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Assessment of Water Quality in Relation to Fishery Perspective in Flood Plain Wetlands of Subansiri River Basin Assam, India

Budhin Gogoi, Akash Kachari and Debangshu Narayan Das
Fishery and Aquatic Ecology Laboratory, Department of Zoology, Rajiv Gandhi University, Doimukh, 791112, Arunachal Pradesh, India

Corresponding Author: Budhin Gogoi, Fishery and Aquatic Ecology Laboratory, Department of Zoology, Rajiv Gandhi University, Doimukh, Papumpare, Arunachal Pradesh, India

ABSTRACT
The flood plains wetlands are low laying areas exist along the riverine system with immense production potentials, supports millions of people through wide ranges of resources and services. The state of Assam has total 3513 numbers of flood plain wetlands with an area of 1.0 lakh ha in addition to 2.3 million ha of seasonally flooded rice field. The natural productivity of fishes from beel fisheries is noteworthy because of the favourable water quality and auto stocking of natural fish seeds. The seasonal variation of water quality parameters (DO, BOD, FCO_2, alkalinity, total hardness, calcium hardness, chloride, pH and water temperature in three different categories of flood plains (deep water rice field, oxbow lake and beel of subansiri flood plains) were analyzed for the year 2013-14). The recorded values stand for favourable water quality for fish and fisheries development. The diversification of aquaculture and culture based capture fishery through community participation has the great potential to enhance fish production in the state providing livelihood to rural poor. This study was aimed to focus the limnology and sustainable utilization of flood plains for fisheries development.

Key words: Beel, deep water rice field, oxbow lake, water quality, fisheries, integrated farming

INTRODUCTION
Flood plains are rain fed, shallow and low lying areas characterized by poor drainage and prolonged water logging. These wetlands either as oxbow lake and beels or as Bao (deep water rice) fields support open water fisheries or agro ecology of seasonal rice production in most of the flood plain areas in India. India is bestowed with myriads of flood plain wetlands covering a water area of 3,54,213 ha. The State of Assam located between 21°.57′N-29°.30′N latitude and 89°.46′E-97°.30′E longitude alone possesses total 2,98,865 ha of flood plain wetlands (Table 1). It has 3513 numbers of annual flood plain wetlands locally called as beels with an area of 1.0 lakh ha. The state also has about 2.3 million ha of seasonally flooded land where water remains for 4-6 months (Bhagowati *et al*., 1997; Baruah *et al*., 2000) and serves as a breeding ground for wild fish. These are traditionally rice farming areas associated harbouring natural fish stock (Diallo, 1992; Baruah *et al*., 1999).

Flood plains offer vast potentials for capture fisheries through auto stocking with natural fish seed from over flooded riverine sources and also provide scope for intensification of culture based fishery (Chetiaborah *et al*., 2013) having potential to yield 2.0-2.5 t ha^{-1} $year^{-1}$ of fishes in semi intensive culture system (Patra, 2013). The enormous growth of fish food organisms makes these wetlands very ideal for both capture and culture-based capture fisheries, if suitable measure is

Table 1: Flood plain resources and fish production and productivity (2011-12)

Resources	Area (ha)	Productivity (kg ha^{-1})	Production (t)	Share (%)
Beels-traditional	84,900	300	25,470	10.44
Beels-improved	15,915	1,508	24,000	9.84
Sub total	100,815	491	49,470	20.28
Low-lying/derelict/swamps-traditional	36,000	300	10,800	4.43
Low-lying/derelict/swamps-developed	4,050	1,500	6,075	2.49
Other-paddy fields etc	158,000	238	37,630	15.43
Sub total	198050	275	54505	22.35
Grand total	298865	348	103975	42.35

