where the organisms are identified up to the species level. But here all the specimens were identified up to the genus level only. And the presence of very low number of taxa is an indicator that not all species in the community are represented in the sample collected from the artificial surfaces. All the diversity indices showed some level of fluctuations in different seasons (Table 1) but hardly any significant differences were observed during the study.

Dominance Index in both the beels did not show any significant difference among the Chlorophyceae, Cyanophyceae and Bacillariophyceae (0.2486-0.3949) indicating slightly lower values of Dominance than the Ciliophores, Rotifers and Copepods (0.3455-0.5236). The Shannon Index showed its highest values in B2 (1.75) than in B1 (1.44) for Bacillariophyceae (Table 2). Simpson's index of equitability was highest in B2 for Bacillariophyceae (SI= 0.7514). The evenness value in both the beels for all the groups of organisms were more or less equally distributed indicating any significant change in diversity indices. As no natural communities are never perfectly even [37], the degree of unevenness offers information about the structural configuration of a community and the disturbances it faced [38-39]. All the diversity indices for Chlorophyceae, Cyanophyceae and Bacillariophyceae were found very low indicating least preference of the organisms to be associated on artificial surfaces i.e. on glass slides.

3.2 Water Parameters

In the present study, the studied beel ecosystems showed by a large variation in ecological parameters and fish production due to their differences in time of origin, geomorphology, hydrokinetics, and catchment basin. The B-1 is dependent on catchment run-off for the depth replenishment. In B-2 the riverine ingress served as water filler retained floodwater during monsoon season. As indicated from the seasonal water column of the beel ecosystems these are shallow water bodies and can be classified as littoral lake with gradual slope and depth not exceeding 6 metre [40]. In West Bengal most of the beels showed fluctuation of water levels [41]. Low rainfall causes seasons water balance problems for the closed beels. Sugunan et al. [42] reported in shallow *beels*, the whole water body gets heated up rapidly, thereby increasing the spread of chemical and bio-chemical reactions. The beels, which possess riverine connection, are victimised adversely forwards input-output ratio due to continuous water exchange. Kumar [43] recorded stratified temperature in a beel ecosystem of Nadia district in West Bengal. In the investigated *beel* ecosystems, the water temperature closely followed the atmosphere temperature (Table 3). The present investigation showed water temperature range somewhat in accordance with the study of Bhowmik [44] where the range was reported as 17.5- 32.0 ^{0}C. The pH of the both investigated beels (B-1 & B-2) fluctuated between 7.4 and 8.8 indicating alkanotrophic condition. The surface water was more oxygenated in comparison with the bottom and the difference in oxygen concentrations between the surface and bottom was maximum in the closed and comparatively deeper *beel* (B-1). Kumar [43] also reported similar observation. In the present investigation, alkalinity of the *beel* waters was observed to be within the productive range. Of the two ecosystems, alkalinity of water in B-2 (116 -198 mg l^{-1}) was slightly higher, while in B-1(105 -163 mg l^{-1}) much less throughout the investigated period. The decomposition of dead planktons, macrophytes, and benthic organisms generate some chemicals which in turns increase the alkalinity of water in the studied beels. Sugunan et al. [42] reported similar observations. The entire ecosystems under investigation maintained moderate to high specific conductivity of water and the values (B-1: 163-386 µmhos cm^{-1} & B-2: 218 – 752 µmhos cm^{-1}) were, by and large, higher during dry seasons, summer and winter, whereas comparatively low in monsoon spell of the year. The level of the nitrate was 0.12 - 0.63 mg l^{-1} in B-2 and it was comparatively higher than the observed range of 0.09 to 0.24 mg l^{-1} in B-1. Observations of nitrate for both the beels were limited within the optimum level for growth of plankton [45] and productivity [46]. In the present study, the phosphate values were much lower in comparison with the nitrate values in both the *beel* ecosystems. The level of phosphate was recorded in between 0.02 - 0.08 mg l^{-1} in B1 but in B-2, which is an open system it showed a range of 0.02 - 0.59 mg l^{-1} with higher values during winter in both the years of observation. But this peculiar observation may support the view of Ghosh & Gaur [24], which concluded that the natural growth of the filamentous green algae was directly proportional with the phosphorous enrichment in the water bodies with low flow. The concentration of the silicate was 10.84 – 20.44 mg l^{-1} during investigation period in B-1 and 10.88 -18.08 mg l^{-1} B-2. All the physico chemical parameters of the investigated wetlands were within the range of highly productive water bodies as reported previously by Ziauddin [47] in case of Suguna and Kole beel of gangetic plain of West Bengal.

