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Original Research Article

Physico-chemical features of water in Betana wetland, Belbari, Morang, Nepal

Ganesh Bahadur Thapa[1] and Joydeb Pal[2]
[1]Department of Zoology, Central Campus of Technology, Dharan TU, Nepal.
[2]Department of Zoology, University of North Bengal, Darjeeling, West Bengal, India.
*Corresponding Author: Ganesh Bahadur Thapa, Department of Zoology, Central Campus of Technology, Dharan TU, Nepal, *E-mail: ganeshbdr13@gmail.com*

Abstract:

Different physico-chemical parameters in Betana wetland pond water was studied for two years. Air temperature showed positive and significant correlation with water temperature ($r = 0.947$, $P<0.01$) but it had inverse and significant correlation with free CO_2($r = -0.685$, $P<0.05$), pH ($r = -0.653$, $P<0.05$) and DO ($r = -0.582$, $P<0.05$). The water temperature showed positive and significant correlation with phosphate ($r = 0.635$, $P<0.05$) but it showed inverse and significant correlation with pH ($r = -0.692$, $P<0.05$), DO ($r = -0.576$, $P<0.05$) and free CO_2 ($r = -0.798$, $P<0.01$). Free CO_2 showed inverse and significant correlation with chloride ($r = -0.596$, $P<0.05$). BOD showed no significant positive correlation but it had inverse and significant correlation with pH ($r = -0.613$, $P< 0.05$). Total acidity (TA) showed positive and significant correlation with total hardness (TH) ($r = 0.580$, $P<0.05$) but inverse and significant correlation with water temperature ($r = -0.623$, $P<0.05$) and phosphate ($r = -0.608$, $P<0.05$). All physico -chemical parameters of Betana pond water were within permissible range for wild fish and fish culture. Outbreak of any fish diseases did not occur during Nov.2008-Oct. 2010. Being ecotourism area, maintenance of water quality should be done by periodic evaluation of physico-chemical parameters of the pond water.

Key words: Physico-chemical, variations, Seasons, correlation, Betana wetlands, Nepal

Introduction

Betana wetland consists of an ox-bow lake with an area of 5.5 ha and often flooded during rainy season. It is surrounded by sal forests (Charkoshe Jhaadi) in east, north and west sides and Mahendra highway in the south near Belbari, Morang, Nepal. Now it is being developed as ecotourism area. It has rich biodiversity and provides more research ground but deteriorations of quality of water and species diversity will be faced due to anthropogenic activities. So, periodic evaluation of water quality and maintenance is necessary in Betana wetland.

Several earlier workers who had studied in the field of limnology were: Swarup and Singh (1979); Das (1981); Bhowmick and Singh (1985); Wright et al, (1985); Lohman et al, (1988); Gautam (1990); Jhingran (1991); Bose and Gorai (1993); Jindal and Kumar (1993); Patralekh (1994); Gupta and Shrivastava (1994); McEachern (1994) ;Singh (1995); Pandey and Lal (1995); Rawat et al, (1995); Ormerod et al, (1996); Aryal and Lacoul (1996) and Sharma and Agarwal (1999) Likewise, Latifa and Acharya (2001) in Bangladesh , Barat and Jha (2002) in North Bengal, Palui et al, (2003) in North Bihar, Sakhare and Joshi (2004) in Maharastra, Samal and Majumdar (2005) in Rabindra and Subashsarobar India, Yousuf et al, (2006) in Kashmir, Singh et al, (2008), Acharjee and Barat(2011) in Relli river of Darjeeling and Mary Helen et al, (2011) in Tamil Nadu were some of the other workers in limnology.

Sharma (1996) studied limnology of Koshi River in North Bihar, Jana (1998) summarized the limnological data for about 60 lakes and reservoirs of India. Jain et al, (1999) reported positive correlation between pH and DO and water temperature with pH but negative correlation with free CO_2 and alkalinity of a sacred lake Khecheopalri of Sikkim. Mishra et al, (1999) worked on limnology of a freshwater tributary and reported maximum DO, TA and chloride in winter season and free CO_2 in monsoon season. Onada et al, (2015) found that the values of DO and temperatures showed significant variations between the times of the day in Nazarene Fish Farm, Ibadan, Nigeria. Parisara (2015) studied the physico-chemical parameters and its correlation of Konandur pond in Thirthalli, Karnataka, India and

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showed that mostly positive correlation so the water quality was not much polluted.

