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INTERTIDAL CYANOBACTERIAL DIVERSITY ON A ROCKY SHORE AT BULEJI NEAR KARACHI, PAKISTAN

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Abstract

The present study describes the species diversity of cyanobacteria on a rocky shore at Buleji near Karachi. Species of cyanobacteria were recorded from the surface sediments (edaphic), rock surfaces (epilithic), in rock-pool and open seawater. A total of 109 species were observed and classified under four orders and 24 genera. Eighty five species recorded in this study are new records for intertidal cyanobacteria from Pakistan. About 50% of observed cyanobacteria appeared to inhabit only one niche. A difference in the distribution and diversity of cyanobacteria was also observed with respect to tidal height. Three types of enriched media were employed to boost growth of less abundant cyanobacterial species. A high diversity of cyanobacteria from intertidal environment was observed.

Introduction

Information on the distribution of cyanobacteria in the northern Arabian Sea bordering Pakistan is rather restricted to a few earlier reports (Shameel & Tanaka, 1992) and some recent studies from mangrove swamps (Saifullah & Taj, 1995; Saifullah *et al.*, 1997; Mansoor *et al.*, 2000; Siddiqui *et al.*, 2000; Zaib-un-Nisa *et al.*, 2000) and intertidal areas along Sindh and Balochistan coasts of Pakistan (Shameel *et al.*, 1996; Shameel, 2000, 2001a; 2001b; Siddiqui & Bano, 2001). There are few reports available on the freshwater cyanobacteria from Pakistan (Shameel & Butt, 1984). It is generally known that intertidal areas support a more diverse cyanoacterial population compared to that of open seawater assemblages (Hoffmann, 1999). The intertidal communities of cyanobacteria appeared to be involved in a number of physiological and ecological activities. For example, they act as natural detoxicant for oil and other chemicals (Alhasan *et al.*, 1994; El-Enany & Issa, 2000; Gadd, 2000; Raghukumar *et al.*, 2001) and are also a source for the production of secondary metabolites of ecological significance (Carmichael, 2001). These organisms help in the energy transformation to higher trophic levels (Lee *et al.*, 2001) and also play ecologically significant role in the production of new nitrogen and carbon in the benthic environment (Bashan *et al.*, 1998).

The distribution of cyanobacteria from other adjacent coasts, such as India (Desikachary, 1959; Devassy, 1987; Santra & Pal, 1988; Thajuddin & Subramanian, 1990,1992, 1994, 1995; Anand &Hooper, 1995), Saudi Arabia (Khoja, 1987, Hussain & Khoja, 1993) and Gulf of Elat (Potts, 1980) has been reported. It would therefore be useful to determine the distribution and diversity of cyanobacteria along the coast of Pakistan which will help understand their geographical distribution. The current research is a part of an attempt to describe the distribution and diversity of marine cyanobacteria inhabiting different niches along a rocky shore at Buleji near Karachi. A number of species were identified from niches like surface sediments (edaphic), rock surfaces (epilithic), rock-pools and coastal waters.

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Materials and Methods

Rocky shore of Buleji is a high-energy zone along the coast located between Sandspit and Paradise Point. It provides a variety of habitats and harbours a high diversity of fauna and flora. Samples for cyanobacteria were collected from different niches at low and high tidal levels. Samples of surface sediment, scrapings from the stones and rocks, rock-pool water and coastal waters were randomly collected in replicates. Sterile tools were used and samples were kept separately in sterile bottles.

In the laboratory, samples were examined immediately under a microscope and observations noted. A portion of each sample was inoculated in three seawater based media viz., ASN-III and MN (Rippka, 1988), and Miquel's medium (MM) (Imai, 1977). Samples were incubated at 28 ± 2°C under constant cool white fluorescent light. Any visible growth in culture tubes was observed using a light microscope. Cyanobacteria were classified according to descriptions given by Desikachary (1959), Anagnostidis & Komarek (1988, 1985) and Komarek & Anagnostidis (1989, 1986).

Results

Distribution and species diversity of cyanobacteria in the surface sediments (edaphic), on rock surfaces (epilithic), and in rock-pool and open seawater at Buleji coast is given in Tables 1 and 2. A total of 109 species were observed and classified under four orders and 24 genera (Table 1). The highest number of species were recorded in the order Nostocales (73 spp.) followed by orders Chroococcales (25 spp.), Chamaesiphonales (6 spp.), and Pleurocapsales (5 spp.). The edaphic (70 spp.) and epilithic (57 spp.) cyanobacteria were more diverse compared to the assemblages of cyanobacteria in rock-pools (42 spp.) and coastal waters (27 spp.).

