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Physico-chemical analysis of certain abiotic parameters of a tropical floodplain lake of Tinsukia, Assam (Northeast India)

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Abstract
An investigation of abiotic parameters was under taken during October 2013-September 2015 in Khamti Guali beel of Dibru-Saikhowa Biosphere Reserve. Water temperature was recorded using a centigrade thermometer; pH and specific conductivity were recorded with the help of field probes; dissolved oxygen was estimated by the modified Winkler's method; and the other abiotic parameters were analyzed by following A.P.H.A. (1992). Results revealed that, water temperature corroborated with the geographical location and sub-tropical nature of the sampled beel. Hydrogen ion values affirmed slightly acidic to alkaline nature of waters; specific conductivity recorded low ionic concentrations and thus, warranted inclusion of this sampled beel under 'Class 1' category of Talling and Talling. Dissolved oxygen indicated moderately oxygenated nature of waters and free carbon dioxide is attributed to its insufficient uptake by photo-autotrophs in the sampled floodplain lake. Total alkalinity and total hardness exhibited soft to hard water character; calcium content indicated 'soft to moderately soft' calcium poor waters. Magnesium, an important co-factor in enzymatic transformations resulted in the dominance of Calcium > Magnesium. Chloride concentrations corroborated with the natural waters and thus, indicated lack of influence of organic pollution caused by human impact. The sampled beel recorded low concentrations of dissolved organic matter, total dissolved solids and nutrients namely- phosphate, nitrate, sulphate and silicate during the study period.

Keywords: floodplain, chloride, nutrients, pH, specific conductivity

Introduction
The floodplain lake (beel) is a unique ecosystem which provides water and supports aquatic life forms of diverse range of plants and animals and are considered to be the most important and productive ecosystem (Mitsch and Gosselink, 1986) [16] and (Odum, 1978) [18]. These biotopes are integrate characteristics of aquatic, semi-aquatic, lentic habitats; and exhibit 'ecotone character' with inherent micro-habitat diversity and environmental heterogeneity (Sharma and Sharma, 2008) [30]. The floodplain lakes are considered to be useful in monitoring the impact of climate change namely nutrient retention and carbon sequestration (Céréghino *et al.*, 2014) [5]. These water bodies, serves as fish-food in inland fisheries and aquaculture practices (Lubzens, 1987) [14]; supports socio-economic development through fish production and live stocks. Abiotic factors influences the diverse array of aquatic biota including planktonic and semi-planktonic assemblages which comprise an integral link of aquatic food-webs, role in energy flow, nutrient cycling. The floodplain wetlands serve as ideal environs for limnological considerations vis-à-vis characteristics of water quality. The objective of this research is to augment the hypothesis on biodiverse nature of the floodplains of upper Brahmaputra river basin vis-à-vis abiotic characteristics of the sampled floodplain lakes.

Materials and Methods
Study sites
Limnological investigation was undertaken during October 2013–September 2015, in Khamti Guali beel (27° 34' 23.4"-27° 34' 26.0" N; 95° 20' 27.4"-95° 20' 53.8" E; 97.4 m ASL) located in the 'buffer zone' of the Dibru-Saikhowa Biosphere Reserve, Tinsukia, Assam (Fig. 1).

Fig 1: Khamti Guali beel

Methods of study
The water samples for abiotic parameters were collected from Khamti Guali beel for two years at regular monthly interval during the study period from October 2013-September 2015. The water samples were analyzed for temporal variation in 17 abiotic parameters namely water temperature, rainfall, pH, specific conductivity, dissolved oxygen, free carbon-dioxide, total alkalinity, total hardness, calcium, magnesium, chloride, dissolved organic matter, total dissolved solids, phosphate, nitrate, sulphate and silica. Of these, water temperature was

recorded using a centigrade thermometer while pH and specific conductivity were recorded with the help of field probes. Dissolved oxygen was estimated by the modified Winkler's method and the other abiotic parameters were analyzed by following A.P.H.A. (1992) [1]. The rainfall data was obtained from the Citrus Research Station, Government of Assam, Tinsukia, Assam. Two-way analysis of variance (ANOVA) was applied to ascertain significance of variations of the recorded abiotic parameters of the sampled beel during the study period. Ecological relationships between the abiotic parameters of Khamti Guali beel were determined by Pearson correlation coefficients (r); P values were calculated *vide* http://vassarstats.net/tabs.html and their significance were ascertained after the use of Bonferroni correction.

