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Phytoplankton community of Lake Baskandi anua, Cachar District, Assam, North East India – An ecological study

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Abstract – Diversity, relative abundance and dominance of phytoplankton community of the Lake Baskandi anua, an oxbow lake of Assam, North east India were studied during December 2009 to November 2010. Chlorophyll content and biomass of phytoplankton along with physico-chemical properties of water of the lake were also estimated. The lake is covered with *Hydrilla* and other macrophytes like *Eichhornia, Trapa, Altrnenthera, Polygonum, Ludwizia* sp., etc. Seasonal fluctuations of 41 genera of phytoplankton, belonging to 5 groups (Chlorophyceae, Cyanobacteria, Bacillariophyceae, Euglenophyceae and Dinophyceae) were encountered in the lake. Chlorophyceae was found to be highest in winter, Cyanobacteria and Euglena in monsoon and Bacillariophyceae in pre monsoon. According to Engelmann's scale, *Spirogyra indica* was found eudominant followed by 10 dominant, 24 subdominant and 20 recedent species. Chlorophyll- a content of phytoplankton varied from 14.18 to 33.89 $\mu g \cdot L^{-1}$, during the study period. One way analysis of variance (ANOVA) revealed significant seasonal variation in physico-chemical properties of water like Water temperature, pH, Conductivity, Dissolved oxygen, Free CO_2, Total alkalinity, Calcium, Chloride, Nitrate and Ammonia. Relationship between phytoplankton group assemblage and environmental variables were explored by the ordination method CCA (Canonical Correspondence Analysis).

Key-words: Phytoplankton / diversity / chlorophyll / water quality / anua

Résumé – La communauté phytoplanctonique du lac Baskandi Anua, District de Cachar, Assam, Nord-Est de l'Inde – une étude écologique. La diversité, l'abondance relative et la dominance de la communauté phytoplanctonique du lac Baskandi, un bras mort de l'Assam, au Nord-Est de l'Inde ont été étudiées de décembre 2009 à novembre 2010. La concentration en chlorophylle, la biomasse du phytoplancton et les propriétés physico-chimiques de l'eau du lac ont également été étudiées. Le lac est recouvert d'*Hydrilla* et d'autres macrophytes comme *Eichhornia*, *Trapa*, *Altrnenthera*, *Polygonum*, *Ludwizia* sp., etc. Les fluctuations saisonnières de 41 genres de phytoplancton, appartenant à 5 groupes (Chlorophyceae, Cyanobactéries, Bacillariophyceae, Euglenophyceae et Dinophyceae) ont été observées dans le lac. Les Chlorophyceae ont été plus abondantes en hiver, les Cyanobactéries et *Euglena* pendant la mousson et les Bacillariophyceae avant la mousson. Selon l'échelle de Engelmann, *Spirogyra indica* a été trouvée eudominante suivie par 10 dominantes, 24 sous-dominantes et 20 espèces en diminution. La concentration en chlorophylle du phytoplancton variait de 14,18 à 33,89 $\mu g \cdot L^{-1}$, au cours de la période d'étude. Une analyse de variance (Anova) a révélé une variation saisonnière significative dans les propriétés physico-chimiques de l'eau comme la température de l'eau, le pH, la conductivité, l'oxygène dissous, le CO_2, l'alcalinité totale, le calcium, les chlorures, les nitrates et l'ammoniac. La relation entre l'assemblage des groupes phytoplanctoniques et les variables environnementales ont été explorées par la CCA (analyse canonique des correspondances).

Mots-clés : Phytoplancton / diversité / chlorophylle / qualité de l'eau, bras mort

1 Introduction

Phytoplankton are highly diverse group of photoautotrophic organisms with chlorophyll- a and unicellular reproductive structures, which are important for aquatic habitats (Wetzel, 2001; Ariyadej *et al.*, 2004). They are important primary producers in the base of the food chain, constitute a vital link and an important biological indicator of the water quality (Laskar and Gupta, 2013). Maintenance of a healthy aquatic ecosystem depends on the biotic properties of water and the biological diversity of the ecosystem (Harikrishnan *et al.*, 1999). Thus study of phytoplankton is very useful tool for the assessment of water quality in any type of water body and also contributes to the understanding of basic nature and general