In Nepal, Niroula et al, (2010) revealed pH, conductivity, turbidity, total phosphorus and TA were higher in summer whereas TDS, NO_3^-, TH ($CaCO_3$), DO, BOD and Cl^- content were higher in winter and water temperature, ammonia and carbon dioxide were higher in rainy season. More seasonal fluctuations in turbidity, carbon dioxide and chloride content were observed in Betana pond, Belbari Morang. The physico-chemical parameters of Koshi River were studied at the Kushaha area, Nepal (ThapaChhetry and Pal, 2011). Ambient and surface water temperature showed a significant correlation with free carbon dioxide and BOD and an inverse and significant correlation with pH, DO, total alkalinity, total hardness and chloride. Thapa and Pal (2012) studied the water quality of Baidya fish pond and was normal except high fluctuation of chloride (1±0.241 to 29.84±0.260 mg/L and ammonia 1.55±0.088 to 18.7±0.061 mg/L) during manuaring period. Mondal et al, (2012) reported the physico-chemical status of surface water of Mirik Lake in Darjeeling from seven locations. Thapa and Pal (2014) studied physico-chemical parameters of Singhia and Budhi rivers in Sunsari and Morang industrial corridor, Nepal.

Detailed study of physico-chemical features of water of Betana wetland has not been carried out so far; present study is relevant to reveal the properties of water up to some extent for the maintenance of its ecological condition.

2. Methodology

Site: The site chosen for this study was Betana Wetland, Belbari, Morang (Fig. a and b) which is located at latitude 26°39 '37.79" N and Longitude 87° 25' 55.50" E.

