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DIVERSITY OF CYANOBACTERIAL SPECIES DISTRIBUTION ON ROCKY COAST OF BULEJI, PAKISTAN

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ABSTRACT

Cyanobacteria are widely distributed in natural waters. They constitute the major proportion of total primary production in tropical, sub-tropial and temperate waters. Present research was conducted on biodiversity of epiphytic, epizoic, epilithic, planktonic and edaphic cyanobacteria from a rocky shore (Buleji) and mangrove swamps (Sandspit) backwaters, on the Karachi coast.

A total of 191 species of cyanobacteria were recorded in samples collected from rocky shore and mangrove forest. Out of which 92 species were recorded from only one niche (Table 1) while the rest of the species occurred commonly in various habitats. The highest number of cyanobacteria (124 species) were recorded as epiphytic species associated with green, brown and red seaweeds, followed in descending order by edaphic (73 spp), epizoic (65 spp), epilithic (57 spp), rock pool water (44 spp), mangrove swamp (42 spp) and coastal water (29 spp). *Phormidium* was the most dominant genus recorded from all habitats containing 39 species, the second most abundant genus was the *Oscillatoria* (33 species). Out of 192 species 93 species have been observed from a single habitat, such as, epiphytic (42 spp), epizoic (13 spp), epilithic (9 spp), edaphic (13 spp), rock pools (2 spp), coastal water (3 spp) and mangrove swamp (11 spp).

Key-words: Cyanobacteria, bacterial diversity, distribution, rocky coast, Karachi, Pakistan.

INTRODUCTION

Cyanobacteria are a unique group of photosynthetic prokaryotes previously known as blue–green algae. They are distributed widely in terrestrial and aquatic environment. Among algal forms, cyanobacteria are the most abundant group in the marine environment. There are various reports available on the distribution of cyanobacteria from different part of the world, including countries bordering Indian Ocean, for example, Saudi Arabia (Khoja 1987; Hussein & Khoja 1993; Potts 1980) India (Thajuddin & Subramanian 1992, 1994; Santra & Pal 1988; Santra *et al.*, 1988; Qasim 1970; Nair *et al.*, 1980; Devassy 1987; Maity *et al.*, 1987; Desikachary 1959) and Pakistan (Bano & Siddiqui 2003; Siddiqui & Bano 2001; Shameel 2000; Shameel *et al.*, 1996; Saifullah & Taj 1995; Shameel & Tanaka 1992; Mansoor *et al.*, 2000; Zaib-un-Nisa *et al.*, 2000; Saifullah *et al.*, 1997).

Mangrove forests and rocky shores offer a variety of ecological niches for cyanobacterial colonization. Therefore the present paper reports on the diversity of cyanobacterial species found in various niches at a rocky shore (Buleji, Karachi coast) and mangrove swamps (Sandspit backwaters).

MATERIALS AND METHODS

Cyanobacterial samples were collected during 1994-1998 from different habitats of rocky shore of Buleji and from mangrove forests at Sandspit Backwaters. Samples of coastal water, rock pool water, stone surfaces, sediments, macroalgae, molluscan shells, scraping from mangrove pneumatophore and bark and mangrove sediments were randomly collected, placed in a separate sterile plastic bags and brought to the laboratory in a cool box.

The samples were examined directly under the microscope and also inoculated in three types of medium in order to encourage the growth of cyanobacterial cells. Synthetic seawater based ASN III and MN media (Rippka *et al.*, 1979) and natural seawater based Miquel‘s medium (Imai 1977) were used. Inoculated media tubes were incubated under constant light and room temperature (28 ± 2^oC). Direct examination of samples was done using a light microscope. Any observed growth in culture tube was examined under the microscope. Characteristics of cyanobacterial cells and trichoms observed were used for the identification of species according to criteria used by Desikachary (1959), Anagnostidis & Komarek (1985, 1988) and Komarek & Anagnostidis (1986, 1989).