Source: Department of Fisheries, Govt. of Assam

taken for the purpose. However, siltation and various anthropogenic activities were found as the major cause of depletion of fish stocks in floodplain lakes of Assam (Deka *et al*., 2005). Flood plain aquatic habitats are gradually being degraded in India since last two decades due to siltation, eutrophication, accumulation of agricultural run-off and human settlement (Goswami *et al*., 1999; Sugunan and Bhattacharjya, 2000; Khan, 2002) in and around. The development of aquaculture sector in Assam has high bearing on rural economy because the rice and fish together constitute the basic diets of the people of the state. The advanced technologies of fish culture hardly touched the rural Assam by and large and has remained traditional only covering 5% area under scientific fish farming, so, the village pond still produces as low as 600 kg ha^{-1} (Kalita, 2006) in an average throughout the state. Obviously the current fish production of 3.00 lakhs Mt in 2012-13 is unable to meet the demand for which annually around 0.25 lakh tones of fish are imported from other states. The main role of fish farming is to improve livelihood, improve nutritional standard and also sustainable utilization of water and land resources.

On the above backdrop, a study was carried out on the seasonal variations of water quality parameters in three different categories of flood plains viz., deep water rice field, oxbow lakes and beels of subansiri river basins in Lakhimpur, Assam. The state of Assam with plenty of such flood plain wetlands possesses great potential of fishery development with technological inputs, entrepreneurial initiatives and financial investment. Water quality parameters play key role in fish's microhabitat predilection and may be used as index of biological productivity in freshwater ecosystem. Hence, proper scientific management of parameters like temperature, hardness, pH, dissolved gases (oxygen and CO_2), salinity etc., seems to be essential prerequisite for maintaining and monitoring wetlands health. So, studies on limnology of flood plains wetland are necessary to prevent further degradation of this fragile ecosystem as well as to conserve such wetlands enhancing sustainable planning of natural resource utilization for rural welfare.

MATERIALS AND METHODS

Study area: Studies were made on three different categories of flood plain wetlands (oxbow lake, beels and deep water rice field) of Subansiri river basin (27°.05′N 94°.06′E, 27°.06′N 94°.08′E and 27°.07′N 94°.08′E) located in the lakhimpur district of Assam (Fig. 1). These flood plains are seasonally flooded by Subansiri river.

Sampling and water analysis: The certain physico-chemical parameters of three different categories of flood plains (oxbow lake, deep water rice field and beels) were analyzed for the year 2013-14. Three different stations were selected in each flood plain for sampling of water. The monthly data were pooled as seasonal variation in four different seasons. The seasons are: monsoon (May-July), post-monsoon (August-October), winter (November-January) and pre-monsoon (February-April). Random samples of water were collected from three different locations of each station at morning. Dissolved Oxygen (DO), free carbon dioxide, pH, alkalinity, total hardness,

