Article

Cyanobacterial diversity in different sites and seasons of Gossaigaon Subdivision, Assam, India

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Abstract
The present study was carried out of cyanobacterial distribution in three different selected sites of Gossaigaon subdivision, BTR, Assam, India, during June 2015 - July 2016 covering four different seasons only in aquatic environment. Altogether 92 species, belonging to 34 genera and 10 families were found. The maximum number of species was recorded from the family Nostocaceae with 25 species. Among these 42 were simple non-heterocystous, 50 were heterocystous filamentous. Among non-heterocystous forms 36 species were unicellular colonial forms. Studies say habitats have distinct cyanobacterial microflora, but the different sites in different geographical regions evidently fluctuate in their diversity as well as in local climatic conditions. Cyanobacteria can be used for practical purposes in different ways. Even in many countries, cyanobacteria are harvested locally from lake, pond and river to use in different purposes.

Keywords Cyanobacteria; diversity; extreme habitat; Gossaigaon subdivision.

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1 Introduction

Cyanobacteria are the simplest forms among all other plant groups of Algae. These are ubiquitous and widely distributed all over the world. They can present in extreme habitats, i.e., they are ecologically adaptable in any kind of environment. In case occurrence among all types of algae cyanobacteria has the maximum adaptability and resistance for survival in different types of environment. They can easily survive in different habitats. They are very comfortable and have the ability to exist in adverse condition too. Many BGA found to be occurred in hot springs, such as *Chroococcus*, *Microcystis*, *Oscillatoria*, *Phormidium*, *Plectonema* and *Scytonema* (Presscott, 1969). Cyanobacteria have vast possibilities towards the humanity in many ways at present time. They are being used as biofertilizer in agriculture since very days back (Whitton, 2000). Due to advancement of science and technologies many new fields on the basis of cyanobacteria for the human welfare have also gained a lot of attention in recent years. These can be used as food and animal feed, in bioremediation of toxic compounds, in biocontrol of pests, production of commercial and laboratory chemicals, restriction enzymes, pharmacological tools (Patterson, 1996) and drugs for the treatment of many risky diseases such as cancer, asthma, diabetes, and wastes treatment (Prassana et al., 2000; Shah et al., 2001; Sadettin and Domez, 2006).

In India there have done many works on this particular algae (Gupta and Kulkarni, 2016; Sao and Samuel, 2018; Saikia et al., 2018; Wagh and Jadhav, 2019; Rajkonwar et al., 2020; Dev et al., 2013). North east India is also very unique location for the diversity in different levels. Many studies were done on cyanobacterial flora from different agricultural and other ecosystems in different parts of India (Nayak and Prasanna, 2007; Dasgupta and Ahmed, 2013; Singh et al., 2014). In Assam, a number of studies have been undertaken on the mere enumeration of blue green algae in different parts of Assam by different worker (Nandi and Rout, 2000; Deb et al., 2013; Borah et al., 2014; Devi, 1981; Deka and Bordoloi, 1991; Saikia and Bordoloi, 1994; Ahmed, 1999; Yashmin, 2003; Rout and Borah, 2009). So, it is clear that, systematic investigations on cyanobacterial algae from this part of western Assam is limited.

2 Study Area and Methodology

2.1 Study area

The present study area is Gossaigaon subdivision, under Kokrajhar district of state Assam, which lies in the foot hill of eastern Himalaya. Phytogeographically Gossaigaon subdivision has a total geographical area of 1287.70 sq km. It is situated at the latitude of 26.4371° N and longitude 89.9767° E. The subdivision shares its boundaries with the state West Bengal on the west, Dotama on the east, Dhubri on the south west. The north is covered by Bhutan which is an important international border. Its total forest areas are 82412.357 hectares. Out of this the total wet land is 93 hectares including ponds. The total rivers in Gossaigaon subdivision are mainly three Sonkosh, Gurfela and Hel. But there are some small tributaries and streams which are flowing from Bhutan.

For the details study the entire area were divided into three sampling sites:

Sampling Site 1: Gossaigaon (including town area)

Sampling Site 2: Grahampur

Sampling Site 3: Saraibil

2.2 Sample collection

The algal samples were collected randomly from different habitats,in different seasons such as winter, spring, summer and autumn during last four years (2014-2017). Planktonic net (Mesh size 25 µm) were used to collect floating members. Soil samples were collected from soil surface. About 10 grams of soil samples were collected from different places of the same sampling site to a depth of 5 cm using sharp knife, scalpel and hand hoe, because algae cannot grow beyond 5cm below the surface of the soil (Sing, 1961). The collected soil samples were dried in shade then powdered. After thorough mixing, about 100 gms of each sample were preserved in polythene bags for isolation.

2.3 Identification

After preliminary observations the algal samples were identified with the help of recent literature and monographs of Desikachary (1959), Fritsch (1936), Geitler (1932), and Prescott (1984).

2.4 Water physico-chemical analysis

Water pH, Nitrate-N (NO_3-N), was determined following standard methods (phenol disulfonic acid method) outlined by Anderson and Ingram (1993). Available phosphorus and potassium was determined by using the molybdenum blue method (Allen et al., 1974). Water Dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical oxygen Demand (COD) were measured by azide modification method (APHA, 2005) (Table

1). Diversity of species was analyzed for relative abundance, diversity index of species (Shannon-Weaver, 1964), and similarity coefficient (Sorensen, 1948).

2.5 Statistical analysis

All the data collected were statistically analyzed to compare temporal and spatial variations among different sites, habitats, seasons etc. One way ANOVA, Correlation analysis etc. were done by the methods given by Zar (1974).

