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Sediment properties of two important beels of Rajshahi, Bangladesh

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Abstract. A comprehensive chemical analysis study was conducted to assess the sediment properties of two important fresh water bodies: beels (Hilna beel and Beel Kumari beel) of Rajshahi division, Bangladesh from July 2007 to June 2008. Average pH, organic matter, organic carbon, total nitrogen, phosphorus, available sulphur, zinc, and potassium of the bottom sediment were 6.33±0.431, 1.426±0.642%, 0.83±0.372%, 0.082±0.027%, 11.92±4.014 ppm, 24.05±7.85 ppm, 1.95±0.449 ppm and 0.404±0.14 me $100g^{-1}$ in Hilna beel and 6.78±0.684, 1.338±0.504%, 0.78±0.292%, 0.068±0.02%, 16.02±3.548 ppm, 22.17±7.24 ppm, 1.64±0.804 ppm and 0.39±0.121 me $100g^{-1}$ in Beel Kumari beel, respectively. The chemical parameters obtained from this study except pH of soil of both beels were within the preferable range and were average productive. The study underlines the baseline information for better understanding the sediment chemistry and productivity of these commercially important freshwater resources of Bangladesh.

Key Words: physico-chemical properties, organic matter (OM), total nitrogen (TN), soil pH, inland water.

Introduction. In natural water body, the physico-chemical properties of water reflect the properties of the bottom soil (Banerjea 1967). The bottom soil of any water reservoir may be considered as a laboratory. Because, it not only holds water for aquatic animals but also enriches the water body with various nutrients required for biological production through nutrient exchange between plants and animals (Saha 2003). From adjacent land of water body, both organic and inorganic nutrients enter into the water body with land washes and rain water. Also after death, the aquatic plants and animals settle on the bottom soil are being released in water through biogeochemical cycle by anaerobic bacterial activity (Habib et al 1986). The nutrients of bottom soil combinedly affect the mixing of inflow of nutrients from bottom soil to water of concern habitat and also they linearly affect the mixing of nutrients from bottom soil to water (Habib et al 1991).

Water quality, especially chemical properties, almost completely depends on the quality of soil of the substrate. Generally good fish production may be expected from a beel of which bottom sediment is fertile for good crop production. If the soil is acidic then the water of the beel is acidic and if there is nutrient deficiency in the substrate then similar nutrient deficiency occurs in the beel water.

The physical properties of soil, i.e., texture, are very important for the determination of water holding capacity. Soil contains sand, silt and clay in definite proportions and accordingly, is classified as sandy, silty, clayey, sand-loam, clay-loam, silty-clay and loam (Alam et al 2007). Besides soil particles, it contains micro-nutrients which are required in small amounts, but they often play a regulative role in development, metabolic functions and enzymatic action. These include potassium, iron, manganese, zinc, boron, etc.

Productivity of beel water depends largely on the bottom-soil. Generally a beel is located in the unproductive agricultural land and it is productive where soil is productive. The best bottom-soil is that where decomposition of organic matter is rapid and soil-water interaction is continuous and favorable to release essential nutrients from bottom-mud (Rahman 1992).

The bottom soil (sediment) acts as the storehouse of nutrients in the aquatic ecosystems (Gupta et al 2001). The release of these nutrients into water and their consequent removal greatly helps in the biological cycle of the ecosystems (Das et al 2001). Such an exchange of nutrients depends upon the characteristics of the sediments and the hydrographic features of the aquatic systems (Habib et al 1991).

Recently, due to anthropocentric activities in beel basin along its connecting channel is accumulating enormous load of agricultural pollutants (Saha et al 2005). As a result, ecosystems of beels have declined in an alarming manner due to degradation of environmental conditions (Saha & Hasan 2004). Although, few published reports related to the pond sediments (Habib & Rahman 1987) were limited to the research of pond bottom soils which was quite different from beel ecosystems. But, information on sediments of beels is inadequate in Bangladesh especially in Rajshahi region (Rahman & Das 2001). The composition of the properties of the beel sediment and their fluctuation over a period of time provide an index of the ecosystem. On account of this, there is not only an urgent need of constant monitoring of the beels, but also to take suitable remedial steps to conserve biodiversity of beels for sustainable management. The objective of this study was to assess the productivity of Hilna beel and Beel Kumari beel of Rajshahi division, Bangladesh by analyzing the chemical properties of sediments.

Material and Method

Field sampling. The study was conducted one year period from July 2007 to June 2008 on Hilna beel and Beel Kumari beel of Rajshahi division, Bangladesh (Figure 1). Hilna beel and Beel Kumari beel are basically floodplains and they cover about 1500 and 996 ha in rainy season and 160 and 156 ha in dry season, respectively. The sediments were sampled monthly and transported to the Fisheries laboratory, Rajshahi University, Bangladesh for further analysis.

