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Exploring the Potential for Concurrent Rice-Fish Culture in Wetlands of Assam, North East India

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Abstract

A study was conducted to explore the potential for concurrent rice-fish culture in the wetland rice fields of Assam, North East India. For the present study, a representative wetland located in Cachar district of Assam, North East India was selected. Water quality parameters such as water temperature, dissolved oxygen, biological oxygen demand, pH, free carbon dioxide, and nutrients like nitrate-N and phosphate-P were analyzed. Besides, qualitative and quantitative estimation of both phyto- and zooplankton communities in the rice fields were also done. A total of 57 genera of phytoplankton belonging to 8 classes viz., Bacillariophyceae, Chlorophyceae, Chrysophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, Xanthophyceae and Zygnemophyceae besides 19 genera of zooplankton belonging to 3 major groups viz. Cladocera, Copepoda and Rotifera were observed in the study area. The present study revealed that the rice fields located in relatively low lying areas of the wetland have abundant nutrient rich water with greater abundance of both phyto- and zooplankton. Most of the water properties in the low lying areas of the wetland were comparable with the relevant standards for freshwater fishery. The study highlights the scope for utilization of the planktonic communities as live feed for fish by introducing the practice of concurrent rice-fish culture in low lying areas of wetlands. This is likely to increase the total production per unit area of wetland rice fields through production of not only the particular rice variety but also additional production of fish. Through this practice the marginal farmers in wetlands will be benefited by greater per capita fish protein availability which they can harvest from their rice fields or can sell the surplus fish to local markets. All these are likely to improve their health, income and socio-economic status.

Keywords: Wetland rice field, water properties, phytoplankton, zooplankton.

Introduction

Rice-fish systems are practiced in China, Egypt, India, Indonesia, Thailand, Vietnam, Philippines, Bangladesh, Malaysia etc[1,2]. The rice-fish systems are important in these areas because they provide food security, reduce the impact of agriculture on the environment, and may be less affected than conventional systems by climate change[3,4]. Integrated rice-fish production can optimize resource utilization through the complementary use of land and water[3]. This practice also improves diversification, intensification, productivity, profitability, and sustainability of the rice agro-ecosystem[5].

In Assam, North East India, rice is the staple crop and fish is the most preferred low cost food protein particularly by the rural people. Thus, rice-fish farming has a great potential to help in improving the status of food security, health and socio-economy of the fishermen and farmer community and hence improving the economy of the region.

In spite of all the boons that rice-fish systems possess, some of the potential areas of wetland rice cultivation in Assam, North East India have not yet been used for concurrent rice-fish culture i.e. cultivation of rice simultaneously with culture of fish in the same plot of land. This might be because of the lack of on-farm studies to look into the efficacy of rice-fish culture in such systems and farther dissemination of the information to the farmers.

With this background information, the present study was taken to resolve the research question as whether it would be a viable option to introduce concurrent practice of rice-fish culture in wetland rice fields of Assam, North East India.

Wetland rice, locally called as ‘Borua’/‘Boro’ rice (summer/spring rice; transplanted in January-February and harvested in April-May) is grown in the low-lying areas of wetlands in Assam and is mainly cultivated as monocrop. Since, ‘Boro’ rice cultivation is done in the low lying areas of wetlands where the soil remains saturated with water and nutrients throughout the year mainly due to entry of nutrient rich runoff water from the surrounding upland areas, these flooded rice fields require no or minimum external input of nutrients for rice production. Moreover, it has been revealed that flooded rice fields like any aquatic systems are rich in aquatic communities[6]. Considering these facts, the present study was undertaken to investigate the ecology of wetland rice fields along with the taxonomic diversity and abundance of planktonic communities and to find out the efficacy of practicing concurrent rice-fish culture in such systems.

Material and Methods

The study area comprised of rice fields of a floodplain wetland, Chatla (24°8' N and 25°8' N latitude and 92°15' E and 93° 15' E longitude), located in district Cachar of state Assam in North-East India. Chatla is a seasonal floodplain wetland which retains water for approximately six months and remains dry during winter except in low lying areas where the local communities cultivate wetland rice, locally called as 'Borua' or 'Boro' rice. During monsoon Chatla is fed by many small streams like Jalangachhara, Baluchhara and Salgonga and when monsoon recedes it drains out the excess water through river Ghagra[7] which is a tributary of river Barak, one of the major rivers in Assam. The most dominant community in this floodplain wetland belongs to the fisherman community like 'Kaivarta', 'Patni' etc. Most of them earn their livelihood through capture fishing in monsoon in the Chatla, and by growing 'Boro' rice during winter. In the study area 'Boro' rice is transplanted during January-February and harvested during April-May. The villagers also harvest wild fish from their 'Boro' rice fields which enter into the rice field during the preceding flood.