RESULTS

List of cyanobacteria observed from different niches is given as Table I. A total of 191 species of cyanobacteria were recorded in samples collected from a rocky shore and mangrove forest. Out of which 93 species were recorded from only one niche while the rest of the species occurred commonly in various habitats. Epiphytic cyanobacterial association with 27 species of seaweeds occurring on the rocky shore was studied. Seaweeds including 10 green algal species (Chlorophytes), 8 brown algal species (Phaeophytes) and 9 red algal species (Rhodophytes) showed a total of 124 species of cyanobacteria were associated with these macroalgal species, of which highest number of species were in the order Nostocales (77 spp) followed with respect to number of species in descending order by Chroococales (35 spp), Chamaesiphonales (8 spp) and Pleurocapsales (4 spp). A total of 66 epizoic cyanobacterial species were recorded from the shell surfaces of gastropods (9 species) and bivalve (1 species). The epizoic species were either unicellular (26 spp) or non-heterocystous filamentous forms (40 spp) belonging to 4 orders, 21 genera. The epilithic cyanobacterial flora attached on the surfaces of stones (57 spp) included both unicellular (18 spp) and filamentous forms (39 spp) pertaining to 4 orders and 14 genera. The edaphic cyanobacteria were more diverse, and 73 edaphic species were observed belonging to 4 orders and 21 genera. The cyanobacterial species including unicellular (22 spp) and both non-heterocystous filamentous (49 spp), and heterocystous forms (2 spp) were observed.

Table 1. Diversity of cyanobacteria on the rocky shore of Buleji and Sandspit, Karachi.

Cyanobacterial species	**Epiphytic**	**Epizoic**	**Epilithic**	**Edaphic**	**Rock Pool Water**	**Coastal Water**	**Managrove Swamp**
Chroococcales							
Aphanocapsa biformis	-	-	-	+	-	-	-
A. littoralis	+	+	+	-	-	-	-
A. rivularis	+	-	-	-	+	-	-
Aphanothece bullosa	+	-	-	-	-	-	-
A. microscopica	-	+	-	-	-	-	-
A. nidulans	+	-	-	-	-	+	-
A. stagnina	-	-	+	-	-	-	-
Chroococcus cohaerens	+	+	+	+	-	+	-
C. dispersus	+	-	-	-	-	-	-
C. gomontii	+	-	-	-	-	-	-
C. hangsgirgi	+	-	-	-	-	-	-
C. indicus	+	-	-	+	-	-	-
C. limneticus	-	-	-	-	-	+	-
C. macrococcus	+	-	-	-	-	-	+
C. minor	+	-	+	+	-	-	-
C. minutus	+	+	+	+	+	-	-
C. montanus	+	+	-	-	-	-	-
C. pallidus	+	-	-	-	-	-	-
C. schizodermaticus	-	-	-	-	+	-	-
C. tenax	+	-	-	-	-	-	-
C. turgidus	+	+	-	+	-	+	-
Chlorogleopsis microcystoides	-	-	-	+	-	-	-
C. fritschii	+	-	-	-	-	-	-
Coelosphaerium kuetzingianum	+	-	-	-	-	-	-
Gloeocapsa calcarea	+	-	+	-	-	-	-