3 Results and Discussion

Total of 92 species belongs to 34 genera under 9 families were found in the study, where 50 species were heterocystous and 42 species were non heterocystous forms. The maximum number of species was recorded from the family Nostocaceae with 25 species. Variations in physico-chemical parameters (such as PH, BOD, DO, COD, Nitrate etc.) of water in different seasons were found (Table 1). The ranges of different water parameters were pH 6.44±0.2 - 6.85±0.25; BOD 4.39±0.48 - 5.8±0.22; COD 13.13±1.0 - 14±0.77; DO 3.85±0.35 - 4.65±0.44; Nitrate 2.25±0.85 - 2.93±1.28; Phosphate 2.1±0.57 - 3.53±0.55; Potassium 3.15±0.39 - 4.45±0.64 and temperature ranges 22.0±1.63 - 29.77±1.71 respectively. Correlation analysis among the seasons for different species at three sites viz. Site I (Gossaigaon), Site II (Grahampur), Site III (Saraibil) were carried out (Table 4). In site I (Gossaigaon), spring has negative correlation with autumn ($r=-0.233^{*}$, $P>0.05$) Summer had negative correlation with winter ($r=-0.207$, $P>0.05$) but positive correlation with winter ($r=0.385^{**}$, $P>0.01$) of site II and autumn ($r=0.294^{**}$, $P>0.01$) of site III. Autumn of site I has significant correlation with winter ($r=0.385^{**}$, $P>0.01$) of site II. The winter of site II has correlation with autumn ($r=0.355$, $P>0.01$) of site III. The spring season of site I has strong correlation with summer ($r=0.321$, $P>0.01$) of site III.

Linear regression analysis was conducted between the population of cyanobacteria and mean of different water parameters in three different study sites (Fig. 1). It was observed that in Site I (Gossaigaon) the linear regression showed positive significance of mean total algal species count with mean pH ($r^2=0.0043$), mean DO ($r^2=0.4847$), mean phosphate ($r^2=0.466$), mean potassium ($r^2=0.0418$) and negative significance of mean BOD ($r^2=0.5799$), mean nitrate ($r^2=0.0071$) and mean temperature ($r^2=0.0782$). In site II (Grahampur), the linear regression were positive significance of mean total algal species count with mean pH ($r^2=0.3338$), mean DO ($r^2=0.2376$), mean potassium ($r^2=0.5857$) and negative significance of mean BOD ($r^2=0.0949$), mean COD ($r^2=0.1804$), mean nitrate ($r^2=0.8499$), mean temperature ($r^2=0.135$) respectively. The linear regression showed positive significance of mean total algal counts with mean pH ($r^2=0.0415$) mean nitrate ($r^2=0.0437$) and negative significance of mean total algal count with mean BOD ($r^2=0.0896$), mean COD ($r^2=0.0364$), mean DO ($r^2=0.0984$), mean phosphate ($r^2=0.4283$), mean potassium ($r^2=0.479$) in Site III (Saraibil). The parameters like mean phosphate ($r^2=0.000$ in site II (Fig. 2) and mean temperature ($r^2=0.000$) in Site III (Saraibil) has not shown any significance.

During the study period the relative abundance, diversity index, species richness and Simpson index of dominance were also calculated in three study sites taking four different seasons (Table 3). Relative abundance of different species is different. *Microcystis flos-aquae* recorded highest relative abundance (4.87%) and *Spirulina meneghiniana* and *Oscillatoria princeps var. crassa* lowest 0.29% (Table 2). During study period the highest number of species recorded during retreating monsoon in all study sites (Table 2, Gossaigaon 632, Grahampur 453 and Saraibil 593) and lowest (157 species) recorded during pre-monsoon in Saraibil. Among different study site it was observed that highest 1726 species was found in Gossaigaon and lowest 1064 species in Grahampur.

In Gossaigaon, the species abundance was ranged between 255-632, minimum during spring and maximum in autumn. Species richness was ranged between 14-30, minimum was found during winter and maximum in autumn. Shannon-Weiner index (H) was ranged between 2.52-3.25 minimum 2.52 in winter and maximum during autumn. Simpson index of dominance (D) was ranged between 0.04-0.09, maximum during winter, minimum in autumn. Simpson's index of diversity was ranged between 0.91-0.96, maximum in autumn and minimum in winter respectively.

In Grahampur, maximum species abundance was recorded 543 during autumn and minimum 190 in winter. Species richness was found maximum 19 in summer and minimum 9 in spring. Shannon-Weiner index (H) recorded maximum 2.88 in autumn and minimum 2.11 in spring. Simpson index of dominance (D) was recorded maximum (0.13) in spring and winter season, minimum (0.06) in both summer and autumn respectively. Simpson's index of diversity was maximum (0.94) both in summer and autumn, minimum (0.87) both in spring and winter respectively. However, species richness was ranged between 9-21, minimum during spring and maximum in autumn.

During the study period it was observed that the species abundance was maximum in 593 during autumn and minimum during spring season in Saraibil. Species richness was maximum 24 during autumn and minimum 9 in spring season, the Shannon-Weiner index (H) was recorded maximum 3.07 in autumn and minimum 2.08 in spring season. Simpson index of dominance (D) was ranged between 0.05-0.14, maximum during spring, minimum in autumn. Simpson's index of diversity was maximum 0.95 in autumn, minimum 0.86 both in spring. Species richness was ranged between 9-24, minimum during spring and maximum in autumn.

Table 1 Physico-chemical parameters of water samples collected from different study sites during different seasons.