3.3 Soil Characteristics

The soil texture of B1 showed 20-22% Clay, 28-30% Silt and 48-62% of Sand; whereas in B2 it was found as 20-25% clay, 25-28% silt and 47-55% sand. In the present study, relatively acidic nature of the sediment layers of both the beels could be due to the production of organic acids as a result of accumulation of detritus in anoxic condition [48]. The observed organic carbon level in B1 is somehow lower in range (4.3-4.6 mg g^{-1}) than the B2 (9.0-9.2 mg g^{-1}). Mathew et al. [49] observed similar range of Organic carbon in their study in Tamilnadu. Bhowmik [50] and Mandal [51] observed the seasonal fluctuation with definite pattern of peaks of organic carbon. Kumar [43] reported organic carbon values ranged from 3.8 - 4.8 in a *beel* located at Kalyani which is very similar to the values observed for B1. In the present study, available nitrogen in the *beel* sediment was varying between 10.6 - 23.2 mg 100 g of soil $^{-1}$ in B-1, 21.5 - 25.3 mg 100 g of soil $^{-1}$in B-2 and the nitrogen along with phosphorus are the most limiting nutrients in wetlands [52]. Availability of Nitrogen and phosphorous in adequate quantity in the sediment of wetlands favours the growth of algal biomass [53-54]. Sediment organic matter or carbon and total nitrogen and C/N ratio are the regulating factors for the wetland productivity [55-56]. The *beel* systems contained available phosphorus as 1.6 - 2.3 mg 100 g of soil $^{-1}$ in B-1 and 1.7 - 2.2 mg 100 g of soil $^{-1}$ in B-2. These values in both the beels indicate high infestation of weeds in both the systems [42]. The C/N ratio was almost 8.2-8.8 & 9.2-10.6 in B1 and B2 respectively and almost comparable with the observation of Prusty et al. [52]. Banerjea [46] showed the C/N ratio in the range 5.0 to 10.0 is the sign of productive ecosystem, but a range of 10.0 - 15.0 is ideal for aquatic system (Table 3).

