

An Account of Lichen Diversity in Islands of Marine Protected Area, Jamnagar, Gujarat

Komal K. Ingle^{1,2}, S. Nayaka^{1*}, R. Bajpai¹, J. R. Rawal³, D.K. Upreti¹ and S. Trivedi²

¹Lichenology Laboratory, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow-226 001

²Department of Botany, Motilal Vigyan Mahavidyalaya, Bhopal-462 026

³Jay Gurudev Career Academy, F-13, Astha Complex, Malgodun Road, Mehsana-384 002

*Email: nayaka.sanjeewa@gmail.com

Introduction

The islands are home for almost one tenth of world's population. Islands not only depicts unique culture but also preserve rich biodiversity. The importance of the islands in terms of biodiversity and evolutionary process have been recognized way back during Wallace (1876) and Darwin (1909) period. In India Andaman - Nicobar and Lakshadweep are the major islands while remaining smaller islands are mostly located in west coast of the country. Several studies on the flora and fauna are already available for these major islands, however such studies for scattered, smaller islands are lacking. These smaller islands can be refuge of biodiversity and centres of microevolution. In the present study we have documented the lichen diversity in some important islands in Marine Protected Area (MPA) in Gulf of Kutch. The aim of the study is to investigate the reasons for unique lichen diversity in the islands in comparison to main land.

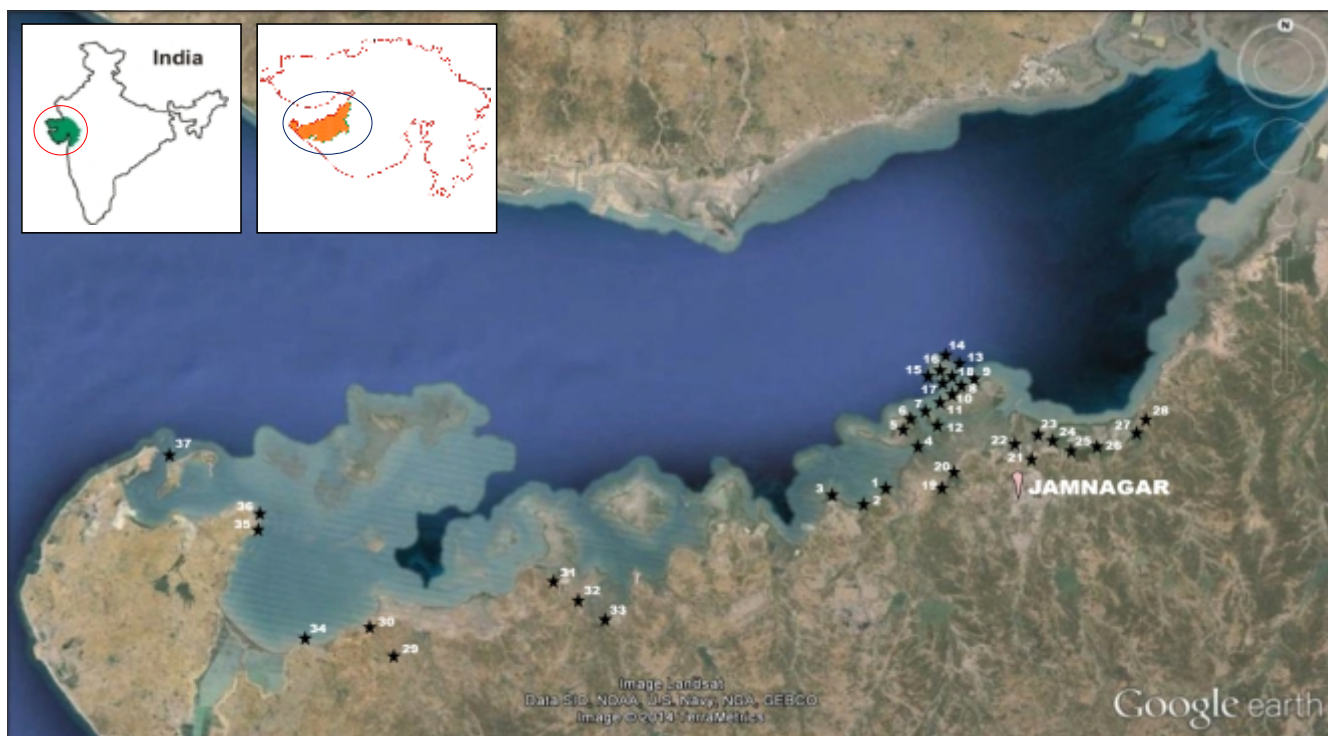
Lichens are composite, symbiotic life forms made up of members from as many as three evolutionary lines; fungi, algae and cyanobacteria. They are able to colonise a vast range of habitats including the maritime area. They are an essential part of the coastal ecosystem and also significant indicators of air pollution and environmental health. A lot of lichen study has been carried out in various islands around the world. Mandeel & Aproot (2004) surveyed the Bahrain Island group of Arabian Gulf and reported seven lichen species which are new records for the country. Aproot (2008) surveyed St. Helena and Ascension Island of South Atlantic Ocean and reported 220 and 110 lichen species respectively most of which have never been reported from the Island. In India much of the lichen studies in island context were carried out in Andaman Islands from. Recently, Sethy *et al.* (2012) compiled the lichens growing on mangrove plants in Andaman Islands and reported twenty-nine species which included 14 new records to the region and five new records to India.