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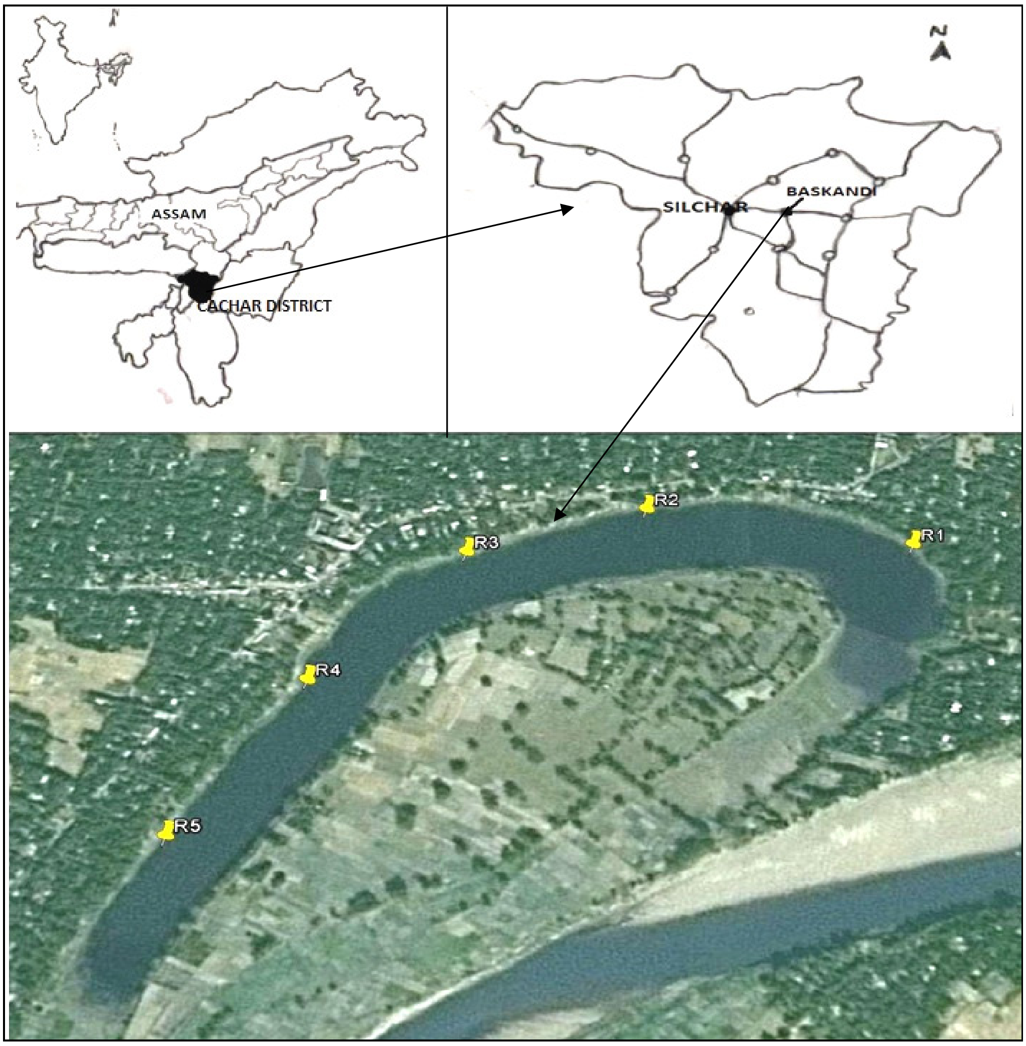

Fig. 1. Map after showing study sites.

economy of the lake (Pawar *et al.*, 2006). Occurrence and abundance of phytoplankton species depends on the physico-chemical characteristics of water. For effective monitoring and maintenance of water quality, it is very important to know about different physico-chemical and biological characteristics of water.

The Baskandi Lake, locally known as 'Baskandi anua' in Cachar district is formed by the meandering of the course of the River Barak (Gupta and Devi, 2014). The lake serves as habitat for diverse animals and plants. Villagers around the lake fully depend on its resources particularly fish for their livelihood and water for everyday use. Further the lake water act as source of irrigation during the dry season. Thus the lake has substantial impact on the socio-economy of the surrounding community. Increasing human habitation led to over-exploitation of aquatic resources especially fish.

In Cachar district a few studies were conducted on phytoplankton and zooplankton communities of different fresh water systems (Dutta Gupta *et al.*, 2004; Bhuiyan and Gupta, 2007; Laskar and Gupta, 2009, 2013; Das *et al.*, 2011; Dalal and Gupta, 2013; Devi *et al.*, 2013; Gupta and Devi, 2014). Gupta and Devi (2014) made a very preliminary study on phytoplankton and zooplankton community of Baskandi anua. But till now no detail information is available on seasonal variations in phytoplankton community of Baskandi anua, its chlorophyll content and biomass. In order to fill up this lacuna, this study was taken up to investigate phytoplankton diversity, chlorophyll content and biomass along with physiochemical properties of water of the lake in different seasons.

