INT. J. BIOL. BIOTECH., 13 (1): 49-57, 2016.

DISTRIBUTION OF EPIZOIC CYANOBACTERIA ON MOLLUSCAN SPECIES OCCURRING AT A ROCKY SHORE (BULEJI), KARACHI, PAKISTAN

Azra Bano[1] and Pirzada J. A. Siddiqui [2]

[1]*Lasbela University of Agriculture Water and Marine Sciences, Uthal-90150, Baluchistan,*
[2]*Centre Of Excellence in Marine Biology, University of Karachi, Karachi-75270, Pakistan*
* Corresponding author: Azra Bano; Phone number: 92-0853-610919; E-mail address: azrabano2006@yahoo.com

ABSTRACT

The present study is the part of investigation involving identification of cyanobacteria from coastal water of Karachi. As report on the distribution cyanobacterial epizoic in coastal area of Pakistan is uncommon. In this study sixty five species of cyanobacteria were identified from various marine molluscan species collected from Buleji, a coast of Karachi. Most of cyanobacteria were from the order Chroococcales and Nostocales and only a small number of species were found to belong to Chamaesiphonales and Pleurocapsales. The epizoic species consists of 26 unicellular and 39 filamentous non-heterocystous cyanobacterial species. Heterocystous forms were not found during these studies. Cyanobacterial species showed a variable capacity to grow in various type of media. Also, some cyanobacteria were observed specifically on particular molluscs species, while other were common on all species.

Key-words: Cyanobacteria, epizoic, molluscas, Buleji, Karachi.

INTRODUCTION

Symbiosis is an interrelationship between two organisms which range from simple parasitism to physiological interdependence of the species (Green, 1977). The symbiotic relationship on the degree of association is termed as commensalism, inequalism, mutualism and parasitism. In commensalism, one member achieves the benefits but does not cause harm its host. Inequalim is a relationship where one member lives, in the body (digestive tract) or in the home of other member without being parasite. Mutualistic symbiosis benefits both partners, whereas parasitism refers to an association where one species live in or upon another and take nutrition from the host, where host is affected adversely.

Though symbiosis is common among organisms in both terrestrial and aquatic habitats but well developed in the marine environment, such as tropical water (Li, 2009; Charpy *et al*., 2012: Díez *et al.*, 2007**).** In marine environment symbiosis can vary from random, casual or facultative association through more obligatory groupings that benefits one or both member of to finally those which are parasites (O'Brien *et al.*, 2005).Marine cyanobacteria have been recorded in a variety of symbiotic association with marine plants and animals, for example, species of the genera: Protozoa, Porifera, Polychaeta, Cnidaria and Mollusca, as well as marine algae and other plants (Adams, 2000; Rai *et al*., 2000, 2002; Adams *et al*., 2006; Bergman *et al*., 2007). Cyanobacteria may grow on the surface of these organisms (epizoic & epiphytic) and they infect and proliferate inter and intracellularly in these organisms (endosymbiotic).

In the marine environment, symbioses was observed between cyanobacteria and sponges, ascidians (sea squirts), echiuroid worms, diatoms, dinoflagellates and a protozoan (Carpenter, 2002). The interaction between cyanobacteria and algae is restricted to shallow, sub-tidal or intertidal benthic and pelagic zone of the ocean (Carpenter and Capone. 1992).

CYANOBACTERIAL ASSOCIATION WITH MARINE FAUNA

The symbiotic association of epizoic cyanobacteria with sponges has long been known (Alex *et al*., 2012; Usher, 2008; König *et al*., 2006; Thajuddin and Subramanian 2005; Thacker and Starnes, 2003: Feldman, 1933) and *Oscillatoria* and *Aphanocapsa* species reportedly occur endosymbiotically (Caroppo *et al.*, 2012: Pagliara and Caroppo, 2010; Sara 1971; Vacelet, 1971; Berthhold *et al*., 1982; Wilkinson, 1978). Cyanobacteria has also been reported associated with ascidians (Wegley *et al*., 2007; Lafargue and Duclaux, 1979; Sybesma and Bak, 1979; Lewins, 1977), cnidarians (Charpy *et al*., 2012; Costa *et al*., 2004) copepode (O'Neil, 1998; O'Neil and Roman, 1992; Magalef, 1953), fish guts beaks and scales (Aleem, 1980; Tsuda *et al*., 1972; Prescott, 1969), rotifers (Huber-Pestalozii and Naumann, 1929), Polyzoa (Gerdes, 2005; Desikachary, 1959; West and Annandale, 1911), sea urchin

(Mortensen and Rosenvinge, 1934), polychaete tubes and molluscan shells (Radea *et al*., 2010**;** Pantazidou, 2006; Aleem, 1980; Park and Moor, 1935; Fritsch, 1945).