These studies clearly indicates that the islands harbour rich and unique diversity of lichens.

Materials and methods

Study site: The southern shores of Gulf of Kutch in Jamnagar district are demarcated as the Marine National Park (MNP) and Sanctuary (collectively designated as Marine Protected Area – MPA). The notified area includes 148.92 km² of 42 islands in the Gulf and 309 km² of inter-tidal zone along the coast. The protected area has a great diversity of habitats ranging from coral reefs, mangroves, mudflats, creeks, estuaries, sandy strands to saline grasslands, marshy areas and rocky shores. Among the 42 islands of MPA only two are inhabited; Beyt Dwarka, is an important temple and pilgrim site while Ajad supports a small farming community. Many of the islands such as Chusna, Pirotan, Ajad and Beyt are pir and dargah sites (traditional religious sites) having annual pilgrimages and fairs. These islands are more or less uniformly scattered in the gulf and located at close proximity to the mainland. A survey revealed that 20 out of 42 islands in MPA support a good mangrove vegetation (Singh 2006). The mangroves present in these islands are of the open scrubby type with low wooded *Avicennia marina* as a dominating species and others include *A. offinalis*, *Rhizophora mucronata*, *Ceriops tagal* and *Aegiceras* sp. The associated mangrove plants include *Salvadora persica*, *Salicornia branchiata*, *Suaeda* sp. and *Alueropus* grass. These mangroves provide a unique habitat for a variety of life forms.

Lichen collection and identification: About 250 lichen specimens were collected from MPA both from mainland and islands, especially from Bagula bailey, Bhesbid, Mundega, Narara, Pathapir, Pirotan, Poshitra and Saneda islands where mangrove plants are luxuriantly growing (Table 1, Figure 1 – 2). The lichens are identified following standard procedure by observing their external morphology, anatomy and



Sites: 1 – 2. Sikka village, 3. Sikka port, 4. Mundega Island, 5 – 6. Pathapir Island, 7. Bhesbid Island, 8 – 11. Saneda Island, 12. Bagula bailey Island, 13 – 18. Pirotan Island, 19 – 20. Sarmat, 21 – 28. Khijadiya Bird Sanctuary, 29. Enroute to Asota Mota, 30. Virpur, 31. Chudeshwar, 32. Dhaba, 33. 2 Km before Salaya, 34. Pindara, 35 – 36. Poshitra Island, 37. Beyt Dwarka.

Figure 1. Map of Marine Protected Area in Jamnagar showing the location of lichen sampling sites.

chemistry. Thin Layer Chromatography was performed in solvent system C following Orange *et al.* (2001). The specimens were identified up to the species level following literatures of Awasthi (1991, 2007), Egea & Torrente (1993), Ertz & Diederich (2007), Ertz (2009). The nomenclature and classification was updated following Lumbsch & Huhndorf (2007). The identified specimens are preserved in herbarium of CSIR-National Botanical Research Institute, Lucknow (LWG).