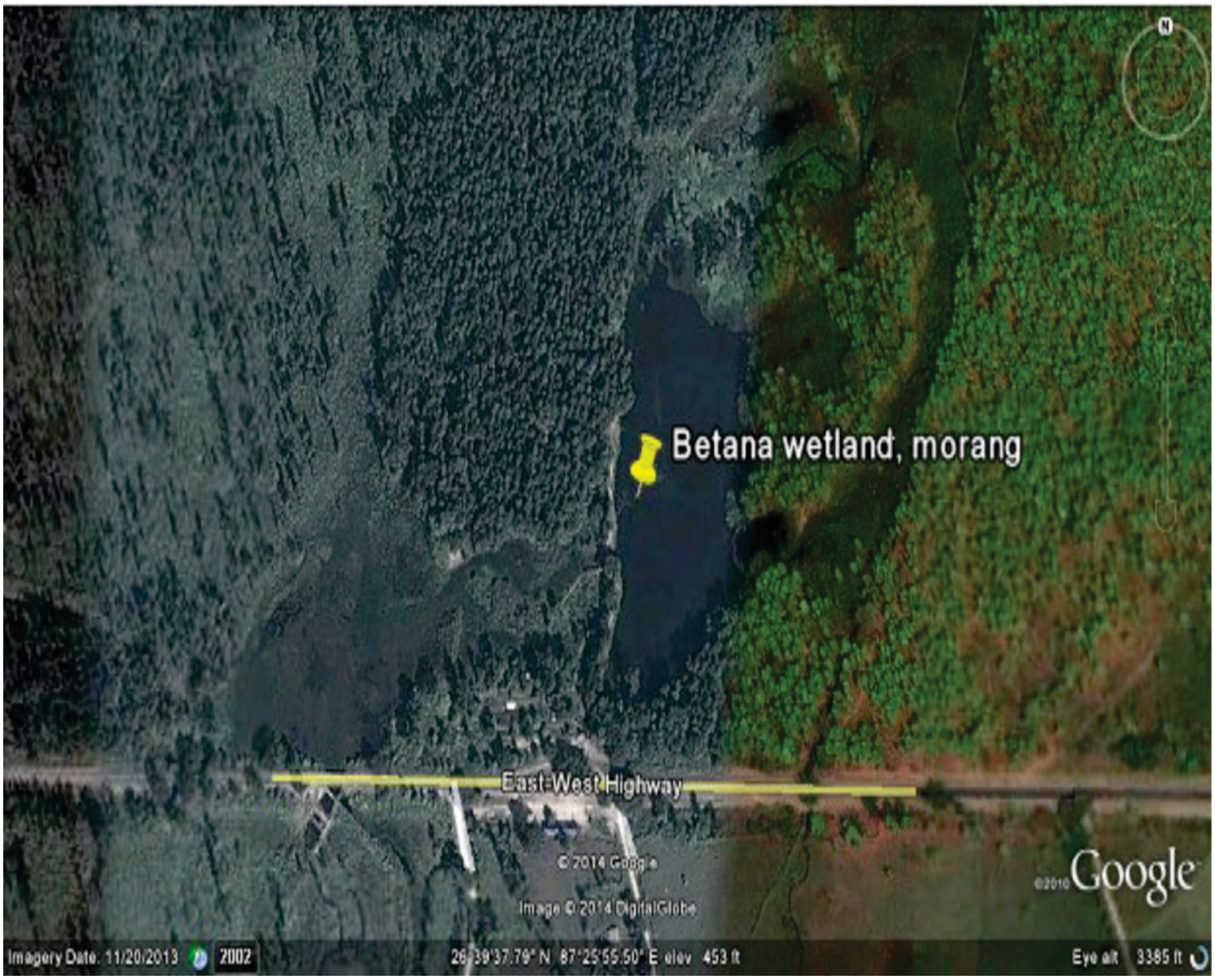

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Fig 1. Betana wetland, Belbari, Morang

Physico-chemical parameters of water samples

Sample was collected between 8.00-11.00 A.M. on 15thday of each month during two years (Nov.2008-Oct.2010) in an ice box. Temperature was recorded on the site by glass thermometer. The pH of water was determined on the site by Hanna's pocket pH meter. All other physico-chemical analysis of water like Dissolved Oxygen (DO), Biological oxygen demand (BOD), free carbon dioxide (free CO_2), chloride ions (Cl^-), total alkalinity (TA), total hardness (TH) and phosphate were determined following standard methods (Trivedy and Goel, 1986; APHA, 2005). Obtain values were compared with standard values from the Betana pond.

Statistical Analysis

Standard deviation, Mean, correlation coefficient were calculated by using Microsoft excel statistical function of computer software. The significance of correlation coefficient was tested by applying t-test by using SPSS-V20 computer software.

Results and Discussion

Results of the air temperature and physico-chemical parameters of pond water of Betana wetland are shown in **Tables 1** and **2**. **Table 1** shows the results of air temperature and physico-chemical parameters of water of the first year (Nov.2008 – Oct.2009) study period. **Table 2** shows the results of air temperature and physico-chemical parameters of water of the second year (Nov. 2009- Oct. 2010). **Table 3** shows the correlation coefficient (r) of air temperature and different physico-chemical parameters of water at the site.

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Air temperature

The minimum air temperature was 18.03 ± 0.347 ^{0}C in December and maximum was 31.01± 0.274^{0}C in August during the Nov.2008– Oct.2009 (Table 1). The maximum air temperature was 29.1± 0.285 ^{0}C in the month of March and minimum 17.10 ±0.237 ^{0}C in the month of January during the Nov. 2009- Oct.2010 (Table 2). Air temperature showed positive and significant correlation with water temperature (r =0.947, P<0.01) but it had inverse and significant correlation with free CO_2 (r= -0.685, P<0.05), pH (r = -0 .653, P<0.05) and DO (r = -0.582, P<0.05) (Table 3).

During first year (Nov.2008 – Oct.2009), the air temperature showed declining trend in the month of November. In the month of December 2008, it was lowest (18.03 ± 0.347 ^{0}C) and it increased slightly (18.10 ±0.523) in the month of January, 2009. Thereafter it increased February onwards up to March (Table 1).The air temperature during the second (Nov. 2009- Oct.2010) year showed decreasing trends from November to January and during the months of August to October in both years (Tables 1, 2). The results of the study on water parameters clearly showed that different physico-chemical factors of the Betana wetland varied during the two years study period. The highest air temperature was recorded in the month of March and August in S4. It was mainly due to geographical positions and weather conditions. The minimum air temperature was recorded in the month of December and January in the site. Air temperature showed positive and significant correlation with water temperature at the site (Table 3). Rawat et al, (1995) also obtained strong positive significant correlation between air and water temperatures.