G. compacta	+	+	+	+	-	-	-
G. cripidinum	+	+	+	+	-	-	+
G. gelatinosa	-	+	-	-	-	-	-
G. punctata	+	-	-	-	-	-	-
G. pleurocapsoides	-	-	-	+	-	-	-
G. kuetzingianum	+	-	-	-	-	-	-
Gloeothece fusco-lutea	-	+	-	-	-	-	-
G. palea	-	+	-	-	-	-	-
G. rhodochlamys	+	+	+	+	+	+	-
G. samoensis	+	+	-	-	-	-	-
G. rupestris	+	-	-	-	-	-	+
Merismopedia convoluta	-	-	-	+	-	-	+
M. elegans	+	+	+	+	-	+	+
M. glauca	+	-	+	-	-	-	-
M. minima	+	-	-	-	-	-	-
M. punctata	+	-	-	+	-	-	-
M. tenuissima	+	-	-	-	-	+	-
Microcystis litoralis	-	-	-	+	-	-	-
M. viridis	-	-	-	-	-	-	+
Synechococcus cedrorum	+	-	-	-	-	-	-
S. elongatus	+	+	-	-	-	-	-
Stanieria cyanosphaera	-	-	-	-	-	-	+
Synechocystis aquatilis	+	+	+	-	+	+	+
S. pevalekii	+	+	-	+	-	-	+
Chamaesiphonales							
Chroococidiopsis indica	+	+	-	-	-	-	+
Chamaecalyx swirenkoi	+	-	-	-	-	-	-
Dermocarpa clavata	+	+	-	-	+	-	+
D. flahaultii	+	+	-	+	-	-	-
D. hemisphaerica	-	-	-	-	-	-	+
D. leibleiniae	+	+	+	+	+	+	+
D. olivacea	+	+	+	-	+	+	+
D. parva	-	+	-	+	-	-	-
D. versicolor	+	-	-	-	-	-	-
D. sphaerica	+	+	+	-	-	-	-
Pleurocapsales							
Hydrococcus rivularis	-	-	-	-	+	+	

Hyella caespitosa	+	-	-	-	-	-	+
Myxosarcina burmensis	+	+	+	-	+	-	+
M. spectabilis	+	+	+	+	+	+	+
Xenococcus acervatus	+	-	-	+	-	-	-
X. cladophrae	-	-	+	-	-	-	-
X. kerneri	-	-	-	+	-	-	-
Nostocales							
Anabaena anomala	+	-	-	-	-	-	-
Arthrospira sp.	-	-	-	-	-	-	+
Borzia susedana	+	-	-	-	-	-	+
B. tricularis	-	+	-	-	-	-	-
Calothrix brevissima	-	-	-	+	-	-	-
C. fusca	-	-	-	+	-	-	-
Hormoscilla pringsheimii	-	+	-	-	-	-	-
Johannesbaptitia pellucida	-	-	-	-	-	-	+
Komvophoron anabaenoides	+	+	+	-	-	-	-
K. constrictum	+	-	-	-	-	-	+
K. crassum	+	+	-	+	-	+	+
K. epiphyticum	+	-	-	+	-	-	-
K. minutum	+	+	+	+	+	+	+
K. pallidum	+	-	-	-	-	-	-
K. schmidlei	+	+	+	+	-	+	-
Katagnymene accurata	-	-	-	-	-	+	-
Lyngbea aestaurii	-	-	+	-	-	-	-
L. allorgeii	+	-	-	-	-	-	-
L. borgertii	+	-	-	+	-	+	-
L. chlorospira	+	-	+	+	+	-	-
L. cryptovaginata	+	-	-	-	-	-	-
L. gardnerii	+	-	-	-	-	-	-
L. infixa	-	-	-	-	+	-	-
L. lagerheimii	+	-	+	-	-	-	-
L. major	-	-	+	-	-	-	-
L. martensiana	+	-	-	-	-	-	-
L. nordgardhii	+	-	-	-	-	-	-
L. polysiphoniae	+	-	-	-	-	-	-
L. prelagans	-	+	-	-	+	-	-
L. spirulinoides	-	-	-	-	-	-	+
Limnothrix amphigranulata	-	-	-	+	-	-	-
Microchaete grisea	-	-	-	-	-	+	-
Oscillatoria acuminata	+	-	-	-	-	-	-
O. amphigranulata	-	+	-	+	+	-	-
O. angusta	-	-	-	+	+	-	-