There are few studies s on epizoic cyanobacteria from Pakistan and these are on freshwater fauna. Cyanobacterial species *Oscillatoria anguina*, *Phormidium fragile* and *P. tenue* were reported from the shell of turtle, *Trionnyx gagiticus* curier (Anjum *et al*., 1980). In another study the cyanobacterial species, *Lyngbea martensia*, *Microcystis aeruginosa*, *Oscillatoria formosa*, *O. princeps*, *Phormidium fragile* and *Anabaena* sp. were reported on shells of snails (*Lymnaea sp.* (Hussein and Anjum, 1982). No information is available on cyanobacterial association with marine organisms inhabiting the Pakistani coast. In the present study the biodiversity of cyanobacteria and its association with marine fauna has been explored.

MATERIALS AND METHODS

The mollusks species belonging to the three classes Amphineura, Gastropoda and Bivalvia were collected in plastic bags separately from rocky shore. Lists of mollusk studied is given in Table 2. The loosely attached meiofauna and flora on each shells was washed with sterilized filtered sea water using soft brush. Each shell was then scraped by sterilized scalpel. Collected material was inoculated in three different media i. e. ASNIII, MN and Miquels media (Bano and Siddiqui, 2003). The samples were incubated in constant light at 30 ± 2^{o}C. Cultures were periodically observed for any visible growth of cyanobacteria. Actively growing material was taken with sterilized wire loop and smeared on glass slide and observed using a light microscope. Scraping from shells were also observed directly under a microscope. The taxonomic assessment was done according to Rippka *et al*., (1979), Desikachary, (1959), Anagnostidis and Komarek, (1985, 1988) and Komarek and Anagnostidis, (1986, 1989).

RESULTS

In the present study a survey of cyanobacterial flora association with 1 species of amphineura, 8 species of gastropods and 1 species of bivalve were carried out (Table 1 and 2). A total of 65 species of cyanobacteria were identified belonging to 21 genera, 4 orders and 7 families. All the epizoic species are new record for the coastal waters of Pakistan and among the 65 species of cyanobacteria, 26 were unicelluar and 39 were non-heterocystous filamentous forms (Table 1). Among the four orders of Cyanobacteria associated with mollusc were order Nostocales, represented by 40 species of cyanobacteria followed by the order Chroococcales representing 17 species. In the order Pleurocapsales and Chaemaesiphonales the number of species were 2 and 7 respectively (Table 1 and 2). The association between cyanobacteria and molluscan species showed that the highest numbers of cyanobacterial (36 species) were present on the shell of *Xancus pyrum* and the lowest number (8 species) was recorded from *Pecten crasiocostatus*. (Table 1 and 2). The other gastropod species, *Nerita albicilla*, *Turbo coronatus*, *Cerithium carbonarium* and *C. hanely*i showed the presence of 15, 14, 13 and 12 cyanobacterial species, respectively. There were certain species of mollusc, that is, *Cerithium rubus, Monodonta australis, and Pecten crasiocostatus* which showed no association with cyanobacterial species belonging to the orders Chroococcales, Pleurocapsales and Chaemaesiphonales, respectively (Table 1 and 2). .

Cyanobacterial species attached to molluscan species were compared with the species observed from the other habitats of rocky shore (Bano and Siddiqui, 2003). The comparative data showed that that thirteen species were specifically associated with molluscan shells and were not found in other habitats of rocky shore.

Molluscan-species-specific association with cyanobacteria was also observed in the present study. It may be noted that out 65 epizoic species 33 species showed a molluscan species-specific association, that is, they grow on the shell of only one of the ten species of mollusc studied. Among the 33 species-specific, nearly 50% were recorded on the shell of *Xancus pyrum* (17 species) (Table 1 and Fig. 1) . Similarly cyanobacteria species specificity was as follows for *Chiton oceanica,* (3 species), *Monodonta australis* (1 species), *Planaxis sulcatus* (5 species), *Nerita albicilla* (2 species), *Turbo coronatus* (2 species), *Cerithium rubus* (1 species) and *C. carbonarium* (2 species) (Table 1). *Pecten crasiocostatus* and *C. hanelyi* had no cyanobacterial species that is specific on their shells. The species-specific cyanobacteria were represented by both unicellular and filamentous forms. The maximum number of species-specific cyanobacteria were classified under genus *Phormidium* (9 species) and genus *Oscillatoria* (5 species). Three species each were represented in the genera *Planktothrix* and *Chroococcus*. The genus *Gloeocapsa* represented two such species, and only one species each was included in genera *Gloeothece, Synechococcus, Aphanothece, Dermocarpa, Borzia, Pseudoanabaena, Lyngbea* and *Hormoscilla* (Table 1). Cyanobacterial species *Myxosarcina spectabilis, M. burmensis* and *Phormidium amplivaginatum* appeared to be associated with all molluscan species. There are some 15 species which commonly grow on four or more types of mollusk (Table 1).

