Bangladesh J. Bot. **39**(2): 153-159, 2010 (December)

LIMNOLOGY OF LAKE BOGAKAIN, BANDARBAN, BANGLADESH

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Key words: Bogakain, Limnology, Macrophyte, Phytoplankton, Bangladesh

Abstract

Bogakain, a natural high altitude (372 m) lake of Bangladesh has been limnologically investigated for the first time. At mid-point, the depth of the lake was measured 46.54 m and the Secchi visibility was 2.37 m. Water temperature from 1-10 m depth gradient showed slight stratification in the lake which varied from 27.0 - 22.4° C at 1.00 pm. pH at the different depths ranged from 7.8 - 9.1, conductivity from 75 - 80 µS/cm and TDS from 39 - 42 mg/l. Alkalinity ranged from 0.8 - 1.24 meq/l and DO from 0.61 - 11.39 mg/l. A total of 40 species of phytoplank-ton were recorded from the lake of which 21 belonged to Chlorophyceae followed by Cynaophyceae (5), Bacillariophyceae (4), Cryptophyceae (4), Euglenophyceae (3), Dinophyceae (2) and Chrysophyceae (1). Bloom by *Synnechocystis salina* Wisl was observed at 10 m depth. Water temperature correlated negatively and significantly with depth. Phytoplankton biomass as chl *a* correlated positively with phytoplankton density and water depth. The former variable showed negative correlation with pH and water temperature. Lake Bogakain is the deepest natural lake of Bangladesh and many of the previous concepts regarding the lake i.e., fishless, highly turbid water and it has got a thermal spring at the bottom was found invalid.

Introduction

In Bangladesh nearly 7-8 million ha of wetlands do exist (Akonda 1989). These include rivers, *haors*, *baors*, ponds, *beels*, true lakes, man-made lakes, floodplains and reservoirs. Only three true lakes have been recognized in Bangladesh. These are Rainkyhongkine and Bogakain of Bandarban district and Ashulia Beel (though so called, is more properly a lake) of Dinajpur district (Khan *et al*. 1994, Rashid 1991). But, none of these lakes has been properly investigated from the limnological point of view except an algological report on Lake Rainkhyongkine by Islam and Uddin (1969). So, the present attempt was made to conduct a limnological investigation on Lake Bogakain.

Materials and Methods

The Bogakain (popularly known as Boga Lake) is a natural lake located at a height of 372 m above the mean sea level (Rashid 1991), on one of the plateau of the Politai Mountain Range at Naitong Mauza of Ruma upazila, district Bandarban and about 29 km east of the banks of the river Shankha. It is bounded on three sides by mountain peaks and thus given it a parallelogram or rectangular in shape and quite deep. There is no outlet from the lake and the basin is composed of the soft rocks of the Bhuban Formation. The main source of water is from the spring and also water from rainfall, surface drainage and seepage. The lake is situated at 21°58′49″ N and 92°28′11″ E and is approximately 500 km south-east of Dhaka city. It is believed that the lake is either the crater of an inactive mud volcano or it was originated due to falling of meteorites (Rahman and Chowdhury 2006). Some also argue in favor of a big landslide. It is venerated by the local Khumi tribes (Rahman and Chowdhury 2006, Rashid 1991, Khan *et al*. 1994). The lake is quite inaccessible because of bad communication.

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The present limnological expedition to Lake Bogakain was carried out on 10 March, 2010. The sampling was carried out in the mid point of the lake (Fig.1A) using a wooden boat from 1.00 - 3.00 p.m. The depth was measured by a graduated nylon rope. The Secchi visibility was measured by a Secchi disc of 20 cm in diameter. A 5 liter capacity Schindler's Sampler was used to record vertical water temperature profile, bottom water temperature (at 46.54 m) and collection of water and phytoplankton samples at 1 m interval starting from surface to 10 m depth. Samples were stored in 500 ml capacity plastic screw capped bottles containing Lugol's iodine. Simultaneously, the rest of the water sample was used to measure conductivity, TDS and pH *in situ* by using respective field meters (HANNA Instruments HI 9033, 9044 and). Ten BOD bottles (Pyrex, UK) were filled with sample water from each depth of the lake and fixed *in situ* for DO analysis. The sampling was completed at 15:00 h and all the collected samples were transported in a Cool Box to Limnology and Hydrobiology Laboratory, Department of Botany, University of Dhaka and analyzed immediately (after 16 - 18 hours of collection).

