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Species diversity of Cyanobacteria in Cochin estuary

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Original Article

Abstract

The seasonal variation and the effect of physico-chemical factors on cyanobacterial diversity along Cochin backwater were studied during 2002-2004. In all, 75 species of cyanobacteria from 24 genera across 7 families and 4 orders of the class Cyanophyceae were recorded. Of these thirty one species were unicellular colonial forms, 43 were filamentous forms without heterocyst and two were heterocystous filamentous forms. The predominant species observed were *Chroococcus turgidus, Chroococcus tenax, Synechococcus elongatus, Synechocystis salina, Oscillatoria foreaui, Oscillatoria remyii, Oscillatoria pseudogeminata, Oscillatoria subtillissima, Oscillatoria willei, Phormidium purpurescens* and *Phormidium tenue*. Water temperature, salinity and euphotic depth had a positive correlation with the cyanobacterial density, whereas, nutrients had a negative impact when they were in excess. Pre-monsoon season was characterised by high density of these organisms, whereas, cell count was very low during monsoon season. All the backwater stations and the mangrove station showed significantly higher cyanobacterial community when compared to sea shore site which suggests that the ecological conditions of Cochin estuary support a rich cyanobacterial flora.

Key words: *Species diversity, cyanobacteria, Cochin estuary*

Introduction

Cyanobacteria (blue green algae) are nature's unique gift to mankind, as they possess several innate properties that make them ideal organisms with potential for multifaceted biotechnological applications. On account of their immense applied biotechnological potentials, they are being explored widely. Cyanobacteria are Gram-negative prokaryotes as they lack internal organelles, a discrete nucleus and the histone proteins associated with eukaryotic chromosomes, but form a connecting link with algae because of their pigment composition and photosynthetic mechanism. Cyanobacteria show wide ecological tolerance and they occur in almost every conceivable habitat on earth in different morphologies including unicellular and filamentous forms (Pearl and Millie, 1996; Castenholz, 2001).

The basic and fundamental requirement for initiating cyanobacterial biotechnology is to enumerate the available natural cyanobacterial wealth and to understand their ecobiological properties. Therefore, it is necessary that a detailed survey of the surrounding habitats are to be made, to identify the available cyanobacterial species and subsequently to isolate, purify and establish a culture collection which could be used for further studies. Aquatic ecosystem in the south west coast of India is noted for its diversity of habitats. Very often, these environments turn blue-green when these organisms bloom consequent to eutrophication. Growth and productivity of cyanobacteria depend on the hydrographic parameters of the particular environment (Gopinathan *et al.*, 2001), and since the hydrographic parameters such as temperature, salinity, light intensity, dissolved oxygen and nutrients vary from place to place and season to season, frequent monitoring of these parameters are highly essential.

In view of the great biotechnological potential of cyanobacteria and the abundance of their biomass in the marine environment of the world in general, and the Indian subcontinent in particular, an extensive study was carried out on their qualitative and quantitative distribution along Cochin estuary with respect to physico-chemical parameters. Cochin backwater system is the longest estuarine system on the south west coast of India, which forms a permanent part of Vembanadu Lake. It extends between Thanneermukkam bund at the south and Azhikode at the north (9°30′-10°12′N and 76°10′- 76°29′E) and extends over an estimated length of 60 kms and an area of 21 ,050 ha.

The main objectives of the present study were to find out the qualitative and quantitative distribution of cyanobacteria in Cochin estuary and to evaluate the effect of physico-chemical parameters on cyanobacterial distribution and abundance.

Material and methods

Sampling sites

The sampling sites are shown in Plate 1 and Table 1. Out of the ten stations, Eloor (Stn.1), Varappuzha (Stn.2) and Vaduthala (Stn 3) recorded salinity near zero and hence considered as fresh water regions whereas the next five stations such as Bolghatty (Stn.4), Barmouth (Stn.5), Mattanchery (Stn.6), Thevara (Stn.7) and Edakochi (Stn.8) are considered as saline regions as they recorded salinity above 30ppt. The 9th station, Kannamali was selected as the seashore station where salinity was in the range of 25-37 ppt throughout the year. Puduvaippu, which was selected as the 10th station of this study was one of the mangrove areas in Cochin.

Sampling procedures and processing

Monthly collection of water and sediment samples from Cochin backwaters and near shore areas were made from April 2002 to March 2003. In the second year of the study (April 2003 to March 2004), sampling was held bimonthly. Water samples were collected using a Niskin water sampler and transferred aseptically to sterile bottles and transported to laboratory.