Table1. Distribution of cyanobacterial species on ten different species of molluscs inhabiting a rocky shore near Karachi.

Cyanobacteria species	**Medium**	***Chiton oceanica***	***Xancus pyrum***	***Monodonta australis***	***Planaxis sulcatus***	***Nerita albicila***	***Turbo coronatus***	***Cerithium rubus***	***Cerithium hanelyi***	***Cerithium carbonarium***	***Pecten crasiocostatus***
Ckroococcales											
Synechocystis pevalekii	ASNIII, MN, MM	-	+	-	+	-	-	-	+	-	+
S. aquatilis	MN	-	-	-	-	-	-	-	+	-	+
Gloeocapsa gelatinosa	ASNIII, MM	+	+	-	-	-	-	-	-	-	-
G. Compacta	ASNIII	-	-	-	-	-	-	-	-	+	-
G. cripidinum	MN	-	-	-	-	-	+	-	-	-	-
Chroococcus cohaerence	MN, MM	-	+	+	-	-	-	-	-	-	-
C. turgidus	MM	-	+	-	-	-	-	-	-	-	-
C. minutus	ASNIII, MM	-	-	-	+	-	-	-	-	-	-
C. montanus	MN	-	-	-	-	+	-	-	-	-	-
Synechococcus elongatus	MN	-	+	-	-	-	-	-	-	-	-
Gloeothece palea	MM	-	+	-	-	-	-	-	-	-	-
G.samooensis	ASNIII, MM	-	-	+	-	-	+	-	-	+	-
G. rhodochlymys	ASNIII, MN, MM	-	-	-	+	+	+	-	+	+	-
G.fusco-lutea	MM	-	-	-	+	-	-	-	-	+	-
Aphanocapsa littoralis	ASNIII, MN	+	+	-	-	-	+	-	+	-	-
Aphanthece microscopica	ASNIII	-	+	-	-	-	-	-	-	-	-
Merismopedia eleganse	ASNIII, MN, MM	+	-	+	+	+	-	-	-	-	-
Chamaesiphonales											
Chroccocidiopsis indica	ASNIII, MN	-	+	-	+	-	-	-	-	-	-
Dermocarpa leibleiniae	ASNIII, MN, MM	+	+	-	-	+	-	+	-	+	-
D. olivacea	ASNIII, MN, MM	-	-	-	-	+	-	-	-	-	+
D.flahaultii	ASNIII, MN	-	-	-	-	+	+	-	-	-	-
D. parva	MN	-	-	-	-	+	-	-	-	-	-
D. clavata	ASNIII, MM	-	-	-	-	+	-	+	-	-	-
D.sphaerica	ASNIII, MN, MM	-	-	-	-	-	+	+	+	-	+
Pleurocapsales											
Myxosarcina spectabilis	ASNIII, MN, MM	+	+	+	+	+	+	+	+	+	-
M. burmensis	ASNIII, MN, MM	+	+	+	+	+	+	+	+	-	-

Nostocales											
Borzia tricularis	MM	-	+	-	-	-	-	-	-	-	-
Komvophoron anabaenoides	ASNIII, MN	-	+	+	-	-	-	-	-	-	-
K. schmidlei	ASNIII, MN, MM	-	+	-	-	+	+	-	-	+	-
K. minutum	ASNIII, MN, MM	-	+	+	+	+	+	-	-	+	+
K. Crassum	ASNIII, MN	-	-	-	-	+	+	-	-	-	-
Psuedoanabaena galeata	ASNIII, MN, MM	-	-	+	+	-	-	+	+	+	+
P. limnetica	MM	-	-	-	-	-	+	-	-	-	-
P. lonchoides	ASNIII, MM	-	-	-	-	-	-	+	+	-	-
Lyngbea preleganse	MM	-	-	-	+	-	-	-	-	-	-
Hormoscilla pringsheimii	ASNIII	-	+	-	-	-	-	-	-	-	-
Oscillatoria limnetica	ASNIII, MN, MM	+	+	-	-	-	-	-	-	-	-
O. tenuis	ASNIII	+	-	-	-	-	-	-	-	-	-
O.amphigranulata	ASNIII, MN	+	-	-	-	-	-	-	-	-	-
O. minnesotensis	ASNIII	-	+	-	-	-	-	-	-	-	-
O. annae	ASNIII	-	+	-	-	-	-	-	-	-	-
O.nitida	MN	-	+	-	-	-	-	-	-	-	-
O. pseudogaminata	ASNIII, MM	-	+	+	+	-	-	-	-	+	-
Spirulina labyrintheformis	ASNIII	+	+	-	-	-	-	-	-	-	-
S. subsalsa	ASNIII, MM	-	+	-	-	-	-	-	-	-	-
S. major	MM	-	+	-	-	-	-	-	-	-	-
Tychonerhodonemama	ASNIII	+	-	-	-	-	-	-	-	-	-
Planktothrix mougeotii	ASNIII	-	-	+	-	-	-	-	-	-	-
P. agardhii	ASNIII	-	+	-	-	-	-	-	-	-	-
P. planctonica	MM	-	-	-	+	-	-	-	-	-	-
Phormidium purpurascence	ASNIII	-	+	-	-	-	-	-	-	-	-
p. tenue	ASNIII, MN	-	+	-	-	-	-	-	-	-	-
P. insigni	ASNIII	-	+	-	-	-	-	-	-	-	-
P. angusstissimum	ASNIII, MN, MM	-	+	-	-	+	-	-	+	-	-
P. corium	MN	-	+	-	-	-	-	-	-	-	-
P.kuetzingianum	ASNIII, MN, MM	-	+	-	-	-	-	+	+	+	-
P. africanum	MN	-	+	-	-	-	-	-	-	-	-
P.amplivaginatum	ASNIII, MN, MM	-	+	+	+	-	+	+	+	+	+
P. fragile	ASNIII, MM	-	+	-	+	+	-	-	-	-	+
P. breve	MM	-	-	-	+	-	-	-	-	-	-
P. incrustatum	MM	-	-	-	+	-	-	-	-	-	-
P. retzii	ASNIII, MM	-	+	-	+	-	-	-	-	-	-
P.mucicola	ASNIII, MN	-	-	-	-	-	+	+	-	-	-
P. luteum	MM	-	-	-	-	-	-	+	-	-	-
P. Papyraceum	MM	-	-	-	-	-	-	-	-	+	-