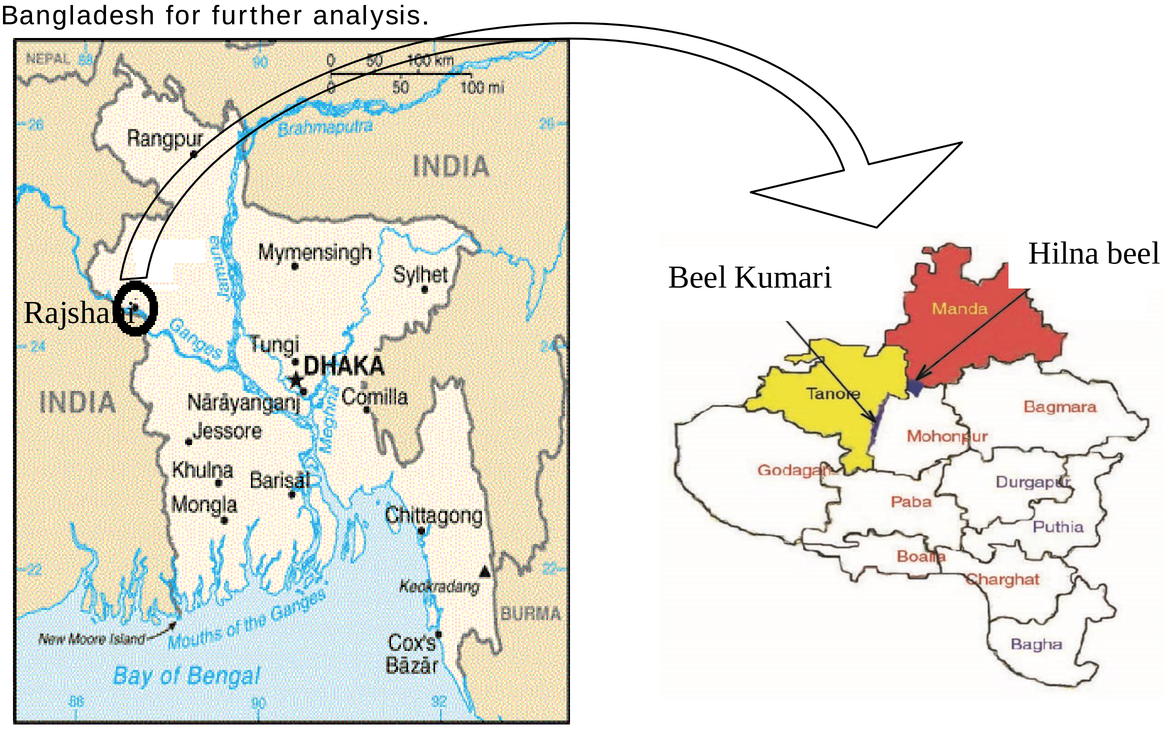

Figure 1. Maps indicating study areas. Closed circle and arrow denotes sampling site (Hilna beel and Beel Kumari beel) (source: http://simple.wiktionary.org/wiki/Bangladesh).

Laboratory analysis

Soil pH. The pH of the soil was measured electro-chemically using a glass electrode pH meter (HANNA instrument, model- HI 921 ON ATC). The ratio of soil and water as well as soil and 0.01M $CaCl_2$ solution was 1:2.5, as suggested by Jackson (1962).

Organic Carbon (C). Soil organic carbon of the samples was determined by dry combustion method with Leco-C-200 Carbon Analyzer.

Organic matter (OM). The organic matter of the experimental soil was determined by multiplying the percentage of organic carbon with conventional Van-Bemmelen's Factor of 1.724 (Piper 1950).

Total Nitrogen (TN). The total nitrogen of the soil samples was determined by Micro-Kjeldhal method as suggested by Jackson (1962).

Phosphorus (P). Available phosphorus of the soil samples was extracted by Ammonium floride (NH_4F) extraction method, as proposed by Bray & Kurtz (1945) and determined by Spectrophotometer Lamda-II, UV/vis (Perkin Elmer) at 890 nm wavelength after developing blue colour in ammonium molybdate ascorbic acid solution.

Potassium (K). At first soil extraction was done with 1 M ammonium acetate and the content of potassium was measured using a flame photometer. For calculation, the following equation was used:

$$\text{meq K per 100 g soil} = \frac{a \times 25}{g},$$

where, a = cmol (+) K per L measured on the flame photometer.

Sulphur (S). The available sulphur of soil of the study area was extracted using calcium dihydrogen phosphate solution and determined by turbidiometric method using Lumbda-II Absorbance Spectrophotometer at 535 nm wavelength.

Zinc (Zn). From the soil sample the Zinc content was measured by AAS (Atomic Absorption Spectrometer) on undiluted soil extract.

Data analysis. All statistical analyses were performed with Microsoft office Excel 2003 and SPSS 11.5. Data were analysed by means of ANOVAs (Underwood & Navaretta 1997). The Tukey test was used to compare the means of the different results (Simon et al 2012). Cochran's test was used prior to the ANOVA to test the assumption of homogeneity of variances (Underwood & Navaretta 1997).

Results

Soil pH. The pH value of beel sediments was found to slightly acidic to circum neutral ranging from 5.7 to 7.1 in Hilna beel and from 5.3 to 8.2 in Beel Kumari beel with an average of 6.33±0.431 and 6.78±0.684, respectively (Table 1 and Figure 2.a). The maximum pH values were recorded on September 7.10 and 8.20 in Hilna beel and Beel Kumari beel, respectively. However, the lowest pH value, 5.7 was recorded in Hilna beel on April and 5.30 in Beel Kumari beel on February (Figure 2.a). In Hilna beel, the correlation of pH with organic matter, organic carbon, nitrogen, phosphorus, sulphur, zinc and potassium was not significant (Table 2) but in Beel Kumari beel, it has inverse significant correlation with Zn ($p < 0.05$; $r = -0.593$) (Figure 3.a).