Site	Seasons	pH	BOD (mg/l)	COD (mg/l)	DO (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Potassium (mg/l)	Temperature (C°)
Gossaigaon	Spring	6.73±0.15	5.53±0.68	13.13±1.00	4.35±0.29	2.5±0.28	2.48±1.02	3.78±0.46	28.5±1.73
	Summer	6.85±0.24	4.39±0.48	13.15±0.41	4.4±0.29	3.0±0.98	3.53±0.55	4.45±0.64	25.5±0.58
	Autumn	6.7±0.22	4.81±0.30	13.23±0.79	4.5±0.55	2.43±0.9	2.68±0.65	3.53±0.51	24.75±0.96
	Winter	6.78±0.32	4.98±0.70	13.35±0.51	3.88±0.36	2.93±1.28	2.2±0.43	3.75±0.66	23.5±1.29
Grahampur	Spring	6.71±0.18	5.35±0.93	14±0.50	4.4±0.29	3.9±0.37	3.48±0.41	4.13±0.29	28.75±3.10
	Summer	6.72±0.28	4.58±0.39	13.35±0.75	4.65±0.44	2.85±0.61	2.63±0.70	4.25±0.17	25.5±1.29
	Autumn	6.85±0.25	5.40±0.55	13.78±0.60	4.38±0.57	2.25±0.84	2.73±1.34	4.23±0.22	23.75±0.43
	Winter	6.8±0.57	5.80±0.22	13.9±0.59	4.15±0.13	3.23±0.69	2±0.87	4±0.16	23±0.82
Saraibil	Spring	6.44±0.20	5.35±0.44	13.73±0.41	4.55±0.40	2.6±0.97	2.73±0.19	3.48±0.75	29.75±1.71
	Summer	6.7±0.29	4.95±0.37	14.3±0.77	4.43±0.15	3.53±0.66	2.23±0.56	3.33±0.21	26±0.82
	Autumn	6.63±0.53	5.35±0.53	13.3±0.35	4±0.57	2.73±0.94	2.1±0.57	3.15±0.39	26.5±1.29
	Winter	6.78±0.21	5.63±0.59	13.4±0.22	3.85±0.35	2.73±0.88	2.15±0.83	4.1±0.08	22±1.63

Table 2 Occurrence and distribution of blue green algal species number (ml^{-1}) in different sites.

No.	Species	Family	**Site I** (Gosaigaon)				**Site II** (Grahampur)				**Site III** (Saraibil)				Total	RA
			Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win		
1	*Microcystis aeruginosa*	Chroococcaceae	-	45	-	-	20	-	-	-	-	-	-	-	65	1.54
2	*Microcystis flos-aquae*	Chroococcaceae	-	45	50	-	-	-	-	50	-	-	60	-	205	4.87
3	*Chroocuccus macrococcus*	Chroococcaceae	-	8	14	-	-	-	2	-	-	-	-	-	24	0.57
4	*Chroococcus pallidus*	Chroococcaceae	10	2	-	-	8	-	3	-	20	-	-	-	43	1.02
5	*Chroococcus varius*	Chroococcaceae	-	-	-	-	-	-	-	-	-	9	16	-	25	0.59
6	*Gloeocapsa atrata*	Chroococcaceae	-	6	20	-	-	-	-	-	-	25	-	-	51	1.21
7	*Gloeocapsa montana*	Chroococcaceae	-	-	-	-	-	-	-	-	-	30	-	12	42	1
8	*Gloeocapsa polydermatica*	Chroococcaceae	9	-	-	-	-	-	-	-	15	-	-	-	24	0.57
9	*Gloeocapsa punctata*	Chroococcaceae	-	-	-	-	-	20	-	-	-	-	12	-	32	0.76
10	*Gloeothece samoensis*	Chroococcaceae	-	-	30	-	-	-	25	-	-	-	-	-	55	1.31
11	*Gloeothece samoensis var. major*	Chroococcaceae	-	-	10	-	-	-	-	-	-	-	15	-	25	0.59
12	*Aphanocapsa crassa*	Chroococcaceae	-	-	-	-	-	-	-	10	-	-	20	-	30	0.71
13	*Aphanocapsa koordersi*	Chroococcaceae	-	24	-	-	-	-	-	-	-	-	20	-	44	1.05
14	*Aphanothece microscopica*	Chroococcaceae	-	30	-	-	-	28	-	-	-	-	40	-	98	2.33
15	*Aphanothece stagnina*	Chroococcaceae	-	38	-	-	-	-	-	-	38	55	-	-	131	3.11
16	*Aphanothececa stagnei*	Chroococcaceae	-	-	35	-	-	-	-	-	-	-	-	-	35	0.83
17	*Synechococcus aeruginosus*	Chroococcaceae	40	24	-	-	-	-	-	-	-	-	26	-	90	2.14
18	*Synechococcus elongatus*	Chroococcaceae	12	-	-	-	-	-	-	13	-	-	-	-	25	0.59
19	*Synechosystis aquatilis*	Chroococcaceae	23	-	-	-	-	-	-	-	-	-	-	-	23	0.55