For quantitative measurements, samples were preserved at the sampling site itself using acidified Lugol's Iodine solution and were concentrated by sedimentation using a measuring cylinder (Shaw and Smith, 2000). The enumeration of cyanobacterial cells was carried out using Sedgewick-Rafter chamber and identification of the strains was done based on their morphology, using a phase contrast microscope, as per the methods of Desikachary (1959); Skulberg *et al.* (1993); Golubic and Browne (1996).

In case of filamentous forms, the cells within each trichome were counted. The final result, expressed as cells per millilitre was calculated as;

$$\text{Cells per ml} = \frac{\text{Number of cells counted x 1000}}{\text{Sample concentration factor x No. of fields examined}}$$

The physicochemical parameters of the sampling sites were determined using standard procedures (APHA 1998; Grasshoff *et al.*, 1983). Correlation between hydrography and cyanobacterial cell count for both the surface and bottom samples were determined.

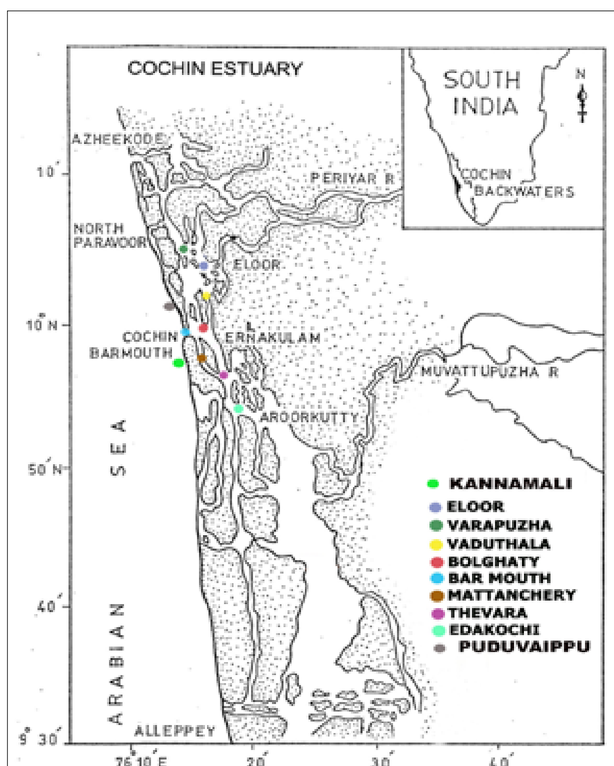

Fig.1.Sampling sites in Cochin estuary

Table 1. Details of the sampling sites

Sl.No.	Stations	Position	Depth (m)	Description	
		Latitude	Longitude		
1	Eloor	10°5′23″N	76°17′49″E	5.3	Industrial belt, Freshwater
2	Varappuzha	10°4′30″N	76°16′48″E	3.9	Industrial belt, Freshwater
3	Vaduthala	10°12′13″N	76°15′9″E	1.5	Disposal of domestic wastes, Freshwater
4	Bolghaty	9°58′52″N	76°15′50″E	3.5	Inland navigation and other tourism operations, saline.
5	Barmouth	9°58′26″N	76°14′39″E	4.6	Cochin Harbour entrance. saline
6	Mattanchery Harbour	9°56′47″N	76°15′52″E	3.3	The fishing and processing unit operations; saline
7	Thevara	9°55′35″N	76°17′53″E	2.1	Sewage outfall, saline
8	Edakochi	9°54′33″N	76°17′35″E	1.4	Domestic sewage outfall, saline
9	Kannamali	9°52′7.5″N	76°15′47.9″E	——	Sea shore area
10	Puduvaippu	9°59′26.1″N	76°14′8.4″E	——	Mangrove area

The data set was treated with various univariate and multivariate analyses of PRIMER-5 (Plymouth Routines in Multivariate Ecological Research) for community structure study. Diversity indices such as Margalefs index (species richness-d), Pielou's index (species evenness-J'), Shannon index (species diversity-H') and Simpson's index (species dominance-A') were estimated. Multivariate analysis was performed using the Bray-Curtis similarity measure (Clarke and Warwick, 1994).

