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Cyanobacterial Diversity in the Hypersaline Environment of the Saltpans of Southeastern Coast of India

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Abstract: The composition, distribution and biodiversity of cyanobacteria were investigated in relation to salinities of several saltpans of Southeastern coasts of India from Vedharnyam (10°22' N; 79°51' E) to Mandapam (9°17' N; 79°7' E). Sixty one species belonging to 21 genera and six families were identified. The salinity was ranged from 48 to 185 ppt. Almost all species were found along the range from 48 to 89 ppt., while there was a relative reduction in species composition and biodiversity with salinity of 150 and 185 ppt. The most widespread cyanobacteria were *Spirulina subsalsa*, *S. labyrinthiformis*, *Oscillatoria willei*, *O. salina*, *O. subbrevis*, *O. laete-virens*, *Phormidium tenue* and *Microcoleus chthonoplastes*. *Aphanothece microscopica*, *Arthrospira platensis*, *Dermocarpa leibleiniae*, *Oscillatoria terebriformis*, *Oscillatoria acuminata* and *Synechocystis salina* were limited in their distribution to lower salinities. *Nostoc* sp. was the only heterocystous form recorded in the hypersaline environment.

Key words: Cyanobacteria, hypersaline, saltpans, survey

INTRODUCTION

Microbial diversity represents the largest untapped reservoir of biodiversity for potential discovery of new biotechnological products, including new pharmaceuticals, new enzymes, new chemicals or new organisms that carry out novel processes. The long coastlines of tropical India offer a rich scope to explore marine cyanobacterial resources for human welfare and national development.

Saltpans are one of the hypersaline extreme environments. They are characteristically exposed to a wide range of environmental stress and perturbations manifest mainly through salinity changes. Among halophilic microorganisms, bacteria, cyanobacteria, diatoms, green algae and fungi are abundant in saltpans. (DasSarma and Arora, 2002). Marine cyanobacteria are capable of adapting salinity stress. Mechanism of salt adaptation in marine cyanobacteria has been elucidated in terms of osmoprotective compounds and maintenance of low internal contents of inorganic ions. These substances even in high concentration are compatible with cellular metabolism, it is assumed that they are able to protect macromolecules against denaturation and thus to improve their function in a cell environment of reduced water potential (Grant and Tindall, 1986; Reed and Stewart, 1988; Apte and Bhagwat, 1989; Molitor *et al*., 1986; Lu and Zhang, 2000). The objective of this study has been, therefore, to acquire information of the composition, distribution and biodiversity of the cyanobacteria occurring in the Southeastern coast saltpans of the Indian coasts.

MATERIALS AND METHODS

The survey was carried out in several saltpans extending from Vedharnyam (lat. 10°22'N and long. 79°51'E) to Mandapam (lat. 9°23'N and long. 79°12'E) encompassing the regions like Kodiakarai, Adirampattinam, Kattumavadi, Manamelgudi, Ammapattinam, Kottaipattinam, Thondi, Devipattinam, Valianokam and Ramanathapuram in the year 2005. Saltpan water samples and visible cyanobacterial specimens were collected in polythene bags and plastic vials with code numbers pertaining to the place and area of collection. Specimens were later transferred to Erlenmeyer flasks containing respective culture media like Mn medium and modified MN medium containing 100 ppt of salinity (Rippka *et al*., 1979). They were maintained in culture room at the Department of Microbiology, J.J. College of Arts and Science, Pudukkottai, Tami lNadu, India under white fluorescent lamps (1400 lux): 14+10 L/D at room temperature until examination. Routine microscopic examinations of specimens were carried out

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recording cell size and characteristic morphological features. Camera Lucida diagram and or microphotographs (microprocessor controlled Leitz Diaplan Microscope, Germany) of most of the species were made. Identification of the cyanobacterial samples were carried out using the taxonomic publications of Biswas (1926, 1949), Geitler (1932), Iyengar and Desikachary (1944), Smith (1950), Prescott (1951), Desikachary (1959), Starmach (1966), Tilden (1968), Zaneveld (1972), Hum and Wicks (1980) and Anand (1989). The diversity index like Simpson's index, Shannon index, Shannon evenness, Species richness and Dominant index were calculated using the procedures of Beena *et al.* (2000).