20	*Gomphosphaeria aponina*	Chroococcaceae	-	-	38	-	-	-	-	-	-	-	-	40	78	1.85
21	*Myxosarcina burmensis*	Pleurocapsaceae	-	38	-	-	-	-	45	20	-	-	32	-	135	3.21
22	*Hydrococcus rivularis*	Hyellaceae	30	-	-	-	-	-	-	-	-	28	-	-	58	1.38
23	*Spirulina meneghiniana*	Oscillatoriaceae	-	12	-	-	-	-	-	-	-	-	-	-	12	0.29
24	*Spirulina subtilissima*	Oscillatoriaceae	-	-	8	-	-	-	-	6	-	-	-	-	14	0.33
25	*Oscillatoria annae*	Oscillatoriaceae	8	-	-	-	-	-	-	-	-	-	-	8	16	0.38
26	*Oscillatoria acuta*	Oscillatoriaceae	4	-	-	-	-	12	-	-	-	-	-	8	24	0.57
27	*Oscillatoria formosa*	Oscillatoriaceae	-	-	-	10	-	8	-	5	-	-	-	-	23	0.55
28	*Oscillatoria limosa*	Oscillatoriaceae	10	12	-	-	-	-	-	20	16	-	-	14	72	1.71
29	*Oscillatoria ornate var. crassa*	Oscillatoriaceae	-	8	-		-	-	16	-	-	10	-	-	34	0.81
30	*Oscillatoria princeps var. crassa*	Oscillatoriaceae	-	8	-	-	-	-	-	-	-	15	-	-	23	0.55
31	*Oscillatoria splindida*	Oscillatoriaceae	-	-	-	-	-	12	-	-	-	-	-	-	12	0.29
32	*Phormedium retzii*	Oscillatoriaceae	-	12	-	-	-	21	10	-	-	-	14	11	68	1.62
33	*Phormedium tenue*	Oscillatoriaceae	-	-	6	-	-	-	-	-	9	20	-	-	35	0.83
34	*Lyngbya allorgei*	Oscillatoriaceae	-	-	-	-	-	-	-	-	-	-	25	-	25	0.59
35	*Lyngbya arboricola*	Oscillatoriaceae	-	-	12	-	-	14	-	-	-	-	-	20	46	1.09
36	*Lyngbya ceylanica*	Oscillatoriaceae	-	30	-	-	-	24	-	-	-	-	-	-	54	1.28
37	*Lyngbya majuscula*	Oscillatoriaceae	-	13	-	-	-	-	27	-	22	-	-	-	62	1.47
38	*Lyngbya martensiana var. calcarea*	Oscillatoriaceae	-	16	-	-	-	-	-	-	-	-	12	-	28	0.67
39	*Schizothrix lacustris*	Oscillatoriaceae	-	-	15	-	-	-	20	-	-	-	-	-	35	0.83
40	*Microcoleus acutissimus*	Oscillatoriaceae	-	-	23	-	-	-	-	-	-	-	48	-	71	1.69

41	*Microcoleus chthonoplastes*	Oscillatoriaceae	-	-	-	30	-	-	-	-	-	-	-	20	50	1.19
42	*Microcoleus subtorulosus*	Oscillatoriaceae	-	-	30	-	-	-	-	-	-	-	-	-	30	0.71
43	*Anabaenopsis arnoldii var. indica*	Nostocaceae	-	-	5	-	-	-	20	-	-	-	-	-	25	0.59
44	*Cylindrosperm um alatosporum*	Nostocaceae	-	26	-	-	-	-	-	-	-	-	-	-	26	0.62
45	*Cylindrosperm um michailovskoen se*	Nostocaceae	13	-	-	-	8	-	-	-	-	-	-	-	21	0.5
46	*Cylindrosperm umm uscicola*	Nostocaceae	-	23	-	-	-	-	21	-	-	-	-	-	44	1.05
47	*Cylindrosperm um muscicola var. kasmiriensis*	Nostocaceae	-	-	-	-	-	-	-	-	-	40	-	-	40	0.95
48	*Cylindrosperm um stagnale*	Nostocaceae	-	-	28	-	-	-	-	-	-	-	-	-	28	0.67
49	*Cylindrosperm um stagnale f. variabilis*	Nostocaceae	-	-	-	30	-	-	-	-	-	-	-	-	30	0.71
50	*Nostoc calcicola*	Nostocaceae	8	-	-	-	30	35	-	-	-	6	-	-	79	1.88
51	*Nostoc hatei*	Nostocaceae	-	20	25	-	36	-	24	-	-	13	27	-	145	3.45
52	*Nostoc linkia*	Nostocaceae	-	-	45	-	-	-	-	28	-	-	-	-	73	1.73
53	*Nostoc ellipsosporum*	Nostocaceae	10	-	-	-	-	26	-	-	-	-	-	9	45	1.07
54	*Nostoc punctiforme*	Nostocaceae	-	-	-	-	-	-	23	-	-	-	-	-	23	0.55
55	*Anabaena azollae*	Nostocaceae	8	-	12	13	-	-	-	4	-	10	-	12	59	1.4
56	*Anabaena circinalis*	Nostocaceae	-	-	20	14	-	-	18	-	-	-	-	-	52	1.24
57	*Anabaena doliolum*	Nostocaceae	-	15	-	-	-	-	-	-	-	-	-	-	15	0.36
58	*Anabaena fertilissima*	Nostocaceae	-	-	30	10	-	-	-	-	-	-	-	-	40	0.95
59	*Anabaena fuellibornii*	Nostocaceae	8	-	-	-	-	-	-	-	-	-	-	-	8	0.19
60	*Anabaena iyengarii*	Nostocaceae	-	-	14	-	-	9	-	-	-	-	-	9	32	0.76
61	*Anabaena*	Nostocaceae	-	-	10	-	-	-	-	15	-	27	-	-	52	1.24