Result and discussion

The present study revealed the occurrence of 30 species belonging to 17 genera and 11 families from whole of MPA (Table 2). Roccellaceae is the dominant family represented by 10 species, followed by Arthoniaceae with 6 and Teloschistaceae with 3 species. The mangrove plant *Rhizophora mucronata* harboured maximum growth of 12 lichens, followed by *Ceriops tagal* with 9 and mangrove associated tree *Salvadora persica* supported 8 lichen species. It is interesting note that the major mangrove vegetation in MPA consisted of

Avicennia sp. which hosted poor diversity of lichens represented by only one fruticose lichen *Roccella montagnei*. A *Cactus* sp. growing on coastal rocks of Beyt Dwarka and Poshitra Islands harboured four lichen species such as *Arthonia cinnabarina*, *A. radiata*, *Cresponea flava* and *Dirina indica*.

The islands as a whole is represented by 24 species dominated by crustose lichens with 18 species but also three squamulose *Gloeohyppia turgida*, *Phyllicium indicum* and *Phyllicium testudineum* were encountered. *Dirinaria consimilis* is the only foliose lichen recorded from the islands. Similarly, *Lepraria lobificans* and *Roccella montagnei* are the only leprose and fruticose lichen respectively recorded from islands (Table 2). The mainland lichen diversity shows the occurrence of 12 species of which six lichen species (*Arthonia radiata*, *A. tumidula*, *Dirina indica*, *Dirinaria consimilis*, *Gloeohyppia turgida*, *Phyllicium testudineum*) are common with islands habitats (Table 2). A total of six species (*Arthonia polymorpha*, *Caloplaca cupulifera*, *C. squamosa*, *C. subpoliotea*, *Dirinaria confusa*, *Peltula obscurans*) were restricted to islands. Out of the 8 islands studied for