Results and discussion

In the present study, a total number of 75 species of cyanobacteria from 24 genera belonging to 7 families and 4 orders of the class cyanophyceae were recorded of which, 31 were unicellular colonial forms, 43 non heterocystous filamentous forms and two were heterocystous filamentous forms. Cyanobacteria from Cochin estuary belonged to the following genera: *Aphanocapsa, Aphanothece, Chroococcus, Coelosphaerium, Dactylococcopsis, Eucapsis, Gloeocapsa, Gloeothece, Microcystis, Synechococcus, Synechocystis, Johannesbaptistia, Chlorogloeoa, Dermocarpa, Myxosarcina, Spirulina, Arthrospira, Oscillatoria, Phormidium, Lyngbya, Anabaena, Pseudanabaena, Plectonema* and *Tolypothrix*. Among these, Oscillatoria was represented by maximum number of species; 19 species were observed in this genera followed by *Phormidium* 13 species, *Gloeocapsa* 7 species, *Lyngbya* 6 species, *Chroococcus* 5 species, *Aphanocapsa, Aphanothece, Gloeothece, Microcystis, Synechococcus* and *Synechocystis* 2 species each and others by a single species. Fig. 2 depicts the generic composition of cyanobacteria in both surface (Fig. 2a) and bottom water (Fig. 2b)

The seasonal and spatial distribution of cyanobacteria in the ten selected stations is given in Table 2. *Chroococcus turgidus, C. tenax, Synechococcus elongatus, Synechocystis salina, Oscillatoria foreauii, O. fremyii, 0. pseudogeminata, O. subtillissima, O. willei, Phormidium purpurescens* and *P. tenue* were observed in all the ten stations at least once and are considered as versatile species. Pre-monsoon period was characterized by high temperature and light intensity, supported maximum growth of cyanobacteria. All the stations exhibited almost a similar pattern of cyanobacterial distribution, about 44 to 54 species were observed in all the stations except in station 9, *i.e.*, the seashore region where only 14 species were recorded. Low nutrients and sandy substratum observed in the seashore area might be the