	oscillarioides															
62	*Anabaena spiroides var. contracta*	Nostocaceae	-	-	-	-	21	12	-	-	-	18	-	-	51	1.21
63	*Anabaena unispora*	Nostocaceae	10	-	-	-	-	6	-	-	-	-	20	-	36	0.86
64	*Anabaena utermöhlii*	Nostocaceae	-	-	27	21	-	-	28	-	-	-	12	-	88	2.09
65	*Pseudanabaena schmidlei*	Nostocaceae	10	16	-	-	-	7	15	-	-	-	-	-	48	1.14
66	*Aulosira pseudoramosa*	Nostocaceae	-	-	20	-	-	-	-	-	-	-	26	-	46	1.09
67	*Scytonema bohneri*	Scytonematacea e	-	-	-	-	-	-	-	-	-	15	-	-	15	0.36
68	*Scytonema hofminni var. crassa*	Scytonematacea e	-	-	-	-	-	-	-	-	-	-	22	-	22	0.52
69	*Scytonema schmidtii*	Scytonematacea e	-	-	-	-	-	-	-	-	-	-	20	-	20	0.48
70	*Scytonema simplex*	Scytonematacea e	-	-	-	-	-	23	-	-	-	12	-	-	35	0.83
71	*Tolypothrix byssoidea*	Scytonematacea e	-	-	-	16	23	-	-	-		27	-	-	66	1.57
72	*Microchaete tenera*	Microchaetaceae	-	-	21	14	-	-	-	-	-	-	-	-	35	0.83
73	*Microchaete teneravar.tenui s*	Microchaetaceae	-	-	-	-	28	-	-	-	15	-	-	-	43	1.02
74	*Microchaete uberrima f. minor*	Microchaetaceae	-	-	-	-	19	-	-	-	-	-	-	18	37	0.88
75	*Calothrix brevissima*	Rivulariaceae	10	-	-	6	-	12	-	-	-	9	-	-	37	0.88
76	*Calothrix elenkinii*	Rivulariaceae	-	16	-	-	-	-	-	-	-	-	-	18	34	0.81
77	*Calothrix fusca*	Rivulariaceae	-	5	14	-	-	-	-	-	-	-	-	-	19	0.45
78	*Calothrix marchica*	Rivulariaceae	-	-	-	-	-	-	14	-	16	-	-	-	30	0.71
79	*Calothrix membranacea*	Rivulariaceae	-	-	6	-	-	-	9	-	-	-	-	-	15	0.36
80	*Calothrix parietina*	Rivulariaceae	6	-	-	-	-	15	-	-	-	-	-	-	21	0.5
81	*Calothrix wembaerensis*	Rivulariaceae	-	-	38	-	-	-	50	-	-	-	-	-	88	2.09
82	*Dichothrix*	Rivulariaceae	-	25	-	-	-	-	-	-	-	-	-	-	25	0.59

	gypsophila															
83	*Rivularia aquatica*	Rivulariaceae	-	-	8	23	-	22	-	10	-	-	23	10	96	2.28
84	*Rivularia beccariana*	Rivulariaceae	-	-	-	-	-	-	15	-	-	-	10	-	25	0.59
85	*Gloeotrichia echinulata*	Rivulariaceae	-	-	-	18	-	-	-	-	-	-	-	-	18	0.43
86	*Gloeotrichia intermediavar.kanwaensis*	Rivulariaceae	-	-	18	-	-	-	-	9	-	-	-	-	27	0.64
87	*Gloeotrichia natans*	Rivulariaceae	8	-	-	-	-	12	-	-	6	-	-	-	26	0.62
88	*Nostochopsis lobatus*	Nostochopsidaceae	10	-	-	43	-	-	39	-	-	-	40	-	132	3.14
89	*Hapalosiphon hibernicus*	Stigonemataceae	-	18	-	-	-	-	29	-	-	-	-	-	47	1.12
90	*Westiellopsis prolifica*	Stigonemataceae	-	-	-	20	-	-	-	-	-	-	26	-	46	1.09
91	*Stigonema informe*	Stigonemataceae	-	24	-	-	-	-	-	-	-	-	-	-	24	0.57
92	*Stigonema mamillosum*	Stigonemataceae	8	12	-	-	-	-	-	-	-	-	27	-	47	1.12
	Total		255	571	632	268	193	318	453	190	157	369	593	209	4208	

Spr=Spring, Sum=Summer, Aut =Autumn, Win=Winter, RA=Relative abundance.

Table 3 Species richness, abundance and diversity indices.

Location	Seasons	No. of individuals (N) (Species abundance)	Species richness	Diversity index			Evenness (E)
				Shannon (H)	Simpson's dominance (D)	Simpson's diversity (1-D)	
Gossaigaon (Site I)	Spring	255	21	2.87	0.07	0.93	0.84
	Summer	571	29	3.20	0.05	0.95	0.85
	Autumn	632	30*	3.25*	0.04*	0.96*	0.86
	Winter	268	14	2.52*	0.09	0.91	0.89
	Spring	193	9*	2.11	0.13	0.87	0.91*
Grahampur	Summer	318	19	2.84	0.06	0.94	0.90
(Site II)	Autumn	543	21	2.88	0.06	0.94	0.85
	Winter	190	12	2.23	0.13	0.87	0.78
	Spring	157	**9***	2.08	**0.14***	0.86	0.89
Saraibil	Summer	369	18	2.73	0.08	0.92	0.85
(Site III)	Autumn	593	24	3.07	0.05	0.95	0.90
	Winter	209	14	2,52	0.09	0.91	0.89

Table 4 Correlation among the seasons for different species at three sites viz. Site I (Gossaigaon), Site II (Grahampur), Site III (Saraibil).