RESULTS

Cyanobacterial biodiversity in the saltpans were greatly influenced by the variations in the salinity. The samples were collected in different salinities of the saltpans namely 48, 50, 62, 91, 98, 150 and 185 ppt showed variations in their biodiversity (Table 1, Fig. 1). Surprisingly, 51 cyanobacterial species were recorded in 48, 50 and 62 ppt. The decline in the biodiversity was noticed in the higher salinities (Table 1). Based on the biodiversity in different salinities, the following species viz., *Synechococcus aeruginosus*, *Synechocystis aquatilis*, *Spirulina subsalsa*, *S. labyrinthiformis*,

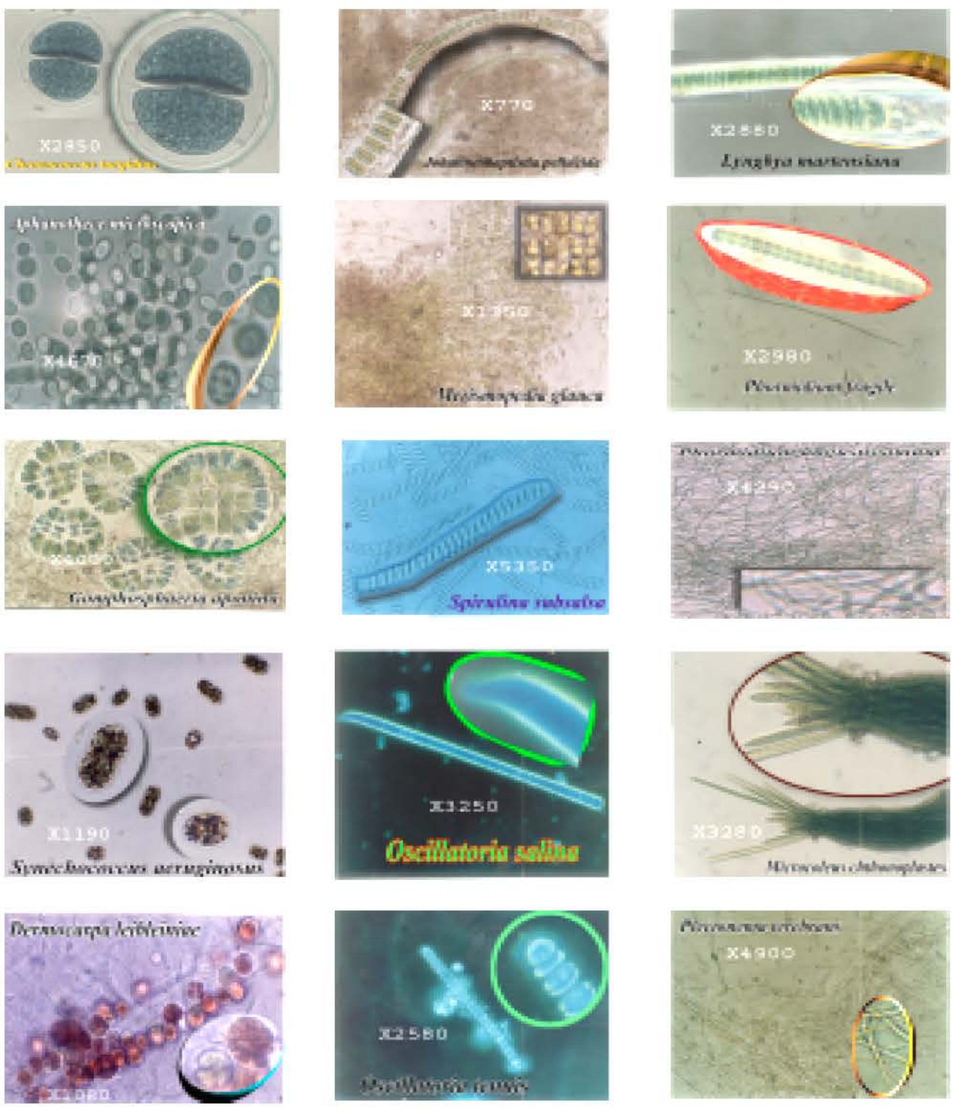

Fig. 1: Cyanobacterial flora of the salt pans

Table 1: Cyanobacterial flora from saltpans of different salinities

S. No.	Name of the organism	Salinity (ppt) 48	50	62	91	98	150	185
	Family: Chroococcaceae							
1	*Microcystis litoralis* (Hansg.) Forti[1,2,3]	+++++	+++++	+++++	+++++	+++	-	-
2	*Chroococcus minutus* (Kütz.) Nüg.[1,2]	+++++	+++++	+++++	+++++	+++	-	-
3	*Chroococcus turgidus* (Kütz.) Nüg.[1,2]	+++++	+++++	+++++	+++++	++++	-	-
4	*Gloeocapsa stegophila* (Itzigs.) Rabenh[1,2]	++++	++++	++++	++++	+	-	-
5	*Gloeocapsa gigantea* sp. Nov.[1,2]	++++	++++	++++	+	+	-	-
6	*Gloeocapsa crepidinum* Thuret[1,2]	++++	++++	+++	+	-	-	-
7	*Aphanocapsa littoralis* Hansgirg[1,2]	++++	++++	+++	+	-	-	-
8	*Aphanocapsa elachista* W.et G.S.West[1,2]	++++	++++	++++	+	-	-	-
9	*Aphanothece microscopica* Nüg.[1,2]	++++	++++	+	-	-	-	-
10	*Aphanothece naegelii* Wartm.[1,2]	++++	+++	+++	+	-	-	-
11	*Synechococcus elongatus* Nüg.[1,2,3]	+++++	+++++	+++++	+++++	+	-	-
12	*Synechococcus aeruginosus* Nüg.[1,2,3]	+++++	+++++	+++++	+++++	+++	+	+
13	*Synechocystis salina* Wislouch[1,2]	+++++	+++++	+++++	++++-	-	-	-
14	*Synechocystis aquatilis* Sauv.[1,2,3]	++++	++++	++++	+++	+++	+	+
15	*Synechocystis pevalekii* Ercegovic[1,2]	++++	++++	++++	+++	+++	-	-
16	*Gomphosphaeria aponina* Kütz.[1,2]	++++	++++	++++	+++	+	-	-
17	*Merismopedia glauca* (Ehrenb.) Nüg.[1,2]	+++++++	++++	+++	+++	+	-	-
	Family: Entophysalidaceae							
18	*Johannesbaptistia pellucida* (Dickie) Taylor et Drouet[1,2]	++++	++++	+++	+	+	-	-
	Family: Dermocarpaceae							
19	*Dermocarpa leibleiniae* (Reinsch) Born.et Thur.[1,2]	++++	++++	+++	-	-	-	-
20	*Dermocarpa olivacea* (Reinsch) Tilden[1,2]	++++	++++	+++	+	+	-	-
	Family: Oscillatoriace							
21	*Arthrospira platensis* (Norast.) Gomont[1,2]	++++	+++	+	-	-	-	-
22	*Spirulina subsalsa* Oerst. ex Gomont[1,2,3]	+++++	+++++	+++++	+++++	+++++	+++++	+++++
23	*Spirulina labyrinthiformis* (Menegh.) Gomont[1,2,3]	+++++	+++++	+++++	+++++	+++++	+++++	+++++