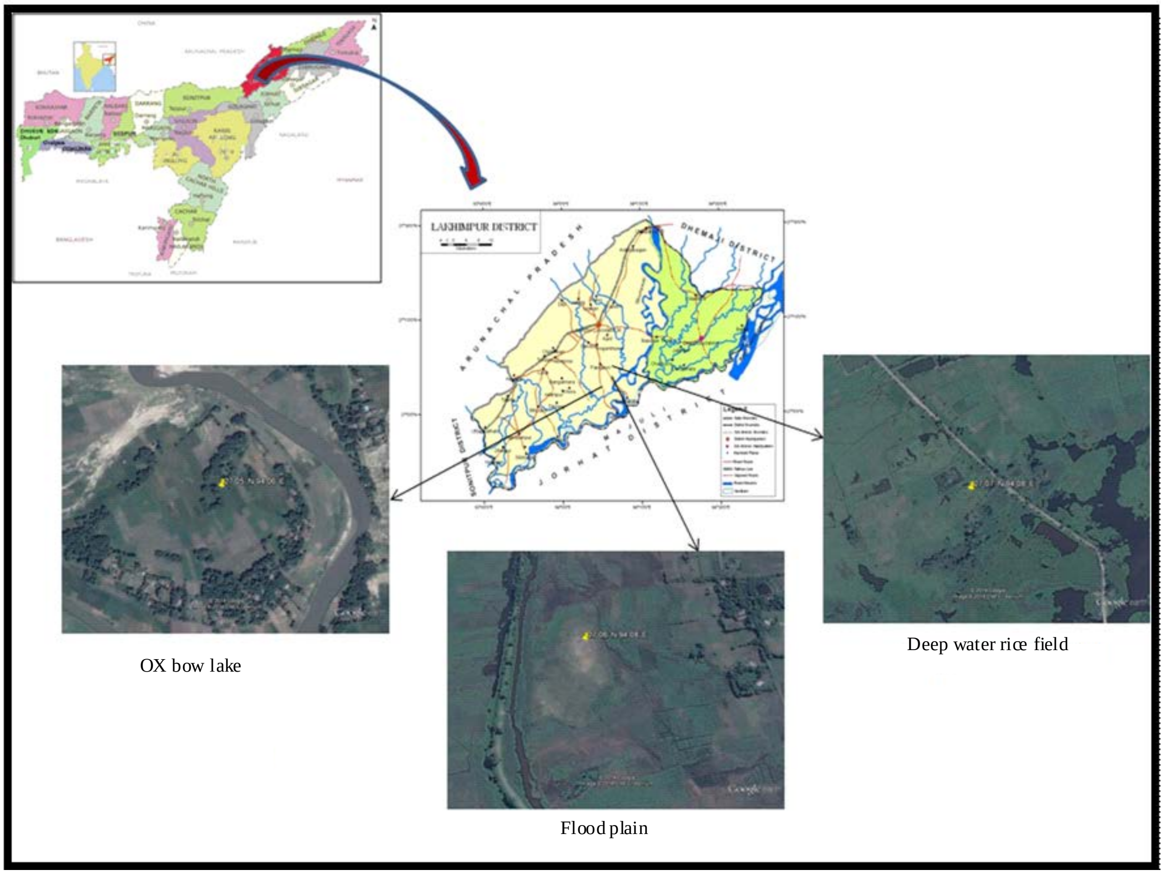

Fig. 1: Map of study area

calcium hardness and chloride were deter-mined using standard methods (Trivedy *et al*., 1987; APHA., 1995; Dutta, 2011). A celsius thermometer (scale ranging from 0-100°C) was used to measure surface water temperature of water. pH of water was measured directly in a digital electronic pH meter (Water analyser 371, Systronics).

Statistical analysis: All the data were presented as Mean±SD. Statistical differences among estimated parameters among seasons were validated using one way ANOVA in oxbow lake and beel followed by DMRT (Duncan Multiple Range Test). In case of deep water rice field having only two seasons, level of significance of seasonal variation were analysed using unpaired t-test.

RESULTS AND DISCUSSION

All the parameters in both oxbow lake and beel showed significant seasonal variation ($p<0.05$, ANOVA, DMRT) except alkalinity. In deep water rice field, seasonal variation was also observed on certain water parameters (Unpaired t-test) except BOD, FCO_2, hardness and pH. Monsoon and post-monsoon seasons did not have any significant effect on pH, FCO_2 and total hardness in entire flood plain area (t-test). However, seasonal variation had significant effect ($p<0.05$, t-test) on BOD in both beel and oxbow lake which revealed a slightly different trend from the deep water rice field. The alkalinity did not show any significant variation between monsoon and post-monsoon in both oxbow lake and beel however exhibited significant ($p<0.05$, t-test) difference in deep water rice field.

Dissolved Oxygen (DO): Dissolved oxygen being essential for many metabolic processes (Ahmed, 1995) showed seasonal variation in entire study area. The DO recorded ranged from 2.4-5.9 mg L^{-1} in oxbow lake, 2.03-5.49 mg L^{-1} in beel and 2.12-6.52 in deep water rice field (Table 2-4). The DO was significantly lower during monsoon and post monsoon and maximum during winter and post monsoon in oxbow lake ($p<0.05$, ANOVA, DMRT). In beel, the DO values were insignificant, however, monsoon had lower value than winter and pre-monsoon (DMRT). The DO value was significantly lower in monsoon and higher in post-monsoon ($p<0.05$, t-test) in deep water rice field. A seasonal fluctuation of DO content was reported earlier by Dey (1981), Lahon (1983), Yadava *et al.* (1987) and Hussain and Biswas (2011) from beels of Assam that showed

