



A comparative analysis of the ecology of cyanobacterial bloom and water parameters in two lentic ecosystem of Kamrup district of Assam, India

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Abstract

Cyanobacterial population in blooms are an important component of algal bloom in the tropical regions. Bloom-forming cyanobacteria form an important part of the diverse group of phototrophs that comprise the phytoplankton and are influenced by an array of environmental conditions. The occurrence and abundance of cyanobacterial population was studied during the winter and premonsoon season of 2020-2021. Samples were collected seasonally. Some physico-chemical parameters of water such as water temperature, pH, Dissolved Oxygen(DO), Biological Oxygen Demand (BOD), NO₃-N, PO₄³⁻-P, Total Nitrogen (TN), Total Phosphorus (TP), etc. were studied and their relationship with the bloom formation by cyanobacteria are discussed. *Microcystis aeruginosa* was the most dominant species during the bloom period. The formation and persistence of natural bloom of cyanobacteria, especially *Microcystis* was found to be triggered by relatively high temperature, alkaline pH and nutrient enrichment by nitrogen and phosphorus. Variability of cyanobacterial populations was seen in response to different or changing environmental conditions. These changes indicate the importance of short-term and long-term observations of the waterbodies for understanding the variation in phytoplankton groups in a lentic ecosystem.

Keywords: algae, lentic ecosystem, cyanobacteria, bloom

Introduction

Algae are a ubiquitous group of organisms of the kingdom Protista. They are predominantly aquatic photosynthetic organisms known to human being since time immemorial. The word 'algae' originated from the Greek word 'phykos' meaning 'seaweed' and the study of algae is known phycology. This group of organisms form a major chunk of the aquatic ecosystems (both lentic and lotic). Lakes, ponds, pools, wetlands, puddles, tanks, reservoirs, ditches, etc. are examples of lentic ecosystems. Algae are also referred to as the phytoplanktons. They inhabit the upper layers of water illuminated by sunlight layer of almost all freshwater ecosystems and form part of the lentic system biota. They are the principal photosynthesisers and primary producers of the aquatic food web. Most algae are annuals and survive the non-growing seasons as dormant spores or other cells capable of survival. Changes in algal population have been reported seasonally, but the dominant species may differ from year to year (Transeau, 1916) [14]. According to Bellinger & Sigee, 2015 [2] the term algae is applied to a broad assemblage of organisms that can be defined both in terms of morphology and general physiology. They are widely present in almost all freshwater environments, such as lakes and rivers. These microscopic organisms that are visible only with the aid of a microscope are typically present in almost all freshwater environments. Although they are relatively inconspicuous, but play a major role in the freshwater environment. Phytoplanktons show great diversity in different seasons and with variation of the physico-chemical characteristics of water. They are an important ecological component of lentic ecosystem. Phytoplankton communities are influenced by washout, i.e., the rate of replacement of the water mass. (Moss, 2018) [11]. Cyanobacteria are ancient organisms (Schopf and Packer 1987) [19]. Blooms of cyanobacteria have been recorded through historical times (Francis 1878 [7]; Codd *et al.* 1994) [4]. Distribution of algae is wide and varied such as aquatic algae, planktonic algae, terrestrial algae and many more. Majority of algae (about 90%) are aquatic. In freshwater ecosystems, particularly in the lentic ecosystems, they form a scum on the surface of the water. The abundance of algae of different kinds is rather closely associated with restricted seasonal periodicity, differing of course in widely separated geographical locations. Sometimes algae burst forth into dense growths under favorable nutritional conditions. This is known as algal bloom. Algal bloom results when the numbers of planktonic algae in water bodies grow rapidly. Lentic ecosystems are more susceptible to blooms. Bloom formation depends on factors such as temperature increase, high level of inorganic nutrients like nitrogen and phosphorus and long photoperiod (Margalef, 1978) [10]. The intimate association of algae with aquatic habitats makes them an interesting tool for such studies. Algal blooms can represent very large numbers of algal cells. Some algal blooms have been recorded in excess of 800,000 cells per ml of water (Water Facts, Water Rivers Commission, 1998) [25]. An excessive growth of microscopic algae is defined as a bloom when it reaches high densities of cells/ml in a water sample. Cyanobacteria play a key role in bloom formation. Bloom