24	*Oscillatoria chalybea* (Mertens) Gomont[1,2,3]	++++	++++	++++	+++	+	+	+
25	*Oscillatoria tenuis* Ag. ex Gomont[1,2,3]	+++++	+++++	+++++	+++++	+++++	+++++	+++++
26	*Oscillatoria terebriformis* Ag. ex Gomont	++++	++++	+	-	-	-	-
27	*Oscillatoria salina* Biswas[1,2,3]	+++++	+++++	+++++	+++++	+++++	+++++	+++++
28	*Oscillatoria brevis* (Kütz.) Gomont[1,2]	+++	-	-	-	-	+	+
29	*Oscillatoria subbrevis* Schmidle[1,2]	-	-	-	++++	+++	+	+
30	*Oscillatoria chlorina* Kutz.ex Gomont[1,2,3]	+++++	+++++	+++++	+++++	+++++	+++++	+++++
31	*Oscillatoria laete-virens* (Crouan) Gomont	++++	++++	++++	+++	+	-	-
32	*Oscillatoria guttulata* Van Goor*[1,2]	-	-	-	-	-	++++	+
33	*Oscillatoria willei* Gardner em. Drouet[1,2]	++++	++++	++++	++++	+++	+	+
34	*Oscillatoria formosa* Bory ex Gomont[1]	-	-	-	++++	+	-	-
35	*Oscillatoria acuminata* Gomont	++++	++++	+++	-	-	-	-
36	*Oscillatoria limnetica* Lemm.	++++	++++	+++	+	+	-	-
37	*Oscillatoria curviceps* Ag. ex Gomont[1,2,3]	++++	++++	++++	+++	+	-	-
38	*Oscillatoria minnesotensis* Tilden	++++	++++	++++	+++	+	-	-
39	*Oscillatoria nigroviridis* Thwaites ex Gomont[1,2]	++++	++++	++++	+++	+	-	-
40	*Oscillatoria cortiana* Meneghini ex Gomont[1,2]	++++	++++	++++	+++	+	-	-
41	*Oscillatoria foreaui* Fremy	++++	++++	++++	+++	+	-	-
42	*Phormidium angustissimum* W. et G.S West[1,2,3]	++++	++++	+++	-	-	+	-
43	*Phormidium tenue* (Menegh.) Gomont[1,2,3]	+++++	+++++	+++++	+++++	+++++	+++++	+++++
44	*Phormidium valderianum* (Delp.) Gomont[1,2,3]	++++	++++	++++	+++	+	-	+
45	*Phormidium corium* (Ag.) Gomont[1,2,3]	++++	++++	++++	+++	+++	+	+
46	*Phormidium fragile* (Meneghini) Gomont[1,2,3]	++++	++++	++++	+++	+	-	-
47	*Lyngbya martensiana* Menegh. ex Gomont[1,2,3]	+++++	+++++	+++++	+++++	+++++	+++++	+++++
48	*Lyngbya confervoides* C. Ag. Ex Gomont[1,2]	-	-	-	+	+	+	-
49	*Lyngbya semiplena* (C. Ag.) J. Ag ex Gomont	-	-	-	-	-	+	-
50	*Lyngbya infixa* Fremy[1]	-	-	-	+++	+	-	-
51	*Lyngbya aestuarii* Liebm.ex Gomont[1,2]	-	-	-	+++	+	-	-
52	*Lyngbya acuminata* sp. Nov.[1,2]	++++	++++	+++	+++	+	+	-
53	*Lyngbya lutea* (Ag.) Gomont[1,2]	++++	++++	++++	+++	+	+	-
54	*Lyngbya tayloriae* Forti[1,2]	++++	++++	+++	+	+	-	-
55	*Symploca hydnoides* Kutzing ex Gomont[1]	++++	++++	+	-	-	-	-
56	*Katagnymene pelagica* Lemm.[1]	++++	++++	+++	+	+	-	-
57	*Microcoleus acutissimus* Gardner[1,2]	-	-	-	+	+	-	-
58	*Microcoleus chthonoplastes* Thuret ex Gomont[1,2,3]	+++++	+++++	+++++	+++++	+++++	+++++	+++++
	Family: Nostocaceae							
59	*Nostoc* sp.[1]	-	-	-	-	-	-	+
60	*Pseudanabaena schimdlei* Jaag. O[1,2]	++++	++++	++++	++	+	-	-
	Family: Scytonemataceae							
61	*Plectonema terebrans* Born. et ex Gomont[1,2,3]	+++	++++	++++	+++	+	-	-
	Total No. of species	51	51	51	48	45	20	18