Table 2. Total number of species observed on surface of molluscan species. Species are grouped according to their taxonomic order.

Cyanobacterial orders	***Chiton oceanica***	***Xancus pyrum***	***Monodonta australis***	***Planaxis sulcatus***	***Nerita albicila***	***Turbo coronatus***	***Cerithium rubus***	***Cerithium hanelyi***	***Cerithium carbonarium***	***Pecten crasiocostatus***
Chroococcales	3	8	3	5	3	4	-	4	4	2
Chamaesiphonales	1	2	-	1	5	2	3	1	1	2
Pleurocapsales	2	2	2	2	2	2	2	2	1	-
Nostocales	5	24	6	10	5	6	6	5	7	4
Total	11	36	11	18	15	14	11	12	13	8

Table 3. . Lists of mollusk species studied for the epizoic species of cyanobacteria.

Amphineura	**Gastropoda**	**Bivalvia**
Chiton oceanica	*Xancus pyrum*	*Pecten crasiocostatus*
	Monodonta australis	
	Planaxis sulcatus	
	Nerita albicila	
	Turbo coronatus	
	Cerithium rubus	
	C. hanelyi	
	C. carbonarium	

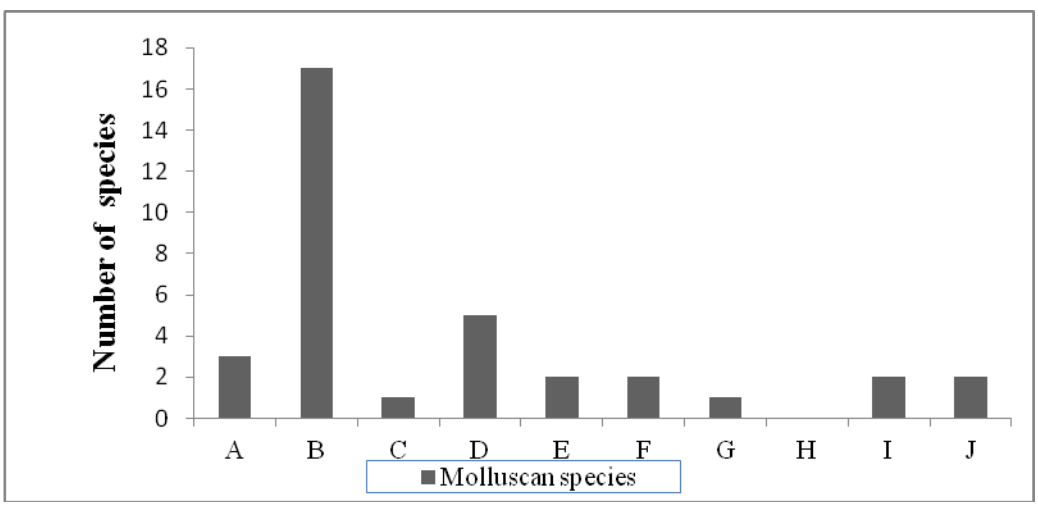

Fig. 1. Species-specific cyanobacteria associated with A-*Chiton oceanica*, B-*Xancus pyrum*, C-*Monodonta australis*, D-*Planaxis sulcatus*, E-*Nerita albicilla* F-*Turbo coronatus*, G-*Cerithium rubus,* H- *Cerithium hanelyi*, I-*Cerithium carbonarium*, J-*Pecten crasiocostatus.*