For the present study sampling was done in Chatla wetland during the cropping cycle of the wetland rice from February to May, 2012. The farmers informed that the broadcast of cow dung, urea and potash were done on the relatively upland rice plots; however, no agrochemical was applied on the low-lying regions. On the basis of the information provided by the local farmers a total of four plots of approximately 250 m^2 were selected for the present study. While stations 1 and 2 were located in relatively upland area, stations 3 and 4 were located in the low lying regions of the wetland as shown in figure-1.

Water samples were collected from the sampling stations during the rice cropping season, from February to May 2012. Samples for dissolved oxygen (DO) were collected directly in BOD bottles and were fixed in the field using alkaline iodide and manganous sulphate. Air and water temperatures were measured in situ with the help of a mercury bulb thermometer (0-100°C). For analyzing other chemical parameters of the rice field water, the samples were taken in PVC bottles and were brought to laboratory. pH and conductivity of the water samples were recorded using pH meter (make: Systronics; model: 103621) and conductivity meter (make: ESICO; model: 1601) respectively. Other parameters like dissolved oxygen (DO), biological oxygen demand (BOD), free carbon dioxide (CO_2), nitrate-N, and phosphate-P were estimated following standard methods[8, 9].

For analyzing the planktonic community, 2 litres water sample were taken from different areas of each sampling stations and passed through fine mesh (40 μm) plankton net. The water samples after passing through the plankton net were collected and preserved in a glass vials using 2ml formalin (4%) which were later on brought to the laboratory. In the laboratory, further concentration of the plankton samples was done by centrifugation at 2000 rpm for 10 minutes which resulted in the settling down of the plankton samples at the bottom of the centrifuge tube. These samples were collected in a separate vial after decanting the supernatant from the centrifuge tube. The volume of the concentrated plankton sample was adjusted to 10 ml by adding distilled water. This was followed by standardization of the plankton sample by finding out the volume of one drop of the concentrated plankton sample. Identification of phyto- and zooplankton was done by taking one drop of the concentrated plankton sample on a glass slide and looking through binocular microscope (Olympus, Model B-2). Likewise a total of ten drops were considered for the qualitative and quantitative estimations of the phyto- and zooplankton from each sampling station after every sample collections. Microscopic identifications of phyto- and zooplankton were done at 40X and 10X magnifications respectively. Finally, results were expressed as number of individuals $litre^{-1}$ following Lackey's drop method[10]. Microscopic identifications of the plankton were performed up to genera following Needham and Needham[11], Pentecost[12], Anand[13, 14], Battish[15], Tripathi and Pandey[16], Prasad and Singh[17] and Michael and Sharma[18].

Statistical analyses of the data were done using PAST version 2.17c.

Results and Discussion

Physico-chemical properties of water in different rice fields of Chatla are represented in table-1. Least values for water temperature in station 1 might be attributed to the reason that the sampling was done during the morning time. Station 1 had least value of water depth. This is attributed to its location in relatively upper terrain that could not retain water for longer duration due to runoff of excess water to the lower terrain and also due to evaporation loss. Besides, lowest values for BOD and CO_2 and highest value for pH in station 1 reveal less microbial activities in the rice field water at this point. However, highest values for conductivity and nitrate-N in station 1 reveal the presence of concentrated water condition and the presence of nitrogenous matters like urea and cowdung which were broadcasted by the farmers during the field preparation. Greater values of dissolved oxygen and least value of nitrate-N in station 2 reveal greater photosynthetic activities of both the rice plants and phytoplankton that resulted in greater liberation of oxygen and exhaustion of nitrate-N from the rice field water. Greater water temperature in station 3 might be due to the reason that the sampling was done during noon time when solar intensity was high. Besides, station 3 had greater value for free CO_2 which might be due to greater water temperature that facilitated greater microbial activities. However, station 3 had least value for conductivity and phosphate-P thereby reflecting the dilution effect with increasing water volume at this point. Greater values for water depth, and phosphate-P in station 4 might be attributed to its location at lower terrain which facilitated the entry of runoff water from the upland agricultural plots carrying detached soil particles rich in organic matters and nutrients particularly phosphate-P. All these in turn lead to more microbial activities that resulted in the drop in pH and dissolved oxygen and hike in BOD.