algae belonging to the genera *Microcystis*, *Anabaena*, *Euglena*, etc. are a common sight in the tropics during late winters and summers. However, in tropical regions growth are found to be nearly continuous when sufficient nutrients are available (Pal and Choudhury, 2014) ^[16]. With high physiological adaptability, cyanobacteria have evolved to survive with limiting resources which have proved highly successful in allowing them to occupy a niche in the pelagic zone of lakes (Vincent 2009) ^[22]. (Reynolds 1987; ^[18] Oliver and Ganf, 2000) ^[12] have reported that human beings are frequently responsible for the increased occurrences of cyano bacterial blooms by modifying the physical and biogeochemical conditions of aquatic systems. Phytoplankton are sensitive aquatic organisms and their community structure could reflect the eutrophic situation in a short time (Jing *et al.*, 2014) ^[9]. No previous comparative studies have been carried out on the cyanobacterial bloom dynamics in Dighalipukhuri and Dora *beel* in Assam. The study is aimed at assessing the cyanobacterial community composition and changes during transition from monsoon, 2020 to pre-monsoon season 2021, in the above mentioned study sites. So, the aim of this study was to analyse the ecology of cyanobacterial bloom dynamics in Dighalipukhuri and Dora *beel* in Assam with respect to water parameters which will help in providing baseline data on the knowledge of the phytoplankton assemblages in the lentic ecosystem.

Materials and Methods

Study Area

The present study has been conducted in two study sites - Dighalipukhuri and Dora *beel* in Kamrup district of Assam (Fig. 1). Dighalipukhuri is a rectangular artificial pond situated in Guwahati, originally supposed to have been dug out from the Brahmaputra. Its co-ordinates are 26°11'15''N and 91°45'4''E. It lies in the heart of the city of Guwahati. The other study site is Dora *beel* towards the southern part of the Kamrup district in Assam. Its co-ordinates are 26°53'76''N latitude and 91°2'99''E longitude. It is located near Kukurmara, Palashbari Revenue Circle, Kamrup district. The *beel* is very rich in biotic communities.

Water sampling and analysis of physico-chemical parameters of water

Replicates of water samples were collected from different sampling locations by point sampling method (also known as Grab sampling) for studying different physico-chemical characteristics. Water samples were collected in three replicates from five different sites and mean values of all three observations were taken into consideration. Samplings were done on a seasonal basis (winter and pre-monsoon) from selected sites and continuous monitoring for algal blooms was carried out during the study period i.e. winter and pre monsoon season. The selection of stations was made on the basis of the previous occurrence of algal blooms. The terms WIN and PRM are used to represent winter and pre-monsoon respectively. The physico-chemical parameters such as pH, temperature, conductivity and TDS were studied in the field itself. Samples for other parameters like DO, BOD, nitrogen (NO₃-N), phosphorus (PO₄³⁻-P), Total Nitrogen and Total Phosphorus were brought to the laboratory for further analysis following the standard methods (Baird *et al.*, 2017) ^[1]

Collection of bloom algae

Algae samples were collected from five sampling points that were at a distance apart from each other. The sampling points were mainly based on the anthropogenic activities such as fishing, bathing, washing, defecating, waste disposal and household sewage that are discharged directly into the water body. The sampling points were assigned as I, II, III, IV and V. The sampling was done at approximately the same time of day each time, preferably in the morning. This is because the algae move up in the water towards the surface in the morning and tend to sink to lower regions in the afternoon. Replicate samples were collected and the data was averaged.

Sampling of bloom algae

Bloom algae samplings were done from the water surface wherever a visible appearance of the bloom was observed. Sampling of the bloom was done by moving the sample bottle through the surface of the scum. They were then put in an ice box for transfer to the laboratory for further study.

Phytoplankton study and identification

For the study of the algal samples, they were fixed in Lugol's iodine solution immediately after collection. This is one of the most widely recommended preservative. A larger proportion of Lugol's solution is required for field samples wherein 10 drops of Lugol's solution was added per 200 ml of sample or until the appearance of weak colour of tea. (Lugol's is made by dissolving 100g Potassium Iodide (KI) in 1L of distilled water, then 50 g crystalline iodine (I₂) is dissolved in this solution and then 100 ml of glacial acetic acid is added). Identification of phytoplanktons was carried out following the monographs of Tiffany and Britton (1952)^[13]; Desikachary (1959)^[6]; Smith, G. (1951)^[20], Fritsch (1945)^[8] and Davis (1955)^[5]. Classification was done by algaebase.org.