Table 2: Seasonal variation in water quality parameter in Oxbow lake during 2013-14

	Seasons				
Parameters	Monsoon	Post-monsoon	Winter	Pre-monsoon	Annual range
DO (mg L^{-1})	3.76 ± 1.26^{a}	3.99 ± 0.56^{a}	5.89 ± 1.14^{b}	5.61 ± 0.33^{b}	2.40-6.3
BOD (mg L^{-1})	1.35 ± 0.18^{b}	0.49 ± 0.28^{a}	$2.50\pm0.71^{b,c}$	$1.51\pm0.55^{b,c}$	0.22-2.93
Free CO_2 (mg L^{-1})	5.18 ± 0.83^{b}	5.25 ± 0.77^{b}	5.67 ± 0.9^{b}	2.50 ± 0.5^{a}	2.00-7.01
Alkalinity (mg L^{-1})	38.67 ± 18.69^{a}	26.67 ± 10.56^{a}	29.67 ± 1.29^{a}	36.00 ± 5.32^{a}	19.00-71.0
Total hardness (mg L^{-1})	43.55 ± 3.78^{a}	$47.96\pm3.87^{a,b}$	$52.43\pm5.61^{a,b}$	41.00 ± 1.61^{a}	40.00-59.0
Calcium hardness (mg L^{-1})	17.22 ± 4.64^{b}	12.01 ± 0.99^{b}	20.24 ± 8.65^{b}	9.75 ± 0.93^{a}	10.20-31.8
Chloride (mg L^{-1})	8.93 ± 1.87^{a}	17.67 ± 2.37^{b}	20.55 ± 3.07^{b}	20.01 ± 3.18^{b}	7.35-24.81
pH	6.83 ± 0.32^{a}	6.99 ± 0.28^{a}	7.92 ± 0.23^{b}	8.26 ± 0.5^{b}	6.54-8.87
Water temp (°C)	$28.67\pm0.5^{b,c}$	24.33 ± 3.278^{b}	19.67 ± 1.32^{a}	24.00 ± 1.73^{b}	20.00-29.0

(N = 9 for each season), values are Mean±SD, different letters within a row shows significant variation between mean values, DO: Dissolved oxygen, BOD: Biological oxygen demand

Table 3: Seasonal variation in water quality parameter in a Beel during 2013-14

	Seasons				
Parameters	Monsoon	Post-monsoon	Winter	Pre-monsoon	Annual range
DO (mg L^{-1})	3.08 ± 1.2^{a}	3.64 ± 0.58^{a}	4.66 ± 0.60^{a}	4.28 ± 0.96^{a}	2.03-5.49
BOD (mg L^{-1})	1.81 ± 0.33^{b}	2.11 ± 0.52^{b}	1.98 ± 0.96^{b}	1.32 ± 0.16^{a}	1.11-3.44
Free CO_2 (mg L^{-1})	5.49 ± 0.46^{b}	5.71 ± 0.46^{b}	$7.00\pm0.95^{b,c}$	3.50 ± 1.33^{a}	2.50-8.0
Alkalinity (mg L^{-1})	41.17 ± 15.8^{a}	29.00 ± 9.07^{a}	33.33 ± 2.21^{a}	37.67 ± 3.47^{a}	22.00-63.0
Total hardness (mg L^{-1})	47.08 ± 6.27^{a}	55.80 ± 10.4^{a}	$64.33\pm4.7^{a,b}$	52.00 ± 8.47^{a}	41.00-69.2
Calcium hardness (mg L^{-1})	19.39 ± 3.15^{b}	19.10 ± 2.20^{b}	13.62 ± 0.78^{a}	14.69 ± 1.07^{a}	12.42-23.24
Chloride (mg L^{-1})	10.65 ± 3.22^{a}	13.37 ± 0.30^{a}	15.87 ± 4.31^{a}	20.51 ± 7.92^{a}	8.16-30.27
pH	6.87 ± 0.83^{a}	6.65 ± 0.20^{a}	$7.70\pm0.27^{b,c}$	7.82 ± 0.53^{b}	6.25-8.0
Water temp (°C)	30.00 ± 0.86^{b}	23.67 ± 3.04^{a}	20.33 ± 1.32^{a}	25.00 ± 0.86^{a}	19.00-31.0

