

## Diversity and ecology of fungi on mangroves of Bay of Bengal region - An overview

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An overview on the diversity and ecology of fungi colonizing litter of mangroves in Bay of Bengal region (mangroves of Godavary and Krishna deltas of Andhra Pradesh, Pichavaram of Tamil Nadu, and Andaman and Nicobar Islands) are presented in this paper. A total number of 131 species belonging to 77 genera have so far been reported from the three regions. *Verruculina enalia* showed highest percentage occurrence at all the sites and on different hosts. The fungi exhibited vertical zonation in their occurrence with more number occurring in the intertidal zone. While some fungi occurred throughout the tidal range many showed affinity to a particular level. Ascomycetes with immersed or semi-immersed fruit bodies occurred in water inundated niches.

[**Key words:** Mangrove fungi, seasonal occurrence, substratum preference, vertical distribution, Bay of Bengal, diversity, ecology]

### Introduction

The primary productivity from mangroves is enormous and various organisms such as woodborers, fungi and bacteria are involved in recycling the detritus. Such nutrient recycling helps in maintaining ecological balance in the estuarine environment. Of all, fungi have been found to play a major role in the nutrient regeneration cycles<sup>1</sup>. The fungi colonizing mangrove substrata can be divided into terrestrial mycota, colonizing the plant parts above the water column, and marine fungi colonizing the parts inundated either completely or intermittently by the tidal waters. At the interface, a mixture of both terrestrial and marine fungi occur<sup>2</sup>. Marine mycology, as a specialized branch of science, has evolved relatively recently. Nearly 1500 species, excluding those that form lichens, have been estimated<sup>3</sup>, although 444 formerly described higher marine fungi have been reported recently<sup>4</sup>.

Although marine fungi grow on diverse substrata including wood, sediments, seaweeds, dead corals, calcareous tubes of mollusks and intertidal grasses<sup>2,5</sup>, it is mangrove substrata viz. decaying leaves, seedlings, prop roots and pneumatophores which support half of the known marine fungi. In recent times more efforts are being undertaken to study the

microbial diversity in mangroves in view of the dangers posed on mangrove ecosystems and to suggest the conservation programs from a microbiologist point of view.

The first marine fungus from Indian mangroves, viz. *Dactylospora haliotrepha* (Kohlm. And E. Kohlm.) Hafellner (Ascomycota) has been reported by Raghukumar<sup>6</sup>. Biodiversity and ecological observations on manglicolous fungi from west coast of India have been reported by some workers<sup>7-13</sup>. Ravikumar<sup>14</sup> carried out the biodiversity and ecological studies from east coast of India. Substrate preference of manglicolous fungi on *Rhizophora* spp. has been reported by Ravikumar & Vittal<sup>15</sup>. Diversity, frequency of occurrence, substrate preference, seasonal and vertical distributions of fungi were made by Sarma & Vittal<sup>16-19</sup> and Sarma *et al.*<sup>20</sup> from Godavari and Krishna deltaic mangroves in Andhra Pradesh state along east coast of India. In the present paper the work done on diversity and ecology of fungi on mangroves of east coast of India is reviewed. In all these studies the direct examination method refined by Kohlmeyer & Kohlmeyer<sup>2</sup> was followed to enumerate the manglicolous fungi.

### Biodiversity

The mangroves of east coast are distributed in all the 4 states that have coast along peninsular India (Table 1). In addition, mangroves are also found in

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Table 1—List of fungi reported from mangroves of Bay of Bengal region<sup>11,14,18</sup>

(OM = obligately marine; FM = facultatively marine)