Water temperature

The maximum water temperature was 29.12 ± 0.235 ^{0}C in August and minimum 17.14 ± 0.316°C in the month of January during the first year (Nov.2008–Oct.2009) (Table 1). During the second year (Nov. 2009 – Oct.2010) study period, the maximum water temperature was 28.12 ± 0.523°C in August and minimum 18.04 ± 0.365 ^{0}C in the January (Table 2). The water temperature showed positive and significant correlation with air temperature (r =0.947, P<0.01) P<0.01) and phosphate (r=0.635, P<0.05) but it showed inverse and significant correlation with pH (r = - 0.692, P<0.05), DO (r=-0.576, P<0.05) and free CO_2(r=-0.798, P<0.01) (Table 3).

The water temperature showed decreasing trend during the winter months from November to January and also in August to October in both years (Tables 1, 2). Water temperature is influenced by air temperature and intensity of solar radiation. It showed positive and significant correlation with free CO_2 and BOD at this site but had inverse and significant correlation with pH, DO, TA and TH. Bose and Gorai (1993) reported negative significant correlation between water temperature and DO.

pH

The maximum pH was 8.15±0.365 in the month of January and minimum 6.64 ± 0.271 in September during the first year (Nov.2008 – Oct.2009) study period (**Table 1**). The maximum pH was 7.60 ± 0.327 in December and minimum was 6.61±0.229 in February during second year (Nov.2009 – Oct.2010) (**Table 2**). pH showed inverse and significant correlation with air temperature (r=-0.653, P<0.05), water temperature (r=-0.692, P< 0.05) and BOD (r=-0.613, P<0.05) (**Table** 3).

pH of the study site varied in different seasons. The maximum pH in winter season may be attributed to algal blooms as shown by Hutchinson et al, (1992) and Roy (1955). Several workers have reported low pH during the low photosynthesis due to the formation of carbonic acid (Bais et al, 1995). But Gautam (1990) reported highest pH in summer and lowest in rainy season. The pH showed positive and significant correlation with DO at the site. It was inverse and significantly correlated with air temperature and water temperature at the site (Table 3). Rawat et al, (1995) reported positive correlation with TA and inverse correlation with water temperature.

Free carbon dioxide

The maximum free CO_2 was recorded to be 73.92 ± 1.552 mg/L in September and minimum 3.37 ± 0.638 mg/L in May during the first year (Nov.2008 – Oct.2009) study period (Table 1). The maximum free CO_2 was 23.75 ± 0.874 mg/L in January and minimum 2.24 ± 0.557mg/L in April during the second year (Nov.2009 – Oct.2010) (Table 2). Free CO_2 showed inverse and significant correlation with chloride (r = -0.596, P<0.05), water temperature (r = -0.798, P<0.01), air temperature (r = -0.685, P<0.05) (Table 3).

The maximum free CO_2 was recorded in summer, it may be due to high temperature, high rate of decomposition of organic matter, low volume of water etc. Michael (1969) stated that the concentration of CO_2 is directly correlated with the amount and nature of biological activity in water. Pahwa and Mehrotra (1966), Ray et al, (1966), Gautam (1990), and Pandey and Lal (1995) also found minimum free CO_2 in winter. Free CO_2 of water showed positive and significant correlation with water temperature and BOD and inverse and significant correlation with DO (**Table** 3). Pahwa and Mehrotra (1966) observed inverse correlation of free CO_2 with DO.

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Dissolved Oxygen

The maximum DO was 7.31 ± 0.185 mg/L in January and minimum 3.19 ± 0.379 mg/L in August during the first year (Nov.2008 – Oct.2009) study period (Table 1). The maximum DO was 9.74 ± 0.235 mg/L in April and minimum 3.19 ± 0.254 mg/L in June (Table 2). The DO showed inverse and significant correlation with water temperature ($r = -0.596$, $P<0.05$) and air temperature ($r = -0.582$, $P<0.05$) (Table 3).