Site/seasons		Gossaigaon (Site-I)				Grahampur (Site-II)				Saraibil (Site-III)			
		Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Gossaigaon	Spring	1	-.034	-.233*	-.032	-.027	.031	-.107	-.034	.031	.006	.029	-.042
	Summer	-	1	-.071	-.207*	.061	-.006	.113	.290**	.165	.041	.294**	-.111
	Autumn	-	-	1	-.007	-.056	-.204	.147	.385**	-.159	-.112	.138	.098
	Winter	-	-	-	1	-.039	-.049	.155	-.044	-.109	-.065	.145	.084
Grahampur	Spring	-	-	-	-	1	.130	-.009	-.090	.067	.140	-.034	-.024
	Summer	-	-	-	-	-	1	-.166	-.081	-.114	-.068	.026	.096
	Autumn	-	-	-	-	-	-	1	-.005	.018	-.140	.110	-.150
	Winter	-	-	-	-	-	-	-	1	-.001	-.051	.358**	-.001
Saraibil	Spring	-	-	-	-	-	-	-	-	1	.321**	-.151	-.040
	Summer	-	-	-	-	-	-	-	-	-	1	-.168	-.064
	Autumn	-	-	-	-	-	-	-	-	-	-	1	-.135
	Winter	-	-	-	-	-	-	-	-	-	-	-	1

* denotes Correlation is significant at the 0.05 level (2-tailed).

** denotes Correlation is significant at the 0.01 level (2-tailed).

They also varied their number in different habitats such as pond, pool, streams, river, paddy field etc. most of the species found in ditches/pool and minimum species number was recorded from stream/river habitat. Ditches/pool is narrow depth water bodies found near to the roads, households, agricultural lands. Maximum occurrence of algae in theses pools might be due to excess amount of nutrients which came from the agricultural lands or households. Similar results from little-known habitats in tropical regions are place of high diversity and even led to discoveries of new taxa (Sant'Anna et al., 2011; Dadheech et al., 2014; Hašler et al., 2014; Dvořák et al., 2015). Many authors such as Neustupa and Škaloud (2010) found that tropical habitats posses higher diversity than corresponding temperate habitats. From there it was clear that the microhabitat conditions, characteristically humidity and light, may have an important role on determining algal and cyanobacterial diversity. However, minimum species in streams/river may be due to maximum current/flow of water and unfavorable factors the growth and population of algae.

Algae species diversity varied in different seasons in different sites and habitats as well. In all the seasons algae were found but autumn season found most favorable for algal growth among three sites. Spring season was the least favorable for algal population except site I. this might be due to the autumn best suits the growth. Temperature, humidity, nutrients during this season was the best for the species. Similar studied reported by Prasad (1970-1983) on the algae of Andaman and Nicobar Islands.

In aquatic habitats, the environmental factors of water such as solubility of gases and solids, the penetration of light, temperature and density are responsible for the variations in algal diversity and population. Temperature is one of the most important and essential parameter of aquatic habitats because almost all the physical, chemical and biological properties are governed by it. It influences the oxygen contents of water quantity and quality of autotrophs, while affecting the rate of photosynthesis and also indirectly affecting the quantity and quality of heterotrophs (Barnabe, 1994). The temperature of water varies throughout the year with seasonal changes in air temperature, day length, and solar radiations. Animals are stressed when temperature changes rapidly, because there is no enough time for physiological adaptation (Boyd, 1998). Water temperature depends on many factors such as climate, sunlight and depth. The intensity and seasonal variation in temperature of water directly affect the productivity of lakes. All organisms including fish possess limits of temperature tolerance. Seasonal variation of temperature influences the feeding habits of the fish. All biological activities like ingestive variation, reproduction, movement and distribution are greatly influenced by water temperature. Decrease in temperature is also directly related to increase in DO. The seasonal and diurnal variation was observed to be due to high nutrient value of the water.

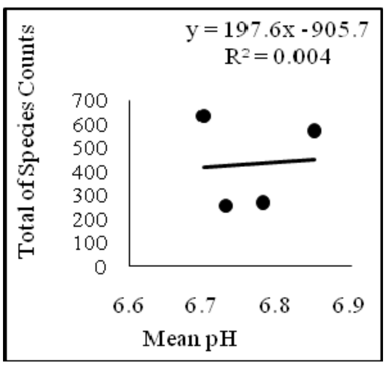


Fig. 1.1 pH of Gossaigaon.

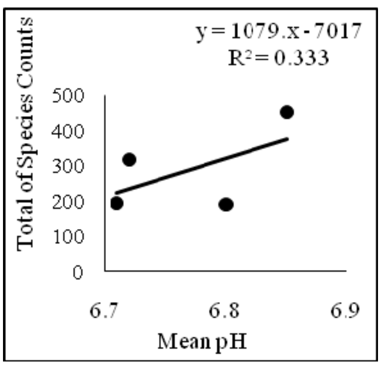


Fig. 1.2 pH of Grahampur.

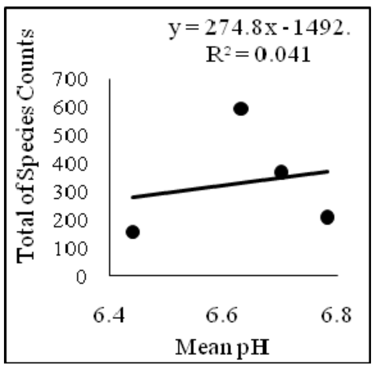


Fig. 1.3 pH of Saraibil.

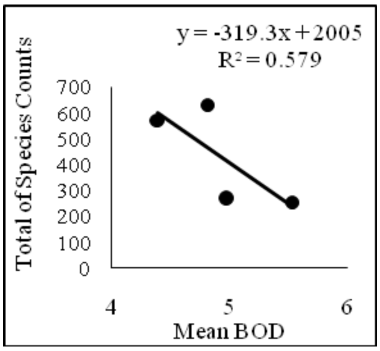


Fig. 1.4 BOD of Gossaigaon.