Figs 1A-C: A. Open water of Lake Bogakain. B. *Polygonum* sp. (foreground), submerged *Egeria densa* Planchón and parts of floating hydrophytes. C. *Nymphaea pubescens* Willd.

Chlorophyll *a* (chl *a*), soluble reactive phosphorus (SRP), soluble reactive silicate (SRS), dissolved oxygen (DO) and alkalinity were determined on the same day (Marker *et al*. 1980, Murphy and Riley 1962, Wetzel and Likens 1979). However, an overnight digestion of samples

for nitrate nitrogen analysis (Müller and Wiedemann 1955) was carried out. Phytoplankton cell number were counted using a Hawksley microplankton counting chamber with improved Neubauer Rulling (Hawksley Ltd., Lancing, England) under a Nikon compound microscope (Japan) at a magnification of 400×.

Results and Discussion

The lake water looked sky blue in a sunny weather. At mid-point, the depth of the lake was measured 46.54 m and the Secchi visibility was 2.37 m. All other physicochemical data have been presented in Table 1. Air temperature was 33.0° C, surface and bottom water temperatures were 27.0 and 22.2° C, respectively. Water temperature at 1 - 10 m depths gradient showed slight stratification in the lake which varied from 22.3 - 27.0° C (Table 1). pH at different depths ranged from 7.8 - 9.1, conductivity from 75 - 80 µS/cm and TDS from 39 - 42 mg/l. Whereas, the alkalinity ranged from 0.8 - 1.24 meq/l and DO from 0.61 - 11.39 mg/l (Table 1). The SRP and NO_3-N concentrations in the first meter of water depths were very high such as 154.32 µg/l and 24.73 mg/l, respectively (Table 1). While, at 2 - 10 m depths were 41.85 - 87.95 µg/l and 0 - 1.4 mg/l, respectively. But at 3 - 4 and 6 - 9 m of water depths no detectable NO_3-N was recorded.

Table 1. Physical, chemical and biological features of water in Lake Bogakain.

Z (m)	Temp. (° C)	pH	Cond. (µS/cm)	TDS (mg/l)	Alkal. (meq/l)	DO (mg/l)	SRP (µg/l)	SRS (mg/l)	NO_3-N (mg/l)	Phaeo. (µg/l)	Chl *a* (µg/l)	Cell density $\times 10^3$/l
1	27.0	9.1	75	39	0.88	8.54	154.32	0.36	24.73	2.59	2.96	686.62
2	26.6	9.0	78	41	1.04	11.18	59.21	0.23	1.4	3.68	3.95	890.70
3	26.3	9.1	80	41	0.96	11.18	50.10	0.56	0	0.32	5.92	2445.86
4	25.2	9.1	77	40	1.18	11.39	53.92	0.69	0	2.51	7.89	2211.46
5	24.2	8.2	76	40	0.9	6.50	61.85	0.16	0.6	1.15	14.80	1433.12
6	23.8	8.1	75	41	0.88	3.87	87.97	0.62	0	4.99	8.88	25837.80
7	22.5	8.2	78	42	0.96	1.43	68.60	0.59	0	7.76	8.88	2601.78
8	22.3	7.9	79	41	1.24	0.61	64.49	0.59	0	8.16	9.87	1919.23
9	22.5	7.9	74	41	0.88	1.63	41.85	0.39	0	3.99	9.87	3256.05
10	22.4	7.8	78	39	0.94	1.22	51.58	0.43	0.1	2.35	43.41	409381.73

Silicate concentration ranged from 0.41 - 0.69 mg/l at 1 - 10 m depths. Chl *a* concentration was higher at 5 and 10 m depths of the lake. Values recorded in this two depths were 14.80 and 43.41 µg/l, respectively. At other depths, chl *a* varied from 2.96 - 9.87 µg/l being the lowest record at 1 m depth. In lake Anibal of Brazil seasonal maxima of Chl *a* occurred from 6-14 m (Reynolds 1997). Phaeopigment showed a range of 0.32 - 8.16 µg/l, while the highest at 8 m and lowest at 3 m depth of water (Table 1). Phytoplankton total density varied from 686.62 - 409381.73 × 10^3 ind/l, the highest being for *Synnechocystis salina* only at 10 m depth. The second longest taxon was *Trachelomonas volvocina*.