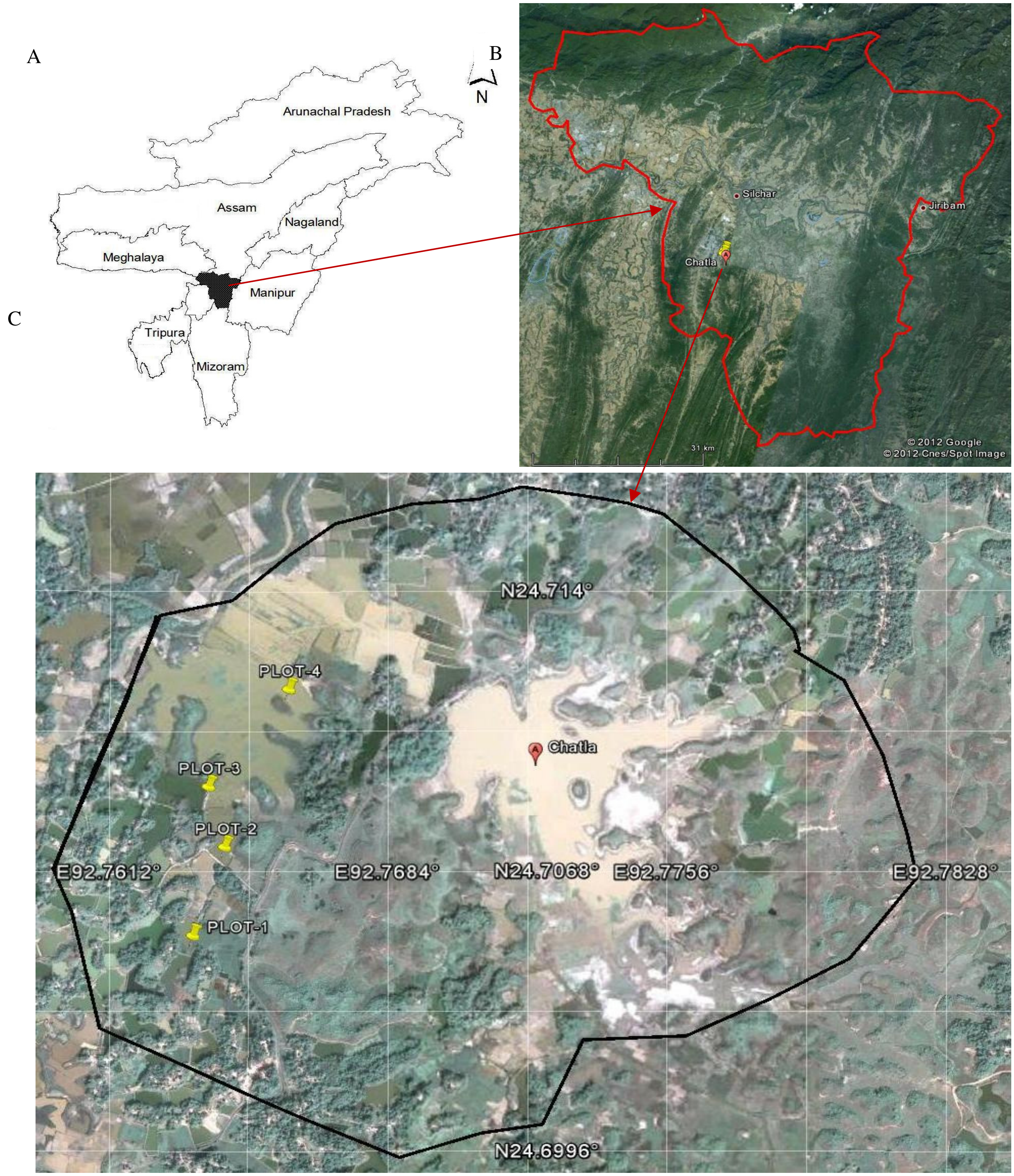

Figure-1
Map showing the location of the sampling plots. (A) Cachar district in North East India, (B) Chatla floodplain wetland in Cachar district, and (C) Four sampling plots (stations) in the Chatla

Distribution and abundance of phytoplankton in rice fields of Chatla is represented in Table-2. It reveals the presence of a total of 57 genera of phytoplankton belonging to classes Bacillariophyceae, Chlorophyceae, Chrysophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, Xanthophyceae and Zygnemophyceae in the rice fields of Chatla. Amongst all the stations, stations 2 and 4 had maximum number of phytoplankton genera. This might be due to presence of preferable microhabitats of the diverse phytoplankton for their growth and reproduction. Bacillariophyceae was the most dominant class in stations 1, 2 and 4 shown in figure-2A, which indicates the presence of silica rich condition in those stations[19]. The dominance of Cyanophyceae in station 3 shown in figure-2A was due to greater water temperature, more CO_2[20] accompanied by optimum water depth and nutrients that facilitated their rapid growth and development.