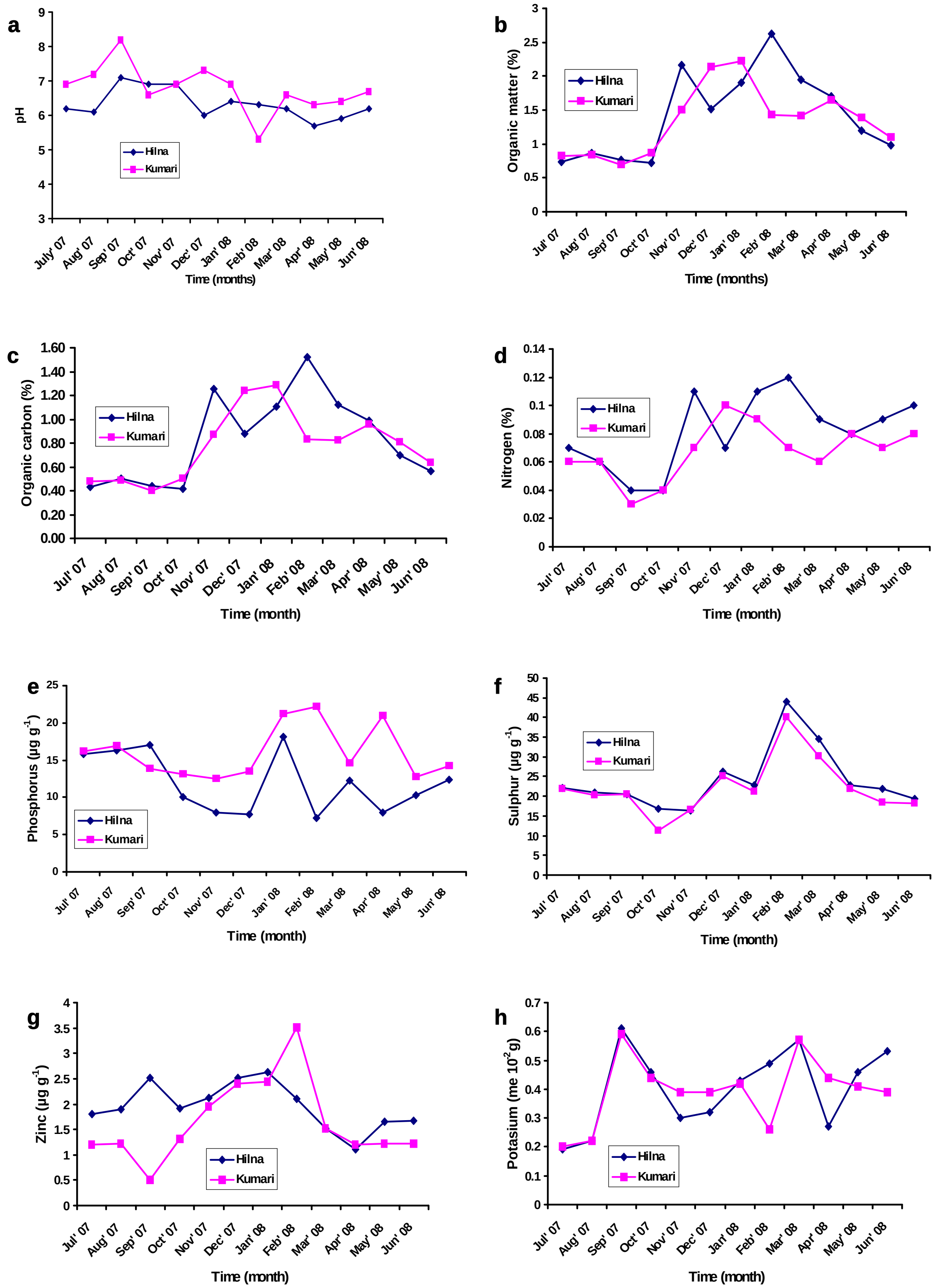

Figure 2. Monthly variation in the sediment properties of the two studied beels over a period from July 2007 to June 2008: (a) pH, (b) OM, (c) OC, (d) N, (e) P, (f) S, (g) Zn and (h) K.

Table 1

Chemical parameters of two beels (Hilna and Beel Kumari) sediments over a period from July 2007 to June 2008

Parameters	Unit	Hilna	Beel Kumari
		Mean ± SD (Range)	*Mean ± SD (Range)*
pH	-	6.3250±0.43091 (5.7-7.1)	6.7750±0.68374 (5.3-8.2)
Organic matter	%	1.4258±0.64208 (0.72-2.62)	1.3375±0.50352 (0.69-2.22)
Organic Carbon	%	0.8283±0.37241 (0.42-1.52)	0.7767±0.29178 (0.40-1.29)
Nitrogen	%	0.0817±0.02657 (0.04-0.12)	0.0675±0.01960 (0.03-0.1)
Phosphorus	ppm	11.9200±4.01413 (7.2-18.1)	16.0158±3.54779 (12.44-22.2)
Sulphur	ppm	24.0500±7.84619 (16.4-44.0)	22.1667±7.24121 (11.4-40.0)
Zinc	ppm	1.9533±0.44894 (1.11-2.63)	1.6442±0.80423 (0.51-3.51)
Potassium	$me100g^{-1}$	0.4042±0.14003 (0.19-0.61)	0.3933±0.12078 (0.2-0.59)

Organic matter (OM). The organic matter value of beel sediments was found ranging from 0.72 to 2.62% in Hilna beel and from 0.69 to 2.22% in Beel Kumari beel with an average of 1.426±0.642% and 1.338±0.504%, respectively (Table 1 and Figure 2.b). The maximum organic matter value recorded 2.62% from Hilna beel in February and 2.22% from Beel Kumari beel in January and minimum value 0.72 in October from Hilna beel and 0.69% in September from Beel Kumari. In Hilna beel OM has positive and highly significant correlation ($p < 0.01$) with Nitrogen ($r = 0.801$; Table 2 and Figure 4.a) and organic carbon ($r = 1.00$; Table 2). In Beel Kumari beel, OM has positive and highly significant correlation with Nitrogen ($p < 0.01$; $r = 0.847$; Table 2; Figure 3.b) and a positive significant correlation with Zn ($p > 0.05$; $r = 0.628$; Table 3; Figure 3.a).