About 50% of cyanobacteria appeared to inhabit any one niche only. For example, out of 109 species recorded from the rocky shore, 50 species were observed from any one habitat which includes 15 epilithic species, 21 edaphic species, 10 species from rock-pool and 4 species from coastal waters. A difference in the distribution and diversity of cyanobacteria was also observed with respect to tidal heights (Table 2). Habitat at low tide supports higher number of cyanobacteria (85 spp.) whereas high tidal zone had comparatively fewer species (59 spp.). Again some of the species were only present at either low or high tidal zone. The number of cyanobacterial species recorded from the low tide was higher (50 spp.) compared to the number of species observed only at high tide areas (24 spp.). Some 35 species were commonly present at both tidal heights.

All samples collected from the field were inoculated in three different media (ASN-III, MN & MM). The species of cyanobacteria observed from each media are shown in Table 1. ASNIII and MM appeared to be the best culture media which supported a large number of cyanobacteria (70 and 68 spp., respectively). MN medium supported 59 species. It is interesting to note that some cyanobacterial species grew only in one culture media used, for example 21 species were recorded only from MM culture medium and 16 and 13 species were only observed in ASN III and MN culture media, respectively.

Table 1. Distribution of cyanobacteria in different niches of rocky shore at Buleji Karachi.

Cyanobacterial species	Culture media	Epilithic	Edaphic	Rock-pool water	Coastal water
Chroococcales					
Aphanocapsa biformis	ASN-III	-	+	-	-
A. littoralis	ASN-III, MN	+	-	-	-
A. rivularis	MM	+	-	-	-
Aphanothece nidulans	ASN-III	-	-	-	+
A. stagnina	MN	-	-	+	+
Chlorogloeopsis microcystoides	MM	-	+	-	-
Chroococcus cohaerense	ASN-III, MN	+	+	-	-
C. indicus	MM	-	+	-	+
C. limneticus	MN	-	-	-	+
C. minor	ASN-III, MM	+	+	-	+
C. minutus	ASN-III, MN, MM	+	+	+	-
C. schizodermaticus	MM	-	-	+	-
C. turgidus	ASN-III, MN	-	+	-	-
Gloeocapsa calcarea	ASN-III	+	-	-	+
G. compacta	MM	+	+	-	-
G. cripidinum	ASN-III, MN, MM	+	+	-	-
G. pleurocapsoides	MN	-	+	-	-
Gloeothece rhodochlamys	ASN-III, MM	+	+	+	-
Merismopedia convoluta	MM	-	+	-	+
M. elegans	ASN-III, MN, MM	+	+	-	-
M. glauca	MN	+	-	-	+
M. punctata	ASN-III	-	+	-	-
Microcystis litoralis	ASN-III	-	+	-	-
Synechocystis aquatilis	ASN-III, MM	+	-	+	-
S. pevalekii	ASN-III, MM	-	+	-	+
Chamaesiphonales					
Dermocarpa clavata	MM	-	-	+	-
D. flahaultii	MN	-	+	-	-
D. leibleiniae	ASN-III, MN, MM	+	+	+	-
D. olivacea	ASN-III, MM	+	-	+	+
D. parva	MN	-	+	-	+
D. sphaerica	MN	+	-	-	-
Pleurocapsales					
Hydrococcus rivularis	ASN-III, MN	-	-	+	-
Myxosarcina burmensis	MN, MM	+	-	+	+
M. spectabilis	ASN-III, MN, MM	+	+	+	-
Xenococcus cladophorae	MM	+	-	-	+
X. kerneri	ASNIII	-	+	-	-

Table 1. (Cont.)

Nostocales					
Calothrix brevissima	ASN-III	-	+	-	-
C. fusca	ASN-III	-	+	-	-
Komvophron anabaenoides	ASN-III	+	-	-	-
K. crassum	ASN-III, MN, MM	-	+	-	+
K. minutum	ASN-III, MN, MM	+	+	+	+
K. schmidlei	ASN-III, MN, MM	+	+	-	+
Lyngbea aestaurii	MN, MM	+	-	-	-
L. borgertii	ASN-III, MM	-	+	-	+
L. chlorospira	ASN-III, MM	+	+	+	-
L. infixa	MN	-	-	+	-
L. lagerhemii	ASN-III	+	-	-	-
L. major	ASN-III, MN	+	-	-	-
L. prelagans	MN	-	-	+	-
Microchaete grisea	ASN-III	-	-	-	+
Oscillatoria amphigranulata	ASN-III, MN	-	+	+	-
O. angusta	ASN-III	-	+	+	-
O. chalybea	MM	-	+	-	-
O. chlorina	ASN-III	-	+	-	-
O. claricentrosa	MM	+	-	-	-
O. deflexa	ASN-III, MN, MM	+	+	-	-
O. earlei	MM	-	+	-	-
O. fremyii	ASN-III	-	-	+	-
O. grossegranulata	MM	-	+	+	-
O. koprophilla	MM	+	-	-	-
O. limnetica	ASN-III	-	-	+	-
O. nigroviridis	MN	-	+	-	-
O. nitida	ASN-III, MN, MM	-	-	+	+
O. pseudogaminata	ASN-III, MN, MM	+	+	+	-
O. raoi	ASN-III, MN	-	+	+	-
O. sancta	MN, MM	+	+	-	-
O. tenius	MM	+	-	-	-
Phormidium africanum	ASN-III, MN, MM	+	+	+	-
P. ambiguum	ASN-III, MN, MM	+	+	+	-
P. amplivaginatum	ASN-III, MN, MM	+	+	+	-
P. angustissimum	ASN-III, MN, MM	+	+	+	+
P. animale	ASN-III, MN	-	+	-	-
P. breve	ASN-III, MN	+	+	-	+