Results and Discussion

Analysis of the Physico-chemical parameters

After analysis of the physico-chemical parameters it was found that all the parameters varied in both the seasons and the study sites as well (Table 1). Water temperature is one of the critical factors for *Microcystis* development during the whole annual cycle (Reynolds *et al.* 1981 ^[17]; Wu *et al.* 2010) ^[25]. Temperature is especially important for buoyancy regulation. Temperature was found to increase from 19.06°C in winter to 25.86°C in the pre-monsoon in Dighalipukhuri which is located in the heart of the city. Similarly, Dora *beel* too showed an

increasing trend through winter to pre monsoon. pH was alkaline in nature in both the study sites. The maximum pH recorded was 7.87 in Dighalipukhuri in the winter season and the minimum was recorded at 7.26 respectively. Total Dissolved Solids was highest in Dighalipukhuri at a level of 164.05mg/L and the lowest was recorded in the same study site at a level of 137.15mg/L. Dissolved oxygen was highest in Dighalipukhuri at 9.21mg/L in winter. Dora *beel* also recorded a high DO at 8.72mg/L in the same season. One of the crucial factors influencing different stages of formation of cyanobacterial colonies is oxygen concentration in the main waterbody (Caceres and Reynolds, 1984^[3]; Trimbee and Harris, 1984)^[21]. Biological oxygen demand too shows a similar trend as dissolved oxygen. Dora *beel* recorded a minimum of 4.14mg/L in the pre-monsoon season and a highest value of 4.90mg/L during the winter season. Nitrate-nitrogen was quite high at 1.11mg/L in Dighalipukhuri during the pre-monsoon season and it showed a minimum of 0.74mg/L in winter. However Dora *beel* recorded a maximum of 0.89mg/L in pre monsoon season and it showed a minimum of 0.57mg/L in winter season. Phosphorus is widely accepted as the main nutrient controlling the development of natural populations of cyanobacteria in many freshwater environments. The main sources of Phosphorus for *Microcystis* sp. species are orthophosphates, but they can also use organic forms. Phosphorus was recorded at 0.08mg/L in both the study sites during the pre-monsoon season. Whereas the minimum level was recorded at 0.03mg/L in Dora *beel*. Total Nitrogen is another important water quality characteristic responsible for lush growth of algae. Maximum values were recorded at Dighalipukhuri as 2.64mg/L in winter whereas the minimum was recorded at 0.61mg/L in the pre-monsoon season. A field investigation (Wu *et al.* 2010)^[25] of the seasonal dynamics of *M. aeruginosa* indicated that total P, total N and transparency are important correlative factors influencing its succession. Total Phosphorus was highest at 2.46mg/L in Dighalipukhuri in the winter season and there is a huge difference with its minimum in pre monsoon season. Dora *beel* recorded a maximum of 0.08mg/L in pre monsoon and 0.05mg/L in winter.

Table 1: Water quality parameters from the two experimental study sites during the study period.

Water Parameters	Code	Dighalipukhuri		Dora <i>beel</i>	
		Winter, 2020	Pre Monsoon, 2021	Winter, 2020	Pre Monsoon, 2021
Temperature (°C)	Tem	19.06 ± 0.42	25.86 ± 0.26	20.00 ± 0.42	25.82 ± 0.26
pH	pH	7.87 ± 0.20	7.28 ± 0.12	7.40 ± 0.08	7.26 ± 0.06
Conductivity (µS/cm)	Con	152.20 ± 5.30	160.40 ± 2.58	151.27 ± 7.69	158.40 ± 4.41
TDS (mg/L)	TDS	137.15 ± 2.54	164.05 ± 3.22	148.15 ± 3.44	156.22 ± 3.48
DO (mg/L)	DO	9.21 ± 0.32	8.10 ± 0.24	8.72 ± 0.38	7.19 ± 0.27
BOD (mg/L)	BOD	5.13 ± 0.22	4.57 ± 0.35	4.90 ± 0.34	4.14 ± 0.26
Nitrate [NO ₃ -N] (mg/L)	NO	0.74 ± 0.04	1.11 ± 0.12	0.57 ± 0.07	0.89 ± 0.06
Orthophosphate [PO ₄ ³⁻ -P] (mg/L)	PO	0.05 ± 0.02	0.08 ± 0.02	0.03 ± 0.01	0.08 ± 0.02
Total Nitrogen (mg/L)	TN	2.64 ± 3.71	1.18 ± 0.15	0.61 ± 0.08	0.94 ± 0.11
Total Phosphorus (mg/L)	TP	2.46 ± 4.80	0.09 ± 0.01	0.05 ± 0.01	0.08 ± 0.02

