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Full Length Research Paper

Cyanobacterial abundance and diversity in coastal wetlands of Kanyakumari District, Tamil Nadu (India)

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Coastal wetlands are physiologically unique from freshwater and marine water environments. They support the growth of both marine and freshwater organisms with affluent diversity. In this study, abundance and diversity of cyanobacteria from the coastal wetlands of Kanyakumari District (Tamil Nadu) in India was studied. Water samples were collected from ten different sampling sites during the month of January 2010 to March 2010. Totally 17 morphologically different cyanobacteria were identified by microscopic examinations and culture-dependent processes. Both unicellular and filamentous cyanobacteria like *Microcystis flos-aquae, Microcystis lamelliformis, Gloeocapsa* sp, *Aphanocapsa* sp, *Aphanothece* sp and *Synechocystis* sp. *Oscillatoria earlei, Oscillatoria pseudogeminata, Oscillatoria tenuis, Oscillatoria amoena, Phormidium fragile, Phormidium retzii, Phormidium* sp., *Lyngbya* sp, *Symploca* sp. *Microchaete* sp. and *Spirulina subtilissima* were identified. In addition, the species richness index was ranging from 0.779 to 1.097 in the samples collected in month of February (S8- Muttam). Substantial diversity was also detected in different sampling regions, Shannon-Wiener's (H^i) diversity index of cyanobacterial population ranged from 0.423 to 0.788. In our findings, all the identified cyanobacteria were belonging to non heterocystous forms.

Key words: Cyanobacteria, coastal wetland, Oscillatoriaceae, Chroococcaceae.

INTRODUCTION

The cyanobacteria (blue green algae) are a morphologically distinct group of oxygenic, photosynthetic organisms that inhabit terrestrial and aquatic ecosystems (Thajuddin and Subramanian, 2005). The term biodiversity is used here to describe the number, variety and variability of living organisms in the ecosystem. India is one of the mega-biodiversity countries of the world, having almost all possible kind of climatic variations, with a great diversity of microbes especially the cyanobacteria (Litavitis, 2002). Traditionally, cyanobacteria have been classified based on the morphological and ecological characters (Geitler, 1932; Desikachary, 1959). The most fundamental meaning of biodiversity probably lies in the concept of species richness that is indicating the number of species occurring at a site, in a region or ecosystem. Uncontrolled dumping off waste, nutrient discharges from intensive agriculture and human activities are the major cause of biodiversity variation (Vidyavathy, 2007).

Cyanobacterial diversity possesses the largest untapped metabolites from the various reservoirs of biosphere which reserve the diverse novel bioactive products. It has been reported that the saline tolerant cyanobacteria possess the single cell protein (Allnutt, 1996). In addition, it has also been reported that many cyanobacteria have ability to fix the molecular atmospheric

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nitrogen by the presence of heterocyst (Usha et al., 2002). Coastal wetlands are the transition zones, "in-between" the areas that may be amazing both in dry uplands and open water environments which often have a richer flora and fauna than the other environments. So far, limited survey has been done in coastal wetlands, especially in Kanyakumari District. Hence, the present investigation was aimed to study the distribution and abundance of cyanobacteria in coastal wetlands of Kanyakumari District, Tamil Nadu.

MATERIALS AND METHODS

Study area

The sites were selected for this present study includes coastal wetlands of Kanyakumari District [(77° 15' and 77° 36' of east of longitudes and 8° 03' and 8° 35' north of Latitudes) about 1 km distance from the coast]. The following ten different coastal areas of Kanyakumari District were selected for this study, Thengapattanam (S1), Ramanthurai (S2), Melmidalam (S3), Colachel (S4), Ammandivilai (S5), Muttam (S6), Pillathoppu (S7), Rajakkamangalam (S8), Manakudi (S9), Kanyakumari (S10) were selected for sampling (Figure 1; Table 5). Samples were collected from January to March 2010.

Sample collection and identification

Wet soil and water samples were collected in a sterilized bottle and were transported to the laboratory immediately. The collected water samples were concentrated by centrifugation at 4000 rpm for 10 min. To the samples, one drop of Lugol's iodine solution was added for cell count estimation. A small quantity of the concentrated samples were analyzed for the dominant cyanobacterial group based on the colour of the thallus, unicells, colony formation, arrangement of trichome and presence or absence of mucilaginous sheath, etc. under 10X and 40X objectives of light microscope (Desikachary, 1959; Tilden, 1968).