Table 1. (Cont.)

P. ceylanicum	MM	+	-	-	-
P. corium	ASN-III, MM	+	+	+	-
P. endolithicum	MN	+	-	-	-
P. faveolarum	MN	+	-	-	-
P. favosum	MN	-	+	-	-
P. fragile	ASN-III, MN, MM	+	+	+	+
P. incrustatum	ASN-III, MN, MM	-	+	-	-
P. insigni	ASN-III, MN	-	+	+	-
P. jadianianum	ASN-III, MM	-	-	+	-
P. kuetzingianum	MM	+	-	-	-
P. laminosum	MM	-	+	-	-
P. luteum	MM	-	-	+	+
P. molle	MM	+	+	-	-
P. mucicola	ASN-III, MN, MM	+	+	+	+
P. mucosum	MM	-	-	+	-
P. okenii	ASN-III, MN, MM	+	+	-	-
P. papyraceum	ASN-III, MN, MM	-	+	+	+
P. purpurascens	ASN-III, MM	+	+	-	-
P. retzii	ASN-III, MN, MM	+	+	+	-
P. tenue	ASN-III, MN, MM	+	+	+	-
P. valderianum	ASN-III, MM	-	-	+	-
Plnktothrix clathrata	MM	-	+	-	-
P. compressa	ASN-III, MN	-	-	-	+
Pseudoanabaena biceps	ASN-III, MN, MM	-	+	-	+
P. catenata	ASN-III, MN, MM	+	+	+	-
P. galeata	ASN-III, MN, MM	+	+	-	+
P. limnectica	ASN-III, MN, MM	+	+	-	-
P. lonchoides	ASN-III, MM	+	+	-	-
P. papillaterminata	ASN-III, MN	+	-	+	-
Spirulina labyrinthiformis	ASN-III, MN, MM	+	+	+	-
S. major	ASN-III, MN, MM	+	+	-	+
S. meneghiniana	ASN-III, MM	-	+	-	-
S. subsalsa	ASN-III, MN, MM	-	+	+	-
S. subtilissima	MN, MM	-	+	-	-
Symploca muscorum	ASN-III	+	-	-	-
Tychonema bourrellyi	MN, MM	+	+	-	-

Table 2. Cyanobacterial species inhabiting low and high tidal levels. Some species were common at both tidal levels

Species at low tide	Species at high tide	Common species
	Chroococcales	
Aphanocapsa biformis	*Merismopedia convoluta*	*Synechocystis pevalekii*
A. littoralis	*M. elegans*	*Gloeothece rhodochlamys*
A. rivularis	*M. glauca*	
Aphanothece nidulans	*M. punctata*	
A. stagnina	*Microcystis litoralis*	
Chroococcus cohaerense	*Synechocystis aquatilis*	
C. indicus		
C. limneticus		
C. minor		
C. minutus		
C. schizodermaticus		
C. turgidus		
Chlorogloeopsis microcystoides		
Gloeocapsa calcarea		
G. compacta		
G. cripidinum		
G. pleurocapsoides		
	Chamaesiphonales	
Dermocarpa parva	*Dermocarpa clavata*	*Dermocarpa leibleiniae*
D. sphaerica	*D. flahaultii*	*D. olivacea*
	Pleurocapsales	
Xenococcus cladophorae	*Hydrococcus rivularis*	*Myxosarcina burmensis*
X. kerneri		*M. spectabilis*
	Nostocales	
Calothrix brevissima		
C. fusca	*Komvophoron anabaenoides*	*Komvophoron crassum*
Lyngbea borgertii	*Lyngbea lagerhemii*	*K. minutum*
L. infixa	*L. major*	*K. schmidlei*
L. prelagans	*Oscillatoria chalybea*	*Lyngbea aestaurii*
Microchaete grisea	*O. earlei*	*L. chlorospira*
Oscillatoria angusta	*O. fremyii*	*Oscillatoria amphigranulata*
O. chlorina	*O. nitida*	*O. grossegranulata*
O. claricentrosa	*Phormidium breve*	*O. pseudogaminata*
O. deflexa	*P. ceylanicum*	*O. sancta*
O. koprophilla	*P. jadianianum*	*Phormidium ambiguum*
O. limnetica	*P. laminosum*	*P. amplivaginatum*
O. nigroviridis	*Pseudoanabaena galeata*	*P. angustissimum*
O. raoi	*Spirulina subsalsa*	*P. corium*
O. tenius	*S. subtilissima*	*P. fragile*
Phormidium africanum	*Tychonema bourrellyi*	*P. incrustatum*
P. animale		*P. insigni*
P. endolithicum		*P. molle*