Comparative analysis of the cyanobacterial members in the bloom (season wise)

Table 2 and 3 show the list of species composition and distribution in Dighalipukhuri and Dora *beel* in both the seasons. From the Table 2 and 3 it is observed that cyanobacterial phytoplanktons are more in numbers during the pre-monsoon season in both the study sites as compared to the winter season. This can be correlated with increase in temperature during the pre-monsoon season (Reynolds *et al.* 1981^[17]; Wu *et al.* 2010)^[25]. A total of 9 species is found to occur in Dighalipukhuri during the pre-monsoon season. In Dora *beel* however only two cyanobacterial members make its appearance in the total bloom composition during the winter season.

Table 2: List of species of the cyanobacterial members in the bloom in Dighalipukhuri (Season wise)

Sl. No.	Winter, 2020	Pre Monsoon, 2021
1	<i>Microcystis aeruginosa</i>	<i>Microcystis aeruginosa</i>
2	<i>Microcystis pseudofilamentosa</i>	<i>Microcystis flos-aquae</i>
3	<i>Microcystis robusta</i>	<i>Microcystis ramose</i>
4	<i>Microcystis smithii</i>	<i>Anabaena sphaericus</i>
5	<i>Lyngbya major</i>	<i>Anabaena variabilis</i>
6	<i>Oscillatoria tenuis</i>	<i>Anabaena planktonica</i>
7	----	<i>Oscillatoria pseudofilamentosa</i>
8	----	<i>Nostoc muscorum</i>
9	----	<i>Lyngbya versicolor</i>

Table 3: List of species of the cyanobacterial members in the bloom in Dora *beel* (Season wise)

Sl. No.	Winter, 2020	Pre Monsoon, 2021
1	<i>Microcystis robusta</i>	<i>Microcystis aeruginosa</i>
2	<i>Microcystis pseudofilamentosa</i>	<i>Microcystis flos-aquae</i>

3	----	<i>Microcystis smithii</i>
4	----	<i>Lyngbya connectens</i>

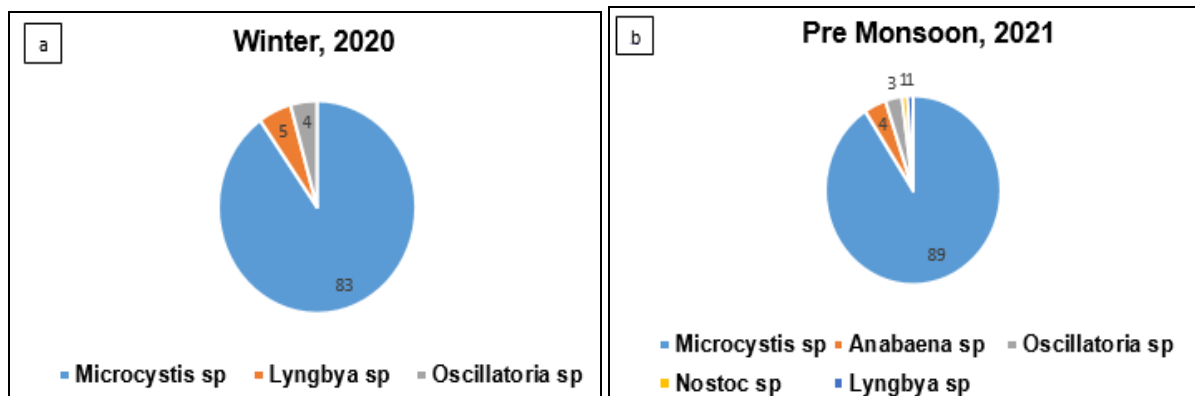


Fig 1 (a-b): Distribution of Cyanobacterial members in the bloom in Dighalipukhuri (Genus and Season wise)