(N = 9 for each season), values are Mean±SD, different letters within a row shows significant variation between mean values, DO: Dissolved oxygen, BOD: Biological oxygen demand

Table 4: Seasonal variation in water quality parameter in a Deep water rice field during 2013-14

	Seasons		
Parameters	Monsoon	Post-monsoon	Annual range
DO (mg L^{-1})	3.65 ± 1.91^{a}	7.53 ± 0.70^{b}	2.12-6.52
BOD (mg L^{-1})	1.39 ± 0.19^{a}	1.78 ± 0.39^{a}	1.1-2.12
Free CO_2 (mg L^{-1})	5.33 ± 0.62^{a}	7.00 ± 3.09^{a}	4.0-10.0
Alkalinity (mg L^{-1})	43.43 ± 19.5^{b}	21.6 ± 0.54^{a}	21.2-70.0
Total hardness (mg L^{-1})	57.33 ± 5.89^{a}	62.35 ± 14.7^{a}	38.0-76.0
Calcium hardness (mg L^{-1})	17.15 ± 0.83^{a}	19.76 ± 0.42^{b}	16.23-29.25
Chloride (mg L^{-1})	8.58 ± 1.47^{a}	13.15 ± 1.48^{b}	6.57-14.4
pH	6.71 ± 0.26^{a}	6.43 ± 0.07^{a}	6.33-6.95
Water temp (°C)	28.33 ± 0.50^{b}	24.45 ± 1.7^{a}	24.0-29.0

(N = 9 for each season), values are Mean±SD, different letters within a row shows significant variation between mean values, DO: Dissolved oxygen, BOD: Biological oxygen demand similar trend in our study. The value of DO level in all the sites indicated very congenial habitat for aquatic organisms where seasonal variations were found related with water temperature and biological activities (Chapman and Kimstach, 1992). The low water temperature and better transparency of water during winter season might be the cause for increase in DO content. However, the floating aquatic vegetation and pit formation (organic matter) in wetlands probably lowered the DO level in monsoon (Hazarika, 2013).

BOD: According to Adakole (2000) the BOD of unpolluted waters remains <1.00 mg L^{-1}; moderately polluted within 2.0-9.0 mg L^{-1} and heavily polluted waters >10.0 mg L^{-1}. In the present study, the value ranged 1.0-2.93, 1.1-3.44 and 1.1-2.12 mg L^{-1} in oxbow lake, beel and deepwater rice field, respectively (Table 2-4). In oxbow lake, BOD was significantly lower during monsoon but during winter it was higher than the BOD of pre-monsoon season ($p<0.05$, DMRT). In beel, the BOD was significantly lower during pre-monsoon ($p<0.05$, DMRT) and rest did not show any significant variation. The BOD did not exhibit any significant difference in deep water rice field. The high value of BOD indicates more consumption of oxygen due to pollution load (Sharma and Capoor, 2010) whereas, flood plain wetlands in general depicted negligible pollutant load.

Free CO_2: Free CO_2 is one of the water parameter, presence of which indicates level of decomposable organic matter and bacterial action as well as physiological activities of available biotic component (Sawant *et al*., 2010). The value ranged 2.5-7, 3-8 and 4-10 mg L^{-1} in ox bow lake, beel and deep water rice field respectively (Table 2-4). FCO_2 was significantly lower in pre-monsoon ($p<0.05$, DMRT) both in oxbow lake and in beel but in beel, during the winter it had significantly higher value than the FCO_2 of monsoon ($p<0.05$, DMRT). In deep water rice field it did not exhibit significant difference. High CO_2 value in flood plain wetlands during winter may be due to the presence of decaying macrophytes, leaf litters etc., (Kachari *et al*., 2014).