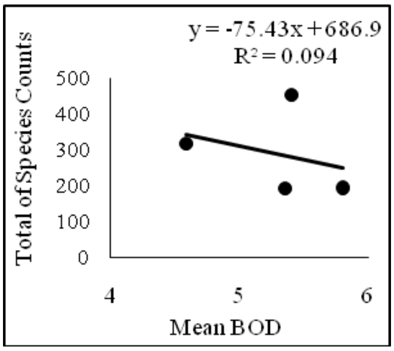


Fig. 1.5 BOD of Grahampur.

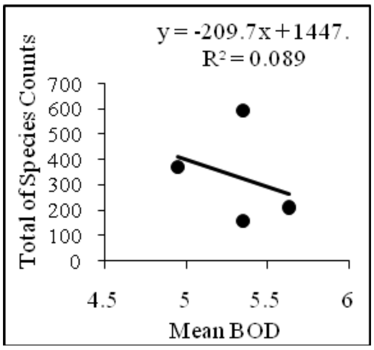


Fig. 1.6 BOD of Saraibil.

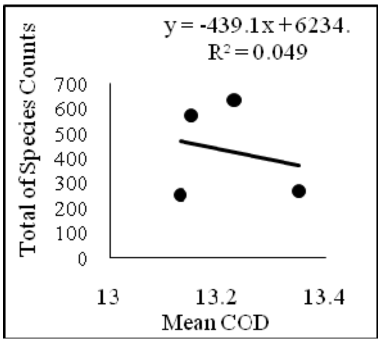


Fig. 1.7 COD of Gossaigaon.

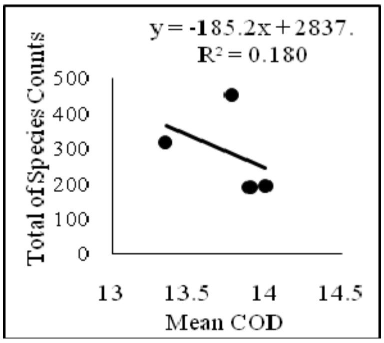


Fig. 1.8 COD of Grahampur.

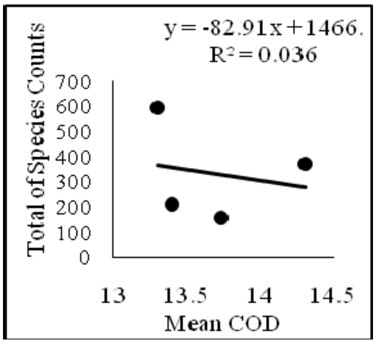


Fig. 1.9 COD of Saraibil.

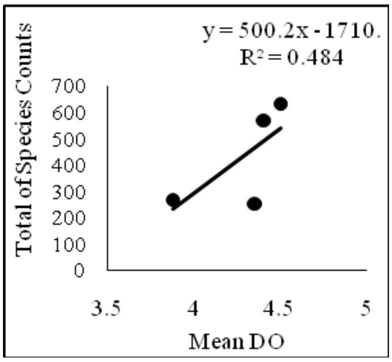


Fig. 1.10 DO of Gossaigaon.

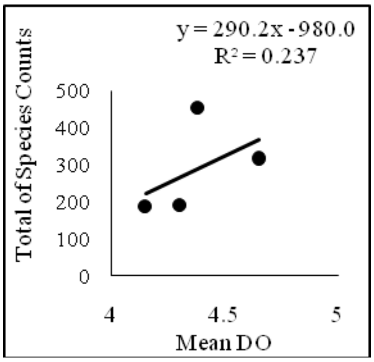


Fig. 1.11 DO of Grahampur.

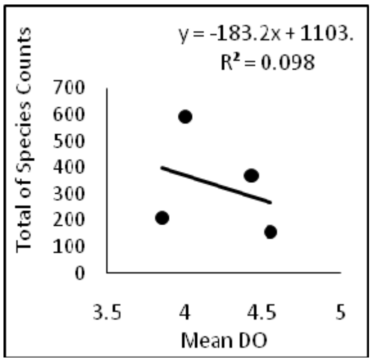


Fig 2.12 DO of Saraibil.

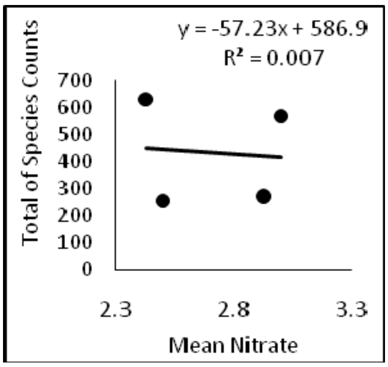


Fig. 1.13 Nitrate of Gossaigaon.

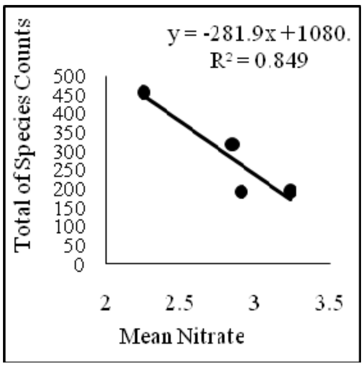


Fig. 1.14 Nitrate of Grahampur.