Table 4: Proportion of the cyanobacterial members in the bloom

Dighalipukhuri	
Winter, 2020	Pre-Monsoon, 2021
Proportion of individual species	Proportion of individual species
<i>Microcystis aeruginosa</i> (75%)	<i>Microcystis aeruginosa</i> (82%)
<i>Microcystis pseudofilamentosa</i> (4%)	<i>Microcystis flos-aquae</i> (4%)
<i>Microcystis robusta</i> (3%)	<i>Microcystis ramose</i> (3%)
<i>Microcystis smithii</i> (1%)	<i>Anabaena sphaericus</i> (2%)
<i>Lyngbya major</i> (5%)	<i>Anabaena variabilis</i> (1%)
<i>Oscillatoria tenuis</i> (4%)	<i>Anabaena planktonica</i> (1%)
----	<i>Oscillatoria pseudofilamentosa</i> (3%)
----	<i>Nostoc muscorum</i> (1%)
----	<i>Lyngbya versicolor</i> (1%)

The genus *Microcystis* makes the highest contribution in the bloom in both the study sites in both the seasons. *Microcystis* colonies float up into the higher irradiance near the water surface (Visser *et al.* 2005) [23]. In Dighalipukhuri its contribution is 89% in pre monsoon and 83% in winter [Fig 1 (a & b)]. Table 4 and 5 shows the individual proportion of species where it is observed that *Microcystis aeruginosa* is the most dominant and abundant cyanobacterial algae to make its presence in both the study sites in both the seasons except in winter in Dora beel. *Microcystis aeruginosa* alone makes up 82% of the population in Dighalipukhuri during pre-monsoon season. The total cell count of the bloom is 1.5×10^4 cells/ml during this season in Dighalipukhuri. However, *Microcystis smithii* comprises 1% of the total number in the population in the same study site during winter season. Fig.1 & 2 (a & b) shows the proportion of the cyanobacterial members in the bloom genus wise. It is seen from the Fig.2 (a & b) that *Oscillatoria* as a genus makes a fair presence at 14% in Dora beel during winter whereas it is 4% in Dighalipukhuri during the pre-monsoon season. The total cell count of the bloom is 1.03×10^4 cells/ml in Dora beel during winter. Table 5 shows that *Microcystis robusta* (44%) has the highest share in the genus *Microcystis* in the winter season. *Lyngbya connectens* (9%) has the smallest proportion amongst all the cyanobacterial members in the bloom.

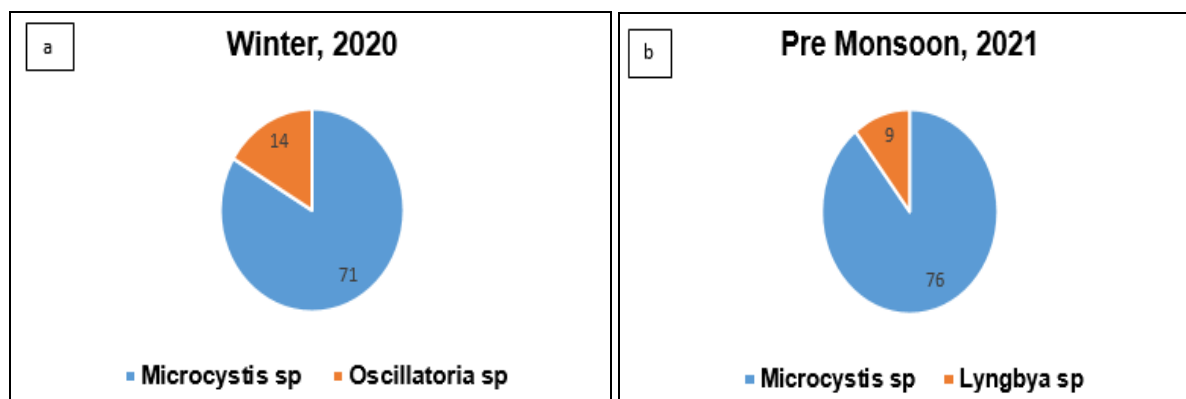


Fig 2 (a-b): Distribution of Cyanobacterial members in the bloom in Dora beel (Genus and Season wise)

Table 5: Proportion of the cyanobacterial members in the bloom

Dora Beel	
Winter, 2020	Pre-Monsoon, 2021
Proportion of individual species	Proportion of individual species
<i>Microcystis robusta</i> (44%)	<i>Microcystis aeruginosa</i> (39%)
<i>Microcystis pseudofilamentosa</i> (27%)	<i>Microcystis flos-aquae</i> (24%)
<i>Oscillatoria princeps</i> (8%)	<i>Microcystis smithii</i> (13%)
<i>Oscillatoria acutissima</i> (6%)	<i>Lyngbya connectens</i> (9%)