Table-3 shows the distribution and abundance of zooplankton in rice fields of Chatla. It shows the presence of a total of 19 zooplankton genera belonging to groups Cladocera, Copepoda and Rotifera in the rice fields of Chatla. Amongst all the stations, stations 2, 3 and 4 had maximum generic richness of zooplankton thereby indicating presence of favorable water condition and food resources for the secondary production of diverse zooplankton in those stations. Cladocera was the most dominant zooplankton group in all the stations shown in Figure-2B thereby indicating the shallowness of the rice field system with presence of nutrients[21]. Similar results were also observed in lower Manair reservoir located in Karimnagar district of Andhra Pradesh[22]. Since cladocerans are the most desirable crustaceans in terms of live fish feed due to presence of rich nutrients in their body biomass[23] their presence reveal the potential source of live feed in case the fishes are stocked in such systems.

Among all the four stations abundance of both the phyto- and zooplankton communities were more in the low lying rice fields of the wetland i.e. stations 3 and 4 shown in Figure-2C. This can be attributed to the deposition of nutrient rich runoff water from the upland areas of the wetland which created favorable environmental conditions for the rapid growth and development of planktonic organisms.

Table-1
Physico-chemical properties of water in 'Boro' rice fields of Chatla floodplain wetland

Parameters	Up lands		Low lands	
	*Station 1	*Station 2	*Station 3	Station 4
Air temperature (°C)	27.67±1.45	27.75±0.93 (22.67-30.67)	28±1.25 (23-31)	26.33±0.88 (22.33-30.67)
Water temperature (°C)	20.67±1.85	25.42±0.95 (22.67-29)	25.78±1.04 (21.67-28)	25.39±0.73 (21.33-29)
Water depth (cm)	3.1±0.6	4.9± 0.6 (3.0-6.2)	6.1±0.8 (4.5-7.6)	8.9±0.8 (6.0-12.1)
pH	6.87±0.003	5.69±0.11 (5.26-6.11)	6.04±0.035 (5.98-6.18)	5.59±0.11 (4.9-6.28)
Conductivity (µS)	48±0.33	41.69±2.70 (30.2-53.5)	33.8±0.44 (32.4-35.4)	46±3.65 (27.1-66)
Dissolved oxygen (mg l^{-1})	10.38±0.33	11.16±0.22 (9.1-13.32)	11.03±0.26 (8.63-13.67)	8.77±0.16 (6.74-13.02)
Biological oxygen demand (3days at 20°C)(mg l^{-1})	0.4±0.03	4.92±0.16 (2.10-6)	4.42±0.26 (8.62-13.72)	5.1±0.30 (1.10-9.2)
Free CO_2 (mg l^{-1})	5.99±0.03	10.98±0.04 (7.18-13.1)	13.98±0.06 (10.58-18.57)	10.76±0.04 (7.18-12.58)
Phosphate-P (mg l^{-1})	0.27±0.03	0.17±0.06 (0.02-0.28)	0.15±0.02 (0.11-0.19)	0.57±0.39 (0.18-1.34)
Nitrate-N (mg l^{-1})	1.27±0.008	0.19±0.15 (0.13-0.48)	0.39±0.41 (0.07-1.22)	0.29±0.08 (0.04-0.53)

Mean ± SE; *n=1, *n=2 and *n=3 in stations 1, 2 and 3 respectively due to seasonal dryness; n=4 in station 4; number in parenthesis designate the respective ranges of mean values of the physico-chemical properties of water during different months.

Table-2
Distribution and abundance of phytoplankton (No. of individuals l^{-1}) in 'Boro' rice fields of Chatla floodplain wetland