Table 1. Details of the localities surveyed in Marine Protected Area, Jamnagar

Locality	Sites	Latitude	Longitude	Alt. (m)	Vegetation
Sikka village	1	N 22°26' 43.4"	E 69°52' 07.5"	7.4	<i>Avicennia</i> , <i>Rhizophora</i> & <i>Salvadora</i>
	2	N 22°26' 18.6"	E 69°52' 06.4"	10.5	
	3	N 22°25' 57.6"	E 69°49' 26.3"	70	
Mundega Island	1	N 22°31' 07.7"	E 69°55' 50.6"	2.4	Dense <i>Avicennia</i> & <i>Rhizophora</i> sp.
Pathapir Island	1	N 22°31' 21.0"	E 69°55' 44.6"	13.8	<i>Avicennia</i> , <i>Rhizophora</i> & <i>Ceriops</i> sp.
Bhesbid Island	1	N 22°32' 49.8"	E 69°56' 23.4"	69.3	<i>Avicennia</i> , <i>Rhizophora</i> & <i>Salvadora</i> sp.
Saneda Island	1	N 22°33' 32.9"	E 69°57' 30.1"	30	<i>Salvadora</i> sp.
	2	N 22°33' 46.1"	E 69°57' 30.9"	10	<i>Avicennia</i> sp.
	3	N 22°33' 25.4"	E 69°57' 28.0"	10.9	<i>Salvadora</i> & <i>Ceriops</i> sp.
	4	N 22°33' 15.7"	E 69°57' 26.9"	5	<i>Avicennia</i> sp.
Bagula baily Island	1	N 22°31' 51.8"	E 69°56' 35.7"	10	<i>Avicennia</i> , <i>Ceriops</i> & <i>Rhizophora</i> sp.
Pirotan Island	1	N 22°35' 56.7"	E 69°57' 46.2"	8	<i>Avicennia</i> , <i>Ceriops</i> & <i>Rhizophora</i> sp.
	2	N 22°36' 04.6"	E 69°57' 37.5"	1.8	<i>Avicennia</i> sp.
	3	N 22°35' 49.6"	E 69°57' 12.2"	0.6	<i>Salvadora</i> sp.
	4	N 22°35' 54.4"	E 69°57' 15.2"	-3	<i>Rhizophora</i> sp.
	5	N 22°35' 49.8"	E 69°57' 17.9"	-1	<i>Salvadora</i> sp.
	6	N 22°35' 48.2"	E 69°57' 23.7"	-8.6	<i>Ceriops</i> , <i>Rhizophora</i> & <i>Salvadora</i> sp.
Poshitra Island	1	N 22°23' 19.6"	E 69°11' 50.0"	6	<i>Cactus</i> , <i>Salvadora</i> sp. & Coastal rocks
Beyt Dwarka	1	N 22°27' 36.3"	E 069°06' 07.6"	12	<i>Cactus</i> , <i>Salvadora</i> & Coastal rocks
Sarmat	1	N 22°28' 47.9"	E 69°57' 24.2"	39	<i>Prosopis</i> & Rocks
	2	N 22°29' 06.0"	E 69°57' 35.0"	17	<i>Avicennia</i> plantation
Khijadiya Bird Sanctuay	1	N 22°30' 42.8"	E 70°07' 05.8"	9	<i>Prosopis</i> sp.
	2	N 22°31' 15.7"	E 70°07' 12.8"	8.2 m	<i>Avicennia</i> & <i>Rhizophora</i> sp.
	3	N 22°32' 30.4"	E 70°10' 25.8"	-3 m	
	4	N 22°31' 24.2"	E 70°07' 57.7"	12 m	<i>Ceriops</i> & <i>Rhizophora</i> sp.
	5	N 22°31' 21.5"	E 70°08' 04.1"	1 m	<i>Prosopis</i> sp.
	6	N 22°31' 19.9"	E 70°08' 10.8"	-10 m	<i>Acaccia</i> sp.
	7	N 22°31' 22.3"	E 70°08' 34.6"	20 m	
	8	N 22°32' 43.7"	E 70°10' 36.4"	18 m	<i>Ficus</i> sp.
Enroute to Asota	1	N 22°14' 28.1"	E 69°21' 50.9"	48 m	<i>Cactus</i> , <i>Prosopis</i> sp. & Rocks
Virpur	1	N 22°17' 04.0"	E 69°19' 39.2"	8.5 m	No mangroves
Chudeshwar	1	N 22°20' 44.1"	E 69°32' 26.8"	1.6 m	<i>Prosopis</i> sp.
Dhaba	1	N 22°19' 32.5"	E 69°33' 13.2"	-3 m	<i>Ficus</i> sp.
2 km before Salaya	1	N 22°18' 18.1"	E 69°35' 05.6"	1.9 m	<i>Avicennia</i> sp.
Pindara	1	N 22°15' 59.4"	E 69°15' 10.7"	2 m	<i>Cactus</i> , <i>Prosopis</i> , <i>Salvadora</i> sp. & monumental rocks.