3.4 Fish Production

From the point of view of fish crop, the B1 was most productive as indicated by the annual fish yield being 1601.01 - 1688.58 kg $ha^{-1}yr^{-1}$ (B-1). The major carp to the tune of 54.17 - 87.53 % contributed maximum towards production. The per cent contribution of miscellaneous group of fishes in B1 was 9.59-45.83 during the course of this study. The annual average fish production of the B2 fluctuated between 353.76 – 442.85 kg $ha^{-1}yr^{-1}$. The major contributor to the fish catches were the miscellaneous species sharing on an average about 62% of total fish catch. The carps contributed 6.64 – 68.95% of the fish production (B-2) (Fig. 3A & 3B). The apparent high value of fish production in B1 may be due to the management practice adopted for the wetland as culture-based capture fisheries i.e. in general partial stocking with fast growing Indian and Exotic carps greatly influenced the production turn up. Simple Linear Regression were used to test for association between Water and soil quality parameters with fish production. Percentage of total variance of Fish production (Dependent Variable) is explained by the Predictor variables as Dissolved oxygen (39.9%), Organic carbon of soil (83.5%), Available Phosphorus of soil (47.3%) and C/N ratio of soil (87.1%) (Table 4). This observation of association was almost similar with many other studies from different parts of India [57-58]. Same type of observation was also reported from around the world by Nsor and Obodai [59]; Vega-Cendejas et al. [60] and Roy et al. [61]. The fish production in wetland of West Bengal has been reported by various workers [42,62] and mentioned to be largely dependent on the management procedure adopted thereof. The fish production in the wetlands depends on the changes in the ecological system, species composition and abundance, seasonal variation and changes in habitat [63]. The open system B-2 showed very low production to the tune of 384.4 kg $ha^{-1}yr^{-1}$ (Fig. 3C), which is attributable to the uncontrolled water spread and management incredibility for holding the fish stocks to its desired densities and species composition and also proportionate retrieval. But the overall production and fish species variation was reported to decline from the studied wetlands from the previous decades may be a consequence of loss of connectivity of river, high infestation of aquatic weed, excessive siltation, shrinkage of water area, agricultural activities around the wetlands, discharge of wastes from domestic and municipal sources, and other anthropogenic stresses [64-67]. Sarkar et al. [68] emphasized on direct or indirect effect of climate change towards reduction of fish yield and changed nature of the overall system.

The solar penetration, more transparency and available nutrients influenced periphytic growth in the *beels* ecosystem and as a result, variability in diversity and density of the organisms was observed among the *beels.* The community similarity analysis through Sorenson's Coefficient (0.933) showed high similarity or overlap of periphytic communities among the two types of beel studied [22]. The secondary producers of aquatic ecosystem prefers periphytic habitat due to the complexity of habitat, protection form predation and food availability, which in turn enhance the natural feed for the fishes in the beels [9].

Table 1. Seasonal variation in Diversity Indices of periphytic communities in the studied beel ecosystems

Shannon_H	**Winter'18**		**Summer'19**		**Monsoon'19**		**Winter'19**		**Summer'20**		**Monsoon'20**	
	B1	**B2**	**B1**	**B2**	**B1**	**B2**	**B1**	**B2**	**B1**	**B2**	**B1**	**B2**
Periphytic flora	2.163	2.487	2.098	2.309	2.157	2.329	2.198	2.402	2.197	2.386	2.225	2.156
periphytic fauna	1.752	1.861	1.888	1.766	1.808	1.819	1.867	1.925	1.848	1.856	1.85	1.812
Dominance_D												
Periphytic flora	0.129	0.09648	0.1448	0.1186	0.1325	0.1129	0.1307	0.1116	0.1317	0.1159	0.1257	0.1558
periphytic fauna	0.1983	0.1673	0.1597	0.1949	0.1788	0.1852	0.1624	0.1486	0.1718	0.1661	0.1698	0.174
Simpson_1-D												
Periphytic flora	0.871	0.9035	0.8552	0.8814	0.8675	0.8871	0.8693	0.8884	0.8683	0.8841	0.8743	0.8442
periphytic fauna	0.8017	0.8327	0.8403	0.8051	0.8213	0.8148	0.8376	0.8514	0.8282	0.8339	0.8302	0.826
Evenness_e^H/S												
Periphytic flora	0.7247	0.802	0.6792	0.7192	0.7201	0.6846	0.7505	0.6901	0.7501	0.6794	0.7715	0.5396
periphytic fauna	0.8239	0.9189	0.9441	0.8352	0.8708	0.8809	0.9245	0.9795	0.9067	0.9136	0.9082	0.8747

Table 2. Diversity Indices of periphytic community groups found in the studied beel ecosystems (B1 and B2) during the study period