Class	Genera	Up lands		Low lands	
		*Station 1	*Station 2	*Station 3	Station 4
Bacillariophyceae	*Achnanthes*	25	13±10 (0-50)	8±8 (0-25)	4±4 (0-25)
	Amphora	-	25±21 (0-100)	8±8 (0-25)	13±13 (0-75)
	Amphipleura	650	218±85 (0-475)	150±63 (75-275)	225±100 (125-700)
	Calonies	-	6±5 (0-25)	-	38±20 (0-100)
	Cymbella	75	31±16 (0-75)	33±8 (25-50)	163±53 (0-325)
	Encyonema	-	-	-	4±4 (0-25)
	Eunotia	-	63±41 (0-200)	25±25 (0-75)	75±28 (0-175)
	Frustulia	325	144±72 (0-300)	125±90 (0-300)	113±38 (0-275)
	Fragillaria	-	-	-	17±17 (0-100)
	Gomphonema	25	-	-	-
	Mastogloia	-	-	8±8 (0-25)	-
	Melosira	150	13±111 (0-50)	-	138±77 (0-500)
	Navicula	375	406±131 (200-850)	117±44 (50-200)	425±161 (75-975)
	Neidium	-	13±11 (0-50)	17±17 (0-50)	29±29 (0-175)
	Nitzschia	25	13±11 (0-50)	50±38 (0-125)	96±63 (0-400)
	Pinnularia	-	44±24 (0-125)	25±25 (0-75)	25±13 (0-75)
	Rhopalodia	-	19±16 (0-75)	8±8 (0-25)	-
	Synedra	-	200±173 (0-800)	-	-
	Tabellaria	-	6±5 (0-25)	8±8 (0-25)	38±26 (0-150)
Chlorophyceae	*Ankistrodesmus*	-	13±6 (0-25)	-	13±9 (0-50)
	Apiocystis	-	-	-	4±4 (0-25)
	Cosmarium	-	63±54 (0-250)	-	-
	Cladophora	-	-	8±8 (0-25)	25±25 (0-150)
	Closterium	150	25±15 (0-75)	317±317 (0-950)	17±12 (0-75)
	Chlamydomonas	-	150±130 (0-600)	67±36 (0-125)	8±8 (0-50)
	Docidium	-	13±6 (0-25)	17±8 (0-25)	-
	Desmidium	-	19±16 (0-75)	-	-
	Dicloster	50	-	-	-
	Euastrum	-	13±6 (0-25)	-	-
	Geminella	25	-	-	-
	Microspora	-	-	33±33 (0-100)	-
	Pediastrum	-	-	-	4±4 (0-25)
	Pandorina	-	-	8±8 (0-25)	-
	Staurastrum	-	38±30 (0-125)	17±17 (0-50)	4±4 (0-25)
	Scenedesmus	50	69±33 (0-125)	67±30 (25-125)	8±5 (0-25)
	Stigeoclonium	-	6±5 (0-25)	-	-
	Selenastrum	-	-	8±8 (0-25)	-
	Spirogyra	-	106±85 (0-400)	25±25 (0-75)	96±50 (0-300)
	Ulothrix	25	6±5 (0-25)	-	33±24 (0-150)
	Volvox	-	-	17±17 (0-50)	-
Chrysophyceae	*Uroglena*	-	6±5 (0-25)	-	-
Cyanophyceae	*Gloeocapsa*	75	28±222 (0-1050)	1792±1426 (100-4625)	513±235 (0-1325)
	Lyngyba	-	13±11 (0-50)	17±17 (0-50)	83±78 (0-475)
	Microcoleus	-	-	42±42 (0-125)	-
	Oscillatoria	-	6±5 (0-25)	-	4±4 (0-25)
	Synechococcus	50	13±11 (0-50)	17±8 (0-25)	-
Dinophyceae	*Ceratium*	-	-	-	4±4 (0-25)
Euglenophyceae	*Euglena*	25	119±103 (0-475)	8±8 (0-25)	4±4 (0-25)
	Phacus	75	419±348 (0-1625)	200±101 (0-325)	96±58 (0-350)
	Trachelomonas	-	-	-	4±4 (0-25)

Xanthophyceae	*Arthodesmus*	-	6±5 (0-25)	-	-
	Chlorobotrys	-	25±22 (0-100)	17±8 (0-25)	-
	Centritractus	-	13±11 (0-50)	-	8±8 (0-50)
	Tribonema	100	75±65 (0-300)	8±8 (0-25)	4±4 (0-25)
Zygnemophyceae	*Hyalotheca*	-	-	-	33±33 (0-200)
	Micrasterias	-	50±43 (0-200)	-	-
	Zygogonium	-	6±5 (0-25)	-	-
Total genera:	57	18	40	32	35

Mean ± SE; *n=1, *n=2 and *n=3 in stations 1, 2 and 3 respectively due to seasonal dryness; n=4 in station 4; number in parenthesis designate the respective ranges of the mean abundance; '-' indicates absence of the genus concerned

Table-3
Distribution and abundance of zooplankton (No. of individuals l^{-1}) in 'Boro' rice fields of Chatla floodplain wetland

Group	Genera	Up lands		Low lands	
		*Station 1	*Station 2	*Station 3	Station 4
Cladocera	*Bosmina*	175	93±6 (0-250)	37±4 (0-75)	41±3 (0-150)
	Ceriodaphnia	50	24±2 (10-50)	26±3 (10-50)	48 ±4 (0-175)
	Simocephalous	-	14±2 (0-25)	50±5 (0-150)	50±4 (0-200)
	Diaphanosoma	-	-	-	4±1 (0-25)
	Macrothrix	-	-	11±2 (2.5-25)	66±4 (0-250)
	Pleuroxus	-	-	2±1 (0-5)	-
	Alona	-	2±1 (0-7.5)	3±1 (0-10)	-
	Moina	-	1±1 (0-2)	18±3 (0-50)	4±1 (0-25)
	Chydorus	-	6±2 (0-25)	-	-
Copepoda	*Cyclops*	25	22±3 (0-55)	17±2 (10-25)	15±2 (0-50)
	Neodiaptomus	-	2±1 (0-5)	8±2 (0-25)	16±2 (0-75)
	Canthocamptus	25	-	-	-
Rotifera	*Brachionous*	-	1±1 (0-3)	24±2 (8-40)	2±1 (0-5)
	Monostyla	-	1±1 (0-3)	-	-
	Lepadella	-	1±1 (0-3)	3±1 (0-10)	-
	Keratellla	-	1±1 (0-5)	-	-
	Lecane	-	-	-	1±1 (0-5)
	Trichocerea	-	-	-	1±1 (0-5)
	Filinia	-	-	2±1 (0-5)	1±1 (0-2)
Total genera:	19	4	12	12	12