Table 2 : List of lichens and their distribution in Marine Protected Area

S. No.	Lichen sp.	Family	Growth forms	Collection localities, MPA													
				Islands								Coastal areas					
				Bhesbid	Beyt Dwarka	Mundega	Narara	Pathapir	Pirotan	Poshitra	Saneda	Chudeshwar	Dhaba	Asota	Khijadiya	Pindara	Sarmat
1	Arthonia antillarum (Fée) Nyl.	Arthoniaceae	Cr							+							
2	A.cinnabarina (DC) Wallr.	Arthoniaceae	Cr									+				+	
3	A. medusula (Pers.) Nyl.	Arthoniaceae	Cr					+		+							
4	A. polymorpha Ach.	Arthoniaceae	Cr														+
5	A. radiata (Pers.) Ach.	Arthoniaceae	Cr					+		+	+		+	+			
6	A. varia Stirt.	Arthoniaceae	Cr							+							
7	Bactrospora sp.	Roccellaceae	Cr							+							
8	Caloplaca cupulifera (Vain.) Zahlbr.	Teloschistaceae	Cr													+	
9	C. squamosa (de Lesd.) Zahlbr.	Teloschistaceae	Cr													+	
10	C. subpoliotera Y. Joshi & Upreti	Teloschistaceae	Cr													+	
11	Cresponea flava (Vain.) Egea and Torrente	Roccellaceae	Cr	+	+	+			+	+	+	+					
12	Diorygma megasporum Kalb & al.	Graphidiaceae	Cr							+							
13	Dirina indica Upreti & Nayaka	Roccellaceae	Cr	+	+	+			+	+	+	+				+	
14	Dirinaria confusa D.D. Awasthi	Physciaceae	Fl													+	
15	D. consimilis (Stirt.) D.D. Awasthi	Physciaceae	Fl					+									+
16	Enterographa pallidella (Nyl.)	Roccellaceae	Cr					+		+							
17	Gloeohoppia turgida (Ach.) Gyelnik	Gloeohoppiaceae	Sq									+					+
18	Graphis striatula (Ach.) Spreng.	Graphidiaceae	Cr					+									
19	Lecanora achroa Nyl. in Cromb.	Lecanoraceae	Cr							+							
20	Lepraria lobificans Nyl.	Stereocaulaceae	L								+						
21	Opegrapha albocinerea Vain	Roccellaceae	Cr					+		+							
22	O. arabica (Müll. Arg.) Vain.	Roccellaceae	Cr	+				+		+			+				
23	O. graphidiza Nyl.	Roccellaceae	Cr	+				+		+				+			
24	O. varians (Müll. Arg.) Vain.	Roccellaceae	Cr	+				+		+				+			
25	O. vulgata Ach.	Roccellaceae	Cr	+				+			+						
26	Peltula obscurans (Nyl.) Gyeln.	Peltulaceae	Sq													+	
27	Phylliscum indicum Upreti	Lichinaceae	Sq			+											
28	P. testudineum Henssen	Lichinaceae	Sq									+			+		+
29	Roccella montagnei Bél. em. D.D. Awasthi	Roccellaceae	Fr	+				+		+			+				
30	Sulcopyrenula staurospora (Tuck. ex H. Willey) H. Harada	Pyrenulaceae	Cr								+						

(Note: Cr = Crustose, Fl = Foliose, Sq = Squamulose, L = Leprose, Fr = Fruticose).



Figure 2. View of study site at MPA. A. Mangrove vegetation (*Avicennia* and *Rhizophora* sp.) at Sikka village, B. Dense Mangrove vegetation (*Avicennia* sp.) at Mundega Island, C. Mangrove vegetation (*Avicennia* sp.) at Pathapir Island, D. Luxuriant growth of *Rocella* sp. on *Rhizophora* twigs at Bhesbid Island, E. Mangrove vegetation (*Avicennia* sp.) at Saneda Island, F. Mangrove vegetation (*Avicennia* sp.) at Bagula bailey Island.

lichen occurrence, **Pirotan Island** showed the **maximum number of 16 species** followed by **Mundega and Pathapir** with 10 and 9 species respectively (Figure 4).

According to 'island biogeography model' proposed by MacArthur and Wilson (1967) islands close to mainland with larger size have more species diversity. Because these islands more readily receive colonists from the mainland and probability of colonization in large islands will be higher than that of small islands. However, the island biogeography theory is less applicable for the present study. Because in MPA the islands have more species diversity and luxuriant growth of lichens than that of the mainland. As mentioned earlier Pirotan Island having comparatively larger size has maximum diversity of lichens. It can be noted that the islands in MPA have **dense mangrove vegetation with negligible anthropogenic disturbances**. Whereas the mainland, especially coastal area of MPA is highly disturbed and polluted. The islands also have varieties of mangrove plants and associated species (*Ceriops*,

Rhizophora & *Salvadora*) those actually support good growth of lichens in comparison to *Avicennia*. Therefore, the luxuriant growth of lichens are witnessed in the islands.

Conclusion

It is clear from the present study that islands in the MPA **are richer in lichens than the mainland**. The undisturbed habitat with dense mangrove vegetation and availability of suitable host plants are main reason for such luxuriant growth of lichens. The uniqueness of lichen biota of MPA is the **dominance of lichen family Roccellaceae** which is not observed in the studies carried out elsewhere in the world and Lumbsch *et al.* (2011) reported sixty six lichen species from the group of islands in Fiji. Similarly, Sethy *et al.* (2012) have observed the dominance of family Graphidiaceae in their studies for Andaman Islands and member of lichen family *Roccellaceae* were completely lacking.