A total of 40 species of phytoplankton from pelagic zone of the lake were recorded. The highest density occurred at 10 m depth, contributed by unicellular cyanobacteria, *Synechocystis salina* Wisl (Table 2), which formed bloom with a cell count 406247.98 × 10^3 cells/l. It is to be noted that *S. salina* did not occur at other depths of the lake. Formation of metalimnetic plates by cyanobacteria has also been observed in some lakes of Brazil (Reynolds 1997). Light, hydrological stability and chemical gradients were found responsible for that. The lowest density of phytoplankton occurred at 1 m depth (Table 2). *Dinobryon divergens* Imhof, *Cyclotella comensis* Grun. and *Peridinium lomnicki* Wolosz. were present at all depths. Among subdominant

Table 2. Phytoplankton species and their density (× 10^3 ind/l) at different depths of Lake Bogakain.

Taxa	Depth (m)										Total No.
	1	2	3	4	5	6	7	8	9	10	
Achnanthes minutissima Kütz.		23.43		21.40		3057.32	75.41		15.28	12.73	3205.6
Actinastrum aciculare Playf.			12.73								12.73
Ankistrodesmus bernardii Kom.			12.73	7.13							19.87
Astasia cylindrica Pring.				7.13							7.13
Characium ornithocephalum var. *pringshemii* A. Br.		11.71	12.73	7.13					22.92		54.52
Chlamydomonas cylindrus (Pa.) Gerl.			25.47								25.47
C. globossa Snow	17.83	11.71									29.55
Chlorococcum humicola (Näg) Rab.					302.54	73987.14	923.82	150.06	466.24	254.77	76084.59
Chroomonas coerulea (Geitl.) Skuja	8.91	11.71									20.63
Cosmarium seeleyanum Wolle							9.42	7.89			17.32
Crucigenia fenestrata (Schmidle) Schmidle				14.26	7.96	3668.78	47.13	7.89	22.92		3768.97
C. tetrapedia (Kirchn.) W. & G.S. West				21.40	7.96						29.36
Cryptomonas ovata Ehr.	8.91		76.43								85.35
C. reflexa Skuja				178.34	238.85	20789.77		157.96	160.50	114.64	21640.09
Cyclotella comensis Grun.	71.33	105.47	292.99	221.14	23.88	11006.35	94.26	15.79	38.21	216.56	12086.03
Cymbella cistula (Hemp. and Ehr.) Kirchner				7.13							7.13
Didymocystis bicellularis (Chod.) Kom.				57.06		6726.10	688.15	15.79	129.93	140.12	7757.18
Dinobryon divergens Imhof	53.50	175.79	305.73	435.15	119.42	1834.39	18.85		22.92	12.73	2978.53
Euglena sp.					7.96					12.73	20.70
Gloeocapsa decorticans (A.Br.) Richter *ex* Wille				7.13	15.92						23.05
Gomphoshaeria lacustris Chodat		11.71	50.95				9.42				72.08
Hyaliella polytomoides Pascher	8.91										8.91
Hyaloraphidium contortum Pascher and Koršikov		105.47	140.12	221.14	87.57	8560.49	18.85		45.85	25.47	9204.96
Merismopedia minima Beck						611.46	56.56	1247.89	1658.60	1656.04	5230.55
Monoraphidium contortum (Thur) Kom.-Legn.		11.71				1834.39	28.28		7.64	12.73	1894.75
Navicula placentula (Ehr.) Grun.						1222.92			7.64		12299.64
Nephroclamys subsolitaria (G.S. West) Koršikov	8.91	11.71	25.47	35.66	47.77		84.84	7.89	15.28		237.53
Oocystis lacustris Chodat	17.83	11.71	25.47				18.85	7.89			81.75
Oscillatoria sp.							9.42		30.57	458.59	498.58
Pandorina morum (Müller) Bory						611.46	9.42				620.88
Peridinium cinctum fa. *westii* (Lemm.) Lef.		23.43	63.69	28.53	55.73	4280.24					4451.62
P. lomnicki Wolosz.	463.69	269.55	1273.88	613.50	191.08	27515.88	94.26	71.08	129.93	12.73	30635.58
Plaktosphaeria gelatinosa Smith		23.43					9.42				32.85
Rhodomonas minuta Skuja	26.75	46.87	76.43	71.33							221.38
Scenedesmus ecornis var. *ecornis* (Ehr.) Chodat			25.47								25.47
S. similageneus Hortob.				28.53	31.84	6114.64	84.84		45.85	12.73	6318.43
Synechosystis salina Wisl.										406248.0	406248
Tetraedron caudatum (Corda) Hansgirg						611.46		7.89			619.35
Trachelomonas volvocina Ehr.		23.43	12.73	221.14	294.58	85604.96	320.50	221.14	435.66	191.08	87325.22
Westella botryoides deWilderman		11.71	12.73	7.13							31.57
Total	686.62	890.70	2445.86	2211.45	1433.12	258037.81	2601.78	1919.23	3256.05	409381.73	693932.90