The maximum DO was recorded in winter season followed by rainy and summer seasons at the site. The maximum DO found in winter season may be due to low temperature as shown by Moitra and Bhattacharya (1965). The minimum DO was found in summer due to high temperature and higher microbial demand for oxygen in decomposition of suspended organic matter (Bhowmick and Singh, 1985; Palharya and Malvia, 1988). Elmore and West (1961) stated that an increase in temperature of water resulted in the decrease of DO content of water. DO content showed positive and significant correlation with TA and TH. It was positively correlated with chloride at the site. It showed inverse and significant correlation with water temperature, free CO_2 and BOD. Bose and Gorai; Jindal and Kumar (1993) also reported inverse and significant correlation of DO with water temperature.

Biological Oxygen Demand

The maximum BOD was 4.62 ± 0.254 mg/L in the month of September and minimum was 0.84± 0.014 mg/L in the month of February during the first year (Nov.2008 – Oct.2009) study period (Table 1). During the second year (Nov.2009 – Oct.2010), the maximum BOD 6.22 ±0.048 mg/L was seen in the month of April and minimum 0.26 ± 0.076 mg/L in the month of December (Table 2). BOD showed no significant positive correlation but it had inverse and significant correlation with pH ($r = - 0.613$, $P< 0.05$) (Table 3). The BOD of water of the study site varied between 0.26± 0.076 mg/L and 6.22 ± 0.048 mg/L during the study period. The maximum BOD obtained in summer may be due to low volume of water and high content of organic matter whereas minimum obtained in winter may be due to low temperature and retarded microbial activity for the decomposition of organic matters. Similar observations were also made by Singh (1995). Ray and David (1966) opined that high BOD value indicates organic waste pollution. BOD showed positive and significant correlation with air temperature, water temperature and free CO_2 and inverse and significant correlation with pH and DO (Table 3). Ray and David (1966), and Barat and Jha (2002) also reported inverse correlation of BOD with DO.

Chloride

The maximum chloride was 5.02 ± 0.531 mg/L in June and minimum was 2.02 ± 0.095 mg/L in September during the first year (Nov.2008 – Oct.2009) study period (Table 1). During the second year(Nov.2009 – Oct.2010), the maximum chloride was 7.05 ± 0.324 mg/L in January and minimum 1.01 ± 0.093 mg/L in March (Table 2). Chloride showed inverse and significant correlation with free CO_2 ($r = -0.596$, $P< 0.05$) (Table 3).

The minimum chloride was recorded in March of the second year(Nov.2009 – Oct.2010) at the site (Table 2). The maximum quantity of chloride recorded at Betana pond in summer season may be due to low volume of water, high temperature and high rate of decomposition of organic matters. Chloride concentration indicates the presence of organic waste of animal origin (Thresh et al, 1949). Ganapati (1941, 1943), and Swarup and Singh (1979) also reported an increase in chloride during summer. Minimum quantity of chloride recorded in rainy season might be due to dilution by rain water. Klein (1957) pointed out a direct relationship between amount of chloride and level of pollution. Chloride showed positive and significant correlation with total alkalinity.

Total alkalinity

The maximum TA was recorded 195.33 ± 1.776 mg/L in February and minimum 69.56 ±1.152 mg/L in December during the first year (Nov.2008 – Oct.2009) study period (Table 1). During the second year (Nov. 2009–Oct. 2010), the maximum TA recorded was 197.43 ± 2.756 mg/L in February and minimum was 103.23±0.867 mg/L in September (Table 2). The TA showed positive and significant correlation with TH ($r = 0.580$, $P<0.05$) (Table 3). TA remained low during August, September and October in the first year study period. TA in the month of June (116.62±0.956 mg/L) significantly ($p<0.01$) decreased in comparison to that of May (132.01±1.742 mg/L) in the first year (Table 1). There were fluctuations in the values of TA during March, April, May and June, 2009. Similar patterns in TA were noticed during second year study period (Table 2).