O. annae	-	+	-	-	-	-	-
O. chalybea	-	-	-	+	+	-	-
O. chlorina	-	-	-	+	-	-	-
O. claricentrosa	-	-	+	-	-	-	-
O. deflexa	+	-	+	+	-	-	-
O. earlei	-	-	-	+	+	-	-
O. fremyii	+	-	-	-	+	-	-
O. grossegranulata	-	-	-	+	+	-	-
O. guttulata	+	-	-	-	-	-	-
O. koprophilla	-	-	+	-	-	-	-
O. lemmermanni	+	-	-	-	-	-	-
O. limnetica	+	+	-	-	+	-	-
O. limosa	+	-	-	-	-	-	+
O. minnesotensis	-	+	-	-	-	-	-
O. nigroviridis	-	-	-	+	-	-	-
O. nitida	-	+	-	-	+	+	-
O. okenii	+	-	-	-	-	-	-
O. peronata	-	-	-	-	-	-	+
O. princeps	-	-	-	-	-	-	+
O. proteus	+	-	-	-	-	-	-
O. pseudogaminata	+	+	+	+	+	-	-
O. quadripunctata	+	-	-	-	-	-	-
O. raoi	-	-	-	+	+	-	-
O. raytonnesis	-	-	-	-	-	-	+
O. sancta	-	-	+	+	-	-	-
O. schultzii	+	-	-	-	-	-	-
O. splendida	+	-	-	-	-	-	-
O. tenuis	+	+	+	-	-	-	-
O. vizagapatensis	-	-	-	-	-	-	+
O. wellei	+	-	-	-	-	-	-
Phormidium acutissimum	+	-	-	-	-	-	+
P. africanum	+	+	+	+	+	-	+
P. ambiguum	+	-	+	+	+	-	-
P. amplivaginatum	+	+	+	+	+	-	-
P. angustissimum	+	+	+	+	+	+	-
P. animale	-	-	-	+	-	-	-
P. anomala	+	-	-	-	-	-	-
P. breve	+	+	+	+	-	+	-
P. cebennense	+	-	-	-	-	-	-
P. ceylanicum	-	-	+	-	-	-	-
P. corium	+	+	+	+	+	-	-
P. endolithicum	-	-	+	-	-	-	-
P. faveolarum	+	-	+	-	-	-	-

P. favosum	-	-	-	+	-	-	+
P. fragile	+	+	+	+	+	+	+
P. incrustatum	+	+	-	+	-	-	-
P. insigni	+	+	-	+	+	-	-
P. inudatum	+	-	-	-	-	-	-
P. ionicum	+	-	-	-	-	-	-
P. jadianianum	+	-	-	-	+	-	-
P. jenkelianum	+	-	-	-	-	-	-
P. kuetzingianum	-	+	+	-	-	-	-
P. laetevirens	+	-	-	-	-	-	-
P. laminosum	+	-	-	+	-	-	-
P. lucidum	+	-	-	-	-	-	-
P. luridum	+	-	-	-	-	-	-
P. luteum	+	+	-	-	+	+	-
P. molle	+	-	+	+	-	-	+
P. mucicola	+	+	+	+	+	+	-
P. mucosum	+	-	-	-	+	-	-
P. okenii	+	-	+	+	-	-	-
P. papyraceum	+	+	-	+	+	+	-
P. purpurascens	+	+	+	+	-	-	+
P. retzii	+	+	+	+	+	-	-
P. rimosum	+	-	-	-	-	-	-
P. subincrustatum	+	-	-	-	-	-	-
P. tenue	+	+	+	+	+	-	+
P. uncinatum	+	-	-	-	-	-	-
P. valderianum	+	-	-	-	+	-	+
Planktothrix agardhii	-	+	-	-	-	-	-
P. clathrata	+	-	-	+	-	-	-
P. compressa	+	-	-	-	-	+	-
P. mougeotii	-	+	-	-	-	-	-
P. planctonica	-	+	-	-	-	-	-
Pseudoanabaena biceps	-	-	-	+	-	+	-
P. catenata	+	-	+	+	+	-	-
P. galeata	+	+	+	+	-	+	+
P. limnetica	+	+	+	+	-	-	-
P. lonchoides	+	+	+	+	-	-	+
P. papillaterminata	+	-	+	-	+	-	+
Pseudoscytonema malayense	-	+	-	-	-	-	-
Spirulina gigantea	-	-	-	-	-	-	+
S. labyrinthiformis	+	+	+	+	+	-	-
S. major	+	+	+	+	-	+	-
S. meneghiana	-	-	-	+	-	-	-
S. subtilissima	-	-	-	+	-	-	-