The environmental factors such as temperature,

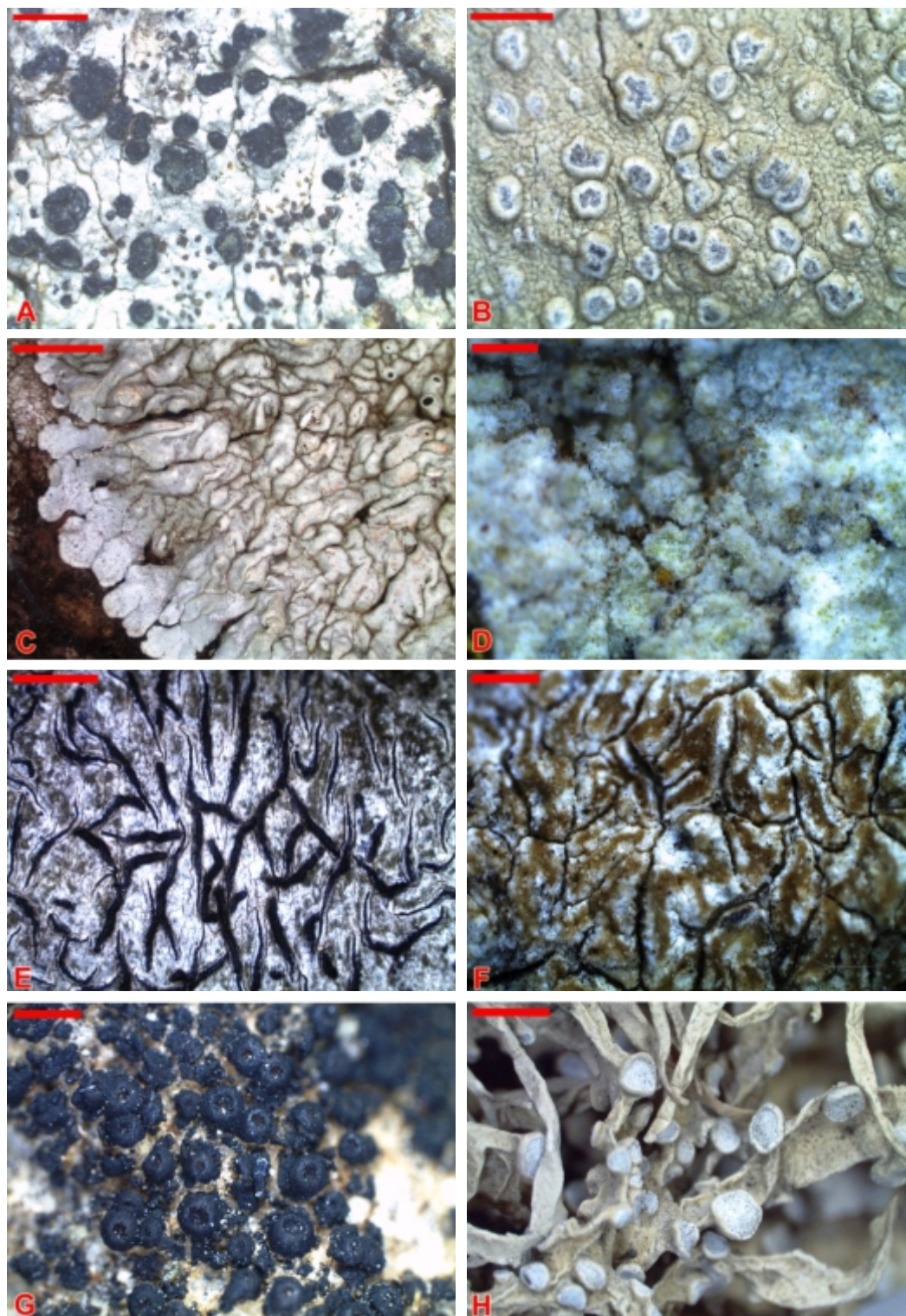


Figure 3 : Some prominent lichens of MPA. A, *Craspedonea flava* (Crustose); B, *Dirina indica* (Crustose); C, *Dirinaria confusa* (Foliose); D, *Lepraria lobificans* (Leprose); E, *Opegrapha graphidiza* (Crustose); F, *Enterographa pallidella* (Crustose); G, *Phylliscum testudineum* (Squamulose); H, *Rocella montagnei* (Fruticose). Scale: A & B = 1 mm; C, E & H = 2 mm; D = 0.2 mm; F & G = 0.5 mm