Physicochemical parameters of water samples

The physico-chemical parameters like salinity, DO, pH, turbidity, nitrate, total phosphorous, sulphates and ammonia in the samples were estimated by standard procedures. Water temperature was measured by mercury thermometer having 0.1°C accuracy; salinity was measured by a refractometer (Atago, Japan), DO was estimated by a titrimetric method, pH was measured by a digital pH meter (Hanna) and other parameters were estimated by standard estimation methods (APHA, 1998).

Statistical method

For cyanobacterial species diversity, diversity index (H') and species richness (d') were; Shannon-Wiener diversity index (Dey et al., 2010) was calculated with the following formulae:

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i);$$

Where, *H'* = Shannon-Wiener index, S = the number of species in a community, Pi = the ratio of number *i* species. Species richness was estimated by Margalef's index (d) (Ogbeibu and Egborge, 1995)

d = S-1/1N;

Where, S = total number of species and N = total number of individuals.

RESULTS

In this study, a total of 30 samples were collected from 10 different sampling sites with the interval of one month. Among the 30 samples, nearly 17 different types of cyanobacteria were identified (Figure 2 and Table 1). They were grouped under two orders such as *Nostocales* and *Chroococcales*. Most of the isolates were characterized and grouped under the family of *Oscillatoriaceae* and *Chroococcaceae*. All isolated cyanobacteria were belonging to 11 different genera (Table 1). In our findings, the genera *Oscillatoria* was dominant, followed by the genera *Microcystis*. Table 2 shows the diversity index of cyanobacterial population in different sampling stations. The highest diversity index was observed in the month of March at S5 (0.87) and the lowest cyanobacterial diversity (0.423) was recorded in the month of January at the station (S7). In January, the maximum diversity was noticed in S1 and minimum diversity was recorded in S7. During the month of February, the maximum diversity was recorded as 0.788 at S3 and minimum diversity noticed at S2 (0.528). In the month of March, maximum diversity was observed in S5 and S-6 but lowest diversity was observed at S3 (0.655). Table 3 shows the species richness of cyanobacterial population in different sampling stations and the higher species were observed in month of February at S8 (1.097) and lower in January at S2 (0.779).

In January, the maximum species was reported at S5 (0.967) and lower species were recorded in S2 (0.779). Further, in the month of February the maximum species was 1.097 at S8 and minimum at S5 was 0.825. During March the maximum species was recorded in S2 and minimum species was recorded at S7 (0.85). The physico-chemical parameters such as the pH, salinity turbidity, dissolved oxygen; ammonia and sulphate were recorded in Table 4. The physico-chemical variations were statistically not significant. The pH of the sample was highest (8.07) in S-6 and the lowest value (7.04) was observed in sample S-7. The higher salinity was recorded as 8 ppt at S6, and the lower salinity was recorded as 2 ppt in a majority of the samples.

DISCUSSION

Cyanobacteria are ubiquitous in nature and they must possess a high potential of adaptation to diverse environments (Garcia-Pichel et al., 2001). Coastal