Organic carbon (OC). The organic carbon value of beel sediments was recorded ranging from 0.42 to 1.52% and 0.40 to 1.29% with average 0.83±0.372% and 0.78±0.292% from Hilna beel and Beel Kumari beel, respectively (Table 1; Figure 2.c). The maximum organic carbon recorded 1.52% from Hilna beel in February and 1.29% from Beel Kumari beel in January and minimum value 0.42 in October from Hilna beel and 0.40 in September from Beel Kumari. Organic carbon has highly significant correlation ($p < 0.01$) with nitrogen ($r = 0.801$) and a significant correlation with sulphur ($r = 0.647$) in Hilna beel (Table 2; Figure 4.c and 4.d). In Beel Kumari, it has positive and highly significant correlation ($p < 0.01$) with nitrogen ($r = 0.847$) and positive significant correlation with zinc ($r = 0.628$) (Table 3; Figure 3.d and 3.e).

Nitrogen (N). Nitrogen value of beel sediments was from 0.04 to 0.12% and 0.03 to 0.1% with an average of 0.082±0.027% and 0.068±0.02% in Hilna beel and Beel Kumari beel, respectively (Table 1 and Figure 2.d). The maximum nitrogen value recorded 0.12% from Hilna beel in February and 0.1% from Beel Kumari beel in December and minimum value 0.04% in September-October from Hilna beel and 0.03% in September from Beel Kumari.

Phosphorus (P). During the study period phosphorus ranged from 7.2 to 18.1 ppm and from 12.44 to 22.2 ppm with an average of 11.92±4.014 ppm and 16.02±3.548 ppm in Hilna beel and Beel Kumari beel, respectively (Table 1; Figure 2.e). The maximum phosphorus recorded 18.10 ppm from Hilna beel in January and 22.20 ppm from Beel Kumari beel in February and minimum value 7.2 ppm in February from Hilna beel and 12.44 ppm in November from Beel Kumari. Phosphorus was found to have no significant correlation with pH, OM, OC, N, S, Zn or K in any of the studied beels (Table 2 and 3).