The TA was found maximum in the month of January/February at the site. It was found maximum in winter season due to high pH Singh (1990) and Mishra et al, (1998) also reported maximum TA during winter. Water bodies having TA from 40 to 90 mg/L is considered as medium productive and above 90 mg/L as highly productive (Jhingran, 1991). This investigation showed that the study area is suitable for aquatic production. TA showed positive and significant correlation with TH and chloride. Barat and Jha (2002) also reported positive and

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significant correlation of TH with hardness. There was significant ($p<0.01$) differences in values of TA of water bodies between months but insignificantly ($p>0.05$) different among corresponding months between first and second years (Table 3).

Total hardness

The maximum hardness was 130.43±1.623 mg/L in February and minimum 97.02±0.754 mg/L in August during the first year (Nov.2008 – Oct.2009) study period (Table 1). During the second year (Nov.2009 – Oct.2010), the maximum TH was 118.84± 1.623 mg/L in February and minimum was 89.13± 0.659 mg/L in September (Table 2). TH showed positive and significant correlation with TA ($r = 0.580$, $P<0.05$) but inverse and significant correlation with water temperature ($r =-0.623$, $P<0.05$) and phosphate ($r =-0.608$, $P<0.05$) (Table 3). The values of TH in March (108.91±0.745 mg/L) showed significant decrease ($p< 0.01$) as compared to February (130.43 ±1.623 mg/L) in the first year. It remained low for six months from March to August (Table 1). In 2010, it showed a decreasing trend from March to September for

Table 1. Temperature, water temperature and physico-chemical parameters of water at Betana wetland pond, Belbari, Morang from November 2008- October 2009 **(Mean ± S.D., N=5).**

Parameters	Months											
Site – I Yr.	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Air Temp. °C	21.18 ±0.259	18.03 ±0.347	18.10 ±.523	24.85 ±0.369	29.99 ±0.628	27.78 ±0.775	27.12 ±0.322	26.05 ±0.731	29.86 ±0.657	31.01 ±0.274	29.15 ±0.362	26.03 ±0.557
Water Temp. °C	19.0 ±0.125	19.01 ±0.217	17.14 ±0.316	22.12 ±0.335	27.06 ±0.523	27.85 ±0.475	26.07 ±0.351	27.13 ±0.328	28.95 ±0.272	29.12 ±0.235	27.3 ±0.534	25.07 ±0.476
pH	7.82 ±0.534	7.66 ±0.327	8.15 ±0.365	7.13 ±0.229	7.61 ±0.576	6.83 ±0.317	7.51 ±0.733	7.34 ±0.256	7.5 ±0.075	6.93 ±0.174	6.64 ±0.271	7.31 ±0.073
Free CO2 (mg/L)	41.36 ±1.476	37.42 ±1.235	12.15 ±0.675	24.96 ±0.887	6.23 ±0.353	4.58 ±0.567	3.37 ±0.638	5.09 ±0.056	8.03 ±0.926	12.54 ±1.323	73.92 ±1.552	55.448 ±0.826
DO (mg/L)	7.08 ±0.356	5.84 ±0.067	7.31 ±0.185	5.89 ±0.124	5.14 ±0.068	6.88 ±0.235	7.17 ±0.342	4.92 ±0.254	4.82 ±0.473	3.19 ±0.379	5.41 ±0.362	7.16 ±0.231
BOD (mg/L)	2.61 ±0.045	2.25 ±0.026	1.35 ±0.029	0.84 ±0.014	1.22 ±0.056	4.32 ±0.067	3.55 ±0.115	2.81 ±0.149	1.83 ±0.057	1.02 ±0.065	4.62 ±0.254	2.11 ±0.056
Chloride (mg/L)	4.10 ±0.063	2.03 ±0.059	4.5 ±0.226	3.61 ±0.342	3.01 ±0.192	4.0 ±0.237	4.01 ±0.135	5.02 ±0.531	5.01 ±0.109	4.03 ±0.275	2.02 ±0.095	3.84 ±0.082
Total Alkalin. (mg/L)	115.64 ±1.253	69.56 ±1.152	122.05 ±2.634	195.33 ±1.776	132.03 ±1.187	117.21 ±1.953	132.01 ±1.742	116.62 ±0.956**	130.02 ±0.987	118.83 ±1.745	109.27 ±0.857	119.73 ±0.995
Total Hard (mg/L)	116.28 ±2.227	112.2 ±1.523	110.03 ±1.378	130.43 ±1.623	108.91 ±0.745**	106.92 ±1.544	110.82 ±1.563	108.90 ±0.976	104.94 ±1.065	97.02 ±0.754	112.32 ±0.957	110.16 ±0.817*
Phosphate (mg/L)	0.03 ±0.005	0.06 ±0.002	0.080 ±0.003	0.09 ±0.001	0.38 ±0.007	0.75 ±0.015	0.58 ±0.002	0.84 ±0.013	0.16 ±0.009	1.23 ±0.028	0.25 ±0.003	0.01 ±0.001