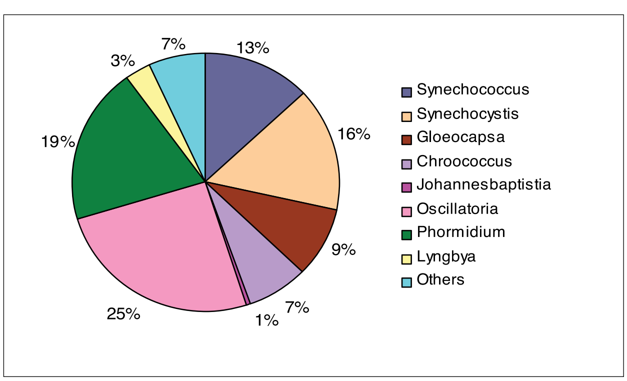

Fig 2a. Generic composition of cyanobacteria in surface water

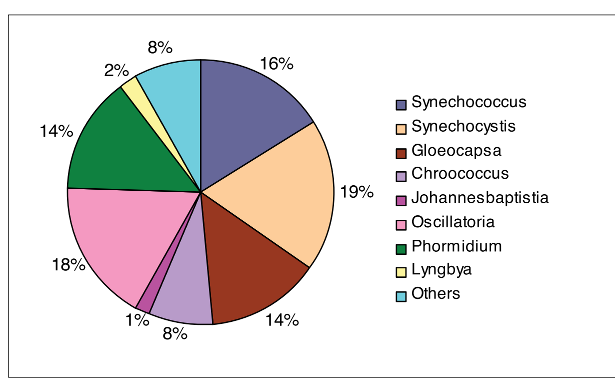

Fig 2b. Generic composition of cyanobacteria in bottom water

Table 2. Seasonal and spatial distribution of Cyanobacteria

Cyanobacteria		1	2	3	4	5	6	7	8	9	10
Phylum : Cyanophyta											
Class : Cyanophyceae Sachs											
Order : Chroococcales Wettsein											
Family : Chroococcaceae Nageli											
1	*Aphanocapsa brunnea* Nag.	*	*	**	**	*	**	**			*
2	*A. littoralis* Hansgirg				*	*		*	*		
3	*A. castagnei* (Breb.) Rabenh.	**	*	*	*	**	*	*			*
4	*A. nidulans* Richter,P.			*	*	*	*	*	*		
5	*Chroococcus coharens* (Breb.) Nag.					*			*		
6	*C. montanus* Hansgirg	*	*	**		**	**	*	*		
7	*C. turgidus* (Kutz.) Nag.	***	***	***	***	***	***	***	***	*	**
8	*C. tenax* (Kirchn.) Hieron.	**	***	***	***	***	***	**	***	*	**
9	*C. minutus* (Kutz.) Nag.	**	*		*		**	**			**
10	*Coelosphaerium dubium* Grunow		**	*		**	*	*	*		*
11	*Dactylococcopsis raphidioides* Hansg.	**		**	*	**	*	*	**		*
12	*Eucapsis minuta* Fritsch				*						
13	*Gloeocapsa compacta* Kutz.	***	***	***	***	**	**	***	***		**
14	*G. crepidinum* Thuret	**	***	***	***	***	***	***	***		**
15	*G. dermochroa* Nag.							*		**	
16	*G. gelatinosa* Kutz.		*	***	*	*	*	**	**		*
17	*G. livida* (Carm.) Kutz.	***	***	***	***	***	**	***	***		***
18	*G. quaternata* (Breb.) Kutz.	***	***	**	***	***	**	**	**		*
19	*Gloeocapsa* sp.	*	*	*				*			*
20	*G. rhodochlamys* Skuja	*									
21	*G. rupestris* (Lyngb.) Bornet	***	***	***	***	***	***	***	***		**
22	*Microcystis orissica* West, W.	**	*		*	**	*	*	**		*
23	*M. stagnalis* Lemm.			**		**		*	**	**	
24	*Synechococcus cedrorum* Sauvageau	**	*	*	***	***	*	**	**		*
25	*S. elongates* Nag.	***	***	***	***	***	***	***	***	***	***
26	*S. aquatilis* Sauv.	***	***	**	***	***	***	*	***		***
27	*S. salina* wislouch	***	***	***	***	***	***	***	***	*	***
Family : Entophysalidaceae											
28	*Johannesbaptistia pellucida* (Dickie) Taylor et Drouet *	*				**	***	*	**		
29	*Chlorogloea fritschii* Mitra	*	**	**	**	***	***	**	***		*
Order : Chaemosiphonales											
Family : Dermocarpaceae											
30	*Dermocarpa olivaceae* (Reinsch) Tilden				*		*	*	*		
Order : Pleurocapsales											
Family : Pleurocapsaceae											
31	*Myxosarcina burmensis* Skuja	*	*	*	*	*	**	**	*		*
Order : Nostocales											
Family : Oscillatoriacea											
32	*Spirulina labyrinthiformis* (Menegh.) Gomont										**
33	*Arthrospira tenuis* Bruhl et Biswas	*	*	**				*			*

34	*Oscillatoria accuminata* Gomont		**	**		*	*	*	**		
35	*O. angustissima* W. et G.S.West	*	**	**	***	***	*	***	**		**
36	*O. acuta* Bruhl et Biswas, orth. Mut. Geitler										*
37	*O. cortiana* Meneghini ex Gomont										*
38	*O. calcuttensis* Biswas		*	*					*		
39	*O. deflexa* W. et G.S. West	*				*	*				
40	*O. foreauii* Fremy	**	**	*	**	***	***	***	***	*	*
41	*O. fremyi* De Toni, J.	***	***	***	***	***	***	***	***	**	***
42	*O. jasorvensis* Vouk.	*						*	*		**
43	*O. kuetzingiana* Nag.		*	*	*						
44	*O. laete-virens* (Crouan) Gomont Var. minimus Biswas					*	*	*	*		
45	*O. limnetica* Lemm.						*				
46	*O. minnesotensis* Tilden	*	*	**	*	*	**	**	**		*
47	*O. pseudogeminata* G. Schmid	***	***	***	***	**	***	***	***	*	***
48	*O. salina* Biswas		**			*					
49	*O. schultzii* Lemm.					*			*		
50	*O. subtillissima* Kutz.	***	***	***	***	***	***	***	***	***	***
51	*O. tenuis* Ag. Ex Gomont					*					
52	*O. willei* Gardner em. Drouet	***	***	**	***	***	***	**	**	*	***
53	*Phormidium abronema* Skuja							*			
54	*P. angustissimum* W. et G.S.West.	**		**	*	*	**	*	**		
55	*P. bohneri* Schmidle	***	***	***	**	***	**	**	**		**
56	*P. corium* (Ag.) Gomont	**	*	**	***	***	**		**		*
57	*P. dimorphum* Lemm.	*	*	*		*	*		*		*
58	*P. foveolarum* (Mont.) Gomont	**	**	**	**	***	*	*	**		*
59	*P. jadinianum* Gomont						*				**
60	*P. purpurescens* (Kutz.) Gomont	*	*	**		*	*	**	*	*	*
61	*P. lucidum* Kutzing ex Gomont			*				*			
62	*P. molle* (Kutz.) Gomont	*	*	*	**	*	*	*	**		*
63	*P. mucicola* Hub.-Pestalozzi et Naumann					*	**	*	*		
64	*P. tenue* (Menegh.) Gomont	***	***	***	***	***	***	***	**	*	***
65	*P. valderianum* (Delp.) Gomont	***	***	***	***	***	**	***	***		***
66	*Lyngbya aerugineo-coerulea* (Kutz.) Gomont	**		*	*	**			*		
67	*L. cryptovaginata* Schkorbatow					**		*			
68	*L. martensiana* Menegh. Ex Gomont	***	***	**	***	*	**	***	***		**
69	*L. nordgardhii* Wille		*		*	*	*				**
70	*L. putealis* Mont. Ex Gomont						*				
71	*L. semiplena* (C.Ag.) J.Ag. Ex Gomont	***	***	***	*	*	*	**	*		**
Family : Nostocaceae											
72	*Anabaena khannae* Skuja	**	*				*	*			
73	*Pseudanabaena schmidlei* Jaag. O f.robusta Skuja			*			*		**		
Family : Scytonemataceae											
74	*Plectonema nostocorum* Bornet ex Gomont						*				
75	*Tolypothrix tenuis* (Kutz.) Johs. Schmidt em.		*	*					*		