Mean±SE; *n=1, *n=2 and *n=3 in stations 1, 2 and 3 respectively due to seasonal dryness; n=4 in station 4, number in parenthesis designate the respective ranges of the mean abundance; '-' indicates absence of the genus concerned

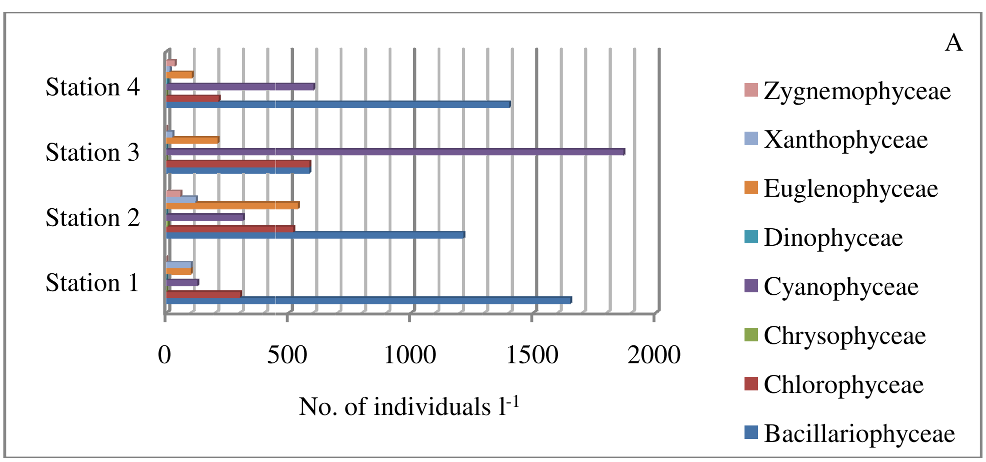

Figure-2(a)

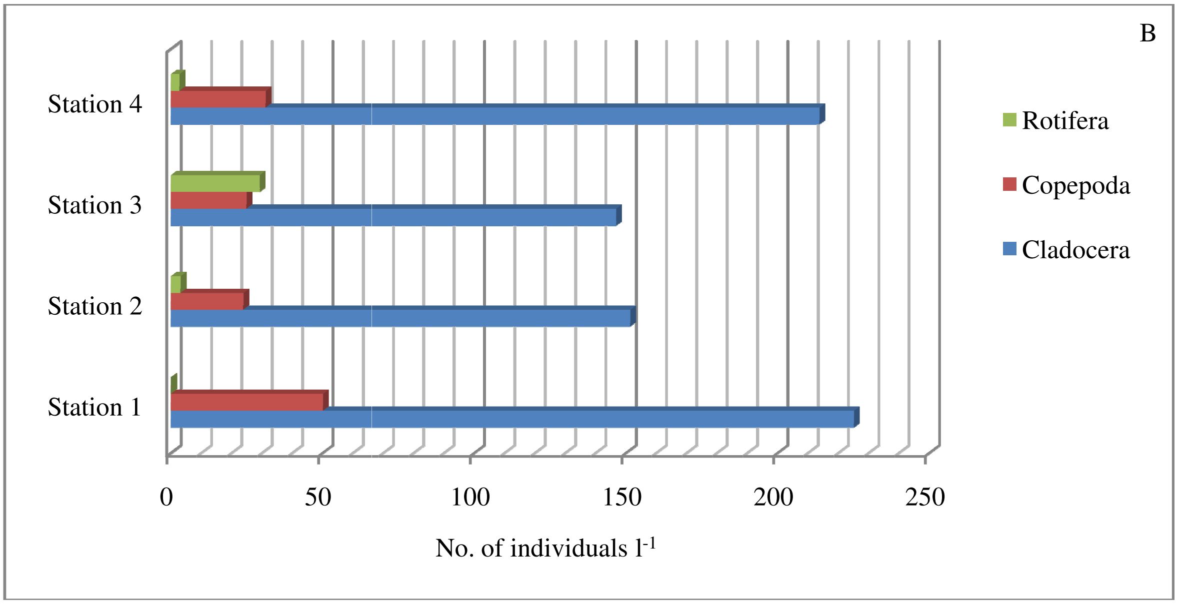

Figure-2(b)