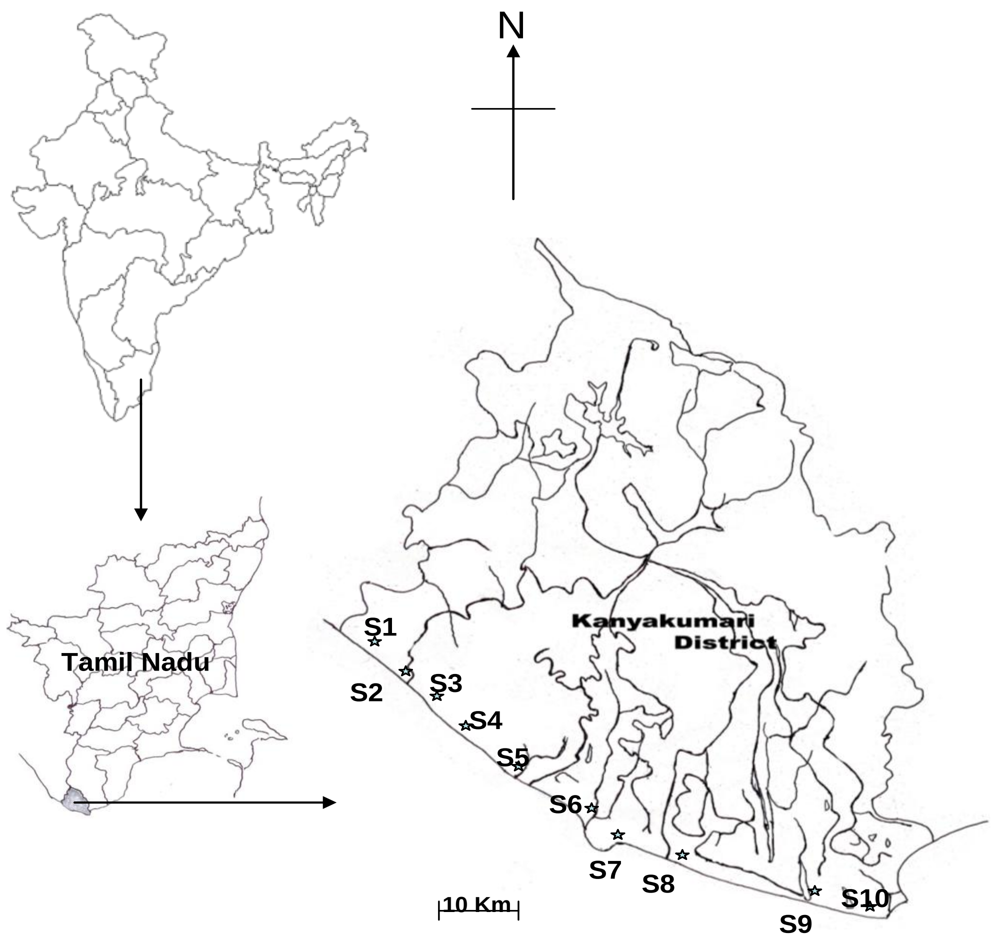

Figure 1. The study area Kanyakumari District coast, India (77° 15' and 77° 36' of east of longitudes and 8° 03' and 8° 35' north of Latitudes). Thengapattanam (S1), Ramanthurai (S2), Melmidalam (S3), Colachel (S4), Ammandivilai (S5), Muttam (S6), Pillathoppu (S7), Rajakkamangalam (S8), Manakudi (S9), Kanyakumari (S10).

wetlands are perennial ecosystems with variable cyanobacterial diversity, which composed optimum levels of light, water, temperature, humidity and nutrient availability that are providing a favorable environment for the luxuriant growth of cyanobacteria. This is the first study to report the abundance of cyanobacteria in the coastal wetlands of Kanyakumari (Figure 1), Tamil Nadu, India. In this study, samples obtained from different sites (Figure 1) possess more than 17 morphologically different cyanobacterial species. Morphological identification of cyanobacteria showed both filamentous and unicellular species, and are grouped under two orders such as *Nostocales* and *Chroococcales.* The isolates identified in this study were grouped under two families that is, *Oscillatoriaceae* and *Chroococcaceae* which includes *Oscillatoria earlei*, *Oscillatoria tenuis, Oscillatoria pseudogeminata, Oscillatoria amoena, Phormidium fragile, Phormidium retzii*, *Phormidium* sp., *Lyngbya* sp*., Symploca* sp*., Microchaete* sp*., Spirulina subtilissima, Microcystis flos-aquae, Microcystis lamelliformis, Gloeocapsa* sp*., Aphanocapsa* sp*., Aphanothece* sp*.* and *Synechocystis* sp*.* (Table 1; Figure 2). No heterocystous cyanobacteria were identified from the study area.

Similar results were supported (Regini and Selva, 2007; Mary et al., 2011) that the perennial ponds in Kanyakumari were rich with cyanophyta in particular *Aphanocapsa* spp., *Chroococcus* sp., *Microcystis* spp., *Spirulina major*, *Oscillatoria* spp. and *Anabaena* spp*.* It is also reported that heterocystous cyanobacteria are less resistant to the turbulence of the running water bodies that might broke the heterocysts where the weaker connections between heterocystous and vegetative cells (Stal and Zehr, 2008). Sugumar et al. (2011) reported that 18 species of marine cyanobacteria were found in salt pans of Cape Comorine coast. Selvakumar and Sundararaman (2009) observed twelve species of unicellular and filamentous species of cyanobacteria belonging to either *Chroococcaceae* or *Oscillatoriaceae* families in estuarine water. Nagasathya and Thajuddin