Alkalinity: The alkalinity values were higher in monsoon and lower in post-monsoon in all sites of flood plain wetlands and ranged 20-43 mg L^{-1} in oxbow lake, 22-63 mg L^{-1} in beel and 21-70 mg L^{-1} in deep water rice field (Table 2-4). The alkalinity did not show any significant difference among the seasons in beel and oxbow lake. However, in deep water rice field the alkalinity was significantly lower in post-monsoon and higher in monsoon ($p<0.05$, t-test). The highest values during monsoon in all study sites were probably because of organic decomposition of aquatic vegetation (Sarma *et al*., 2013). Alkalinity determines the buffering capacity or ability to neutralize acid. Alkalinity above 100 mg L^{-1} is classified as high productive and those with <50 mg L^{-1} are oligotrophic (Anonymous, 2005; Meera and Nandan, 2010).

Total hardness: Hardness of water indicates the presence of Ca^{2+} and Mg^{2+} (Baruah *et al*., 1993). In oxbow lake (Table 2) no significant difference was observed among the seasons however, hardness was lower (41.17 mg L^{-1}) during pre-monsoon than post-monsoon and winter (DMRT). In beel (Table 3) it was significantly low (47.08 mg L^{-1}) during monsoon compared to winter ($p<0.05$). In deep water rice field (Table 4) the hardness did not exhibit significant variation between monsoon and post-monsoon (t-test). The dilution of salts in rain water might be the reason of low hardness in monsoon and leaching of salts from catchment area might be the reason for more hardness during winter. The findings were in conformity with Sarma and Dutta (2012) and Sayeshwara *et al*. (2010) and within the permissible limit (WHO, 1995).

Calcium hardness: The calcium content was significantly low (9.75 mg L^{-1}) during pre-monsoon in oxbow lake (Table 2) whereas in beel (Table 3) it was minimum (13.62 mg L^{-1}) during winter ($p<0.05$, DMRT). In deep water rice field (Table 4) it was significantly low (17.15 mg L^{-1}) in monsoon and higher (19.76 mg L^{-1}) in post- monsoon ($p<0.05$, t-test).

Chloride: The higher concentration of chloride in water is an index of pollution of animal origin (Munawar, 1972). Chloride was low in monsoon in both oxbow lake and deep water rice field (8.93 and 8.48 mg L^{-1}, respectively) however, the rest of the seasons did not show any significant variation ($p<0.05$, DMRT). The mean value (20.55 mg L^{-1}) was higher in winter season at oxbow lake and in pre-monsoon (20.51 mg L^{-1}) at beel. In beel, chloride did not show any significant variation in any season. This minimum value might has been recorded because of runoff animal wastes from nearby area during monsoon. The maximum value may be attributed due to human activities such as harvesting of fishes from the wetland during winter and pre-monsoon.

pH: pH value obtained during the study period was within the acceptable limit which was slightly acidic to neutral during monsoon and post-monsoon and mild alkaline during winter and in pre- monsoon in all the site. The pH ranged 6.54-8.87, 6.25-8.05 and 6.33-6.95 in oxbow lake, beel and deep water rice field, respectively (Table 2-4). In oxbow lake and beel, pH value were significantly lower in monsoon and post-monsoon than winter and pre-monsoon ($p<0.05$, DMRT). There was no significant difference of pH value between the seasons in deep water rice field (t-test). Higher pH value is normally associated with the high photosynthetic activity in water (Hujare, 2008) and pH ranging between 6.09 and 8.45 is ideal for supporting aquatic life forms (Buttner *et al*., 1993). The lowering of pH in monsoon occurred probably because of effluents from the adjacent catchment area having slightly acidic soil.

Water temperature: It is one of the most important ecological factors, which controls the physiological behaviour and distribution of organisms (Moundiotiya *et al*., 2004). In the present findings, water temperature in entire three study site showed maximum values during monsoon and minimum in winter. The water temperature ranged 18-29°C in oxbow lake, whereas it ranged between 19-31°C in beel and 24-29°C in deep water rice field respectively (Table 2-4). In oxbow lake, temperature showed lower value in winter but rest of the season did not show any significant variation ($p<0.05$, DMRT) however, it was higher in monsoon than that of pre-monsoon. In beel, the temperature showed higher value during monsoon compared to all other seasons ($p<0.05$, DMRT). The temperature was significantly higher in monsoon than the post-monsoon season in deep water rice field ($p<0.05$, t-test). The range of temperature affirmed tropical character of the study area and also corresponded with the earlier observation of Dey and Kar (1987), Sharma and Hussain (1999) and Sharma (2000). Variations observed in water temperature may be due to inflow of water from the surrounding rivers, seasonal influence and also due to fluctuation in atmospheric temperature.