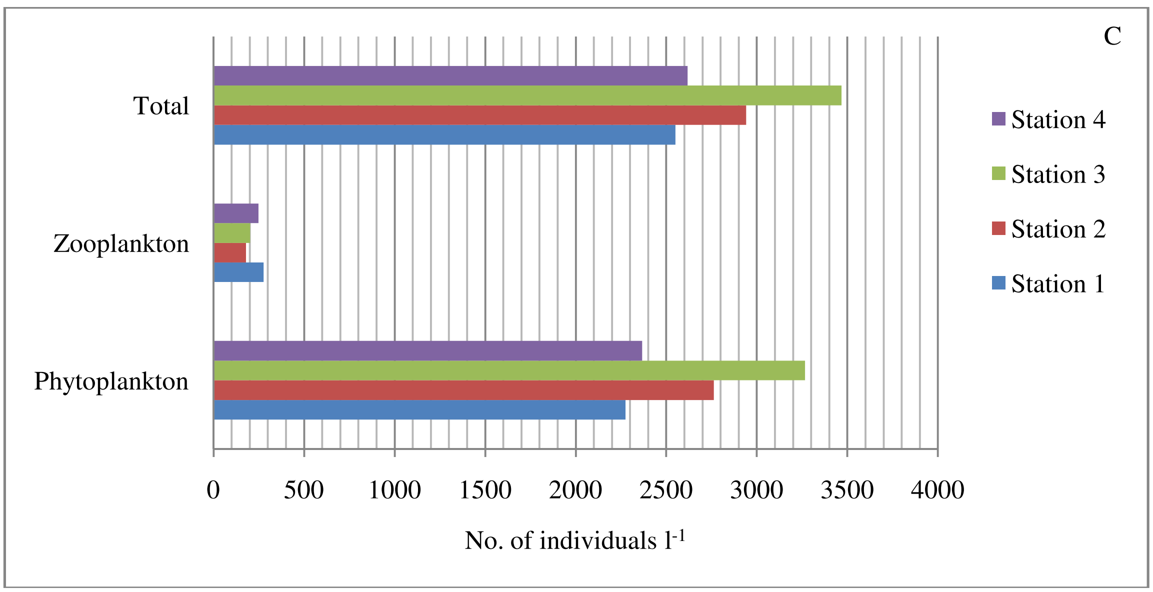

Figure-2(c)

Figure-3 represents a dendrogram showing Gower's similarity amongst the four wet rice field sampling stations based on physico-chemical properties of the rice field water and presence of phyto- and zooplankton communities. It reveals that station 1 had least similarity with other three stations. This is due to its location in the upper most terrain which remained inundated with water for only one month. Ecological features of station 4 were different from those of stations 3 and 2. This is due to the reason that station 4 remained under inundated condition for 4 months as it was located in the lower most terrain of the wetland unlike stations 2 and 3, which were under inundated condition for 3 months. However, if compared station 4 had more similarity with station 3 as both the stations are located in the lower terrain of the wetland because of which they were more influenced by deposition of nutrient rich runoff water and sediments from the upper terrains.

On comparison of water properties of the wet rice fields in the study area with relevant standard of freshwater fisheries for warm water[24, 25] and also with the rice-fish systems in Bangladesh[26] and Apatani Plateau in Arunachal Pradesh of North East India[27] represented in Table-4, it may be stated that the water properties in the low lying regions of the floodplain wetland especially like that of station 4 may be suitable for concurrent rice-fish culture.