Results

Table 1: Temporal variation of Abiotic parameters of Khamti Guali beel

FACTORS	Oct. 2013- Sept. 2014		Oct. 2014- Sept. 2015	
Parameters↓	Range	Mean ± SD	Range	Mean ± SD
Rainfall (mm)	0.0 - 524.0	174.1 ± 180.7	1.0 - 615.0	202.7 ± 212.8
Water temp (ºC)	14.0 - 32.6	25.9 ± 5.7	16.9 - 28.6	24.8 ± 4.0
pH	6.84 - 8.04	7.38 ± 0.46	6.84 - 8.71	7.64 ± 0.61
Sp. conductivity (µS/cm)	74.0 - 150.0	109.7 ± 23.9	65.0 - 140.0	96.6 ± 24.4
Dissolved Oxygen (mg/l)	4.0 - 8.8	5.9 ± 1.3	4.0 - 8.0	5.9 ± 1.3
Free Carbon-dioxide (mg/l)	10.0 - 24.0	16.3 ± 4.2	8.0 - 20.0	14.3 ± 4.7
Total alkalinity m(g/l)	40.0 - 84.0	59.0 ± 13.8	40.0 - 72.0	50.2 ± 9.9
Total hardness (mg/l)	50.0 - 80.0	67.7 ± 9.9	56.0 - 100.0	74.8 ± 14.2
Calcium hardness(mg/l)	14.7 - 27.3	20.8 ± 3.6	14.7 - 27.3	19.1 ± 3.3
Magnesium hardness(mg/l)	7.99 - 15.36	11.38 ± 2.50	8.51 - 19.20	13.55 ± 3.16
Chloride hardness (mg/l)	9.90 - 19.90	14.69 ± 3.86	9.99 - 24.98	14.24 ± 4.67
DOM (mg/l)	0.048 - 0.131	0.104 ± 0.029	0.056 - 0.150	0.096 ± 0.027
TDS (mg/l)	0.0 40 - 0.240	0.123 ± 0.053	0.080 - 0.280	0.190 ± 0.071
Phosphate (mg/l)	0.138 - 0.351	0.225 ± 0.069	0.135 - 0.203	0.165 ± 0.025
Nitrate (mg/l)	0.440 - 1.702	0.852 ± 0.378	0.549 - 0.720	0.604 ± 0.056
Sulphate (mg/l)	6.720 -23.986	15.079 ± 6.906	7.522 -13.836	9.634 ± 2.202
Silica (mg/l)	0.678 - 1.372	0.896 ± 0.212	0.654 - 1.212	0.847 ± 0.182

Annual ranges and mean ± SD values recorded in the different abiotic parameters of Khamti Guali beel of Dibru-Saikhowa Biosphere Reserve, for the period during October 2013 – September 2014 is presented in Table 1. Water temperature corroborated with the geographical location and indicated sub-tropical nature of the beel. The floodplain lake affirmed slightly acidic, soft to moderately soft water character and thus depict moderately oxygenated nature of waters and low concentration of nutrient contents namely- phosphate, sulphate, nitrate and silicate.

Discussion

Rainfall was influenced by the south-west monsoon during the study period. Precipitation impacts the water chemistry and biological productivity by changing the tropic status of aquatic environs. It concurred with the low ionic concentration; as rainfall decreases the pH and conductivity increases. ANOVA affirmed significant monthly rainfall variations ($F_{11, 23} = 6.927$, $p = 0.0016$) and it registered an expected positive correlation with water temperature ($r = 0.612$, $p = 0.0015$). Besides, it recorded significant inverse correlation with dissolved oxygen ($r = - 0.634$, $p = 0.0015$) and thus limited general role vis-à-vis other abiotic factors.