* Presence in premonsoon season ** Presence in monsoon season *** Presence in postmonsoon season

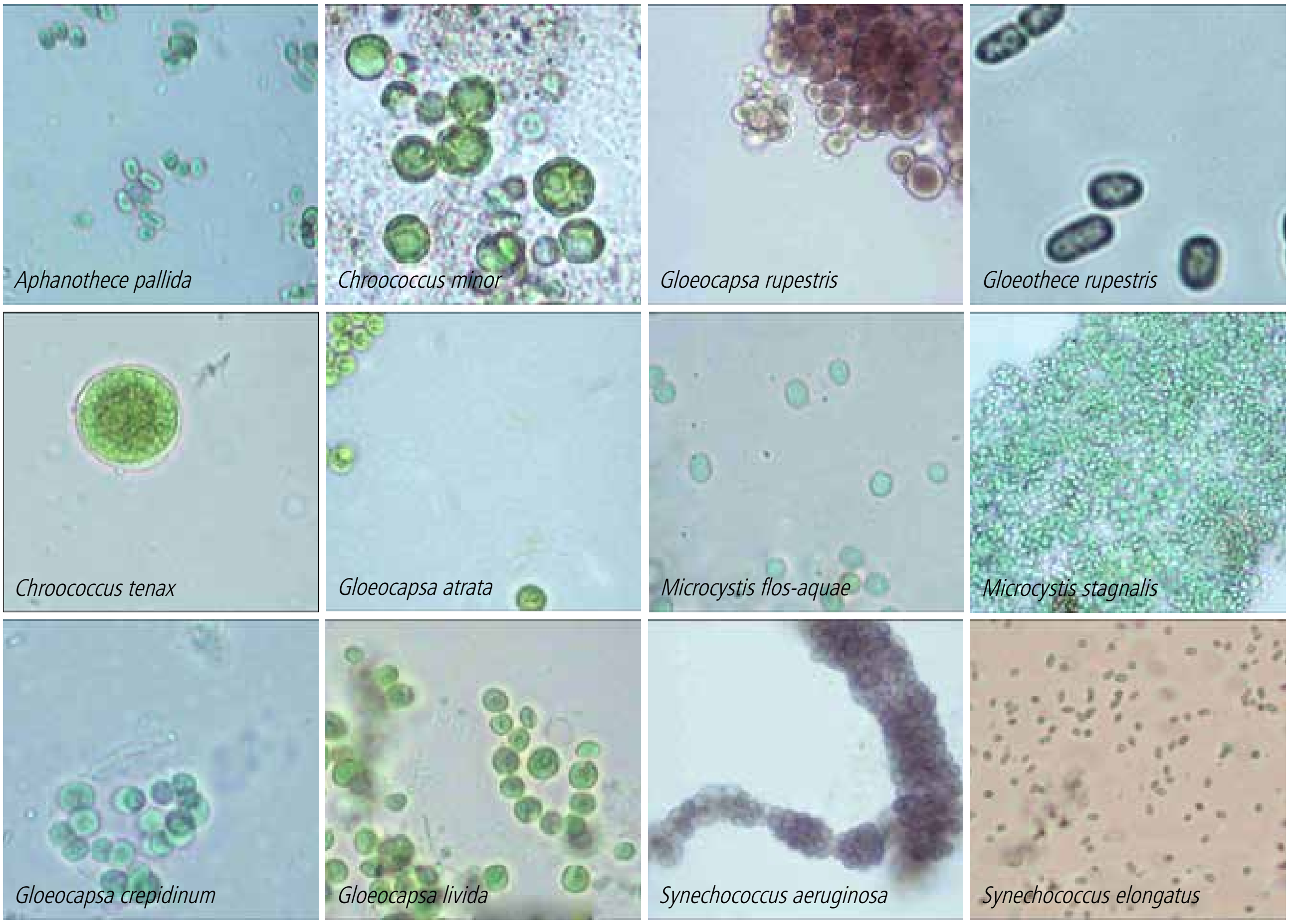

Plate 1 species of cyanobacteria under the genus *Aphanothece, Chroococcus, Gloeocapsa, Microcystis* and *Synechococcus* isolated from Cochin estuary

reason for the low number of Cyanobacteria in this station. Photomicrographs of various species of cyanobacteria isolated from Cochin estuary is shown in Plate 1 and 2.