S. subsalsa	+	+	-	+	+	-	+
Symploca muscorum	-	-	+	-	-	-	-
Tychonema bourrelyii	-	-	+	+	-	-	-
T. rhodonema	-	+	-	-	-	-	-

The cyanobacterial flora in the rock pool water samples had a higher species diversity compared to shore water samples. Forty four species recorded in rock pool waters falling in 4 orders and 14 genera. The coastal water samples showed only 29 species belonging to 16 genera and 4 orders.

Samples collected from different nieches in mangrove forests (e.g. bark, pneumatophore, and sediments) appeared to have quite diverse distribution of cyanobacteria. A total of 42 species of cyanobacteria were recorded including both unicellular (17 species) and non-heterocystous filamentous (25 species) forms.

In summary, highest number of cyanobacteria (124 species) were recorded as epiphytic species associated with green, brown and red seaweeds, followed in descending order by edaphic (73 spp), epizoic (65 spp), epilithic (57 spp), rock pool water (44 spp), mangrove swamp (42 spp) and coastal water (29 spp). *Phormidium* was the most dominant genus recorded from all habitats containing 39 species, the second most abundant genus was the *Oscillatoria* (33 species). Out of 192 species 93 species have been observed from a single habitat, such as, epiphytic (42 spp), epizoic (13 spp), epilithic (9 spp), edaphic (13 spp), rock pools (2 spp), coastal water (3 spp) and mangrove swamp (11 spp).

DISCUSSION

In the present study direct microscopic examination of collected samples showed exceedingly low numbers of cyanobacterial species. Use of three types of medium provides enrichment and boosts the growth of a large number of species which would have escape detection otherwise. This may be the reason for low number of cyanobacterial species (54 spp) recorded from Balochistan coast (Shameel 2000). It may be, however noted that 28 species noted from Balochistan were not present in samples from rocky shore of Buleji and mangrove forests (this study). Therefore 163 species reported in this study are new records.

High species diversity on a rocky shore of Buleji could also be due to the fact that it offers a variety of niches which may suits a wide verity of organisms. The cyanobacterial mats were not obvious on the rocky shore. On the other hand, these are widely distributed in mangrove swamps. These are consumed by a number of benthic organisms (Shafeeq, S. Ph.D. thesis CEMB, University of Karachi). For example, *Cerithium* spp, the abundant gastropods at Buleji (Ahmed and Hameed 1995) and in mangroves (Shafeeq, S. Ph.D. thesis CEMB, University of Karachi), consume cyanobacteria as food (unpublished data). Therefore, high grazing rates appear to be a factor that limits the cyanobacterial growth. In addition low nutrient loading and high wave action may also be responsible for low abundance of cyanobacterial numbers.

Mangrove swamps appear to hold a high diversity of cyanobacteria in this study compared to the previous reports (Zabunnisa *et al.,* 2000; Siddiqui *et al.,* 2000; Saifullah *et al*., 1997). In this study microalgal mats were not included, which as mentioned above, are quite wide spread at certain time of the year on the surface of mud flats near mangroves (personal observation), and can potentially add many more cyanobacterial species.