Table 2. (Cont.)

P. faveolarum	*P. mucicola*
P. favosum	*P. okenii*
P. kuetzingianum	*P. papyraceum*
P. luteum	*P. tenue*
P. mucosum	*Pseudoanabaena biceps*
P. purpurascens	*P. limnectica*
P. retzii	*P. lonchoides*
P. valderianum	*P. papillaterminata*
Planktothrix clathrata	*Spirulina labyrinthiformis*
P. compressa	*S. major*
Pseudoanabaena catenata	*S. meneghiniana*
	Symploca muscorum

Discussion

In the present study a high diversity of cyanobacterial species was recorded (total 109 species) from the rocky shore at Buleji. Comparison of the recorded species with those reported in a previous study, conducted for the coast of Balochistan (Shameel, 2000) revealed that 24 species were commonly observed from Buleji (Sindh coast) as well as from Balochistan coast. Remaining 85 species recorded in the present study from Buleji rocky coast were not observed in samples collected from the entire coast of Balochistan, and therefore may be considered as new records for intertidal marine cyanobacteria from Pakistan. On the rocky shore of Buleji cyanobacteria are not generally observed as mats or as thick growth of encrusting cyanobacteria. This may be a consequence of high wave action on this shore. Grazing of cyanobacteria by herbivorous organisms may also be an added factor, as suggested by results of herbivore-exclusion experiments where the surfaces of experimental rocks showed dominated cyanobacterial growth (Williams *et al.,* 2000). Also species of gastropods have been shown to consume cyanobacteria (Brendelberger, 1997; Lee *et al.,* 2001) which appeared to be one of the most preferred diets of two marine gastropod species inhabiting intertidal area in Pakistan (Siddiqui, P.J.A., unpublished data).

Variation in the assemblages of cyanobacterial species in different niches was observed at Buleji, which is generally expected for other intertidal organisms. The distribution of cyanobacteria is function of a combination of chemical and physical parameters, and seasonal differences in the distribution of cyanobacteria in an intertidal area have been reported (Kennish *et al.,* 1996; Nagarkar & Williams, 1999). The present study showed differences in the species diversity from the sediments, rock surfaces, and coastal and rock-pool waters. It also showed that some species were observed from only one niche. A possible niche-specific relationship of the intertidal cyanobacterial population would be interesting to test in future. The distribution of cyanobacteria also appears to be related with the tidal heights in the littoral zone. This is in agreement with some recent studies indicating differences in the species distribution with reference to tidal height, where higher number of species were restricted to the mid and low tidal heights (Nagarkar & Williams; 1999, Nagarkar, 2002).

Heterocystous cyanobacteria were only scarcely observed at Buleji. Absence of heterocystous cyanobacteria has also been noted at Balochistan coast (Shameel, 2000) and in other saline environments (Howsley & Pearson, 1979; Thajuddin & Subramanian, 1992; Stall *et al.*, 1996). The scarcity of heterocystous forms may be attributed to the nutritive and chemical conditions that exist. For example, high sulphide levels have been found toxic to heterocystous forms (Howsley & Pearson, 1979; Stall *et al.*, 1996). Reduction in the abundance in heterocystous species of cyanobacteria has been noted subsequent to anthropogenically elevated levels of nutrients in a fresh-water ecosystem (Perona *et al.*, 1998).

Use of more than one type of media, as revealed in this study, was useful in allowing a greater number of cyanobacterial species to grow as about 50% of the observed species were supported by only one type of media used. Boosting the growth of cyanobacteria in samples collected from nature made it possible to identify the species that were less abundant in nature and would have escaped detection otherwise.

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