+: Present, ++: Co abundant, +++: Abundant, ++++: Co dominant, +++++: Dominant and versatile, -: Not detected, 1: Bay of Bengal region, 2: Palk Bay region, 3: Palk Strait region

Table 2: Species richness, diversity, evenness and dominance of cyanobacteria in different salinities

S. No.	Name of the organism	Salinity (ppt)	Species richness	Simpson index	Shannon index	Shannon evenness	Dominance index
1	Cyanobacteria	48	12.19	1.430	0.149	0.009	61.50
2		50	12.90	1.430	0.149	0.009	61.50
3		62	11.70	1.550	0.175	0.011	72.13
4		91	10.90	1.760	0.212	0.015	70.49
5		98	10.73	1.838	0.224	0.016	67.20
6		150	4.60	9.300	0.364	0.060	34.42
7		185	4.10	11.490	0.360	0.066	27.86

Oscillatoria chalybea, *O. tenuis*, *O. salina*, *O. chlorina*, *O. willei*, *Phormidium tenue*, *P. corium*, *Lyngbya martensiana*, *Microcoleus chthonoplastes* were considered as versatile species. The diversity index like Simpson's index, Shannon index, Shannon evenness, Species richness and Dominant index were calculated in the different salinities (Table 2). The species richness was higher in lower salinities (48, 50, 62, 91 and 98 ppt) when compared with that of higher salinities (150 and 185 ppt). The Shannon evenness was almost even in all the salinities but the dominance index was high in 62 ppt.