Water temperature ranged between 14.0-32.6 (25.9±5.7) °C in the first year and 16.9-28.6 (24.8±4.0) °C in the second year. Water temperature kept on increasing from December till August and there was slight drop till it reached a maximum water temperature of 32.6 °C in July 2014 and gradually temperature drop to minimum of 14.0 °C and was observed in December, 2013 in the first year. While in the second year maximum of 28.6ºC was observed in the month of June and minimum of 16.9 °C was observed in January in the same year, 2014. In the second year it showed increase from January – June 2015 where the peak was reached and followed by fluctuation in the rest of the months. Water temperature corroborated with the geographical location of Khamti Guali beel; it concurred broadly with the reports from other beels from Assam (Dey and Kar 1987) [9]; (Sharma, 2011) [26]. As water temperature rises, the solubility of oxygen decreases, thus affects the freshwater ecosystem. Water temperature indicated significant inverse correlation with dissolved oxygen ($r = - 0.716$, $p = 0.0015$) during the study.

Hydrogen ion extent by the interaction between H^+ and OH^- ions formed due to dissociation of H_2CO_3 and hydrolysis of bicarbonates (Wetzel, 1983) [35]. The present study affirmed slightly acidic to alkaline nature of waters and it ranged 6.84 - 8.71; thus circumneutral water contributes to the plankton diversity in freshwater ecosystem. pH ranged between 6.84-8.04 (7.38±0.46) in the first year and 6.84-8.71 (7.64±0.61) in the second year, respectively. Maximum value of 8.04 was recorded in November and minimum of 6.84 was observed in October, 2013 in the same year in the first year. While in the second year, a maximum of 8.71 was observed in the December and minimum of 6.84 was observed in October, 2014 in the same year. The results concurred with the reports of Abir (2014) [2] and, Barbaruah and Dutta (2014) [3] but showed higher values than the reports from various aquatic ecosystems of North-eastern India (Sharma and Sharma, 2012) [31]. ANOVA registered significant pH variations between months in Khamti Guali beel ($F_{11, 23} = 3.02624$, $p = 0.03979$).

Specific conductivity is characterized with low ionic concentrations and is, hence, assigned to 'Class I' category of trophic classification *vide* Talling and Talling (1965) [33]. It ranged between 65.0 - 150.0 µS/cm during the study period. It ranged between 74.0–150.0 (109.7±23.9) µS/cm and between 65.0–140.0 (96.6±24.4) µS/cm during two years, respectively. Highest value was recorded during April, 2014 (150.0 µS/cm) and lowest was recorded in July (74.0 µS/cm) in the same year in the first year. While in that of the second year, maximum was recorded in February, 2015 (140 µS/cm) and minimum was recorded in August (65.0 µS/cm) in the same year. The low ionic concentration in a freshwater ecosystem influences the desmid diversity; thus an important indicator. The specific conductivity values concurred with the reports from floodplain lakes of Assam (Sharma, 2000) [22]; (Hazarika, 2010) [11]; (Sharma and Sharma, 2012) [31] and from certain wetland ecosystems of Manipur (Rai and Raleng, 2011) [20]. ANOVA showed significant variation between the months in Khamti Guali beel ($F_{11, 23}$ = 3.5493, p = 0.0231).

Dissolved oxygen affirmed moderately oxygenated nature of water of the sampled beel and is an important factor for distribution, behavior and growth of aquatic organisms (Wetzel, 1983)[35].Dissolved oxygen in Khamti Guali beel showed range between 4.0–8.8 (5.9±1.3) mg/l in the first year and between 4.0–8.0 (5.9±1.3) mg/l in the second year. The maximum dissolved oxygen content recorded during the study period was 8.8 mg/l in the month of October, 2013 whereas the minimum was noticed in August, 2014 (4.0 mg/l) in the first year. While in that of second year, maximum of 8.0 mg/l was recorded twice and it was in the month of December and January in 2013 and 2014 respectively and minimum of (4.0 mg/l) was recorded in June and September 2015. The present results concurred with the reports from the certain floodplain lakes of Assam (Bhagabati and Borkotoki, 2014) [4] and with Rudrasagar wetland, Tripura (Abir, 2014) [2]. ANOVA indicated significant variations of dissolved oxygen between the months ($F_{11, 23}$= 2.227, p = 0.099). Dissolved oxygen did not register any significant correlation except with water temperature in Khamti Guali beel.