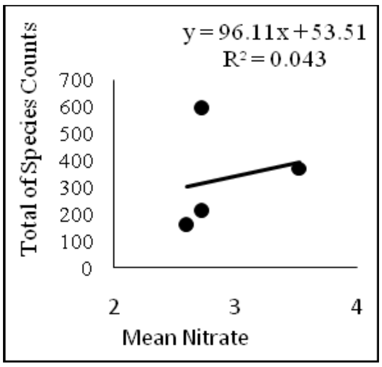
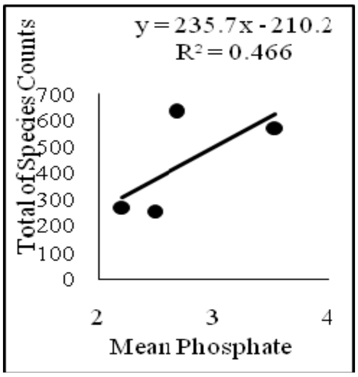
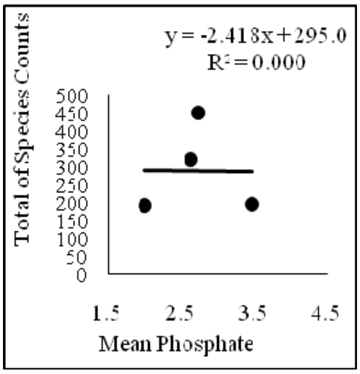


Fig. 1.15 Nitrate of Saraibil.





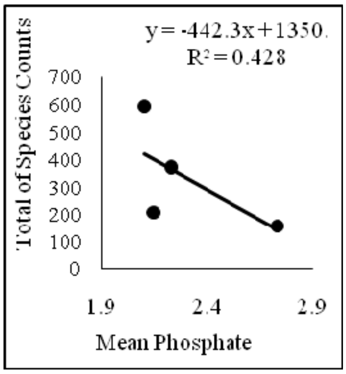
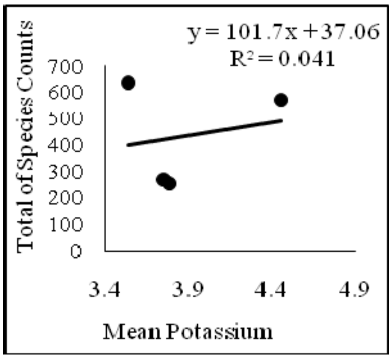
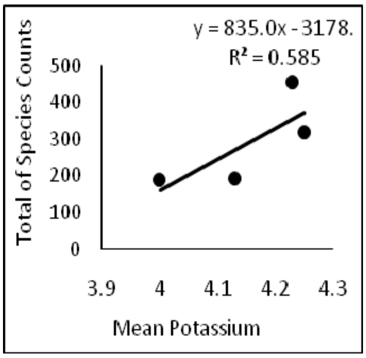


Fig. 1.16 Phosphate of Gossaigaon. Fig. 1.17 Phosphate of Grahampur. Fig. 1.18 Phosphate of Saraibil.





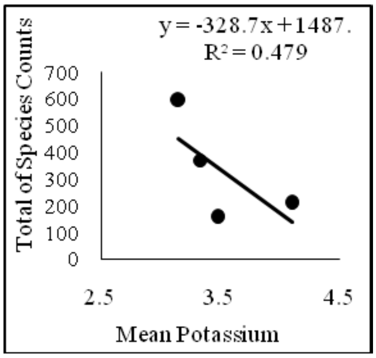
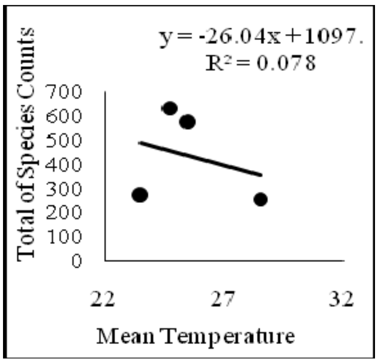
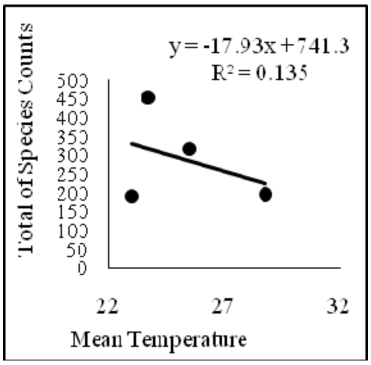


Figure 2.19 Potassium of Gossaigaon Figure.2.20 Grahampur Figure 2.21 Saraibil





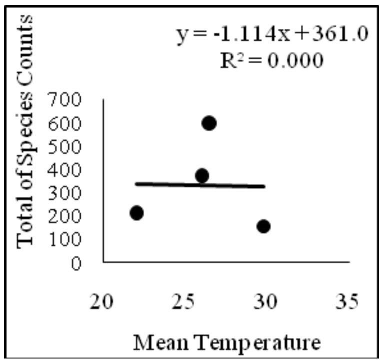


Fig. 1.22 Temp. of Gossaigaon. Fig. 1.23 Temp. of Grahampur. Fig. 1.24 Temp. of Saraibil.

Fig. 1 Linear regression relationship between total of species counts vs. mean water pH at Grahampur.

4 Conclusions

Our study gives information about the appearance of huge diversity of cyanobacteria in fresh water/aquatic habitats in Assam, India. Studies say habitats have distinct cyanobacterial microflora, but the different sites in different geographical regions evidently fluctuate in their diversity as well as in local climatic conditions. Cyanobacteria can be used for practical purposes in different ways. Even in many countries, cyanobacteria are harvested locally from lake, pond and river to use in different purposes. It has also been found that cyanobacteria can be used to improve the soil quality in dry semi-desert regions. *Microcoleus vaginatus*, one of the main species that can be used in that particular purpose. Cyanobacteria are being applied since many decades ago to agricultural lands to increase soil fertility, especially to improve the N status of paddy fields.

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