S. No.	Name of the species	Pichavaram	Godavari	Krishna	A & N Islands
ASCOMYCETES					
1	<i>Acrocordiopsis patilii</i> Borse and K.D. Hyde (OM)	-	-	-	+
2	<i>Aigialus grandis</i> Kohlm. and S. Schatz (OM)	+	+	+	+
3	<i>A. mangrovei</i> Borse (OM)	+	+	+	+
4	<i>A. parvus</i> S. Schatz and Kohlm. (OM)	+	+	+	+
5	<i>Aniptodera chesapeakeensis</i> Shearer and M.A. Mill. (OM)	-	+	+	+
6	<i>A. haispora</i> Vrijmoed, K.D. Hyde and E.B.G. Jones (OM)	-	+		
7	<i>A. mangrovei</i> K.D. Hyde (OM)	-	+	+	-
8	<i>Aniptodera</i> sp. (OM)	-	-	-	+
9	<i>Antennospora quadricornuta</i> (Cribb and J.W. Cribb) T.W. Johnson (OM)	+	-	-	+
10	<i>A. salina</i> (Meyers) Yusoff, E.B.G. Jones and S.T. Moss (OM)	-	-	-	+
11	<i>Anthostomella leptosporae</i> (Lev. and Sacc.) Francis (FM)	+	+	-	-
12	<i>Anthostomella</i> sp. (FM)	+	+	+	-
13	<i>Ascocratera manglicola</i> Kohlm. (OM)	-	-	+	+
14	<i>Bathyascus avicenniae</i> Kohlm. (OM)	-	+	+	+
15	<i>B. grandispora</i> K.D. Hyde and E.B.G. Jones (OM)	-	-	-	+
16	<i>B. mangrovei</i> Ravikumar and Vittal (OM)	+	-	-	-
17	<i>Belizeana tuberculata</i> Kohlm. and Volkm.-Kohlm. (OM)	+	-	-	+
18	<i>Biatriospora marina</i> K.D. Hyde and Borse (OM)	-	-	-	+
19	<i>Caryosporella rhizophorae</i> Kohlm. (OM)	-	-	-	+
20	<i>Ceratospheria</i> sp. (FM)	+	-	-	-
21	<i>Chaetomastia typhicola</i> (P. Karst.) Barr (OM)	-	+	+	-
22	<i>Coccostroma</i> sp. (FM)	+	-	-	-
23	<i>Corollosporella pulchella</i> Kohlm., I. Schmidt and N.B. Nair (OM)	-	-	+	-
24	<i>Coronopapilla mangrovei</i> (K.D. Hyde) Kohlm. and Volkm.-Kohlm. (OM)	-	-	-	+
25	<i>Cryptosphaeria mangrovei</i> K.D. Hyde (OM)	-	+	+	-
26	<i>Cryptovalsa</i> sp. (OM)	-	+	+	-
27	<i>Dactylospora haliotrepha</i> (Kohlm. and E. Kohlm.) Hafellner(OM)	+	+	+	+
28	<i>Didymella avicenniae</i> S.D. Patil and Borse (OM)	+	-	-	-
29	<i>Didymosphaeria</i> sp. (OM)	+	-	-	-
30	<i>Eitheirophora blepharospora</i> (Kohlm. and E. Kohlm.) Kohlm. and Volkm.-Kohlm (OM)				
31	<i>Eutypa bathurstensis</i> K.D. Hyde and Rappaz (OM)	+	+	+	-
32	<i>Gnomonia</i> sp. (FM)	+	+	-	-
33	<i>Halorosellinia oceanica</i> Whalley, E.B.G. Jones, K.D. Hyde and Laessøe (OM)	-	+	+	+
34	<i>Halosarpheia abonnis</i> Kohlm. (OM)	-	+	+	+
35	<i>H. fibrosa</i> Kohlm. And E. Kohlm (OM)	+	-	-	-
36	<i>H. marina</i> (Cribb and J.W. Cribb) Kohlm.(OM)	+	+	+	-
37	<i>H. minuta</i> W.F. Leong (OM)	-	+	+	-
38	<i>H. ratnagiriensis</i> S.D. Patil and Borse (OM)	-	+	+	+
39	<i>H. trullifera</i> (Kohlm.) E.B.G. Jones, S.T. Moss and Cuomo (OM)	+	-	-	-
40	<i>H. viscidula</i> (Kohlm. and E. Kohlm.) Shearer and J.L. Crane (OM)	-	-	-	+
41	<i>H. viscosa</i> (I. Schmidt) Shearer and J.L. Crane (OM)	-	-	+	-
42	<i>Halosarpheia cf. minuta</i> (OM)	-	-	-	+
43	<i>Halosarpheia</i> sp. (OM)	+	-	+	-
44	<i>Halosphaeria cucullata</i> (Kohlm.) Kohlm. (OM)	+	-	-	-
45	<i>Halosphaeria hamata</i> (Hohnk) Kohlm. (OM)	+	-	-	-
46	<i>Hapsidasascus</i> sp.-like (OM)	-	-	+	-
47	<i>Heleococcum japonense</i> Tubaki (OM)	+	-	+	-
48	<i>Helicascus kanaloanus</i> Kohlm. (OM)	+	-	-	+
49	<i>Hypocrea</i> sp. (FM)	-	-	+	-
50	<i>Hypoxyton</i> sp. (FM)	-	+	+	-
51	<i>Hysterium</i> sp. (FM)	-	+	+	-
52	<i>Julella avicenniae</i> (Borse) K.D. Hyde (OM)	+	+	+	+
53	<i>Kallichroma glabrum</i> (Kohlm. and E. Kohlm.) Kohlm. and Volkm.-Kohlm (OM)	-	-	-	+
54	<i>Kallichroma tethys</i> (Kohlm. and E. Kohlm.) Kohlm. and Volkm.-Kohlm. (OM)	+	+	+	+