2 Materials and methods

Baskandi anua is situated between 24° 48.615′ N (latitude) and 092° 55.882′ E (longitude) in Cachar district, Assam, North east India. It is lies 24.7 m above sea level. The length, breadth and area of Baskandi anua is found to be 2230 km, 2.05 km and 3920 km^2 during Full storage level (FSL) (June-Sep) and 2090 km, 1.90 km and 3670 km^2 at Dead storage level (DSL) (Nov-April) (Figure 1). The lake exhibits variable water level ranging from 0.25 m to 5.85 m at FSL and 0.14 m to 4.12 m at DSL. The lake is covered with *Hydrilla* and other macrophytes like *Eichhornia, Trapa, Alternanthera, Polygonum, Ludwizia* sp., etc. Phytoplankton and water samples were collected in winter (Dec, 2009−Feb, 2010), pre-monsoon (March-May, 2010), monsoon (June, 2010−August, 2010) and post- monsoon (Sep, 2010−Nov, 2010) from 5 selected sites across the lake. Physiochemical parameters such as dissolved oxygen (DO), total alkalinity (TA), pH, electrical conductivity (EC), free carbon-dioxide (FCO_2), chloride (Cl), total hardness (TH), calcium (Ca^{+2}), magnesium (Mg^{+2}) and biological oxygen demand (BOD), phosphate (PO_4), nitrate (NO_3) and ammonium-Nitrogen (NH_3-N) were analyzed by standard methods (Michael, 1984; Trivedy and Goel, 1986; APHA, 2005). Transparency (Trans) was measured by Secchi disk. Chlorophyll a, b, c and pheophytin content were determined following Abbasi (1998). By assuming that chlorophyll-a constitutes on the average 1.5% of the dry weight of algae, the biomass was estimated by multiplying the chlorophyll-a content by a factor of 67 (APHA, 2005). Trophic State Index (TSI) was also calculated following Carlson (1977).

For phytoplankton collection, 50 L of water was collected from the surface with minimal disturbance in replicate (5) and filtered in a bolting silk cloth net of mesh size 40 µm. The final volume of the filtered sample was 125 mL which was preserved by adding of 5% formalin. After 24 h, each sample was centrifuged and concentrated to 10ml with distilled water (Michael, 1984; APHA, 2005).The quantitative analysis of phytoplankton is done by Lackey's drop method. The cover slip was placed over a drop of sample in the slide, added a pinch of glycerin and mounted it with a cover slip and was examined under microscope (APHA, 2005).

Fot Lackey's drop method:

$$\text{Organisms per liter } (N) = \frac{R \times A_t \times 10^3}{A_s \times S \times V}$$

where

R = Number of organisms counted per subsample.
A_t = Area of coverslip, mm^2.
A_s = Area of one strip, mm^2.
S = Number of strips counted.
V = Volume of sample under the coverslip, ml.

Therefore, Total organisms per liter = $N \times 1/C$.

Where concentration factor, C =

$$\frac{\text{Volume of original sample (ml)}}{\text{Volume of concentrated sample (ml)}}.$$

For qualitative analysis, phytoplankton samples were screened and various planktonic taxa belonging to each group were identified following standard books (Edmondson, 1959; Prescott, 1982; Anand, 1998). Dominance status of phytoplankton was described on the basis of relative abundance (Engelmann, 1978). Biodiversity indices such as Shannon-Wiener diversity index (H'), Buzas and Gibson's evenness index (e^H/S), and Berger Parker's Dominance index (D) on the basis of phytoplankton abundance were computed using PAST software version 2.13 (Hammer *et al.*, 2001). One way Analysis Of Variance was performed by using SPSS version 16. Canonical correspondence analysis (CCA) was done by using PAST software version 2.13 after logarithmic transformation of data, except for the pH data.

3 Results

Diversity, relative abundance and dominance of phytoplankton community of the Lake were studied during December 2009 to November 2010. A total of 41 phytoplankton taxa belonging to 5 classes (Cyanobacteria, Chlorophyceae, Euglenophyceae, Bacillariophyceae, and Dinophyceae) were quantified in 4 seasons (Table 1). Maximum number of phytoplankton taxa was found in pre monsoon followed by monsoon and minimum was found in post monsoon. A total of 17 species of Chlorophyceae was recorded with highest relative abundance (70.5%) in winter and lowest (8.6%) in monsoon (Table 1), 8 species of Cyanobacteria contributed highest relative abundance (66.7%) in post monsoon and lowest (26.2%) in winter while 10 species of Bacillariophyceae contributed highest relative abundance (14.8%) in post monsoon and lowest (3.3%) in winter (Table 1). Euglenophyceae population consisted of only 5 taxa having highest relative abundance (29.3%) in monsoon and lowest (16.8%) in pre monsoon (Table 1). Only one species *Ceratium hirundinella* belonging to Dinophyceae was recorded in pre monsoon (2.2%). According to Engelmann's scale (1978), during the year of study, *Spirogyra indica* was found only eudominant species in winter. Dominant species in the lake were *Lyngbya* sp. in winter, *Microcystis aeruginosa* in pre monsoon, *Euglena gracilis* in pre monsoon and post monsoon, *Trachelomonas* sp. in monsoon, *Anabaena* sp. and *Nostoc commune* in monsoon and post monsoon and *Oscillatoria* sp. in post monsoon. In the present study, Shannon (H') value was found highest during pre monsoon (1.6 ± 0.24) followed by monsoon (1.3 ± 0.75) and recorded lowest value in winter (0.8 ± 0.30). Buzas and Gibson's evenness index (e^H/S) was found to be highest in pre monsoon (0.9 ± 0.10) followed by monsoon (0.9 ± 0.13) (Table 2).The values of Chlorophyll- a concentration ranged from 14.2 µg·L^{-1} (pre monsoon) to 33.9 µg·L^{-1} (monsoon), Chl-b ranged from 2.8 µg·L^{-1} (pre monsoon) to 9.7 µg·L^{-1} (winter) and Chl-c value ranged from 0.5 µg·L^{-1}(pre monsoon) to 15.1 µg·L^{-1}(winter). Pheophytin values in the lake ranged from 20.1 µg·L^{-1} (pre monsoon) to 61.6 µg·L^{-1} (post monsoon). The phytoplankton biomass was highest in monsoon (2260.5 µg·L^{-1}) (Table 3).