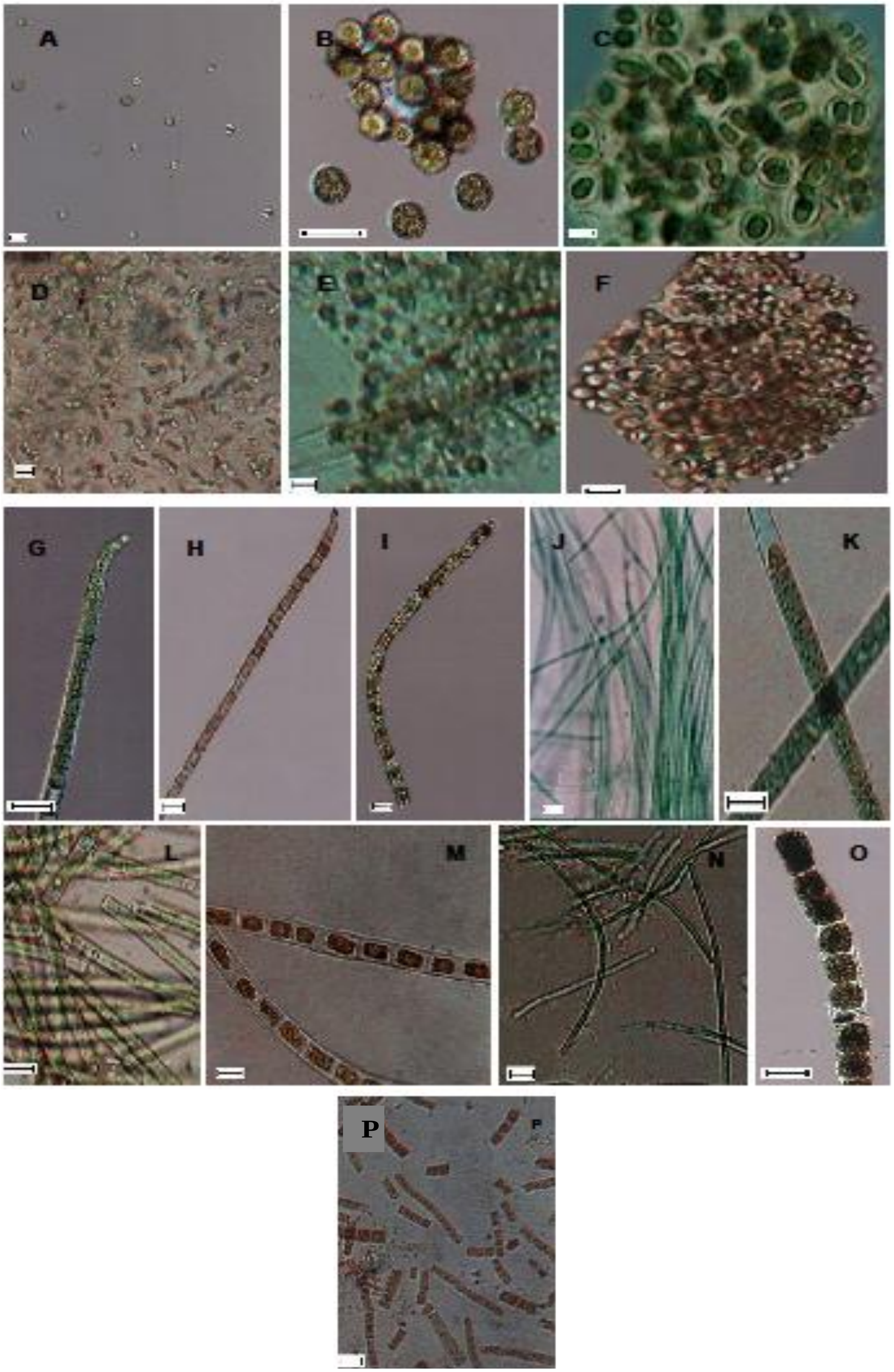

Figure 2. Microphotographs of cyanobacteria from the wet lands of Kanyakumari coast, Tamil Nadu, India, magnification at 450X (- bar indicates 10 µm). A) *Synechocystis* sp. B) *Aphanocapsa* sp. C) *Gloeocapsa* sp. D) *Aphanothece* sp. E) *Microcystis lamelliformis* F) *Microcystis flo-aquae* G) *Oscillatoria amoena* H) *O. earlei* I) O. *pseudogeminata* J) *Phormidium fragile* K) *Lyngbya* sp. L) P. retzii M) *Symploca* sp. N) *Spirulina subtilissima* O) *Microchaete* sp. P) *Phormidium* sp.