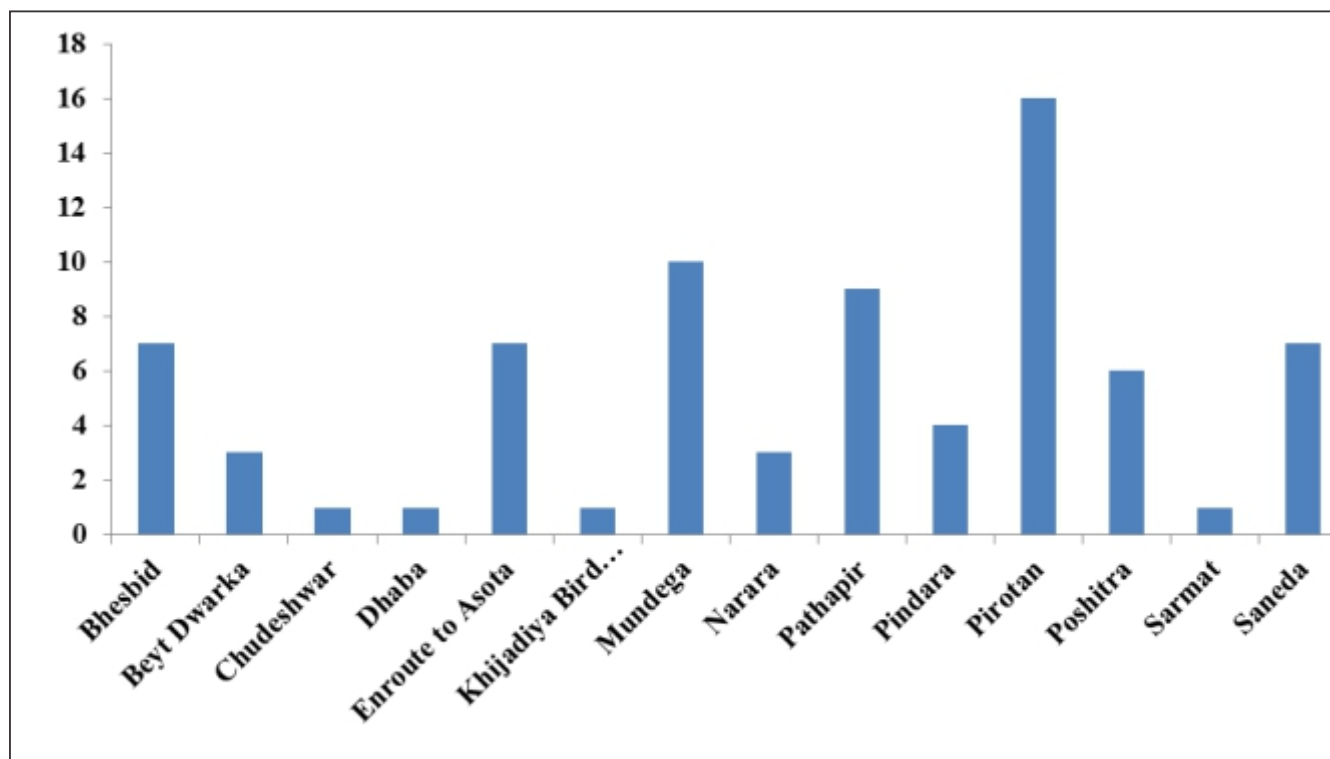


Figure 4 : Number of lichen species represented in Marine Protected Area.

precipitation and seepage of freshwater influence the mangrove plant growth along the coastal area which in turn influence the occurrence of lichens. The coastal areas are also exposed to high human interference in terms of fishing, boating, harbour, oil extraction etc. In Gujarat state in the recent years increased industrial development as well as destruction of mainland tropical forests for agricultural development have indirectly impacted coastal and island mangrove swamps through water pollution from industrial effluent, oil spills, sewer discharge, agricultural and sediment runoff. In MPA the islands are located not far away from the mainland. Such a disturbance in mainland also would influence these islands and modify their climatic conditions which would be detrimental to the island biodiversity. The lichens being sensitive to microclimate changes their diversity and abundance would certainly be affected in due course.