* Significant differences at 1% level, ** Significant differences at 5% level.

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seven months with slight fluctuation. The value in May (106.92 ±1.563mg/L) was significantly decreased (P<0.05) as compared to April (110.78 ±1.544 mg/L) in the second year (Table 2). It remained low for six months from May to October in the second year.

The maximum TH in winter season might be due to low volume and slow current of water. Similar results were obtained by Mishra et al, (1999). Minimum quantity in rainy season may be due to more dilution of water (Patralekh, 1994). It showed positive and significant correlation with TA at the site. Total hardness values of water were significantly (p<0.01) different between months but insignificantly (p>0.05) different among corresponding months of first and second years (Table 3).

Phosphate

Minimum phosphate was 0.01± 0.001 mg/L in October and maximum was 1.23±0.028 mg/L in August during first year (Nov 2008 – Oct.2009) (Table 1). During second year (Nov.2009 – Oct.2010), minimum phosphate level was 0.01±0.001 mg/L in December and maximum was 1.15±0.015 in August (Table 2). It showed positive and significant correlation with water temperature (r =0.635, P<0.05), air temperature but inverse and significant correlation with TH (r = -0.608, P<0.05) (Table 3). Phosphate increases the productivity of ponds.

Table 2. Temperature, water temperature and physico-chemical parameters of water at Site 4 (Betana wetland pond, Belbari, Morang) from November 2009- October 2010 **(Mean ± S.D., N=5).**

Parameters	**Months**											
Site - II Yr.	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Air Temp. ºC	22.03 ±0.359	20.01 ±0.475	17.10 ±.237	24.05 ±0.691	29.1 ±0.285	27.02 ±0.475	26.12 ±0.229	25.05 ±0.318	29.01 ±0.537	29.02 ±0.742	26.15 ±0.624	28.03 ±0.355
Water Temp. ºC	21.81 ±0.225	19.01 ±0.317	18.04 ±0.365	21.13 ±0.357	26.06 ±0.523	28.05 ±0.745	25.02 ±0.351	27.51 ±0.432	27.03 ±0.372	28.12 ±0.523	27.13 ±0.343	25.01 ±0.273
pH	7.12 ±0.534	7.60 ±0.327	7.15 ±0.365	6.61 ±0.229	7.11 ±0.576	6.82 ±0.317	6.95 ±0.733	7.23 ±0.256	7.5 ±0.075	7.01 ±0.174	7.14 ±0.271	7.11 ±0.073
Free CO_2 (mg/L)	17.92 ±0.976	15.05 ±0.735	23.75 ±0.874	23.54 ±0.887	5.12 ±0.325	2.24 ±0.557	3.37 ±0.623	4.59 ±0.076	8.1 ±0.928	13.2 ±0.526	9.15 ±0.755	9.46 ±0.523
DO (mg/L)	5.52 ±0.257	7.43 ±0.067	7.99 ±0.085	5.84 ±0.224	4.82 ±0.068	9.74 ±0.235	4.92 ±0.342	3.19 ±0.254	5.47 ±0.473	5.16 ±0.359	6.88 ±0.462	5.91 ±0.235
BOD (mg/L)	0.85 ±0.055	0.26 ±0.076	3.72 ±0.053	0.84 ±0.026	1.35 ±0.059	6.22 ±0.048	3.61 ±0.107	1.82 ±0.049	1.03 ±0.066	0.44 ±0.073	0.71 ±0.145	0.28 ±0.045
Chloride (mg/L)	2.01 ±0.037	5.02 ±0.065	7.05 ±0.324	4.1 ±0.352	1.01 ±0.093	2.0 ±0.257	5.21 ±0.135	6.02 ±0.537	5.01 ±0.809	5.03 ±0.372	2.02 ±0.065	5.13 ±0.084
Total Alkalin (mg/L)	117.22 ±1.156	114.06 ±1.654	110.05 ±1.563	197.43 ±2.756	130.03 ±1.187	118.81 ±1.753	132.01 ±1.342	115.02 ±0.953*	126.50 ±0.977	116.63 ±1.785	103.23 ±0.867	107.81 ±0.985
Total Hardness (mg/L)	95.04 ±1.325	108.95 ±1.563	114.23 ±1.375	118.84 ±1.623	110.88 ±0.645	110.78 ±1.544	106.92 ±1.563 *	104.94 ±0.976	105.10 ±1.067	95.04 ±0.854	89.13 ±0.659	104.94 ±0.816
Phosphate (mg/L)	0.10 ±0.004	0.01 ±0.001	0.080 ±0.003	0.06 ±0.002	0.46 ±0.007	0.46 ±0.005	0.38 ±0.002	0.93 ±0.021	0.18 ±0.004	1.15 ±0.015	0.21 ±0.002	0.09 ±0.001