Free carbon-dioxide was recorded throughout the study in the sampled beel; in the first year, free carbon dioxide ranged between 10.0–24.0 (16.3±4.2) mg/l and between 8.0–20.0 (14.3±4.7) mg/l in the second year, respectively. The peak value was noticed during April (24.0 mg/l) in the first year whereas the minimum value was noticed during October and May (10.0 mg/l) in 2013 and 2014 respectively. In the second year, a maximum of 20.0 mg/l was recorded in the month of April and June 2015 and minimum of 8.0 mg/l was recorded in the month of December in 2014 and uniform value of 10.0 mg/l was recorded four times i.e. in the month of November 2014, January, February and July 2015 respectively. It ranged between 8.0 - 24.0 mg/l during the study periodand is attributed to its insufficient uptake by photo-autotrophs in the sampled floodplain lake. Free CO_2 indicated no significant influence with other abiotic factors of the sampled beel.

Total alkalinity ranged between 40.0–84.0 (59.0±13.8) mg/l in the first year while in the second year it ranged between 40.0–72.0 (50.2±9.9) mg/l. Peak alkalinity of 84.0 mg/l was recorded in April, 2014, and the lowest value was recorded in July (40.0 mg/l) during the first year of study period. During the second year, a maximum of 72.0 mg/l was recorded in the month of March, 2015 and minimum of 40.0 mg/l was recorded in January, 2015. Total alkalinity ranged between 40.0 - 84.0 mg/l in the sampled floodplain lake; it depicted 'soft to hard water character'. Total alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life. The observed results concurred with the reports from various other aquatic ecosystems of northeast India (Sharma, 2001) [23]; (Sharma and Hussain, 2001) [28]; (Hazarika, 2010) [11]; (Bhagabati and Borkotoki, 2014) [4]. ANOVA indicated significant variations of alkalinity between years ($F_{1, 23}$ = 5.376, p = 0.0406). No significant correlation was recorded with other abiotic factors in the sampled beel.

Total hardness ranged between 50.0–80.0 (67.7±9.9) mg/l in the first year and between 56.0–100.0 (74.8±14.2) mg/l in the second year. Peak hardness was noticed thrice in the month of December, January and April (80.0 mg/l) and minima of 50.0 mg/l were recorded in May during the first year. During the second year, maximum of 100.0 mg/l was recorded in March, 2015 while a minimum of 56.0 mg/l was recorded in October 2014. It indicated 'soft to moderately hard waters' character of the sampled beel *vide* Ohle (1934) [19] and Moyle (1946) [17]. The observed results are higher than the reports of Sharma and Sharma (2012) [31] while it concurred with the reports from floodplain lakes of Assam (Hazarika, 2010) [11]; Bhagabati and Borkotoki, 2014) [4]. Total hardness indicated significant correlation only with Magnesium (r = 0.961, p < 0.0001) during the study period.

Calcium values indicated calcium poor waters and calcium content of the beel ranged between 14.7-27.3 (20.8±3.6) mg/l in the first year and between 14.7-27.3 (19.1±3.3) mg/l in the second year. Peak value of 27.3 mg/l and minima value of 14.7 mg/l was recorded in the first year and second year of the study period. During the first year, maxima value was recorded in March and lowest was recorded in the month of May, 2014 while in second year, maximum was recorded in February and lowest was recorded in July in the same year i.e. in 2015 it ranged between14.7 - 27.3mg/l. The soft water characteristic feature is an important indicator of desmid diversity in freshwater ecosystem. The recorded results are lower than the reports from the floodplain lakes of Manipur (Sharma, 2009) [24] and Assam (Sharma and Sharma, 2012) [31].

Magnesium, serves as an important component of chlorophyll, a co-factor in enzymatic transformations (Wetzel, 1983) [33]. Magnesium ranged between 7.99–15.36 (11.38±2.50) mg/l in the first year and between 8.51–19.20 (13.55±3.16) mg/l in the second year. Its maximum value was recorded during January (15.36 mg/l) and minimum value was noticed during June (7.99 mg/l) in the first year. In the second year, maximum of 19.20 mg/l was recorded in March, 2015 and minimum of 8.51 mg/l was recorded in October, 2014. Low calcium and magnesium concentration attributes to the Chlorophyta richness in freshwater ecosystem. The sampled beel indicated the dominance of Calcium > Magnesium and thus concurred with the reports of Zutshi (1981) [36]; Jhingran (1982) [13]; Vass *et al.* (1989) [34]. The observed values showed slightly higher than the reports from certain floodplain lakes of Northeast India (Sharma, 2011) [26]. Magnesium content indicated significant positive correlation only with total hardness in the sampled beel (r = 0.961, p < 0.0001) on account of inter-dependence of the two factors and affirmed limited role vis-à-vis other abiotic parameters.