It can be noted that a total of 17 species were earlier reported from Jamnagar district, based on the cursory collections from Marine National Park and entire Gujarat state represented 39 lichen species (Nayaka *et al.* 2013). Out of these *Roccella belangeriana* and *Roccella montagnei* are merged together and now it is considered as a single species *R. montagnei*. After the current study Jamnagar district represents 30 species, while Gujarat states records 48 species. The present study would be a baseline data for future biomonitoring studies in MPA utilizing lichens.

Acknowledgements

We are thankful to Director, CSIR-National Botanical Research Institute, Lucknow for providing laboratory facilities, Ministry of Environment and Forests, New Delhi for financial assistance and authorities and Forest Department of Marine National Park for their cooperation.

References

- Aproot, A. 2008. Lichens of St. Helena and Ascension Island. Bot. J. Lin. Soc. 158: 147–171.
- Awasthi, D.D. 1991. A key to microlichens of India, Nepal and Sri Lanka. Biblio. Lichenol. 40: 1–337.
- Awasthi, D.D. 2007. A Compendium of the Macrolichens from India, Nepal and Sri Lanka. Bishen Singh Mahendra Pal Singh, Dehra Dun, India.
- Darwin, C. 1909. The voyage of the beagle. New York, NY: P.F. Collier.
- Egea, J.M. & Torrente, P. 1993. Cresponea, a new genus of lichenized fungi in the order Arthoniales (Ascomycotina). Mycotaxon 48: 301–331.
- Ertz, D. & Diederich, P. 2007. Revision of the Opegrapha species with muriform ascospores (previously Dictyographa) (lichenized Roccellaceae). The Lichenologist 39(2): 143–151.
- Ertz, D. 2009. Revision of the Corticolous Opegrapha Species from the Paleotropics. Bibliotheca Lichenologica No. 102. J. Cramer in der Gebrüder Borntraeger Verlagsbuchhandlung, Berlin and Stuttgart.
- Lumbsch, H.T. & Huhndorf, S.M. (ed). 2007. Outline of Ascomycota. Myconet 13: 1–58.
- Lumbsch, H.T., Lücking, R., Divakar, P., Konrat, M.V. & Naikatini, A. 2011. New records of lichen-forming fungi from Fiji. Telopea 13(3): 375–404.
- MacArthur, R.H. & Wilson, E.O. 1963. The Theory of Island Biogeography. Princeton, N.J., Princeton University Press.
- Mandeel, Q. & Aproot, A. 2004. Lichens of Bahrain. Willdenowia 34: 539–542.
- Nayaka, S., Ingle K.K., Bajpai R., Rawal J.R., Upreti D.K. & Trivedi, S. 2013. Lichens of Gujarat state, India with special reference to coastal habitats. Current Research in Environmental & applied Mycology 3(2): 222–229.
- Orange, A., James, P.W. and White, F.J. 2001. Microchemical Methods for the Identification of Lichens. British Lichen Society, U.K.
- Sethy, P.P., Pandit, G.S. & Sharma, B.O. 2012. Lichens on mangrove plants in Andman Islands, India. Mycosphere 3(4): 476–484.
- Singh, H.S. 2006. Mangroves and their Environment (With emphasis on Mangroves in Gujarat). Gujarat Forest Department, GFRI, Gandhinagar.
- Wallace, A.R. 1876. The Geographical Distribution of Animals: With a Study of the Relations of Living and Extinct Faunas as Elucidating the Past Changes of the Earth's Surface. Harper and Brothers.



Gilligans Island, Bahamas