During the sampling period the study area had annual average rainfall of 255 mm with highest value in monsoon (507 mm) and lowest in winter (2 mm) (Figure 2). The pH values ranged between 5.9 (monsoon) to 7.2 (winter). The highest Trans value (36 cm) was recorded in winter and the lowest (9.9 cm) was recorded in post monsoon. BOD values of the lake ranged between 2 (monsoon) to 3.7 mg·L^{-1} (pre monsoon). TA values ranged between 35.1 (winter) to 52.2 mg·L^{-1} (monsoon). TH ranged between 42.8 to 50.4 mg·L^{-1} , showed highest value in monsoon and lowest in winter. Carlson's Trophic State Index (TSI) values ranged between 63.4 (winter) to 73.2 (Post monsoon) (Table 4).

The influence of eighteen environmental variables on the distribution of phytoplankton groups in Baskandi anua are assessed using CCA (Ter Braak, 1986) (Figure 3). The eigen values of CCA axis 1 and 2 are 0.157 and 0.067 (Table 5) respectively. The CCA axis 1 and axis 2 explained 67.5% and 28.7% (Table 5) variation in the phytoplankton-environment relationships. Axis 1 is mainly associated with WT, NO_3, TH and TA

Table 1. Seasonal distribution, relative abundance and dominance status (Engelmann's scale, 1978) of phytoplankton species in Baskandi anua.

Class	Name of the species	Winter		Pre monsoon		Monsoon		Post monsoon	
		R.A (%)	D.S	R.A (%)	D.S	R.A (%)	D.S	R.A (%)	D.S
Chlorophyceae	*Spirogyra indica*	62.30	E	3.37	SD	–	–	–	-
	Scenedesmus sp.	1.64	R	–	–	–	–	–	–
	Oedogonium sp.	1.64	R	–	–	–	–	–	–
	Uronema sp.	4.92	SD	–	–	–	–	–	–
	Zygnema sp.	–	–	1.12	R	–	–	–	–
	Closteriopsis longissima	–	–	6.74	SD	–	–	–	–
	Tetraedron trigonum	–	–	1.12	R	–	–	–	–
	Arthrodesmus sp.	–	–	1.12	R	–	–	–	–
	Sphaerozosma sp.	–	–	1.12	R	–	–	–	–
	Hormidium sp.	–	–	1.12	R	–	–	–	–
	Ulothrix zonata	–	–	7.87	SD	–	–	–	–
	Closterium sp.	–	–	2.25	R	–	–	–	–
	Sirocladium sp.	–	–	4.49	SD	3.45	SD	–	–
	Gloeotilopsis sp.	–	–	4.49	SD	–	–	–	–
	Cladophora sp.	–	–	2.25	R	–	–	–	–
	Spirotaenia sp.	–	–	1.12	R	–	–	–	–
	Actinastrum falcatus	–	–	–	–	5.17	SD	–	–
Total Chlorophyceae	**17**	**70.49**		**38.20**		**8.62**		**–**	
Cyanobacteria	*Oscillatoria* sp.	3.28	SD	–	–	8.62	SD	14.81	D
	Microcystis aeruginosa	3.28	SD	16.85	D	–	–	–	–
	Lyngbya sp.	14.75	D	4.49	SD	3.45	SD	3.70	SD
	Dactylococcopsis sp.	–	–	1.12	R	–	–	–	–
	Anabaena sp.	–	–	1.12	R	25.86	D	25.93	D
	Nostoc commune	–	–	–		13.79	D	22.22	D
	Merismopedia sp.	4.92	SD	4.49	SD	–	–	–	–
	Synechocystis sp.	–	–	3.37	SD	–	–	–	–
Total Cyanobacteria	**8**	**26.23**		**31.46**		**51.72**		**66.67**	
Bacillariophyceae	*Melosira* sp.	1.64	R	–	–	–	–	–	–
	Meridion sp.	–	–	2.25	R	–	–	–	–
	Pinnularia sp.	1.64	R	–	–	–	–	–	–
	Navicula sp.	–	–	6.74	SD	–	–	–	–
	Neidium sp.	–	–	–	–	3.45	SD	–	-
	Mastogloia sp.	–	–	–	–	–	–	7.41	SD
	Caloneis sp.	–	–	–	–	–	–	7.41	SD
	Frustulia sp.	–	–	–	–	3.45	SD	–	–
	Gomphonema sp.	–	–	2.25	R	1.72	R	–	–
	Anomoneis sp.	–	–	–	–	1.72	R	–	–
Total Bacillariophyceae	**10**	**3.28**		**11.24**		**10.34**		**14.81**	
Euglenophyceae	*Euglena acus*	–	–	2.25	R				
	Euglena gracilis	–	–	13.48	D	3.45	SD	11.11	D
	Phacus sp.	–	–	1.12	R				
	Trachelomonas hispida	–	–	–	–	8.62	SD	7.41	SD
	Trachelomonas volvocina	–	–	–	–	17.24	D	–	-
Total Euglenophyceae	**5**	**–**		**16.85**		**29.31**		**18.52**	
Dinophyceae	*Ceratium hirundinella*	–	–	2.25	R	–	–	–	–
Total Dinophyceae	**1**	**–**		**2.25**		**–**		**–**	
Total phytoplankton taxa	**41**	**10**		**25**		**13**		**8**	