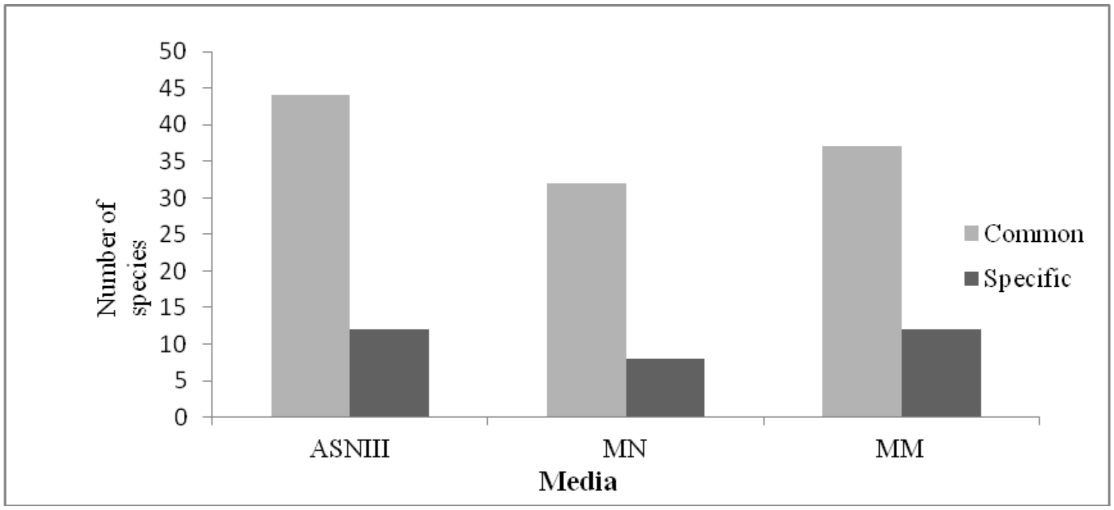

Fig. 2. Cyanobacterial species were common in all three media but some species showed up only in one specific medium.

For the growth of cyanobacteria species in culture three different types of media were used. Some species were more versatile as they appeared in all media and many showed up only in one or two types or media. The observation of the experiments were recorded (Table 1). The data indicates that the best media, in terms of number of species grown was ASNIII medium. A total of 44 species were able to grow in the medium. Whereas, MN and Miquel's media supported 32 and 37 species respectively. Some of the species showed up in all three media (15 species), and twelve species were observed exclusively in ASNIII, Miquel's media each. MN medium supports seven species that did not appear in the other two media (Fig.2). The species specifically growing in any particular media does not appear to be limited to one genera or particular orders. It rather an assorted assemblage of species suggested this to be and individual species characters.

DISCUSSION

From the above result it is concluded that that the molluscan shells are an excellence substratum for the attachment and growth of various cyanobacterial species. The species of mollusk selected were predominant at the intertidal zone of rocky coast (Buleji). Cyanobacterial growth were visible on most of the species by naked eye. Diverse species of cyanobacteria observed as epizoic, which have previously been reported as epiphytic, edaphic, epilithic and planctonic from India (Desikachary, 1959), and also as epizoic from freshwater habitats from Pakistan (Hussein and Anjum, 1982; Anjum *et al*., 1980). The observed species have been reported from marine as well as freshwater habitats from different parts of the world (Aleem, 1980; Desikachary, 1959; Thajuddin and Subramanian, 1990, 1992, 1994; Santra and Pal, 1988; Shameel and Butt, 1984).

Large numer of cyanbacterial species were associated with the shell of *Xancus pyrum* and other gastropos species, while less number with *Pecten crasiostatus* (Table 1 and 2). It is due to fact that *Xancus pyrum* mostly remain submerged in nutrient rich water in euphotic zone of the sea, similarly the other gastropod species are found in the intertidal zone and donot bury in the sand. This exposure to sunlight and nutrient favors the algal growth. Comparatively, the bivalve, *P. crasiocostatus* usually live buried in the sediment, where sufficient light may not be available and this hinders the growth of cyanobacteria on this shell.

Myxosacina species and *P. amplivaginatum* were attached on most of mollusk species. This could be due to species preferred the habitat.