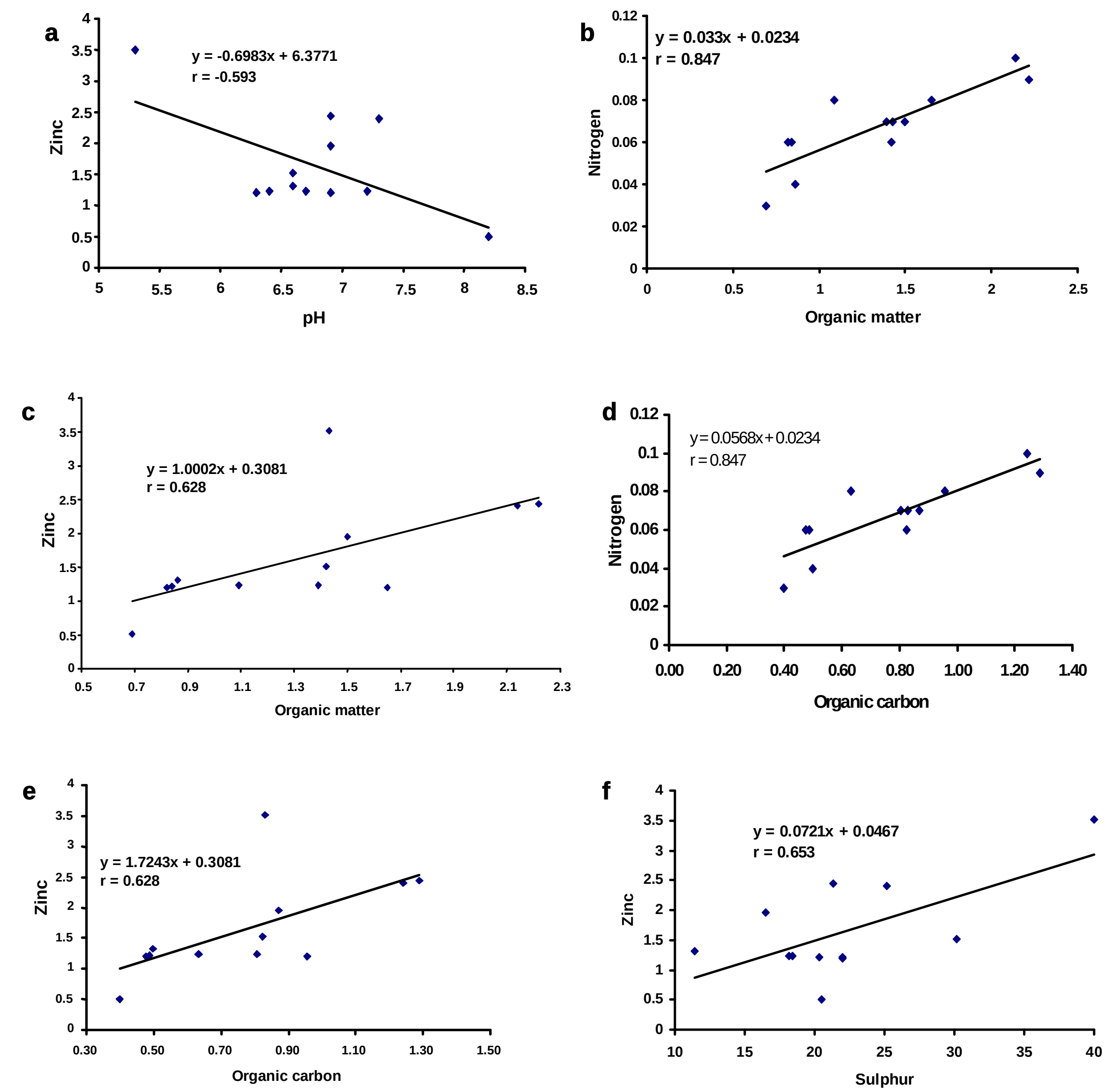

Figure 3. Correlations between different organic matters of Beel Kumari beel over a period from July 2007 to June 2008: (a) pH and Zn, (b) OM and N, (c) OM and Zn, (d) OC and N, (e) OC and Zn, (f) S and Zn.

Table 2

Correlation matrix among the chemical parameters of beel sediment of Hilna beel over a period from July 2007 to June 2008

Parameters	*pH*	*OM (%)*	*OC (%)*	*N (%)*	*P (ppm)*	*S (ppm)*	*Zn (ppm)*	*K (me100g^{-1})*
pH	1							
OM (%)	-0.128	1						
OC (%)	-0.130	1.000**	1					
N (%)	-0.274	0.801**	0.801**	1				
P (ppm)	0.212	-0.497	-0.499	-0.289	1			
S (ppm)	-0.288	0.647*	0.647*	0.440	-0.283	1		
Zn (ppm)	0.534	0.074	0.069	-0.032	0.302	-0.007	1	
K (me100g^{-1})	0.378	0.085	0.085	0.049	0.057	0.278	0.164	1

* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.

Potassium (K). Potassium of the beel sediments were found to be vary from 0.19 to 0.61 me $100g^{-1}$ and from 0.2 to 0.59 me $100g^{-1}$ with an average of 0.404±0.14 61 me $100g^{-1}$ and 0.393±0.12161 me $100g^{-1}$ in Hilna beel and Beel Kumari beel, respectively (Table 1 and Figure 2.h). The maximum potassium value recorded 0.6161 me $100g^{-1}$ and 0.5961 me $100g^{-1}$ in September from Hilna beel and Beel Kumari beel, respectively and minimum value 0.1961 me $100g^{-1}$ and 0.2061 me $100g^{-1}$ in July from Hilna beel and Beel Kumari beel, respectively. Potassium also had no significant correlation with pH, OM, OC, N, S, Zn or K in any of the studied beels (Table 2 and 3).

Table 3

Correlation matrix among the chemical parameters of beel sediment of Beel Kumari beel over a period from July 2007 to June 2008

Parameters	*pH*	*OM (%)*	*OC (%)*	*N (%)*	*P (ppm)*	*S (ppm)*	*Zn (ppm)*	*K (me $100g^{-1}$)*
pH	1							
OM (%)	-0.228	1						
OC (%)	-0.229	1.000**	1					
N (%)	-0.290	0.847**	0.847**	1				
P (ppm)	-0.490	0.329	0.332	0.307	1			
S (ppm)	-0.486	0.275	0.273	0.232	0.562	1		
Zn (ppm)	-0.593*	0.628*	0.628*	0.551	0.497	0.653*	1	
K (me $100g^{-1}$)	0.345	0.113	0.108	-0.250	-0.316	-0.156	-0.338	1

* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.

Sulphur (S). During the study period sulphur of beel sediments ranged from 16.4 to 44.0 ppm and from 11.4 to 40.0 ppm with an average of 24.05±7.846 ppm and 22.167±7.241 ppm in Hilna beel and Beel Kumari beel, respectively (Table 1; Figure 2.f). The maximum sulphur recorded 44.0 ppm from Hilna beel in February and 40.0 ppm from Beel Kumari beel in February and minimum value 16.4 ppm in November from Hilna beel and 11.4 ppm in October from Beel Kumari.