RA- Relative abundance and DS-Dominant status.SR-subrecedent; R-recedent; SD-subdominant; D-dominant and E-eudominant.RA 1% = subrecedent; 1.1–3.1% = recedent; 3.2–10% = subdominant; 10.1–31.6% = dominant and <31.7% = eudominant.

Table 2. Diversity indices on the basis of phytoplankton abundance in Baskandi anua.

Diversity indices	Winter	Pre monsoon	monsoon	Post monsoon
Shannon diversity index (*H'*)	0.85 ± 0.30	1.59 ± 0.24	1.30 ± 0.75	0.99 ± 0.35
Berger Parker Dominance index (D)	0.52 ± 0.16	0.33 ± 0.05	0.38 ± 0.35	0.16 ± 0.14
Buzas and Gibson's evenness index (e^H/S)	0.77 ± 0.18	0.88 ± 0.10	0.87 ± 0.13	0.18 ± 0.001

(Mean ± SD; $n = 20$).

Table 3. Chlorophyll content and biomass of phytoplankton in Baskandi anua with one way ANOVA.

Parameters	Winter	Pre monsoon	Monsoon	Post monsoon	ANOVA F-ratio
Chlorophyll a (μg·L^{-1})	23.17 ± 20.38	14.18 ± 10.14	33.89 ± 15.52	26.15 ± 8.24	1.60
Chlorophyll b (μg·L^{-1})	9.69 ± 10.35	2.83 ± 4.18	4.15 ± 5.78	8.33 ± 5.31	1.16
Chlorophyll c (μg·L^{-1})	15.07 ± 14.93	0.51 ± 1.14	–	–	4.95
Pheophytin a (μg·L^{-1})	23.78 ± 16.48	20.10 ± 10.38	47.19 ± 30.22	61.59 ± 63.85	1.44
Ratio of pheophytin a and chlorophyll a	1.48 ± 1.00	1.60 ± 0.68	1.36 ± 0.47	2.07 ± 1.65	0.44
Biomass (μg·L^{-1})	1545.23 ± 1359.30	945.80 ± 676.23	2260.47 ± 1035.46	1744.18 ± 549.91	1.60

(Mean ± SD; $n = 20$).*$p < 0.01$.

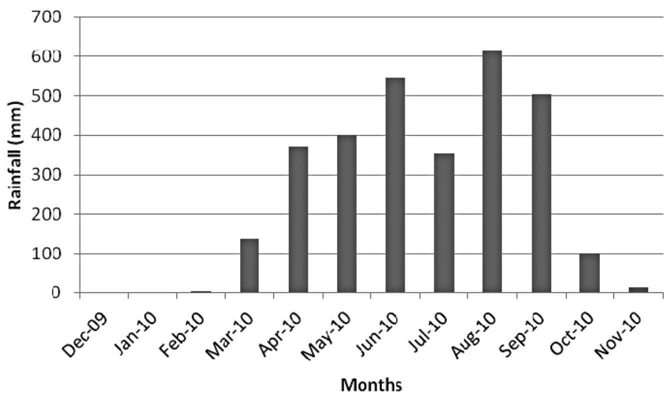

Fig. 2. Monthly variation in rainfall data during the study period (Source: Tocklai Tea Research Station, Silchar, Assam.)

whereas again axis 2 is mainly associated with DO and Cl. Chlorophyceae and Bacillariophyceae lay in CCA axis 1 and Euglenophyceae also lies close to Axis 1. Cyanobacteria have been found to be grouped with monsoon and post monsoon season close to both the axis 1 and 2 toward the center. Dinophyceae recorded only in post monsoon lie close to Axis 2.

4 Discussion

A seasonal change in phytoplankton community with regard to abundance and species composition was evident in the study. Macrophytes were found abundant in the systems which have direct or indirect effect on phytoplankton density and biomass. Excess use of phosphorous and nitrogen by macrophyte reduce nutrient availability to phytoplankton (Stephen *et al.*, 1998). Also aquatic vegetation provides shelter to zooplankton which feed upon phytoplankton and at times reduces phytoplankton densities (Irvin *et al.*, 1990, Stephen *et al.*, 1998). Five different phytoplankton groups (Cyanobacteria, Chlorophyceae, Euglenophyceae, Bacillariophyceae and Dinophyceae) with 41 phytoplankton taxa were quantified in 4 seasons and compared to the previous investigation made by Gupta and Devi (2014) on the same lake where they recorded 30 phytoplankton taxa belonging to Chlorophyceae, Cyanobacteria and Bacillariophyceae during 6 months collections in 2009. Borics *et al.* (2011) recorded 21 species in the Tiszadob oxbow of Carpathian basin, Central Europe. 47 species belonging to seven groups of phytoplankton were identified from the Rewalsar Lake, Himachal Pradesh in two consecutive years (Jindal *et al.*, 2014). Min *et al.* (2011) recorded a total of 46 species in Lake Yueya (Eutrophic lake), Nanjing, China in 2006, which was reduced to 33 species and then to 21 species in the next two years.