Table 1. Distribution of cyanobacteria in different months.

S/N	Cyanobacteria species	S1			S2			S3			S4			S5		
		Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
1	*Oscillatoria earlei*	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-
2	*Oscillatoria pseudogeminata*	-	-	-	-	-	+	-	+	+	-	-	-	+	+	+
3	*Oscillatoria amoena*	+	-	-	-	-	-	-	-	-	+	+	+	+	+	+
4	*Oscillatoria tenuis*	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-
5	*Phormidium* sp.	-	-	-	+	+	+	+	+	+	-	-	-	-	-	-
6	*Phormidium fragile*	-	-	-	+	+	+	-	+	+	-	+	+	+	+	+
7	*Phormidium retzii*	-	-	-	-	-	+	-	+	+	-	-	+	-	+	+
8	*Lyngbya* sp.	+	-	-	+	-	-	-	-	-	-	-	-	+	+	+
9	*Symploca* sp.	-	-	-	-	-	-	+	-	-	+	+	+	-	-	-
10	*Microchaete* sp.	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-
11	*Spirullina subtilissima*	-	-	-	-	-	-	+	+	+	-	-	-	-	+	+
12	*Microcystis flos-aquae*	+	+	+	-	-	-	-	+	+	+	+	+	-	-	-
13	*Microcystis lamelliformis*	+	+	+	+	+	-	-	+	+	+	+	+	-	-	-
14	*Gloeocapsa* sp.	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+
15	*Aphanocapsa* sp.	-	+	+	-	-	-	-	-	-	+	+	+	-	-	-
16	*Aphanothece* sp.	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-
17	*Synechocystis* sp	-	+	+	-	+	-	-	-	-	-	-	-	-	-	+

S/N	Cyanobacteria species	S6			S7			S8			S9			S10		
		Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar	Jan	Feb	Mar
1	*Oscillatoria earlei*	+	+	+	-	+	+	+	+	+	-	-	-	+	+	+
2	*Oscillatoria pseudogeminata*	-	+	-	-	-	+	-	+	+	-	-	-	-	-	+
3	*Oscillatoria amoena*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
4	*Oscillatoria tenuis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	*Phormidium* sp.	-	-	-	-	+	+	-	+	+	-	-	-	-	-	-
6	*Phormidium fragile*	-	-	+	-	-	+	+	+	+	+	+	+	-	-	-
7	*Phormidium retzii*	-	-	+	-	-	-	-	+	+	-	-	-	-	-	-
8	*Lyngbya* sp.	+	+	-	+	-	-	+	-	-	+	+	+	+	+	+
9	*Symploca* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	*Microchaete* sp.	-	-	-	+	-	-	+	-	-	+	+	+	-	-	-
11	*Spirullina subtilissima*	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
12	*Microcystis flos-aquae*	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+
13	*Microcystis lamelliformis*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
14	*Gloeocapsa* sp.	-	+	+	-	-	-	+	-	-	+	+	+	-	-	-
15	*Aphanocapsa* sp.	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
16	*Aphanothece* sp.	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-
17	*Synechocystis* sp.	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-

+ Presence; - Absence. Thangapattanam (S1), Enayam (S2), Melmidallam (S3), Colachel (S4), Manavalakurichi (S5), Kadiyappatanam (S6), Muttam (S7), Rajakamangalam (S8), Manakudi (S9), Kanyakumari (S10).

Table 2. Shannon – Weiner diversity index of cyanobacterial population (Month wish study).

Sample site	Sampling month		
	January	February	March
S1	0.777	0.705	0.754
S2	0.659	0.528	0.692
S3	0.545	0.788	0.655
S4	0.73	0.642	0.741
S5	0.52	0.576	0.87
S6	0.429	0.782	0.81
S7	0.423	0.674	0.779
S8	0.744	0.766	0.68
S9	0.60	0.679	0.678
S10	0.548	0.657	0.68

Thangapattanam (S1), Enayam (S2), Melmidallam (S3), Colachel (S4), Manavalakurichi (S5), Kadiyappatanam (S6), Muttam (S7), Rajakamangalam (S8), Manakudi (S9), Kanyakumari (S10)

Table 3. Species richness index of cyanobacterial population collected during the study period.