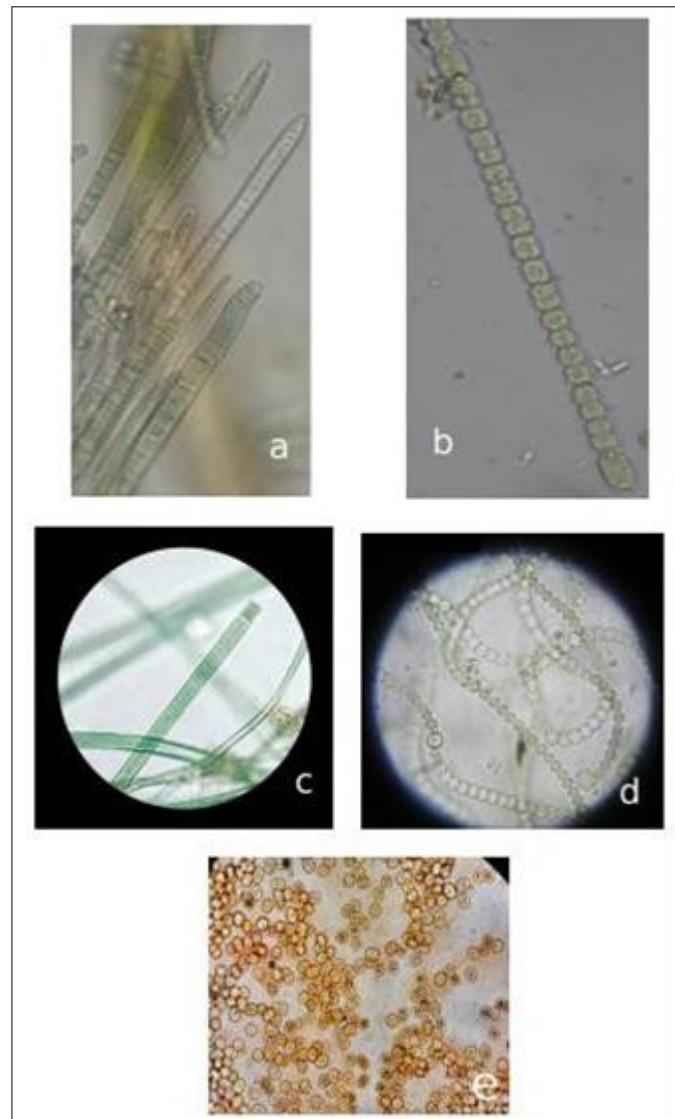


Fig 3: Microscopic view of cyanobacteria (a - e). (a) *Oscillatoria acutissima* (b) *Anabaena sphaericus* (c) *Lyngbya connectens* (d) *Nostoc muscorum* (e) *Microcystis aeruginosa*

Conclusions

The present study revealed the cyanobacterial diversity and its share in the total algal bloom in the respective study sites. This group of phytoplanktons possess a number of key attributes that enable them to be able to accumulate in large concentrations and form surface blooms under certain specific conditions. Dighalipukhuri showed the maximum diversity of the cyanobacterial population as compared to Dora beel. Dighalipukhuri which is affected by pollution and sewage has recorded a high temperature in pre monsoon which favours growth of the *Microcystis* genus (Wu *et al.* 2010) [25]. Temperature is especially important during renewed activity in the spring (Caceres and Reynolds 1984) [3]. This maybe an indication of shift towards eutrophication in the said study site. The study sites showed higher pre monsoon densities of cyanophytes with rise in temperature from winter to pre monsoon (Wu *et al.* 2010) [25]. Interest in the genus has increased with the eutrophication of many freshwaters and the problems associated with increases in *Microcystis* growths. It can be summarized from the above study that there can be seen seasonal variations in the cyanobacterial community within the total bloom of the lentic ecosystem of Dighalipukhuri and Dora beel. Further studies is necessary to predict changes within and between cyanobacterial species and other phytoplankton. It can be concluded from

this study that an understanding of how altered environmental conditions with respect to seasonal changes can enhance the development of cyanobacterial blooms should be undertaken in different lentic ecosystems in Kamrup district of Assam.

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