The recommended standard of aquaculture water quality (Bhatnagar and Devi, 2013) is presented in Table 5 along with the current observations. This excerpt of water quality parameters suitable for good growth of fishes have been worked out from the research of many scientists (Wurts and Durborow, 1992; Swann, 1997; Bhatnagar *et al*., 2004; Bhatnagar and Singh, 2010; Ekubo and Abowei, 2011) in the field of fresh water aquaculture.

Table 5: Water quality of flood plain wetlands compared to recommended standard for aquaculture (Bhatnagar and Devi, 2013)

Parameters	Ranges in subansiri flood plain present (Authors, 2014)	Acceptable range	Desirable range	Stress
		(Bhatnagar and Devi, 2013)		
Water temperature (°C)	19.00-31	15-35	20-30	<12, >35
Dissolved oxygen (mg L^{-1})	2.03-6.3	3-5	5	<5, >8
BOD (mg L^{-1})	0.22-3.44	3-6	1-2	>10
CO_2 (mg L^{-1})	2.00-10.0	0-10	<5, 5-8	>12
pH	6.25-8.87	7-9.5	6.5-9.0	<4,>11
Alkalinity (mg L^{-1})	19.00-71.0	50-200	25-100	<20, >300
Total hardness (mg L^{-1})	38.00-76.0	>20	75-150	<20, >300
Calcium hardness (mg L^{-1})	10.20-31.8	4-160	25-100	<10, >250

The available resources and limnological features clearly disclose that the productivity of the said flood plain wetlands as a whole can be enhanced further by incorporating integrated approaches of farming systems wherever applicable. Most particularly the rice wetlands may be improved through rice fish culture system (Sinhababu *et al*., 1984; Bandhopadhyay and Puste, 2001). The rice fish integration is the best practice for higher yield of rice and fish in flooded rice fields (Roy *et al*., 1990; Das *et al*., 1990; Mukhopadhyay *et al*., 1992; Baruah *et al*., 2000). The integrated fish farming gives an established provision for greater income to the farmers (Coche, 1967; Jintong, 1996). In open water wetlands, introduction of cage culture (Kalita, 2006) and pen culture (Chandra, 2010) would be a feasible options for improvement of the overall productivity. Besides, the capture cum culture of small indigenous fish species in the seasonal impoundments are common practices among the people in and around flood plain wetlands which may also be strengthen through intervention of better management. It is particularly important as capture cum culture fishery supply daily diet to inhabitants of flood plain wetland during flood recession. The substrate based fish culture locally called as a 'xeng fishery' in homestead water logged areas is another such avenue for enhancing productivity (Saikia and Das, 2010). The community participation through cooperative beel fishery would be valuable option for better management of large beels for higher productivity as a means of rural livelihood.

CONCLUSION

The planned exploration and utilization of these flood plain wetlands having favourable water quality for fish and fishery may enhance services to society. These wetlands supports enormous diversity of fresh water fish (Bhaumik *et al*., 2003) and also provide scope for intensification of culture based fishery technology (Chetiaborah *et al*., 2013). The culture based fisheries have the added advantage over traditional form of aquaculture in that it is less resource intensive and is therefore, important for livelihood support (De Silva, 2003; Felsing *et al*., 2003).

The fisherman of the state mainly rely on capture fisheries which contribute 36% of total fish production of the state but over the past few years trend is declined. So, management of these water resources and scientific approach of utilization can play a pivotal role in boosting rural economy in addition to conservation. Thus, there is urgent need to formulate sound management norms for sustainable development of the flood plains.

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