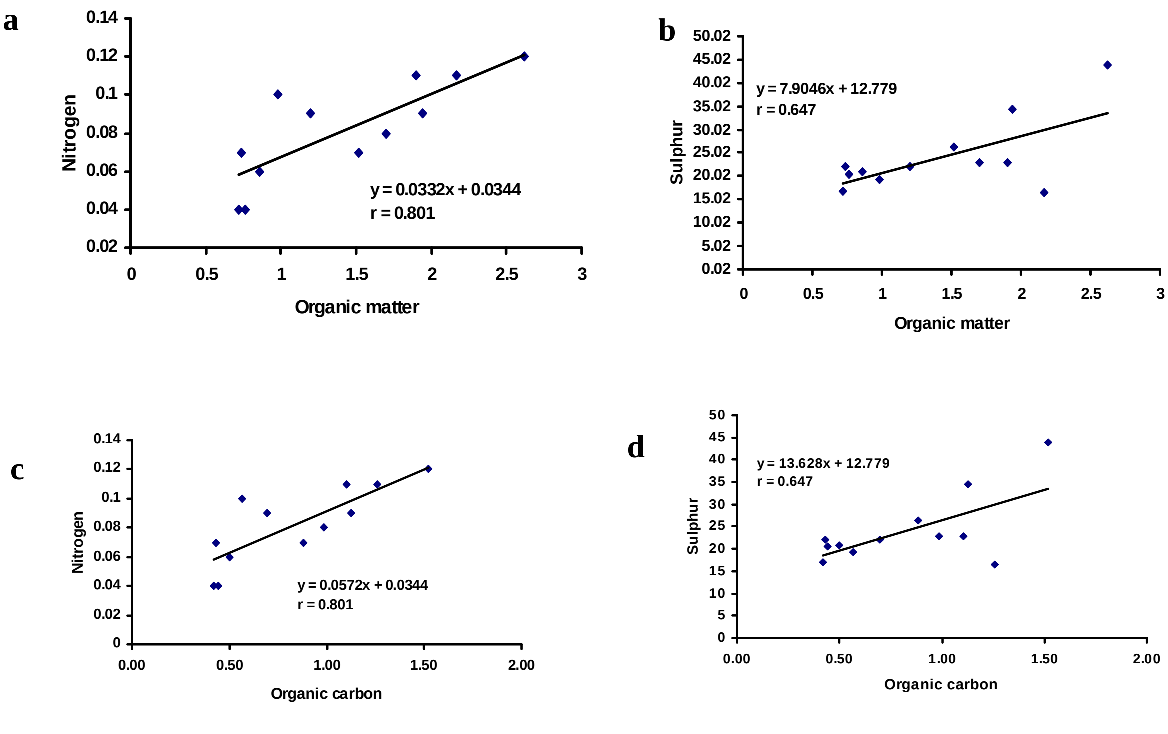

Figure 4. Correlations between different organic matters of Hilna beel over a period from July 2007 to June 2008 (a) OM and N, (b) OM and S, (c) OC and N, (d) OC and S.

Zinc (Zn). The Zn value of beel sediments was found to have a range from 1.11 to 2.63 ppm and from 0.51 to 3.51 ppm with an average of 1.955±0.449 ppm and 1.646±0.803 ppm in Hilna beel and Beel Kumari beel, respectively. The maximum Zn value recorded 2.63 from Hilna beel in January and 3.51 from Beel Kumari beel in February and minimum value 1.11 in April from Hilna beel and 0.51 in September from Beel Kumari. Zn has no significant correlation with other parameter studied in Hilna beel, but in Beel Kumari, it has negative significant correlation with pH and positive significant correlation with organic matter, organic carbon and sulphur (Table 3; Figure 3.a, 3.c, 3.e and 3.f).

Discussion

Soil pH. Soil pH is the most important factor of nutrient availability in soils, because it maintains the productivity of any aquatic ecosystem since it controls most of the chemical reactions. It not only influences the soil microbial activity but also affects the availability of nutrients to beel water, either native or when applied externally. Generally, availability of macronutrients and molybdenum increase as soil pH increases and reverse is true for micronutrients except molybdenum. In most cases, pH near 7 is optimum for adequate availability of nutrients in soils (BARC 2005). The pH value of beel sediments was found to slightly acidic to circum neutral ranging from 5.7 to 7.1 in Hilna beel and from 5.3 to 8.2 in Beel Kumari beel with an average of 6.33±0.431 and 6.78±0.684, respectively. This was closer to Pathak et al (1989) who found pH 5.8 to 6.6 and 6.4 to 6.4 in Media beel and Kulia beel, respectively. Vinci & Mitra (1997) also recorded such acidic pH (6.7) from Banardaha beel of India. Jhingran (1992) reported that sediment pH below 6.5 gives poor production and pH in the range of 6.5–7.5 indicates average to high production. The pH values of the present study varied widely from 5.3-8.2 however the average values indicate that the studied beels productivity is poor to average. Also pH has no significant correlation with OM, N, P, S, Zn or K in Hilna beel, but in Beel Kumari, it has inverse significant correlation with Zn which is supported by BARC (2005).

Organic matter. Soil organic matter comes from plant and animal remnants. It influences the physical, chemical and biological properties of soils. It improves soil physical conditions such as soil structure, water holding capacity, aeration and protects soil erosion. It is storehouse of plant nutrients, chiefly N, P & S. It serves as a food and energy for beneficial organisms like N_2 fixing bacteria. The organic matter value of beel sediments was found ranging from 0.72 to 2.62% in Hilna beel and from 0.69 to 2.22% in Beel Kumari beel with an average of 1.426±0.642% and 1.338±0.504%, respectively. This result was very close to Haque et al (2009) who recorded organic matter 1.67% from inundated rice field of Mymensingh in paddy cum fish culture. Nevertheless, Alam et al (2007) recorded a higher organic matter from Posna beel of Tangail. According to Jhingran (1992), when the organic matter reserve in soil is less than 0.86% it is considered too low, 0.86-2.58% considered average and 2.58–4.31% - highly productive. Consequently the beels of present study are considered as average productive.

Organic carbon. Jhingran (1992) reported that organic carbon reserve when less than 0.5% considered too low, 0.5–1.5% considered average and 1.5–2.5% highly productive. The organic carbon value of beel sediments was recorded ranging from 0.42 to 1.52% and 0.40 to 1.29% with average 0.83±0.372% and 0.78±0.292% from Hilna beel and Beel Kumari beel, respectively. Such lower organic carbon content of sediments was observed by Kumar et al (2004) which varied from 0.01 to 1.46% at near shores water in India. Higher organic carbon content was recorded by Saha (2007), Pathak (1997) and Sugunan et al (2000). Water bodies having more content of organic carbon are more productive (Banerjea 1967) which is not exactly true in the case of floodplain wetlands (Das 2003). However, organic carbon has highly significant correlation ($p < 0.01$) with nitrogen and potassium ($r = 0.801$ and 0.723) and a significant correlation with sulphure ($r = 0.647$) in Hilna beel. In Beel Kumari beel, it has positive and highly significant correlation ($p < 0.01$) with nitrogen ($r = 0.847$) and positive significant correlation with zinc (r = 0.628). Saha (2007) also found a positive and significant ($p < 0.05$) correlation between organic carbon and nitrogen in Borobila beel and Gawha beel.