The observed cyanobacterial species, such as *S. aquatilis, G. gelatinosa, C. minutus, C. tugidus, C. montanus, G. samoensis, A. microscopica, D. leibleiniae, D. parva, M. spctabilis, L. prelagans, O. tenius, O. pseudogaminata, S. subsalsa, S. major, P. angustissimum, P. purpuranscence, P. corium, P. retzii and P. tenue* are reported both as epilithic and edaphic forms from various types of soil and hard substrata in terrestrial and aquatic habitats, such as, river soil, cultivated and non-cultivated soil, mud mangrove swamps, beach rocks and stones surfaces (Desikachary, 1959; Aleem, 1980; Santra and Pal, 1988; Santra *et al*., 1988; Maity *et al*., 1987). *Phormidium fragile* and *P. tenue* have been reported as epizoic on freshwater turtle and snail shells (Hussein and Anjum, 1982; Anjum *et al*., 1980). The comparative study of the organisms showed that above species preferred calcium rich or calcareous hard substrata for their settlement (Józef, *et al*., 2015) In the marine environment calcareous shell of mollusks provide a favorable habitat for attachments of cyanobacteria. Attachment of cyanobacteria and variability of species composition of associative cyanobacteria may simply be a function of variation in the habitat of gastropods as noted above. It seems true for many species growing on molluscan shells and also observed in other niches of Buleji coast. Also many of species reported here have been reported from marine and freshwater habitats from India (Desikachary, 1959; Aleem, 1980; Santra and Pal, 1988; Santra *et al*., 1988; Maity *et al*., 1987; Anand and Hooper, 1987; Thajuddin and Subramanian, 1990, 1992, 1994), and other parts of the world (Hussein and Khoja, 1993; Bauld, 1981; Hogdson and Abbot, 1992; Khoja, 1987).

The present study provide a basic information about epizoic cyanobacteria on various molluscan species inhabiting the rocky shore of Buleji and confirms the presence of many species reported from other parts of the world in the northern Arabian Sea bordering Pakistan. Epizoic cyanobacterial flora on organisms other than mollusca have not been studied nor the other coasts have been studied for the similar purpose in Paksitan. . Therefore, more research work need to be undertaken to get information about the diversity of epizoic cyanobacteria in the marine environment.

Acknowledgments

The authors are thankful to Dr Zarrien Ayub (Professor, Centre of Excellence in Marine Biology, University of Karachi) for her constant support and assistant during the preparation of this manuscript.

REFERENCES

Adams D.G. (2000). Symbiotic interactions. In: *Ecology of cyanobacteria: their diversity in time and space.* (Whitton B, Potts M, eds.). Dordrecht: Kluwer Academic Publishers, 523–561.

Adams D.G., B. Bergman, S.A Nierzwicki-Bauer, A.N. Rai, A. Schu¨ ßler (2006). Cyanobacterial–plant symbioses. In: *The prokaryotes: a handbook on the biology of bacteria. 3rd edn. Vol. 1. Symbiotic associations, biotechnology, applied microbiology* (Dworkin M, Falkow S, Rosenberg E, Schleifer K-H, Stackebrandt E, eds.). New York, NY: Springer, 331-363.

Aleem, A.A. (1980). Cyanopyta from Sierra Leon (West Africa). *Bot. Mar*., 23: 59-61.

Alex, A., V. Vasconcelos, P.Tamagnini, A. Santos and A. Antunes (2012). Unusual Symbiotic Cyanobacteria Association in the Genetically Diverse Intertidal Marine Sponge Hymeniacidonperlevis (Demospongiae, Halichondrida). *Plos One.*, 7 (12): 1-12.

Anagnostidis, K. and J. Komárek (1985): Modern approach to the classification system of cyanophytes, 1–Introduction. *Arch.Hydrobiol. Suppl. 71/Algological Studies*, 38/39: 291-302.

Anagnostidis, K. and J. Komárek (1988): Modern approach to the classification system of cyanophytes, 3–Oscillatoriales. *Arch.Hydrobiol. 80/Algological Studies*. 50–53: 327-472.

Anand, N. and S.K. Hooper (1987). Blue green algae in the rice field in Kerala State. India. *Hydrobiologia*. 144: 223-232.

Anjum, G., F. Hussein and I. Haq. (1980). Algae from turtle shells. *Pak. J. Bot.*, 12: 201-203.

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.

Bauld, J. (1981). Occurrence of benthic microbial mats in saline lakes. *Hydrobiol*., 81: 87-111.

Bergman B, U. Rasmussen, A.N Rai (2007). Cyanobacterial associations. In: *Associative and endophytic nitrogen-fixing bacteria and cyanobacterial associations* (Elmerich C, Newton WE, eds.). Dordrecht: Kluwer Academic Publishers.

Berthhold, R.J., M.A. Borowitzka, and M.A. Mackay (1982). The ultrastructure of *Oscillatoria spongeliae*, the blue-green algae endosymbiot of the sponge *Dysidae herbacea*. *Phycol.*, 21: 327-335.