	Chlorophyceae		**Cyanophyceae**		**Bacillariophyceae**		**Ciliophores**		**Rotifera**		**Copepods**	
	B1	**B2**	**B1**	**B2**	**B1**	**B2**	**B1**	**B2**	**B1**	**B2**	**B1**	**B2**
Taxa_S	3	4	3	3	6	9	3	3	2	2	2	2
Individuals	569	483	677	532	372	495	33	112	47	56	32	46
Dominance_D	0.3387	0.311	0.3734	0.3949	0.3117	0.2486	0.3554	0.3455	0.5183	0.5057	0.5078	0.5236
Simpson_1-D	0.6613	0.689	0.6266	0.6051	0.6883	0.7514	0.6446	0.6545	0.4817	0.4943	0.4922	0.4764
Shannon_H	1.091	1.266	1.041	1.012	1.44	1.75	1.063	1.081	0.6747	0.6874	0.6853	0.6693
Evenness_e^H/S	0.9921	0.8864	0.944	0.9172	0.7034	0.6395	0.9649	0.9823	0.9817	0.9943	0.9922	0.9765

Table 3. Seasonal variation of water and soil quality parameters in the two beels studied (B1 & B2)

Parameters	B1		B2		B1		B2		B1		B2	
	Winter		Winter		Summer		Summer		Monsoon		Monsoon	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
Water temperature (^oC)	19.4-24.6	21.8 ± 0.1	18.4-23.8	21.2± 0.3	28.4-32.8	30.4± 0.2	29.4-33.6	31.5± 0.1	27.8-32.2	30.0± 0.3	24.9-31.2	28.2± 0.3
Transparency (m)	0.75-0.94	0.86±0.002	0.90-0.95	0.88±0.001	0.85-1.10	0.98± 0.001	0.90-1.05	0.98± 0.003	0.90-1.15	1.02±0.005	0.90-1.15	1.0± 0.003
Dissolved oxygen (ppm)	7.2-9.8	8.8±0.04	5.8-7.8	6.9± 0.02	7.6-10.2	8.6±0.06	5.9-7.9	7.0± 0.02	7.2-10.8	8.1± 0.03	6.0-8.8	7.8± 0.02
Water pH	7.4-8.0		7.6-8.3		7.5-8.1		7.4-8.7		7.4-8.0		7.7-8.8	
Alkalinity (ppm)	126-152	136±1.24	142-168	157± 1.6	120-163	140± 1.18	162-198	178± 1.8	105-135	126± 1.21	116-152	138± 1.43
Specific conductivity(mmhos)	163-285	232± 1.86	255-354	308± 2.15	289-386	342± 3.02	454-752	598± 4.65	236-295	272± 2.64	218-327	250± 1.98
Nitrate (NO_3) (ppm)	0.12-0.14	0.14± 0.001	0.18-0.46	0.36± 0.003	0.16-0.24	0.22± 0.002	0.12-0.63	0.42± 0.003	0.09-0.14	0.13± 0.001	0.16-0.21	0.2± 0.002
Phosphate (PO_4) (ppm)	0.02-0.04	0.04± 0.002	0.03-0.05	0.04± 0.001	0.05-0.08	0.06± 0.002	0.04-0.06	0.06± 0.003	0.02-0.04	0.03± 0.001	0.02-0.04	0.04± 0.002
Silicate (ppm)	14.82-20.44	18.02± 0.2	12.82-18.80	14.64±0.2	11.06-15.82	14.1±0.3	12.08-18.80	16.12±0.2	10.84-15.66	12.88±0.1	10.88-16.64	13.65±0.1
Soil pH	6.5-7.1		6.2-6.4		6.4-7.0		6.0-6.4		6.6-7.2		6.0-6.4	
Organic carbon (mg g^{-1})	4.4-4.5	4.35± 0.01	9.1-9.2	9.12± 0.09	4.5-4.6	4.51± 0.04	9.18-9.2	9.19± 0.06	4.3-4.5	4.45± 0.03	9.0-9.05	9.04± 0.06
Available nitrogen (mg 100 g of soil $^{-1}$)	10.6-23.2	15.84± 0.16	24.0-25.3	24.9±0.19	20.0-23.2	20.9± 0.23	21.5-25.3	22.9± 0.18	19.9-22.8	21.5± 0.16	22.1-24.8	23.8± 0.2
Available phosphorus (mg 100 g of soil $^{-1}$)	2.0-2.3	2.1± 0.01	1.7-2.2	2.1±0.02	1.6-2.3	2.1±0.02	1.76-2.2	1.88±0.01	1.98-2.2	2.1±0.01	1.7-2.1	2.0±0.02
C/N ratio	8.5-8.6	8.5± 0.03	9.2-10.2	10.0±0.04	8.6-8.8	8.7±0.05	9.8-10	9.8±0.06	8.2-8.7	8.45± 0.06	10.2-10.6	10.5± 0.07