Total Nitrogen. Nitrogen value of beel sediments was from 0.04 to 0.12% and 0.03 to 0.1% with an average of 0.082±0.027% and 0.068±0.02% in Hilna beel and Beel Kumari beel, respectively. Present observation agreed with the findings of Sugunan et al (2000) who reported open beels having total nitrogen from 0.04 to 0.16%. Saha (2007) recorded a higher organic matter from Boro beel, Borobila beel and Gawha beel. However, nitrogen has a positive and highly correlation with organic matter and organic carbon in both the Beels.

Phosphorus. Phosphorus in beel ecosystem is a limiting factor of production primarily because of its quicker utilization by emergent as well as rooted submerged hydrophytes. Sediments less than 30 ppm available phosphorus are poor, 30-60 ppm is average, and above 60 ppm is optimal (Jhingran 1992). During the study period phosphorus of beel sediments ranged from 7.2 to 18.1 ppm and from 12.44 to 22.2 ppm with an average of 11.92±4.014 ppm and 16.02±3.548 ppm in Hilna beel and Beel Kumari beel, respectively. Saha (2007) observed phosphorus of 13.00 ppm from Gawha beel supporting the result of the present study. Present findings also coincided with Saha et al (1999) who recorded phosphorus 0.8 to 27.0 ppm from assam beel. The maximum phosphorus recorded 18.10 from Hilna beel in January and 22.20 from Beel Kumari beel in February and minimum value 7.2 in February from Hilna beel and 12.44 in November from Beel Kumari beel. Saha (2007) observed the maximum phosphorus in February from Boro beel like Beel Kumari beel of the present study. He also found minimum phosphorus in February agreed with Hilna beel of the present study. Alam et al (2007) observed the minimum phosphorus from Posna beel in winter which is closer to the findings of the present study.

Potassium. Potassium of the beel sediments were found to vary from 0.19 to 0.61 me $100g^{-1}$ and from 0.2 to 0.59 me $100g^{-1}$ with an average of 0.404±0.14 61 me $100g^{-1}$ and 0.393±0.12161 me $100g^{-1}$ in Hilna beel and Beel Kumari beel, respectively. Alam et al (2007) found higher potassium (0.13 to 2.15 me $100g^{-1}$) from Posna beel. Boro beel, Borobila beel and Gawha beel had a higher amount of potassium than that of the present study (Saha 2007).

Sulphur. During the study period sulphur of beel sediments ranged from 16.4 to 44.0 ppm and from 11.4 to 40.0 ppm with an average of 24.05±7.846 ppm and 22.167±7.241 ppm in Hilna beel and Beel Kumari beel, respectively which is much lower than Alam et al (2007) who recorded a very high sulphur in Posna beel (ranging from 30.81 to 68.90 ppm with mean value of 51.20 ppm).

Zinc. During the study period zinc of beel sediments ranged from 1.11 to 2.63 ppm and from 0.51 to 3.51 ppm with an average of 1.955±0.449 ppm and 1.646±0.803 ppm in Hilna beel and Beel Kumari beel, respectively which is agreed with Alam et al (2007) who recorded a medium zinc in Posna beel (ranging from 1.23 to 1.53 ppm with mean value of 1.36 ppm).

Conclusions. This study has provided a clear scenario of sediment properties of the two important water resources (beels) of Bangladesh. From the present study we found that most of the chemical parameters in the beels sediment were within the preferable range as previously reported by Jhingran (1992). As there is no previous study on the sediment chemistry of beels in Bangladesh, this study will enrich the literature on this particular field of study. Nevertheless, more analytical research needed to conduct on the investigation of pollutants namely pesticide contamination in these important freshwater bodies of Bangladesh.

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References

Alam A., Mustafa M. G., Azad M. A. K., 2007 Water and sediment quality and plankton diversity of Posna beel, Tangail. Bangladesh Journal of Aquaculture 30:177-188.

Banerjea S. M., 1967 Water quality and soil conditions of fish ponds in some States of India in relation to fish production. Indian Journal of Fisheries 14:115-144.

BARC (Bangladesh Agricultural Research Council), 2005 Fertilizer recommendation guide-2005. Compiled by Miah M. M. U., Jahiruddin M., Islam M. F., Razia M. S., In: Miah M. M. U., Farid M. T. M., Miah M. A. M., Jahiruddin M., Rahman S. M. K., Quayyum M. A., Sattar M. A., Motalib M. M. A., Islam M. F., Razia M. S. (ed), Peoples Press & Publications, Purana Paltan, Dhaka, Bangladesh, 260 pp.

Bray R. H., Kurtz L. T., 1945 Determination total, organic, and available forms of phosphorus in soils. Soil Science 59:39-46.

Das M. K., 2003 Present status of floodplain wetlands vis-à-vis fish health and environment. In: Fisheries management of floodplain wetlands in India. Vinci G. K., Jha B. C., Bhaumik U., Mitra K. (eds), Central Inland Capture Fisheries Research Institute, Barrackpore, India, Bull. No. 125, pp. 115-128.

Das S. K., Sahoo J. K., Saksena D. N., 2001 Sediment characteristics and benthic biomass in relation to growth of *Penaeus monodon* Fabricius in low saline confined pond. Indian Journal of Fisheries 48(1):55-61.