Caroppo, C., P. Albertano, L. Bruno, M. Montinari, M. Rizzi, G. Vigliotta, and P. Pagliara (2012). Identification and characterization of a new Halomicronema species (Cyanobacteria) isolated from the Mediterranean marine sponge Petrosia ficiformis (Porifera). *Fottea, Olomouc*, 12(2): 315-326.

Carpenter, E.J. (2002). Marine cyanobacterial symbioses. Biology and Environment, 102B, 15-18.

Charpy, L., B. E. Casareto, M.J. Langlade and Y. Suzuki (2012). Cyanobacteria in Coral Reef Ecosystems: A Review. *Journal of Marine Biology* (vol. 2012): 1-9.

Costa, C. F., C.S. Coutinho, R. Sassi, V. Ana Carolina, and L. De. Britto (2004). Microsymbionts Of *Siderastrea Stellata* (Cnidaria, Scleractinia) In Coastal Reefs Of Cabo Branco, State Of Paraíba, *Northeastern Brazil Tropical Oceanography, Recife*, 32 (2): 171-179.

Carpenter, E.J and D.G. Capone (1992). Nitrogen fixation in *Trichodesmium* blooms, p. 211-218. In: *Marine pelagic cyanobacteria: Trichodesmium and other diazotrophs* (E. J. Carpenter, D. G. Capone, and J. G. Rueter eds.). Kluwer

Díez, B., K. Bauer, and B. Bergman (2007). Epilithic Cyanobacterial Communities of a Marine Tropical Beach Rock (Heron Island, Great Barrier Reef): Diversity and Diazotrophy▿. *Appl Environ Microbiol.*, 73(11): 3656-3668.

Desikachary, T.V. (1959). *Cyanophyta. Monographs in algae*. New Delhi. Indian council of Agricultural Research.

Feldman, J. (1933). Sur quelques cyanophcees vivant dans le tissue des eponge des eponge Banyuls. *Arch. Zool. exp. gen.,* 75: 381-404.

Fritsch, F. E. (1945). *Structure and Reproduction of Algae*, Cambridge. 2: 939.

Gerdes, G., N. Kadagies, J. Kaselowsky, A. Lauer, and J. Scholz (2005). Bryozoans and microbial communities of cool-temperate to subtropical latitudes—paleoecological implications. *Facies*, 50: 363-389.

Green, G. (1977). Ecology and toxicity in marine sponges. *Mar. Biol.*. 40: 208-215.

Hogdson, L.M. and A.I. Abbot (1992). Nearshore benthic marine algae of Kape Kina 'U Maui. *Bot. Mar*., 35: 535-540.

Huber-Pestalozii, G. and E. Naumann (1929). *Phormidium mucicola* Naun et Huber. ein. Epibiont in der Gallette pflanlicher und tierischer Planktonorganismen. *Ber. dtsch. bot. Ges.*, 47: 67-76.

Hussein, F. and G. Anjum (1982). Algae from snail shells. *Pak. J. Bot.*, 14: 189-190.

Hussein, 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.

Józef, K., T. Fenchel, M. Kühl, S. Kempe, B. Kremer, B. Łącka, and K. Małkowski (2015). $CaCo_3$ Precipitation in Multilayered Cyanobacterial Mats: Clues to Explain the Alternation of Micrite and Sparite Layers in Calcareous Stromatolites. *Life.*, 5: 744-769.

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

Komárek, J. and K. Anagnostidis (1986). Modernapproach to the classification system of cyanophytes, 2–Chroococcales. *Arch.Hydrobiol. 73/Algological Studies*, 43:157-226.

Komárek, J. and K. Anagnostidis (1989). Modern approach to the classification system of Cyanophytes, 4–Nostocales. *Arch.Hydrobiol. Suppl. 82/Algological Studies*, 56: 247-345.

König, G.M., S. Kehraus, S.F. Seibert, A. Abdel-Lateff, and D. Müller (2006). Natural products from marine organisms and their associated microbes. *Chem. Bio. Chem.*,,7: 229 - 238.

Lafargue, F et and G. Duclaux (1979). Premeir example, en Atlantique tropical d uneassociation symbiotique entre une *ascidie didemnidae* et une cyanphycees Chroococcales: *Trichodesmium cyanophorum* nov. sp. Et. *Synechocystis trididemni* nov. sp. Annals Inst. Oceanogr. Paris (N. S) 55: 163-184.

Lewins, R. A. (1977). Prochloron type genus of the Prochlorophyta. *Phycologia*. 16:.217.

Li, Z.Y. (2009). Advances in marine symbiotic cyanobacteria. In: Handbook on Cyanobacteria (Eds: P. M. Gault and H. J. Marler), 1-9.

Magalef, R. (1953). Materials para una flora de las algas del N. E. Espana IVb, Cyanophyceae. *Coll Bot. Barcin Bot Inst Edit*., 3: 231-260.