* Significant differences at 1% level, ** Significant differences at 5% level.

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The cycling of phosphorus within lakes and river is dynamic and complex, involving adsorption and precipitation reactions, interchange with sediments and uptake by aquatic biota (Borberg and Persson, 1988). The maximum phosphate was recorded during pre-monsoon and monsoon months whereas minimum values were noticed during post monsoon months.

Table 3. Pearson's correlation coefficient (r) for air temperature and physico-chemical parameters of water at Site 4 (average of the corresponding month values) during Nov. 2008 – Oct. 2010; N=12; d. f. =11.

S4-I +II		**Water Temp**	**pH**	**Free CO_2 (mg/L)**	**DO (mg/L)**	**BOD (mg/L)**	**Chloride (mg/L)**	**Total alk(mg/L)**	**Total hard(mg/L)**	**Phosphate (mg/L)**
Air Temp. °C	P Cor.	.947*	-.653**	-.685**	-.582**	.106	.114	.290	-.398	.549*
	Sig.(2-t)	.000	.021	.014	.047	.742	.725	.360	.200	.065
Water Temp.°C	P Cor.	1	-.692**	-.798*	-.596**	.260	.145	.082	-.623**	.635**
	Sig.(2-t)		.013	.002	.050	.415	.653	.800	.051	.026
pH	P Cor.		1	-.185	.312	-.513	.243	-.143	.092	-.520
	Sig.(2-t)			.564	.323	.088	.447	.657	.777	.083
Free CO_2 (mg/L)	P Cor.			1	.174	.285	-.596**	-.241	.301	-.512
	Sig.(2-t)				.589	.369	.041	.451	.342	.089
DO (mg/L)	P Cor.				1	.316	.038	.008	.431	-.569
	Sig.(2-t)					.317	.908	.981	.162	.054
BOD (mg/L)	P Cor.					1	-.225	-.379	-.081	.118
	Sig. (2-t)						.481	.224	.802	.715
Chloride (mg/L)	P Cor.						1	.319	-.238	.253
	Sig.(2-t)							.312	.456	.428
Total alkalinity (mg/L)	P Cor.							1	.580**	-.052
	Sig.(2-t)								.048	.872
Total hardness (mg/L)	P Cor.								1	-.608**
	Sig.(2-t)									.036

* Significant at 1% level (P<0. 01), ** Significant at 5% level (P<0. 05) and Values not marked denote non-significant correlation.

Conclusions

All physico-chemical parameters of water in Betana wetland are within permissible limits for the wild as well as culture fish species and other biota. No outbreak of fish diseases occurred during study period. Due to the ecotourism area,human activities may deteriorate the quality of water and species diversity so periodic evaluations of physico-chemical parameters should be done for the maintenance and protection of the environment inBetana wetland.

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