Gupta B. P., Krishnani K. K., Joseph K. O., Muralidhar M., Ali S. A., Gopal C., 2001 Soil and water characteristics and growth of *Penaeus monodon* fed with formulated feed in experimental tanks. Indian Journal of Fisheries 48(4):345-351.

Habib M. A. B., Rahman M. S., 1987 Interaction in and between some properties of pond bottom and adjacent land soils of three Bangladesh soils. Pakistan Journal of Scientific and Industrial Research 30(5):350-355.

Habib M. A. B., Ahmed M., Mohsinuzzaman M., 1986 Soil water interactions in a pond and their correlations with meteorological factors. Bangladesh Journal of Water Resources Research 7(1):15-23.

Habib M. A. B., Haque I., Ali M. M., 1991 Multiple regression analysis of some bottom soil properties on the growth of benthos in nursery ponds. Indian Journal of Fisheries 38(4):237-241.

Haque M. E., Aktar S., Uddin M. J., Islam M. S., Kabir M. F., 2009 Study the effects of stocking density on growth survival and yield of *Amblypharyngodon mola* in rice fields. Bangladesh Journal of Progressive Science & Technology 7(1):133-136.

Jackson M. L., 1962 Soil chemical analysis. Constable and Co. Ltd., London, 497 pp.

Jhingran A. G., 1992 Recent advances in reservoir fisheries management in India. In: Reservoir fisheries of Asia: Proceedings of the Second Asian reservoir fisheries workshop held in Hangzhou, People's Republic of China. De Silva S. S. (ed), IDRC, Ottawa, pp. 158-175.

Kumar B. M., Katti R. J., Moorthy K. S. V., D'souza R. K., 2004 Macrobenthos in relation to sediment characteristics of nearshore waters of Chitrapur, West coast of India receiving industrial effluents. Asia Fish Sci 17:21-28.

Pathak V., 1997 Abiotic habitat variables in the reservoirs and beels and their role in the production process. Summer School on Fisheries Enhancement in Small Reservoirs and Floodplain Lakes. Central Inland Capture Fisheries Research Institute. Barrackpore, India, pp. 43-53.

Pathak V., Bhagat M. J., Mitra K., 1989 Fisheries potential and management of oxbow lakes of Ganga and Brahmaputra basins. In: Conservation and management of inland capture fisheries resources of India. Jhingran A. G., Sugunan V. V. (eds), IFSI, Barrackpore, India, pp. 143-147.

Piper C. S., 1950 Soil and plant analysis: a laboratory manual of methods for the examination of soils and the determination of the inorganic constituents of plants. Adelaide Univ. Press, Australia, 368 pp.

Rahman M. M., Das M., 2001 Comparison of benthic fauna of two beels under different management system. Bangladesh Journal of Fisheries Research 5(2):155-162.

Rahman M. S., 1992 Water quality management in aquaculture. BRAC Prokashana, Dhaka 1212, 84 pp.
Saha J. K., 2007 Assessment of aquatic biodiversity in three beels of Bangladesh and relationship with environmental parameters. PhD Thesis, Bangladesh Agricultural University, Mymensingh, Bangladesh, 324 pp.
Saha J. K., Hasan M. R., 2004 Assessment of fish fauna of beel Khukshia in Jeshore, Bangladesh. An Abstract. Seventh Asian Fisheries Forum 2004, Penang, Malaysia, 29 November - 4 December 2004, 84 pp.
Saha J. K., Hasan M. R., Habib M. A. B., Ali M. M., 2005 Biodiversity of fish and prawn in Borobila beel of Rangpur, Bangladesh. Abstracts. The IX International Congress of Ecology (INTECOL), Montreal, Quebec, Canada, 8-12 August 2005, 352 pp.
Saha P. K., 2003 Soil characteristics of importance in aquatic ecosystem in relation to fish health. In: Methods of assessment of aquatic ecosystem for fish health care. Sugunan V. V., Das M. K., Vinci G. K., Bhaumik U. (eds), Central Inland Capture Fisheries Research Institute, Barrackpore, India, Bull. No. 115, pp. 66-69.
Saha P. K., Pathak V., Sarkar A., 1999 Chemical properties of soil and water of beels of Assam. In: Eco-friendly management of resources for doubling fish production-strategies for 21st century. Sinha M., Kumar D., Katiha P. K. (eds), Proceedings of the National Seminar, IFSI, Barrackpore, India, pp. 58-62.
Simon K. D., Bakar Y., Mazlan A. G., Zaidi C. C., Samat A., Arshad A., Temple S. E., Brown-Peterson N. J., 2012 Aspects of the reproductive biology of two archefishes *Toxotes chatareus,* (Hamilton 1822) and *Toxotes jaculatrix* (Pallas 1767). Environmental Biology of Fishes 93:491-503.
Sugunan V. V., Vinci G. K., Bhattacharjya B. K., Hassan M. A., 2000 Ecology and fisheries of beels in West Bengal. Central Inland Capture Fisheries Research Institute, Barrackpore, India, Bull. No. 103, 53 pp.
Underwood N., Navaretta C., 1997 Towards a standard for the creation of lexica. Center for Sprogteknologi, Njalsgade, 80 DK 2300 Coopenhagen S, Denmark. EAGLES and ELM specification recommendation for Lexica.
Vinci G. K., Mitra K., 1997 A case study and development needs of two beels in West Bengal. In: Changing perspectives of inland fisheries. Vass K. K., Sinha M. (eds), IFSI, Barrackpore, India, pp. 154-157.
*** http://simple.wiktionary.org/wiki/Bangladesh.

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