...Contd.

Table 1—List of fungi reported from mangroves of Bay of Bengal region<sup>11,14,18</sup> ...Contd  
(OM = obligately marine; FM = facultatively marine)

S. No.	Name of the species	Pichavaram	Godavari	Krishna	A & N Islands
ASCOMYCETES					
55	<i>Kirschsteiniothelia maritima</i> (Linder) D. Haks. (OM)	-	+	-	-
56	<i>Lautospora gigantea</i> K.D. Hyde and E.B.G. Jones (OM)	-	+	-	-
57	<i>Lecanidion atratum</i> (Hedw. Ex Fr.) Endl. (FM)	-	+	+	-
58	<i>Leptosphaeria australiensis</i> G.C. Hughes (OM)	+	+	+	+
59	<i>L. peruviana</i> Speg. (OM)	-	+	+	-
60	<i>Leptosphaeria</i> sp. (OM)	-	+	+	-
61	<i>Lignicola laevis</i> Höhnk(OM)	-	+	-	+
62	<i>L. longirostris</i> (Cribb and J.W. Cribb) Kohlm. (OM)	+	+	+	-
63	<i>L. tropica</i> Kohlm. (OM)	+	+	+	-
64	<i>Lineolata rhizophorae</i> (Kohlm. and E. Kohlm) Kohlm. and Volkm.-Kohlm. (OM)	+	-	+	+
65	<i>Lophiostoma mangrovei</i> Kohlm. and Vittal (OM)	+	+	+	+
66	<i>Lulworthia grandispora</i> Meyers (OM)	+	+	+	+
67	<i>Lulworthia</i> sp. (OM)	+	+	+	+
68	<i>Marinosphaera mangrovei</i> K.D. Hyde (OM)	-	+	+	+
69	<i>Massarina armatispora</i> K.D. Hyde, Vrijmoed, Chinnaraj and E.B.G. Jones (OM)	-	-	-	+
70	<i>M. thalassiae</i> Kohlm. and Volkm.-Kohlm (OM)	+	+	+	+
71	<i>M. velatospora</i> K.D. Hyde and Borse (OM)	+	+	+	+
72	<i>Massarina</i> sp. 1 (OM)	+	+	+	-
73	<i>Massarina</i> sp. 2 (OM)	+	-	-	-
74	<i>Mycosphaerella pneumatophorae</i> Kohlm. (OM)	+	+	-	-
75	<i>Nais glitra</i> J.L. Crane and Shearer (OM)	+	+	-	+
76	<i>Nais</i> sp. (OM)	+	-	-	-
77	<i>Ophiodeira cf. monosemeia</i> (OM)	-	+	+	-
78	<i>Passereniella obiones</i> (H. Crouan and P. Crouan) (OM)	-	-	+	-
79	<i>P. savoryellopsis</i> K.D. Hyde and Mouzouras (OM)	-	-	-	+
80	<i>Payosphaeia minuta</i> W.F. Leong (OM)	-	-	-	+
81	<i>Payosphaeriella</i> sp. (OM)	+	-	-	-
82	<i>Pedumispora rhizophorae</i> K.D. Hyde and E.B.G. Jones (OM)	-	+	+	-
83	<i>Pleospora</i> sp. (OM)	+	-	-	+
84	<i>Pontoporeia</i> sp.1 (FM)	+	-	-	-
85	<i>Pontoporeia</i> sp.2 (FM)	+	-	-	-
86	<i>Quintaria lignatilis</i> (Kohlm.) Kohlm. and Volkm.-Kohlm. (OM)	+	-	+	+
87	<i>Rhizophila marina</i> K.D. Hyde and E.B.G. Jones (OM)	+	+	+	+
88	<i>Saccardoella marinospora</i> K.D. Hyde (OM)	+	+	-	+
89	<i>S. rhizophorae</i> K.D. Hyde (OM)	+	+	+	+
90	<i>Salsuginea ramicola</i> K.D. Hyde (OM)	-	-	-	+
91	<i>Savoryella lignicola</i> E.B.G. Jones and R.A. Eaton (OM)	+	-	+	+
92	<i>S. paucispora</i> (Cribb and J.W. Cribb) Jørgen Koch (OM)	-	-	-	+
93	<i>Splanchnonema cf. britzelmayriana</i> (Rehm.) Boise(OM)	-	+	-	-
94	<i>Sporomiella grandispora</i> (FM)	+	-	-	-
95	<i>Swampomyces arenniacus</i> Kohlm. and Volkm.-Kohlm. (OM)	+	-	-	+
96	<i>Trematosphaeria striatispora</i> (OM)	-	-	-	+
97	<i>Trematosphaeria</i> sp. (OM)	+	-	-	-
98	<i>Tubeufia setosa</i> Sivanesan and W.H. Hsieh (FM)	-	+	-	-
99	<i>Verruculina enalia</i> (Kohlm.) Kohlm. and Volkm.-Kohlm. (OM)	+	+	+	+
100	<i>Zopfiella latipes</i> (N. Lundq.) Malloch and Cain (OM)	-	+	-	-
101	<i>Zopfiella marina</i> Furuya and Udagawa (OM)	-	+	-	-
102	<i>Zopfiella</i> sp. (OM)	-	+	-	-
BASIDIOMYCETES					
103	<i>Halocyphina villosa</i> Kohlm. (OM)	+	+	+	+
104	<i>Nia vibrissa</i> Moore & Meyers (OM)	+	-	-	-
ANAMORPHIC FUNGI					
105	<i>Alveophoma</i> sp. (FM)	-	+	-	-
106	<i>Bactrodesmium linderii</i> (Crane and Shearer) Palm and Stewart (OM)	-	+	+	-
107	<i>Camarosporium roumequerii</i> Sacc. (OM)	+	+	+	-