Highest relative abundance of Cyanobacteria population than that of other groups in monsoon and post monsoon indicated eutrophic condition which is further confirmed by high nutrient content such as PO_4, NO_3, NH_3-N in water and TSI value. This conformed to the studies made by Paramasivam and Srinivasan (1981), Maeda *et al.* (1992), Kumari *et al.* (2008), Ghosh *et al.* (2012). Rain water might have brought more nutrients into the lake as surface run off which enhanced the growth of phytoplankton especially Cyanobacteria and Euglenophyceae. A study in a floodplain lake of Barak Valley showed that red bloom of *Euglena* sp. was induced by high

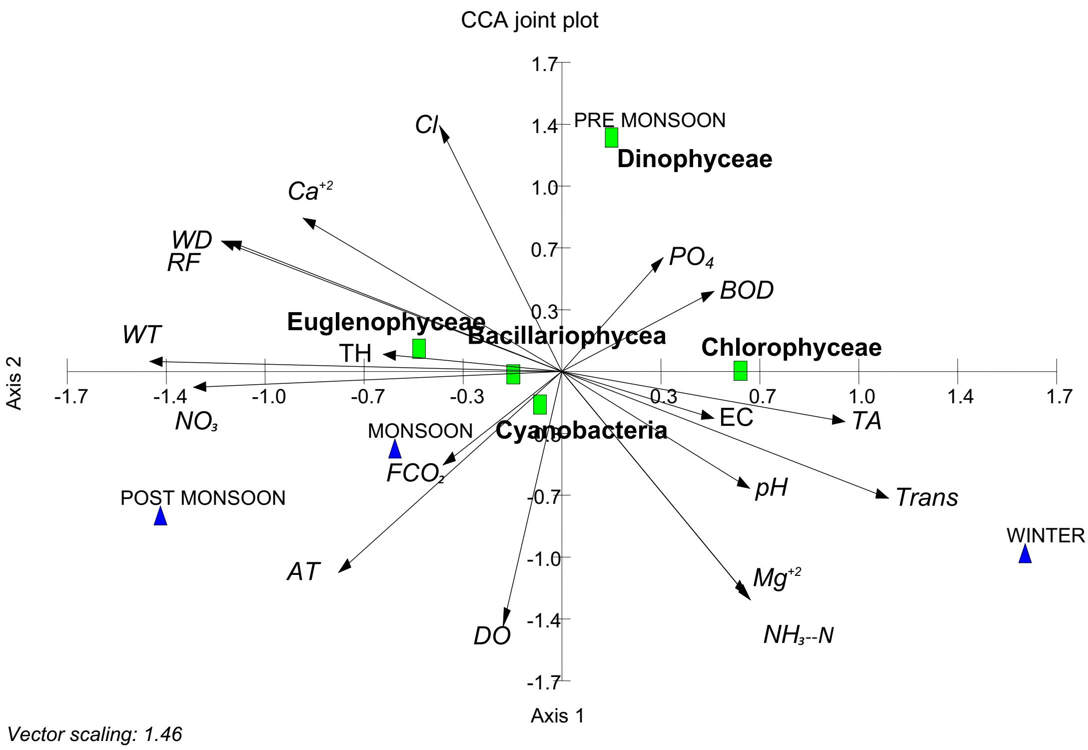

Fig. 3. Canonical correspondence analysis (CCA) diagram of environmental variables and Phytoplankton groups in different seasons in the study area. The phytoplankton groups related to the environmental variables are presented by squares while triangles represent seasons. (WD – Water depth, WT – water temperature, AT – air temperature, EC – electrical conductivity, Trans – transparency, FCO_2 – free carbon dioxide, DO-dissolved oxygen, BOD-biological oxygen demand, TA-total alkalinity, TH-Total Hardness, Ca^{+2} – Calcium, Mg^{+2} – Magnesium, Cl – chloride, NO_3 – nitrate, PO_4-phosphate , NH_3-N – Ammonia nitrogen and RF – rainfall).