Cyanobacteria appear to be distributed at all tidal levels in the intertidal region. As expected, high cyanobacterial diversity was observed in the low tidal zone (data not shown). Low diversity at high tidal level may be attribute to longer exposed periods between tidal inudation leading to an increase in temperature and dessication.

Although cyanobacteria had a high diversity in terms of species, but are largely restricted to only unicellular and non-heterocystous morphotype. The heterocystous forms contributed a very low proportion (4 species) of total cyanobacterial diversity. Lack of heterocystous forms is consistent with the earlier reports and has been attribute to high sulphide concentration in seawater (Howsely & Pearson 1979; Thajuddin & Subramanian 1992). However, nitrogen in the nature and/ or in the enriched media used in this study may have favoured non-heterocystous cyanobacteria to over compete. High cyanobacterial diversity in the intertidal zone and mangrove forests indicates success of these species in these environments, where they provide carbon (photosynthesis) and nitrogen (N_2 fixation) to the ecosystem.

REFERENCES

Ahmed, M. and S. Hameed (1999). Species diversity and biomass of marine animal communities of Buleji rocky ledge, Karachi, Pakistan. *Pak. J. Zool.* 31(1): 81-91.

Anagnostidis, K. and J. Komarek. 1985. Modern approach to the classification system of cyanophytes; 1-Introduction. *Arch. Hydrobiol*./ Suppl. 171. *Algological Studies*. 38/39: 291-302.

Anagnostidis, K. and J. Komarek. 1988. Modern approach to the classification system of cyanophytes; 3-Oscillatoriales. *Arch. Hydrobiol.* 83, *Algological Studies*. 50-53: 327-472.

Bano, A. and P. J. A. Siddiqui. (2003). Intertidal cyanobacterial diversity on a rocky shore at Buleji near Karachi, Pakistan. *Pak. J. Bot*. 35(1): 27-36.

Desikachary, T. V (1959). *Cyanophyta, I. C. A. R. Monographs on Algae*. Indian Council of Agric. Res. New Delhi, India, pp.686.

Devassy, V. P (1987). *Trichodesmium* red tide in the Arabian sea. *Contribution in marine Sciences.* Dr. S. Z. Qasim Sastyrbdapurthi filkication. Volume 61-66.

Howsley, R. and H. W. Pearson (1979). pH dependent sulphide toxicity to oxygenic photosynthesis in cyanobacteria. *FEMS Microbiol. Lett*., 6: 387-292.

Hussain, I. .M. and .T.M. Khoja (1993). Intertidal and sub-tidal blue-green algal mats of open and mangrove areas in the Farasan Archipelago (Saudi Arabia), Red sea. *Bot. Mar*., 36: 377-388.

Imai, T (1977). The culture of microorganisms used as feed. pp. 565-578. In: *Aquaculture shallow seas. Progress in shallow sea culture*. (Ed.): Takeo Imai Translated from Japanese Oxford and IBH Publishing Company, New Delhi, Bombay, Calcutta.

Khoja, T.M (1987). New records of marine algae for the Red sea coast of Saudi Arabia. *Bot. Mar*., 30: 167-176.

Komarek, J. and K. Anagnostidis (1986). Modern approach to the classification system of cyanophytes; 2-Chroococcales. *Arch. Hydrobiol*/ Suppl. 73, *Algological Studies* 43: 157-226.

Komarek, J. and K. Anagnostidis (1989). Modern approach to the classification system of cyanophytes; 4-Nostocales. *Arch. Hydrobiol*./ 83, *Algological Studies* 56: 247-345.

Maity, H. Bandhyopadhay, G. and Santra, S. C (1987). Algal flora of saline habitat of Sundarban, West Bengal and its possible role in reclamation of soil. J. Indian Soci. Coastal. Agri. 5(1): 325-331.

Mansoor, S. N., Siddiqui, P. J. A., Bano, A. and Zaib-un-Nisa (2000). Microbial flora associated with mangroves. In: (ed.), Ahmad, V. U. The Arabian Sea as a source of Biological Diversity. Proceedings of the National O.N.R. Symposium. H.E.J. Institute of Chemistry, University of Karachi. Pp. 157-164.