Fig. 3a, 3b, 3c and 3d show the species richness index, evenness index, diversity index and dominance index for all the stations in various seasons. There was not much seasonal variation in diversity indices. but, spatial variation was prominent at station 9, the seashore site and it was significantly different from all the other sampling sites.

Thajuddin and Subramanian (1992) studied the cyanobacterial flora of the east coast of India and found that the distribution of cyanobacteria depends up on the habitat. Heterocystous forms were observed to be less in number in comparison to non-heterocystous forms. They observed that the shore in the Bay of Bengal region was essentially sandy and therefore, there were only 11 species of cyanobacteria. A similar observation was also made in the present study.

In order to study how the physicochemical parameters affect cyanobacterial abundance in Cochin estuary, correlation between hydrography and cyanobacterial cell count for both the surface and bottom samples were determined by statistical analysis. Table 3 shows the correlation between hydrography and cyanobacterial cell count for both the surface and bottom samples.

The study shows that water temperature, salinity and euphotic depth had a positive correlation with the cyanobacterial densiy, whereas, nutrients had a negative impact when they were in excess. Compared to the unicellular and non-heterocystous filamentous forms, the heterocystous forms were very poor in number and this may be due to the high levels of combined nitrogen in the estuary (up to 79.5 μmol/L NO_3 and 2.08 μmol/L NO_2) (Thajuddin and Subramanian, 1990 ; Sincy Joseph 2005). In a similar study, Selvakumar and Sundararaman (2007) observed twelve species of unicellular and filamentous species of cyanobacteria belonging to Chroococcaceae and Oscillatoriaceae families in estuarine water of Palk Bay region. Subramanian and Thajuddin (1995) correlated high cyanobacterial diversity in the Gulf of Mannar region with higher salinity, pH and nutrient content of the water. In the present study also,