Chloride is generally attributed to dissolution of salt deposits of sodium, potassium and calcium. Chloride recorded a range between 9.90-19.90 (14.69±3.86) mg/l in the first year and in the second year it ranged between 9.99-24.98 (14.24±4.67) mg/l respectively. The maximum chloride content was recorded in October, 2013 (19.90 mg/l) and minimum of 9.90 mg/l was recorded in the month of February, 2014 during the first year. In the second year, maximum value of (24.98 mg/l) was recorded in the month of April, 2015 and minimum of 9.99 mg/l was recorded in June 2014. Chloride ranged between 9.90 - 24.98mg/l; and the result concurred with low concentrations of natural waters (Wetzel, 1983) [35], however human influence could raise its concentration content. The present results concurred with those as expected in natural waters and thus indicated lack of influence of organic pollution caused by human impact as indicated by Vass *et al.* (1989) [34]; Sharma (2001) [23]; and Jain *et al.* (1999) [12]. This halide lacked any importance vis-à-vis other abiotic factors.

Dissolved organic matter (DOM) consists of soluble organic materials derived from the decaying leaves, decomposed aquatic organism, soluble particles released by living organisms and organic matter washed down by rain water from the catchments areas. DOM ranged between 0.048– 0.131 (0.104±0.029) mg/l in the first year and in the second year it ranged between 0.056–0.150 (0.096±0.027) mg/l. Maximum DOM was recorded thrice during March, June and September (0.131 mg/l) in 2014 and a minimum was noticed during February (0.048 mg/l) in 2014 in the first year. During the second year, maximum of 0.150 mg/l was recorded in the month of October, 2014 while minimum of 0.056 mg/l in February and March, 2015. DOM followed nearly identical mean values during the study period. The recorded lower values also concurred with the reports from the floodplains of Manipur (Sharma, 2011) [26] and from the floodplain lakes of Assam (Sharma and Sharma, 2012) [31].

Total dissolved solids (TDS) are comprised mainly of inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the calcium, magnesium, sodium, potassium and the anions carbonate, bicarbonate, chloride and sulphate. TDS ranged between 0.040–0.240 (0.123±0.053) mg/l in the first year and in the second year it ranged between 0.080–0.280 (0.190±0.071) mg/l. Maximum TDS was recorded in April (0.240 mg/l) in 2014 and a minimum of 0.040 mg/l was noticed during July 2014 in the first year. During the second year, maximum of 0.280 mg/l was recorded thrice i.e. in the month of April, August and September, 2015 while minimum of 0.080 mg/l was recorded in the month of October, 2014. TDS registered low dissolved solids content and values ranged between 0.040 - 0.280 mg/l. Low concentration of dissolved solids content corresponded with their low ionic concentrations in general in the sampled beel. TDS values are lower than the reports of Sharma and Pant (1985) [32]; Chakraborty and Saha (1993) [7] and Chakraborty (1998) [6]. TDS showed no significant correlation with abiotic factors in the sampled beel, thus lacked importance vis-à-vis other abiotic factors.

Phosphate is a key nutrient which plays a significant role in biological productivity. In Khamti Guali beel, phosphate ranged between 0.138–0.351 (0.225±0.069 mg/l during the first year and between 0.135–0.203 (0.165±0.025) mg/l in the second year of study period. The peak value was noticed during May, 2014 (0.351 mg/l) in the first year while the lowest value was recorded during November (0.138 mg/l) in 2013. During the second year, maximum value of 0.203 was recorded twice in July and August, 2015 and minimum of 0.135 was recorded in December, 2014. Its concentration ranged between0.135 - 0.351mg/l during the study period. The recorded results concurred with the reports from certain floodplain lakes of northeast India (Hazarika, 2010) [11]; (Das *et al.*, 2011) [8]. Phosphate registered significant positive correlations with nitrate ($r = 0.809$, $p < 0.0001$) and sulphate ($r = 0.839$, $p = 0.0001$); therefore, indicated certain importance of phosphate vis-à-vis other abiotic parameters.