Table 4. Simple Linear Regression Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Predictors: Dissolved Oxygen of Water	.632[a]	.399	.249	2903.46581
Predictors: Organic Carbon of Soil	.914[a]	.835	.794	1519.67915
Predictors: Available Phosphorus of Soil	.688[a]	.473	.341	2719.60297
Predictors: C/N ratio of Soil	.934[a]	.871	.839	1343.10183

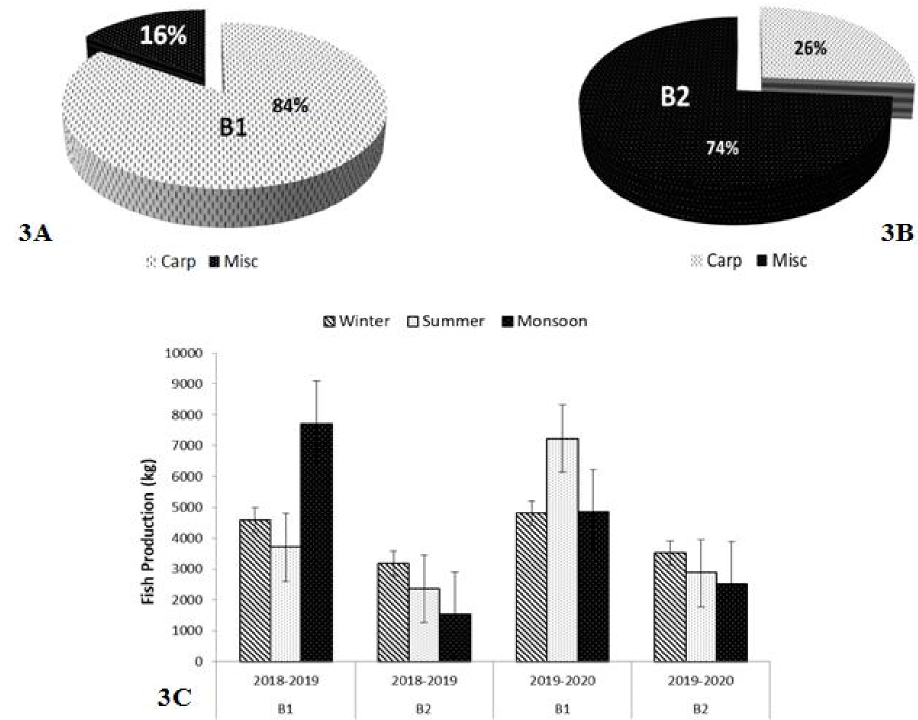

Fig. 3. A) & B) Percent Contribution of carp and miscellaneous fishes in average total fish in the investigated beels B1 and B2. C) Season-wise variation in Total fish production in the investigated beels B1 and B2

4. CONCLUSION

The fish production in the open beel was found to be very low in spite of higher biomass of periphytic community was mainly due to higher siltation rate, poor management, weed infestations and nutrient imbalances, and many more issues related with the river connectivity leading to natural fluctuations in the water level in the beel [69-70]. The situations in these beels are complex and needs the balance to maintain sustainable fish production and associated livelihood in equilibrium with socio-environmental ethics.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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