DISCUSSION

The remarkable adaptability of cyanobacteria to wide ranges of environmental factors or to the salinity is however well known (Ercegovic, 1930; Desikachary, 1959; Fogg *et al*., 1973; Durr and Mitsui, 1992; Carr and Whitton, 1982). Prabaharan (1988) reported that the marine Cyanobacterium *Phormidium valderianum* BDU 30501 was capable of growing in the salinities ranging from 0-90 ppt. In the present study 61 species of cyanobacteria, were found (Table 1) in different saltpans of Tamil Nadu.

It was interesting to note that of these 61 species, 60 species of 20 genera were non-heterocystous belonging to the families Oscillatoriaceae and Chroococaceae. The only heterocystous cyanobacterium *Nostoc* sp. was recorded in the entire survey of saltpans. As stated by Howsley and Pearsons (1979) the high sulphide content and its toxicity to the heterocystous form subsequently disputed these forms. The anaerobic condition prevailing in these dark environments believed to exclude the heterocystous forms (Oren and Shilo, 1979; Stal *et al*., 1985).

Totally 27 species of 13 genera belonging to 4 families namely *Chroococcus minutus*, *Aphanothece microscopica*, *Synechococcus aeruginosus*, *Synechocystis salina*, *Synechocystis aquatilis*, *Dermocarpa leibleiniae*, *Arthrospira platensis*, *Spirulina subsalsa*, *S. labyrinthiformis*, *Oscillatoria chalybea*, *O. tenuis*, *O. terebriformis*, *O. salina*, *O. chlorina*, *O. laete-virens*, *O. willei*, *O. acuminata*, *Phormidium angustissimum*, *P. tenue*, *P. valderianum*, *P. corium*, *Lyngbya martensiana*, *L. acuminata*, *L. lutea*, *Symploca hydnoides*, *Microcoleus chthonoplastes* and *Plectonema terebrans* (Fig. 1) were considered as versatile species, since they were distributed throughout the area of survey agree with the results of Thajuddin (1991), Thajuddin and Subramanian (2005). As stated by DasSarma and Arora (2002), cyanobacteria dominate the planktonic biomass and form microbial mats in many hypersaline lakes. The top brown layer of microbial mats contains a common unicellular cyanobacterial species, *Aphanothece halophytica*. It can grow over a wide range of salt concentrations, ranging from 2-5 mol L^{-1} NaCl -3.5 mol L^{-1}. It uses glycine betaine as the major compatible solute, which it can take up from the medium or synthesize from choline. *Aphanothece halophytica* and similar unicellular cyanobacteria have been described from the Great Salt Lake, Dead Sea, Solar Lake and artificial solar ponds. A planktonic cyanobacterium reported from the Great Salt Lake is *Dactylococcopsis salina* (Das Sarma and Arora, 2002). A variety of filamentous cyanobacteria, e.g., in the order Oscillatoriales, such as *Oscillatoria neglecta*, *O. limnetica*, *O. salina*, *Phormidium ambiguum* and *Microcoleus chthonoplastes* have also been described that develop in the green second layer of mats in hypersaline lakes. These are more moderate halophiles, usually growing optimally at 1-2.5 mol L^{-1} NaCl (Das Sarma and Arora, 2002).

Thajuddin and Subramanian (1992, 1995) reported 50 species of 19 genera of cyanobacteria in saltpans with salinity over 50 ppt. Although several workers had reported the occurrence of cyanobacteria in saltpans and salt lakes with very high salinity (Biswas, 1949; Aggarwal, 1951; Subbaramaiah, 1972; Anand and Venkatesan, 1985; Anand *et al*., 1986; Santra *et al*., 1988; Pinckney *et al*., 1995; Paerl *et al*., 2000; Thajuddin *et al*., 2002) but none of them had recorded such a large number of cyanobacteria from the hypersaline environments.

The present study of surveying the saltpans of TamilNadu not only gives an idea about the enormous diversity and wealth of microbial population but also provides an opportunity in order to exploit these hypersaline forms.

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