Sample site	Sampling month		
	January	February	March
S1	0.92	0.906	0.969
S2	0.779	0.877	0.991
S3	0.905	0.873	0.938
S4	0.949	0.913	0.952
S5	0.967	0.825	0.963
S6	0.899	0.925	0.958
S7	0.887	0.965	0.922
S8	0.956	1.097	0.974
S9	0.874	0.972	0.971
S10	0.91	0.941	0.974

Thangapattanam (S1), Enayam (S2), Melmidallam (S3), Colachel (S4), Manavalakurichi (S5), Kadiyappatanam (S6), Muttam (S7), Rajakamangalam (S8), Manakudi (S9), Kanyakumari (S10).

(2008) isolated 27 species of cyanobacteria belonging to 4 families from salt pans of Southeastern Coast of India. Generally, non-heterocystous *Oscillatoria* spp., *Lyngbya* spp. and *Microcystis* spp. were the dominant cyanobacteria found in this wetland. The intense proliferation of cyanobacteria in coastal ecosystems is well documented in several studies (Kanoschina et al., 2003; Gasiunaite et al., 2005). The differences in cyanobacterial species composition could be conceivably attributed to differences in physicochemical parameters between the cyanobacterial sampling sites. Nutrient accumulation may have different forces on the ecosystem at different periods (Glibert et al., 2007).

It is well known that the environmental degradation which results from eutrophication strength of less tolerant plankton species favors the development of cyanobacteria (Scheffer et al., 1997). It has also been reported that environmental factors (Silva and Pienaar, 2000), nutrient, and hydrologic conditions (Pearl, 2008) may also influence the morphological and cyanobacterial bloom dynamics in aquatic ecosystems. In this present study, the results of physico-chemical composition of sampling sites reveal that they were nutrient rich environments; in particular, total phosphorous, ammonia, and nitrate concentrations were higher and may have greatly supported the abundance of different cyanobacterial morphovers. Among the 17 different cyanobacteria the genus Oscillatoria was dominant; this may have been influenced by higher availability of nutrient, particularly nitrate and phosphate, due to the discharge of sewage.

In our investigation, the cyanobacterial abundance was high at sites 4 and 8. Total phosphorous, ammonia, and nitrate concentrations of site 4 and 8 were higher than the other sampling sites. It has been suggested that environmental nutrient positively influences the magnitude and diversity of cyanobacterial species. High phosphate, nitrate and trace metals and low N:P have been widely reported as major factors limiting cyanobacteria abundance (Elser et al., 1990; Akin-Oriola, 2003). Cyanobacteria grew rapidly in the rice fields that contain ample organic matters in the soil and water, as well as the physico chemical conditions such as pH, temperature, organic sources, etc. that influence the propagation (Choudhury and Kennedy, 2004). In this investigation, most of the cyanobacterial species identified in the water samples did not mach with temperature, DO and pH. *Spirulina* sp. was recorded only in the saline rich environments (15 to 19 ppt). *Spirulina* spp. occurs in the environments with higher nutrient levels and varying temperature and salinity (Vonshak and Tomaselli, 2000). Jewel et al. (2006) reported cyanobacteria especially *Microcystis* sp. was found to be controlled by relatively high temperature (>25°C) and nutrient enrichment especially high nitrate concentration. Affan et al. (2005) and Wetzel (2001) suggested that in summer, blue green algae dominated in water bodies. Some cyanobacteria such as *M. flos-aquae, Microcystis aeruginosa* and *Aphanizomenon subcylindrica* were more susceptible to low pH (Okogwu and Ugwumba, 2009).

Species richness and diversity

In this present investigation, a total of 11 different genera of cyanobacteria were observed (Table 2). Species diversity of the present study was always higher in all sampling stations. Similar species were recorded in a majority of the regions that indicate the dominant group of cyanobacteria. Species richness results proved the diversity of cyanobacteria in various taxonomic groups. Species richness and diversity index of cyanobacteria showed a variable at different sampling period (Tables 2 and 3). The member of *Oscillatoria* sp and *Microstystis* sp

Table 4. Physiochemical parameters of the water sample collected from different sampling sites in Kanyakumari District.