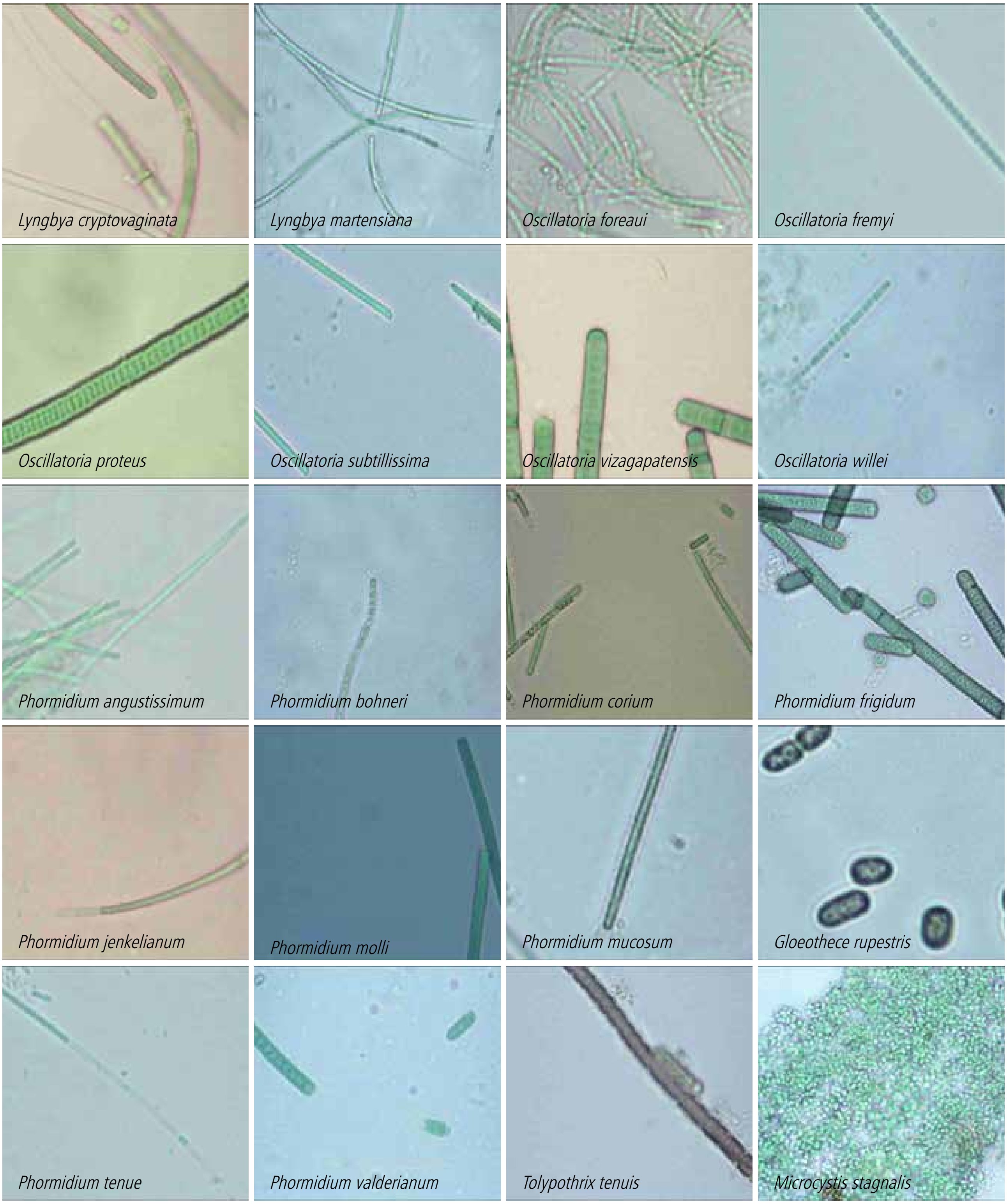

Plate 2 species of cyanobacteria under the genus *Lyngbya, Oscillatoria, Phormidium, Gloeothece, Tolypothrix* and *Microcystis* isolated from Cochin estuary

salinity and pH were found to be in positive correlation with cyanobacterial numbers. A significant positive correlation between the cyanobacterial diversity and micronutrients was observed by Muthukumar *et al.* (2007). The dominance of cyanobacterial species in the backwater system could be due to the remarkable adaptability of cyanobacteria to wide