Nitrate, an important micronutrient for autotrophic production, plays significant role in the freshwater ecosystem. It ranged between 0.440–1.702 (0.852±0.378) mg/l during the first year and between 0.549–0.720 (0.604±0.056) mg/l in the second year. The peak was noticed during February 2014 (1.702 mg/l) in the first year while the lowest was recorded during October (0.440 mg/l) in 2013. During the second year, maximum of 0.720 mg/l was recorded in August, 2015 and minimum was recorded in January, 2015. Nitrate content recorded low concentration and ranged between 0.440 - 1.702 mg/l; thus indicated low usage of nitrogenous fertilizers in the catchment areas (Malthus and Mitchell, 1988) [15]. The recorded values concurred with the reports from floodplain lakes of Assam (Sharma, 2010)[25]. ANOVA indicated significant annual variations in Khamti Guali beel ($F_{1, 23} = 5.851$, $p = 0.034$). Nitrate registered significant positive correlations with sulphate ($r = 0.770$, $p < 0.0001$) and hence recorded certain importance in this study.

Sulphate serves as an important component of proteins, responsible for three-dimensional structures of enzymes and regulates cell division**.** Sulphate ranged between 6.720–23.986 (15.079±6.906) mg/l during the first year and between 7.522–13.836 (9.634±2.202) mg/l in the second year. The peak value was noticed during February, 2014 (23.986 mg/l) in the first year. During the second year, sulphate maximum of 13.836 mg/l was recorded in January, 2015. The present results in the sampled beel was higher than the reports of Sharma and Lyngskor (2003) [29]; Sharma and Bhattarai (2005) [27]; Sharma (2011) [26] and, Bhagabati and Borkotoki (2014) [4] but concurred with the reports of Sharma and Sharma (2012) [31]. ANOVA indicated significant variations in two annual cycles in the sampled beel ($F_{1, 23}= 6.489$, $p = 0.0271$). This study indicated positive correlation with nitrate ($r = 0.770$, $p < 0.0001$) thus indicated limited influences on other abiotic parameters.

Silicate ranged between 0.678–1.372 (0.896±0.212) mg/l during the first year and between 0.654–1.212 (0.847±0.182) mg/l in the second year. The peak was noticed during November, 2013 (1.372mg/l) in the first year. During the second year, maximum of 1.212 mg/l was recorded in August, 2015. Silicate values are lower than the reports by Zutshi *et al.* (1980) [37]; Vass *et al.* (1989) [34]; Dhendup and Boyd (1994) [10]; Sarwar (1999) [21]. It did not register any significant correlation with the other abiotic parameters; thus indicated no certain importance of this nutrient vis-a-vis other abiotic factors.

Conclusions

The limnological investigation of abiotic parameters of the sampled beel of Dibru Saikhowa Biosphere Reserve is characterized by ‘slightly acidic to alkaline nature and affirmed moderately oxygenated water’. Rainfall was influenced by the south-west monsoon and water temperature affirmed tropical character of these wetlands with their corroborated geographical location. Specific conductivity showed low ionic concentrations and thus, warranted inclusion of the sampled beel under 'Class 1' category of Talling and Talling (1965) [33]. Free carbon-dioxide occurred throughout the study in the beel which is attributed to its insufficient uptake by photo-autotrophs in the sampled floodplain lake. Total alkalinity and total hardness exhibited soft to hard water character and calcium poor waters in the sampled beel. Magnesium, an important co-factor in enzymatic transformations resulted in the dominance of Calcium > Magnesium. Chloride registered low concentrations and thus indicated lack of influence of organic pollution caused by human impact in the study site. Dissolved organic matter, total dissolved solids and the nutrients namely - phosphate, sulphate, nitrate and silicate recorded low concentration with limited variations are other salient features of the sampled beel. The floodplain lake recorded low nitrate content and thus indicated low usage of nitrogenous fertilizers in the catchment areas. The results thus affirmed limitations of 'abiotic-abiotic' interactions vis-à-vis limnology of the sampled floodplain lakes particularly in light of habitat disturbances due to influence of floods and un-planned fishing in the beel.

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