concentration of NH_3-N, NO_3, Fe, Mg and to some extend PO_4, Cu, Zn in water (Dutta Gupta *et al.*, 2004). Maximum relative abundance of Chlorophyceae recorded in winter might be due to low temperature which enhanced the growth of green algae (Tiwari and Chauhan, 2006). *Spirogyra indica* belonging to Chlorophyceae was the only eudominant species recorded in winter in the whole study period. Dominant species recorded in different seasons belonged to Cyanobacteria and Euglenophyceae group (Table 1). This indicated poor water quality condition as these are generally seen to appear near sewage outfall (Pandit, 2002). Greater availability of nitrates and phosphates in the rainy season might have supported dominance of blue green algae such as *Microcystis* sp., *Lyngbya* sp., *Merismopedia* sp. *etc*. as shown by Swarnalatha and Narasingrao (1993) and Ghosh *et al.* (2012). *Ceratium hirundinella* was also recorded in another oxbow lake of Cachar District (Das *et al.*, 2011). This species is generally described as a typical species of stratified and warm water of the summer period (Wetzel, 2001) and it often dominates the summer phytoplankton in lakes (Rengefors *et al.*, 1998).The highest Shannon (H') value during pre monsoon followed by monsoon was due to surface runoff from nearby rice fields and human habitats during rainy seasons which made the lake nutrient rich and in turn enhanced the growth of phytoplankton. Highest H' value for phytoplankton population in pre monsoon was also recorded in a floodplain lake of Cachar (Laskar and Gupta, 2009). Buzas and Gibson's evenness index (e^H/S) expressed the degree of uniformity in the distribution of individual among the taxa and it is found to be highest in pre monsoon followed by monsoon. This indicated that species were more evenly distributed in this lake during these seasons.

Chlorophyll content of phytoplankton indicates the physiological status of phytoplankton community and primary production of water. The Chl-a concentration in this lake can be compared with other oxbow lakes such as Atkai-Holt-Tisza (2.4−49 $\mu g \cdot L^{-1}$), Holt-Szamos Tunyogmatolcs (9.4−38.3 $\mu g \cdot L^{-1}$) and Malom-Tisza (2.3−44.9 $\mu g \cdot L^{-1}$) located in the Tisza valley, East Hungary (Krasznai *et al.*, 2010) and Tiszadob oxbow (4−25 $\mu g \cdot L^{-1}$) of Carpathian basin, Europe (Borics *et al.*, 2011). According to Abbasi (1998) greater ratio of pheophytin- a to chlorophyll- a indicates poor water quality and in post monsoon this ratio was found highest in the lake.

Rainfall is the most important cyclic phenomena which bring variation in physico-chemical parameters of water and in turn leads to variation in distribution and diversity of aquatic communities. In this study the environmental variables were found in two different groups. Dpt, TH, Ca^{+2},TA, Cl, PO_4 and NO_3 formed one group which increased from winter to monsoon period and decreased again in post monsoon. The second group pH, EC, FCO_2, Mg^{+2}, NH_3-N, and DO decreased from winter to monsoon and again increased in post monsoon (Table 4). During pre monsoon and monsoon input of sewage, drainage water and fertilizers from nearby rice field has led to the increase of TH, Ca^{+2}, TA, Cl, PO_4 and NO_3. Deposition of these nutrients into water promoted growth of

Table 4. Seasonal variations in environmental variables and Trophic State Index (TSI) of water in Baskandi anua with one way ANOVA.

Parameters	Winter	Pre monsoon	monsoon	Post monsoon	F-ratio
Rainfall (mm)	1.80 ± 3.12	303.37 ± 143.73	506.67 ± 135.74	207.47 ± 261.09	0.296
Water depth (m)	41.17 ± 6.32	41.65 ± 29.39	58.67 ± 12.84	42.56 ± 9.27	0.752
Air temperature (°C)	27.20 ± 2.08	26.10 ± 1.25	27.40 ± 0.96	29.26 ± 1.03	4.37
Water temperature (°C)	22.20 ± 1.04	25.02 ± 1.17	26.40 ± 0.96	28.06 ± 0.56	33.30*
Transparency (cm)	36.05 ± 0.92	14.71 ± 3.40	24.60 ± 4.74	9.90 ± 0.96	240.87*
pH	7.24 ± 0.23	6.31 ± 0.07	5.88 ± 0.07	6.93 ± 0.09	106.68*
Conductivity (mS·cm^{-1})	1.31 ± 0.047	0.91 ± 0.11	0.54 ± 0.03	1.27 ± 0.10	10.50*
Dissolved oxygen (mg·L^{-1})	9.80 ± 0.66	7.28 ± 0.29	9.35 ± 0.67	10.17 ± 0.13	33.78*
Biological oxygen demand (mg·L^{-1})	3.60 ± 1.14	3.69 ± 1.39	2.03 ± 1.36	3.56 ± 1.75	1.56
Free carbon dioxide (mg·L^{-1})	3.39 ± 1.67	2.79 ± 1.09	2.20 ± 0.83	6.72 ± 2.22	8.50*
Total alkalinity (mg·L^{-1})	35.08 ± 1.48	44.83 ± 8.34	52.25 ± 3.44	35.40 ± 2.70	15.00*
Total Hardness(mg·L^{-1})	42.80 ± 7.95	45.20 ± 4.15	50.40 ± 4.10	43.60 ± 3.29	2.16
Calcium (mg·L^{-1})	8.50 ± 0.94	14.59 ± 1.74	15.25 ± 2.31	11.86 ± 2.97	11.54*
Magnesium (mg L^{-1})	14.24 ± 5.70	5.80 ± 2.21	7.65 ± 5.41	9.23 ± 2.95	3.62
Chloride (mg·L^{-1})	12.33 ± 1.08	26.24 ± 0.85	21.07 ± 2.08	20.87 ± 1.99	62.61*
Phosphate (mg·L^{-1})	0.05 ± 0.06	0.06 ± 0.04	0.07 ± 0.05	0.04 ± 0.05	0.549
Nitrate (mg·L^{-1})	0.41 ± 0.12	0.53 ± 0.07	0.71 ± 0.03	0.65 ± 0.10	12.64*
Ammonia-N (mg·L^{-1})	1.92 ± 0.37	0.19 ± 0.05	0.46 ± 0.04	0.55 ± 0.06	82.35*
TSI	63.40 ± 7.24	70.12 ± 2.64	71.32 ± 2.92	73.23 ± 1.24	5.22