Parameters	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
pH	7.42 – 7.61	7.14 – 7.24	7.13 – 7.62	7.32 – 7.95	7.6 – 7.89	7.48 – 8.07	7.04 – 7.34	7.46 – 7.84	7.51 – 7.86	7.49 – 7.85
Salinity (ppt)	10 –16	12 –16	15 – 19	12 – 14	14 – 19	12 – 16	12 – 14	13 –15	12 –15	12 – 17
Turbidity (OD)	0.11 – 0.3	0.1 – 0.13	0.38 – 0.62	0.26 – 0.31	0.49 – 0.8	0.12 – 0.37	0.29 – 0.37	0.19 – 0.48	0.16 – 0.37	0.18 – 0.51
DO (mgl^{-1})	1.0 – 1.2	0.4 – 0.7	0.3 – 1.3	0.6 – 1.1	0.4 – 0.9	0.5 – 1.2	0.6 – 1.9	0.8 – 1.6	1.0 – 1.3	0.9 – 1.8
Ammonia (mgl^{-1})	0.042 – 0.088	0.064 – 0.071	0.068 – 0.08	0.04 – 0.091	0.068 – 0.075	0.07 – 0.08	0.03 – 0.05	0.024 – 0.1	0.036 – 0.083	0.026 – 0.048
Total Phosphorous (mgl^{-1})	0.2 – 0.32	0.21 – 0.3	0.18 – 0.24	0.28 – 0.41	0.17 – 0.28	0.1 – 0.32	0.16 – 0.26	0.3 – 0.39	0.036 – 0.093	0.014 – 0.097
Nitrate (mgl^{-1})	0.2 – 0.36	0.32 – 0.64	0.3 – 0.42	0.44 – 0.86	0.34 – 0.71	0.2 – 0.28	0.19 – 0.32	0.32 – 0.76	0.2 – 0.37	0.26 – 0.34
Sulphate (mgl^{-1})	0.044 – 0.085	0.076 – 0.095	0.034 – 0.046	0.034 – 0.045	0.056 – 0.099	0.2 – 0.32	0.044 – 0.085	0.076 – 0.095	0.034 – 0.046	0.034 – 0.045

Thangapattanam (S1), Enayam (S2), Melmidallam (S3), Colachel (S4), Manavalakurichi (S5), Kadiyappatanam (S6), Muttam (S7), Rajakamangalam (S8), Manakudi (S9), Kanyakumari (S10).

Table 5. Latitudes and longitudes of study sites (Figure 1).

Study sites	Latitudes	Longitudes
1. Thangapattanam	N = 8’14’25.3411	E =77’10’13.3352
2. Enayam	N = 8’13’11.4471	E =77’11’13.9014
3. Melmidallam	N = 8’12’33.4138	E =77’12’20.6433
4. Colachel	N = 8’10’45.1479	E = 77’14’57.6105
5. Manavalakurichi	N = 8’8’59.9325	E = 77’18’0.5328
6. Kadiyappatanam	N = 8’8’4.8749	E = 77’18’25.2521
7. Muttam	N = 8’7’26.9451	E = 77’19’3.5669
8. Rajakamangalam	N = 8’7’37.9571	E = 77’20’20.1965
9. Manakudi	N = 8’5’35.3734	E = 77’28’59.3005
10. Kanyakumari	N = 8’4’51.5449	E = 77’32’39.3018

were found in all the sampling period. Hamish et al. (2004) reported that the commonest cyanobacteria recorded in the sea grass samples belonged to the genera *Oscillatoria, Lyngbya* and *Spirulina*. The members of genus *Oscillatoria* occurred throughout the period and seemed to be the most dominant with the highest diversity followed by the genus *Microcystis.*

In this study, the highest cyanobacterial diversity occurred in the sampling site S5 (H’=0.87) and the lowest was found in S7 (H’=0.432), (Table 2). The lower the index value might be the lack of species richness and degraded state of the ecosystem. A high value of diversity index generally implies healthy ecosystem, while a low value indicates degraded state (Manna et al., 2010). It was observed that cyanobacteria especially *Oscillatoria, Microcystis* and *Phormidium* were observed mostly. The cyanobacterial abundance was significantly higher during March than the January and February months. During this period, higher cyanobacterial diversity was observed. The present basic information of the cyanobacterial distribution and abundance would be a useful tool for further ecological assessment and monitoring of these coastal wet land ecosystems of Kanyakumari

District.

Further molecular identification is required to analyze phylogenetic relatedness of the isolated strains. In addition to this, studies are required to analyze the cyanobacterial diversity at seasonal variation, which would give the clear picture of species richness and diversity variation at this region.

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