Nair, V. R., Devassy, V. P. and Qasim, S. Z (1980). Zooplankton and *Trichodesmium* phenomenon. Indian J. Mar. Sci. 9: 1-6.

Potts, M (1980). Blue-green algae (Cyanophyta) in marine coastal environments of the Sinai Peninsula; distribution, zonation, stratification and taxonomic diversity. *Phycologia*., 19: 60-73.

Qasim, S.Z (1970). Some characteristics of a *Trichodesmium* bloom in the Laccdives. *Deep Sea Research*. 17: 655-660.

Rippka, R., J. Deruelles, J. B. Waterbury, M. Herdman and R. Y. Stainer (1979). Generic assignments, strain histories and properties of pure cultures of cyanbacteria. *J. Gen. Microbiol*. 111:1-61.

Saifullah, S. M. and G. Taj (1995). Marine algal epiphytes on the pneumatophores of mangroves growing near Karachi. In: (Eds.) Thompson, M. F and Tirmizi, N. M. *The Arabian Sea, living marine resources and the environment.* Proceedings of an International conference. American Institute of Biological Sciences, Washington D.C., USA. Pp. 393-400.

Saifullah, S. M., K. Aisha and F. Rasool (1997). Algal epiphytes of mangroves of Balochistan, Pakistan. *Pak. J. Bot.* 29(2): 191-197.

Santra, S. C. and U. C. Pal (1988). Marine algae of mangrove delta region West Bengal, India: Benthic forms. *Indian Biologist*, 20(2): 30-41.

Santra, S. C. and U. C. Pal. Maity, and Bandyopadhyaya, G (1988). Blue green algae in saline habitat of West Bengal: A systematic account. *Biol. Mem.* 14(1): 81-108.

Shameel M. and J. Tanaka (1992). A preliminary check list of marine algae from the coast and inshore waters of Pakistan. In: (Eds.) T. Nakaike and S. Malik. *Cryptogamic flora of Pakistan*, 1:1-64. National Science Museum, Tokyo.

Shameel, M (2000). Biodiversity of the seaweeds growing along Balochistan coast of the northern Arabian Sea. In: (ed.), Ahmad, V. U. *The Arabian Sea as a source of Biological Diversity. P*roceedings of the National O.N.R. Symposium. H.E.J. Institute of Chemistry, University of Karachi. pp. 45-64.

Shameel, M., K. Aisha, and S. H. Khan (1996). A preliminary survey of seaweeds from the coast of Mekran, Pakistan. *Bot Mar.* Vol. 39: 223-230.

Siddiqui, P. J. A. and Bano, A (2001). Distribution of cyanobacteria as epiphyte on macroalgae. *Pak. J. Mar. Biol*. 7(1&2): 251-259.

Siddiqui, P. J. A., S. N. Mansoor, Zaib-un-Nisa, S. Hameed, S. Shafique, S. Farooq, R. A Aziz and S. Saeed (2000). Associated fauna and flora of macro-algal puffs inhabiting mangrove stands at Sandspit backwaters, Karachi. *Pak. J. Mar. Biol.* 6(1): 43-53.

Thajuddin, N. and G. Subramanian (1992). Survey of cyanobacterial flora of the Southern East coast of India. *Bot. Mar*. 35: 305-314.

Thajuddin, N. and G. Subramanian (1994). Marine cyanobacterial flora of South India. *Current Research in Plant Sciences*, p. 1-16.

Zaib-un-Nisa, Mansoor, S. N. and P. J. A. Siddiqui (2000). Species diversity of cyanobacteria growing on pneumatophores and in the adjacent surface sediment in mangrove swamp at Sandspit backwaters Karachi. *Pak. J. Mar. Biol.* 6(1): 59-68.

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