(Mean ± SD; n = 20) *p < 0.01.

phytoplankton (Francis *et al.*, 1997). The highest Trans value recorded in winter might be due to low or no disturbance in water. On the other hand Trans value was found lowest in post monsoon. Transparency can also indicate the turbidity (cloudiness) of a water body. This is influenced by algae, suspended sediments and these values again conferred trophic status of the lake. Baskandi anua water was found moderately polluted as according to Hynes (1960), BOD values between 2–7 mg·L^{-1} represent slightly polluted water. This is also revealed by TA values (Spence, 1964) which indicated moderately rich nutrient condition of the lake. This agreed with the earlier finding in the same lake (Gupta and Devi, 2014). Based on TH (mg·L^{-1}) the water can be categorize into Soft (0–30), moderately soft (30–60), moderately hard (60–120), hard (120–180) and very hard (>180). Accordingly, water of this lake was soft in all the seasons while moderately soft in monsoon (50.40 mg·L^{-1}). Carlson's Trophic State Index (TSI) classification (Carlson, 1977) is used to provide a single trophic criterion for the purpose of classifying and ranking water bodies in complex multi-wetland systems. Carlson's Trophic State Index (TSI) value less than 30 indicates oligotrophic condition, between 50–70 and more than 70 indicates high level of trophic status as eutrophic and hypereutrophic condition. TSI value in this lake indicated eutrophic condition in all the seasons (Carlson, 1977). This can be compared with TSI values of Hansadanga Lake, West Bengal, India (60.97-eutrophic) (Chakrabarty *et al.*, 2010) and shallow lake of Babol city, North Iran (75.06-hypereutrophic) (Rahmati *et al.*, 2011). Highest value of TSI in post monsoon followed by monsoon is attributed to high nutrient loading in these seasons which promoted growth of phytoplankton with higher chlorophyll- a which in turn decreased transparency. According to one way analysis of variance (ANOVA) WT, Trans, pH, EC, DO, FCO_2, TA, Ca^{+2}, Cl, NO_3 and NH_3-N (Table 4) had shown significant seasonal differences. This is further confirmed in the CCA diagram where rainfall had a negative relationship with variables such as pH, EC, TA, Trans, Mg^{+2}, NH3-N and positive relationship with other variables such as Cl, Ca^{+2}, TH, WT as well as WD (Water depth) (Figure 3).This corresponded to the findings in a reservoir-channel, in the semiarid Rio Grande do Norte State, Brazil by Câmara *et al.* (2009).

Table 5. Summary of canonical correspondence analysis (CCA) between phytoplankton groups and environmental variables.

	Axis 1	Axis 2
Eigen values	0.157	0.067
Percentage of Variance	67.531	28.692
Cummulative Percentage variance	67.531	96.224
Spec.-env. correlations	1	1

In CCA analysis, the species environmental correlations for all axes are high; all of them are having a value of 1 (Table 5). Axis 1 is mainly associated with WT, NO_3, TH and TA. *Chlorophyceae* and Bacillariophyceae lay in CCA axis 1. So according to their position in CCA diagram, increase in Chlorophyceae population is associated with increase in EC, TA, BOD and PO_4 (Figure 3). Population of Euglenophyceae and Bacillariophyceae is associated with WT, TH,

NO_3 and RF. Again axis 2 is mainly associated with DO and Cl. The Cyanobacteria grouped with monsoon and post monsoon season is found strongly associated with DO_2, FCO_3, AT and NO_3 Similar observations were made by Dokulil and Teubner (2000), Eynard *et al.*, (2000) and Mischke (2003). Dinophycea is found associated positively with BOD and PO_4 *i.e.* the factors associated with input of organic matters and nutrient in the water.

5 Conclusions

This investigation found the lake Baskandi anua as eutrophic. Hence for arresting deterioration of the lake and for conserving its biodiversity appropriate remedial measures should be taken by the management as well as the inhabitants. Long term biomonitoring of water quality of the lake coupled with socio economic reviews might provide clues for identifying the sources of stress and subsequently environment awareness can be disseminated.

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