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

Mortensen, T. and L.K. Rosenvinge (1934). Sue une algae Cyanophcee Dactylococcopsis echini n. sp., parasite dans un Dansk. Vidensk. Selsk., *Bio. Medd*., 11: n. 7.

O'Brien, H., J. Miadlikowska and F. Lutzoni (2005). Assessing host specialization in symbiotic cyanobacteria associated with four closely related species of the lichen fungus Peltigera. *Eur. J. Phycol.*, 40: 363–378.

O'Neil, J.M. and M.R. Roman (1992). Grazers and Associated Organisms of *Trichodesmium* . Marine Pelagic Cyanobacteria: *Trichodesmium* and other Diazotrophs NATO ASI Series. 362: 61-73.

O'Neil, J. M. (1998). The colonial cyanobacterium *Trichodesmium* as a physical and nutritional substrate for the harpacticoid copepod *Macrosetella gracilis. J. Plankton Res.*, 20(1): 43-59.

Pagliara, P. and C. Caroppo (2010). *Leptolyngbya* species isolated from The Sponge *Petrosia Ficiformis* as Potential Source Of Novel Compounds .*Rapp. Comm. Int. Mer Médit.,* 39: 392.

Pantazidou, A., I. Louvrou and, A. Economou-Amilli (2006). Euendolithic Shell-Boring Cyanobacteria And Chlorophytes Fromthe Saline Lagoon Ahivadolimni On Milos Island, Greece. *Eur. J. Phycol.*, 41(2): 189–200

Park, M. and H. B. Moor (1935). The biology of *Balanus balanides* II. Algal infection of the shell. *J. Mar. Biol.* Ass., U. K., 20.

Prescott, G. W. (1969). *The algae. A review*. Thomas Nelson, London, 436. pp.

Radea, C., I. Louvrou, A. Pantazidou and A. Economou–Amill (2010). Photosynthetic microorganisms as epibionts and euendoliths on biotic substrates in a thermal spring with ferric–iron deposits. *Fottea* 10(1): 129–140.

Rai A.N., B. Bergman and U. Rasmussen (eds). (2002). *Cyanobacteria in symbiosis*. Dordrecht: Kluwer Academic Publishers.

Rai A.N., E. So¨derba¨ck and B. Bergman. (2000). Cyanobacteria–plant symbiosis. *New Phytologist*, 116: 449-481.

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

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

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

Sara, M. (1971). Ultrastructural aspect of the symbiosis between two species of the genus *Aphanocapsa* (Cyanophyceae) and *Ircinia variabilis* (Demospongiae). *Mar. Biol*., 11:214-221.

Shameel, M. and N. I Butt (1984). On the occurrence of Cyanophyta from Karachi, Pakistan. Pak. J. Bot. 16: 75-79.

Sybesma, I. and R.P.M. Bak. (1979).The distribution of *Trididemnum solidum* (van Name), an algae-containing compound ascidian, along the coasts of Curaçao (N.A.). Proc. 14th meet Ass. Isl. mar. labs. Carrib., 14: 6 (Santo Domingo).

Thacker, R.W. and Æ.S. Starnes (2003). Host specificity of the symbiotic cyanobacterium Oscillatoria spongeliae in marine sponges, *Dysidea* spp. *Mar. Biol*., 142: 643-648.

Thajuddin, N. and G. Subramanian (1990). Cyanobacterial phytoplanktons of the Gulf of Mannar region. *Proc. Natl. Symposium on cyanobacterial nitrogen fixation* NFBGA, IARA, New Delhi pp. 457-463.

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. *Curr. Res. Pl. Sci*., 1-16.

Thajuddin, N. and G. Subramanian (2005). Cyanobacterial biodiversity and potential applications in biotechnology. *Current Science*, 89:47-57.

Tsuda, R.T., H.K Larson and R.J. Lujan (1972). Algal growth on the beaks of the live parrot fishes. *Pacif. Sci.*, 26: 20-23.

Usher, K.M. (2008). The ecology and phylogeny of cyanobacterial symbionts in sponges. *Mar. Ecol*., 29:178-192.

Vacelet, J. (1971). Fitude en *microscopie* electronique de l'association entre une Cyano- phycee Chroococcale et une eponge du genre Verongia. *J. of Microscopie.*, 12: 363-380.

Wegley, L., R. Edwards, B. Rodriguez-Brito, H. Liu, and F. Rohwer (2007). Metagenomic analysis of the microbial community associated with the coral Porites astreoides. *Enviro. Microb*. 9: 2707-2719.

West, W. and N. Annandale (1911). Description of the new species associated with Indian freshwater polyzoa. *J and Proc. Asiatic Soc., Bengal.*, 7: 83-84.

Wilkinson, C. R. (1978). Microbial association in sponges I. Ecology, Physiology and microbial population of coral reef sponges. *Mari. Biol*., 49: 161-167.

(*Accepted for publication December 2015*)