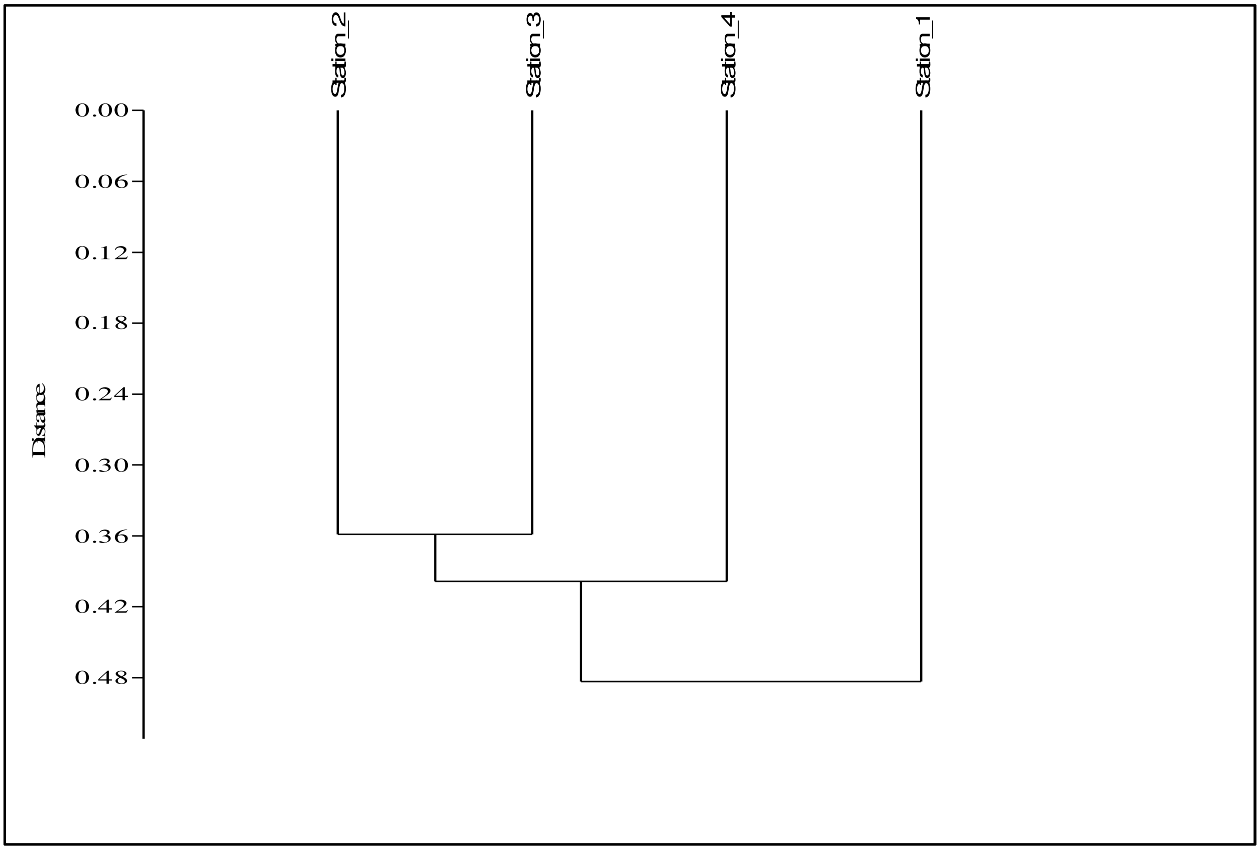

Figure-3

Table-4
Comparison of water properties in 'Boro' rice fields of Chatla floodplain wetland with relevant standard of freshwater fisheries in warm water and rice-fish systems

Water parameters	Standards of water properties for freshwater fisheries in pond as per		Range in water properties in rice-fish system of		Range in water properties in the low lands of rice fields of Chatla floodplain wetland
	Boyd, 1998	Das *et al*., 2013	Bangladesh (Das *et al*., 2011)	Apatani Plateau, Arunachal Pradesh, North East India (Dev Gupta *et al*., 2013)	
Water temperature (°C)	-	25.0-32.0	19.6-33.1	20.0-35.0 *25.0-35.0	21.67-29.0
Water depth (cm)	-	>30.0	-	5.0-21.7 *5.0-25.0	4.5-12.1
pH	7.0-9.0	6.5-8.5	7.2-7.5	4.0-7.9	4.9-6.28
DO (mg l^{-1})	5.0-15.0	5.0-10.0	3.9-6.0	5.12-11.28	6.74-13.67
BOD (mg l^{-1})	-	<10.0	-	0.24-8.44	1.10-13.72
Free CO_2 (mg l^{-1})	1.0-10.0	<3.0	2.3-8.3	4.59-19.9	7.18-18.57
Nitrate-N (mg l^{-1})	0.2-10.0	0.1-3.0	-	0.11-12.31	0.04-1.22
Phosphate-P (mg l^{-1})	0.005-0.2	0.05 - 2.0	-	0.003-1.37	0.11-1.34

*Water temperature and water depth for fish culture in rice-fish system as per standard given by Tamil Nadu Agricultural University, Coimbatore, India,

Conclusion

The study reveals that the low lying areas of wetlands with relatively more water depth are natural depository of planktonic organisms which can serve as source of live feed for the fish if stocked in such systems. Hence, the local farmers involved in cultivation of 'Boro' rice in wetlands may exploit the low lying areas of 'Boro' rice fields for concurrent rice-fish culture. This in turn is likely to increase the total production per unit area of land through production of not only the particular rice variety but also additional production of fish. Through the concurrent rice-fish farming system, the marginal farmers will be benefited by greater per capita fish protein availability besides higher income generation by selling the surplus fish to local markets.

However, more comprehensive research has to be carried out especially with regard to the most suitable fish species for stocking under the prevailing habitat condition in wetland rice field. While selecting the fish species care should be taken that it is tolerant to moderate acidic condition of the wetland rice field water and it increases the aeration of the rice field water while feeding on the natural live food without harming the rice plant.

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