species of phytoplankton, *Chlorococcum humicola* (Näg.) Rab., *Crucigenia fenestrata* (Schmiddle) Schmiddle, *Cryptomonas reflexa* Skuja, *Didymocystis bicellularis* (Chod.) Kom., *Hyaloraphidium contortum* Pascher and Koršikov, *Merismopedia minima* Beck, *Nephrochlamys subsolitaria* (G.S. West) Koršikov, *Scenedesmus similageneus* Hortob. and *Trachelomonas volvocina* Ehr. mostly showed their occurrence until 10 m depth (Table 2). Highest number of species was recorded from algal class Chlorophyceae followed by Cyanophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae and Chrysophyceae (Table 3). The proportion (%) of recorded species under Cyanophyceae and Chlorophyceae in both Bogakain and Kaptai Lake is almost closer to each other except member of Bacillariophyceae where diversity is lower in Lake Bogakain (Table 3). However, the total number of taxa recorded in Lake Bogakain is nearly half than those recorded for Kaptai Reservoir (Bogakain, 40 taxa; Kaptai Lake, 81 taxa of phytoplankton) and this is due to the higher number of greens and diatoms. Lower PO_4-P concentration in the former lake than the latter might be the reason for this (Table 4).

Table 3. Number of species of different classes of phytoplankton from Bogakain and Kaptai Lake, a comparison.

Classes	Recorded species		Percentage of the total	
	Bogakain	Kaptai†	Bogakain	Kaptai†
Cyanophyceae	5	11	12.5	13.5
Chlorophyceae	21	42	52.50	51.9
Euglenophyceae	3	2	7.5	2.5
Bacillariophyceae	4	22	10.0	27.2
Cryptophyceae	4	1	10.0	1.2
Dinophyceae	2	2	5.0	2.5
Chrysophyceae	1	1	2.5	1.2

†Hydrobiology of the Kaptai Reservoir. FAO/UNDP Contract No. DP/BGD/79/O15-4/FI, February, 1986, 21 pp.

Table 4. A comparison of Bogakain and Kaptai lakes from hill districts of Bangladesh.

Parameters	Lake Bogakain	Kaptai lake (Chowdhury and Mazumder 1981)*
GIS	21°58′49″ N and 92°28′11″ E	22°29′ N and 92°17′ E
Altitude (m)	372	31.1
Area (ha)	8-9	583
Z_{max} (m)	46.54	32
Zs (m)	2.37	3.29
Water temp. (° C)	27.5	26.0
TDS (mg/l)	39	76
Conductivity (µS/cm)	75	114
pH	9.1	6.30
Alkalinity (meq/l)	0.88	0.80
DO (mg/l)	8.54	6.25
PO_4-P (µg/l)	154.32	830
NO_3-N (mg/l)	24.73	10.5

* Extrapolated for March value for surface water.