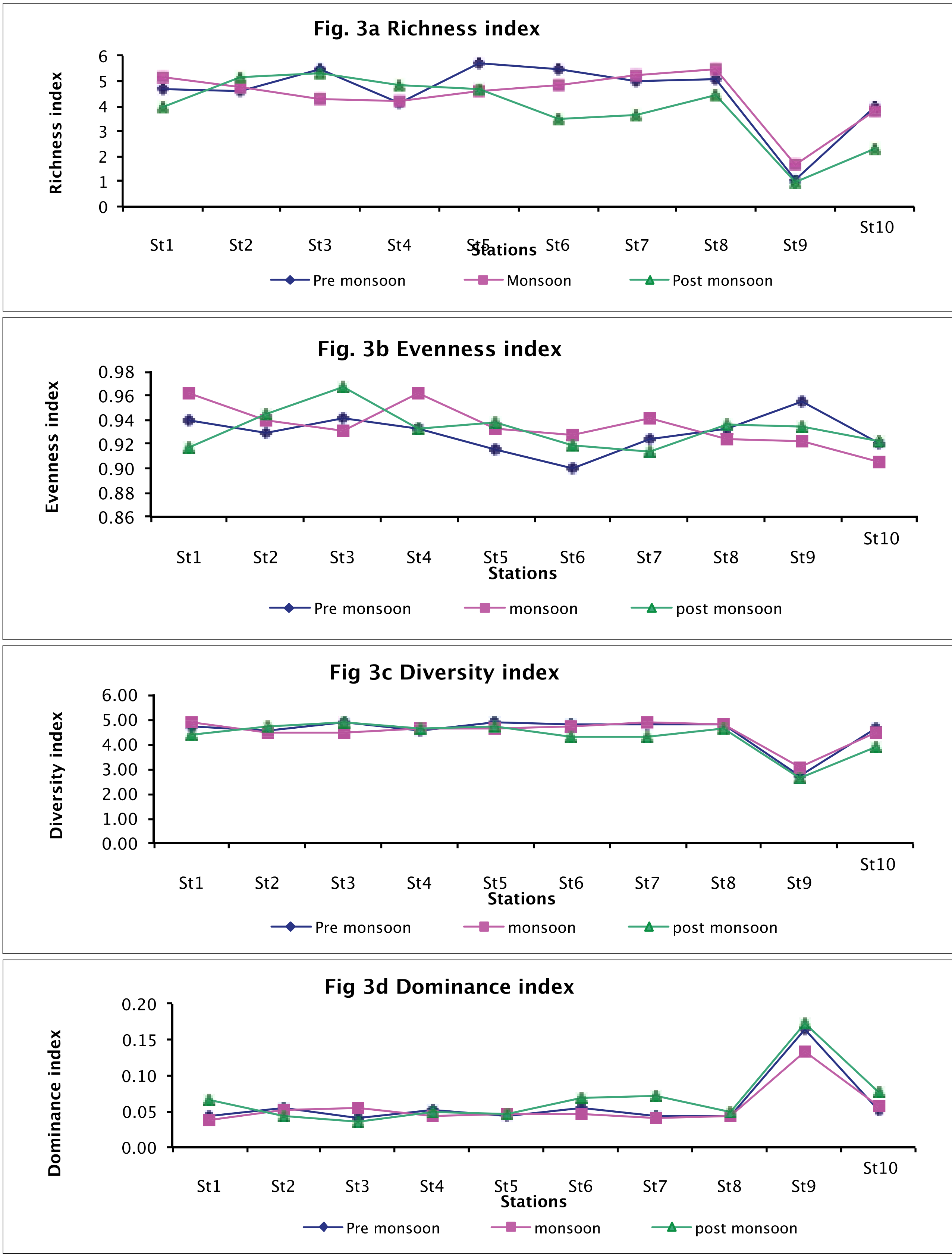

Fig. 3. Species richness index (d), evenness index (J), diversity index (H) and dominance index (λ') for all the stations in various seasons

Table 3. Correlation between Hydrography and Cyanobacterial cell count (*significant at p < 0.05%)

Surface water										
Temp		Salinity	D.O.	pH	Chl-a	Nitrite	Nitrate	Phosphate	Silicate	
Stn. 1	0.238	-0.315	0.049	0.255	0.272	-0.092	0.131	-0.365	-0.027	
Stn. 2	0.47*	-0.2	-0.084	0.193	0.039	0.169	-0.212	0.039	-0.128	
Stn. 3	0.54*	-0.043	-0.525*	-0.327	0.049	-0.227	-0.29	-0.65*	-0.258	
Stn. 4	0.546*	0.087	-0.36	-0.364	0.407	-0.291	-0.528*	-0.578*	-0.573*	
Stn. 5	0.573*	0.339	-0.157	0.039	-0.044	-0.213	-0.376	-0.14	-0.452	
Stn. 6	0.438	0.201	-0.55*	-0.241	0.175	-0.468*	-0.269	-0.189	-0.392	
Stn. 7	0.59*	0.427	-0.041	0.222	-0.12	-0.017	-0.471*	-0.475*	-0.459	
Stn. 8	0.391	-0.061*	-0.019	-0.113	-0.015*	0.191	0.038*	-0.385	0.155	
Stn. 9	-0.02	0.474	0.014	0.125	-0.517	0.382	0.492	0.156	0.222	
Stn. 10	0.312	0.419	-0.116	0.064	0.34	-0.071	-0.245	-0.151	-0.284	
Bottom Water										
Temp	Salinity	D.O.		pH	Chl-a	Nitrite	Nitrate		Phosphate	Silicate
Stn. 1	-0.253	0.077	0.242	0.287	0.36	-0.074	-0.261	0.178	0.065	0.111
Stn. 2	0.432	0.036	-0.376	0.12	0.169	-0.169	-0.19	-0.121	-0.272	-0.2549
Stn. 3	0.459	0.254	-0.241	-0.281	0.11	-0.113	-0.283	-0.445	-0.302	0.3939
Stn. 4	0.236	0.125	-0.199	-0.204	-0.023	-0.041	-0.216	-0.23	-0.379	0.0874
Stn. 5	0.376	0.312	-0.416	0.028	-0.067	-0.288	-0.287	-0.229	-0.329	0.1999
Stn. 6	0.484*	0.483*	-0.23	0.031	-0.158	-0.12	-0.272	-0.118	-0.476*	0.5145*
Stn. 7	0.228	0.009	0.078	-0.022	-0.289	0.2	-0.026	0.32	0.108	0.0895
Stn. 8	0.208	0.503*	0.054	0.192	0.338	-0.379	-0.479*	-0.194	-0.442	0.422

ranges of environmental factors. (Desikachary, 1959; Carr and Whitton, 1982).

The present study provides an insight into the distribution, abundance, diversity and ecology of cyanobacteria of Cochin estuary. From the results, it is evident that the ecological conditions of Cochin estuary support a rich cyanobacterial flora.

Acknowledgements

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