Correlation analysis among the recorded variables vs depths (1 - 10 m, n = 10, one sample from each depth) showed significant positive correlation between chl *a* vs phytoplankton density (Table 5). Highly negative correlation between depth vs water temperature strongly suggests thermally stratified lake. Depth vs chl *a* showed a significant positive correlation, while water temperature vs chl *a* shows a negative correlation. Chl *a* vs pH was negatively correlated. Relationships between chl *a* and all other variables were negative but insignificant (Table 5).

Table 5. Results of correlation analyses between parameters relating physical, chemical and biological factors.[1]

Independent variable (x)	Dependent variable (y)	Correlation coefficient (r)	Probability
Phytoplankton density (ind/l)	Chlorophyll *a* (µg/l)	0.958	$p < 0.01$
Phytoplankton density (ind/l)	Phaeopigment concentration (µg/l)	–0.179	ns
NO_3-N (mg/l)	Phytoplankton density (ind/l)	–0.128	ns
SRP (µg/l)	Chlorophyll *a* (µg/l)	–0.316	ns
Dissolved oxygen (DO) (mg/l)	Chlorophyll *a* "	–0.475	ns
Alkalinity (meq/l)	Chlorophyll *a* "	–0.126	ns
Total dissolved solids (mg/l)	Chlorophyll *a* "	–0.474	ns
Conductivity (µS/cm)	Chlorophyll *a* "	0.126	ns
pH	Chlorophyll *a* "	–0.574	ns
Water temperature (° C)	Chlorophyll *a* "	–0.526	ns
Water depth (m)	Chlorophyll *a* "	0.665	$p < 0.05$
Water depth (m)	Water temperature (° C)	–0.963	$p < 0.01$
SRS (mg/l)	Chlorophyll *a* (µg/l)	–0.087	ns
NO_3-N (mg/l)	Dissolved oxygen (mg/l)	0.241	ns

[1]n = 10, ns = not significant.

Rahman and Chowdhury (2006) mentioned the lake as 38 m deep, acidic and having hot spring at its bottom and due to the discharge of that hot spring the water colour of the lake changes sometimes as highly turbid. But during the present study on 10 March 2010 these features were not found. Again, Rahman and Chowdhury (2006) reported that 'it is fishless and no weed and plant can grow there'. But the lake has a vast littoral area occupied by a number of aquatic macrophytes like *Nymphaea nouchali* Brum.f., *Egeria densa* Planch. (Alfasane *et al*. 2010), *Potamogeton crispus* L., *Polygonum* sp., etc. (Fig. 1 B-C) and 40 species of pelagic phytoplankton. The lake is also invaded by *Oreochromis mossambicus* (Peters) and *Channa marulius* (Hamilton) (personal communication). During the present investigation some small fishes and angling by local people were found.

A comparative analysis of physiographic, morphometric and limnological data for Bogakain and Kaptai Lakes is shown in Table 4. Both the lakes are similar in many respect except a high value of 830 µg/l PO_4-P (Chowdhury and Mazumder 1981). But an unpublished result showed the value as 530 µg/l in Kaptai lake. The high value of PO_4-P (SRP) in Kaptai lake appeared to be due to anthropogenic factors. The NO_3-N value for Bogakain is little more than double of that from Kaptai Lake (Table 4). Kaptai Lake is a manmade reservoir type, where the only hydroelectric power plant of the country is located. On the other hand, Bogakain is considered to be a high altitude, deepest, natural lake of Bangladesh. Compared to area, Kaptai Lake is much bigger than Bogakain. Zs, TDS and conductivity in Kaptai lake is little higher than Bogakain while water temperature and alkalinity of both the lakes are found same for the month of March (Table 4).

It appears that the Lake Bogakain is a thermally stratified (at summer) eutrophic lake. The lake is quite interesting from the limnological perspective and should be investigated thoroughly.

Acknowledgements

The authors are indebted to Professor Dr Md Abul Hassan, Chairman, Department of Botany, University of Dhaka for his encouragement to carry out the expedition. Necessary support extended by Md Amjad Hossain, District Commandant, Ansar and VDP, Bandarban to visit the Boga lake is gratefully acknowledged.

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(Manuscript received on 18 April, 2010; revised on 19 November, 2010)