...Contd

Table 1—List of fungi reported from mangroves of Bay of Bengal region<sup>11,14,18</sup> ... *Contd*  
(OM = obligately marine; FM = facultatively marine)

S. No.	Name of the species	Pichavaram	Godavari	Krishna	A & N Islands
ANAMORPHIC FUNGI					
108	<i>Cirrenalia basiminuta</i> Raghuk. and Zainal (OM)	+	+	+	-
109	<i>C. macrocephala</i> (Kohlm.) Meyers and R.T. Moore (OM)	+	-	-	-
110	<i>C. pygmaea</i> Kohlm. (OM)	+	+	+	+
111	<i>C. tropicalis</i> Kohlm. (OM)	-	+	-	+
112	<i>Corynespora cassicola</i> (Berk. and Curt) Wei (FM)	-	+	-	-
113	<i>Cytospora rhizophorae</i> Kohlm. and E. Kohlm. (OM)	+	-	+	-
114	<i>Dictyosporium zeylanica</i> (FM)	-	+	-	-
115	<i>Ellisemia vagum</i> (C.G. and C.G. and T.F.L.) Subram. (FM)	-	+	+	-
116	<i>Epicoccum purpurascens</i> Ehrenb.: Schlecht (FM)	+	+	+	-
117	<i>Monodictys pelagica</i> (T.W. Johnson) E.B.G. Jones (OM)	+	-	-	+
118	<i>Monodictys</i> sp. (FM)	-	+	+	-
119	<i>Paramassariothea</i> sp. (FM)	+	-	-	-
120	<i>Periconia prolifica</i> Anastasiou (OM)	+	+	+	+
121	<i>Phialophorophoma littoralis</i> Linder (FM)	+	-	-	-
122	<i>Phoma</i> sp. (OM)	+	+	+	+
123	<i>Phomopsis mangrovei</i> K.D. Hyde(OM)	-	+	-	+
124	<i>Phomopsis</i> sp. (OM)	+	+	+	-
125	<i>Sporidesmium fragilissimum</i> (Berk. & Curtis.) Ellis (FM)	+	-	-	-
126	<i>Trichocladium achrasporum</i> (Meyers and R.T. Moore) Dixon (OM)	+	+	+	+
127	<i>T. alopallonellum</i> (Meyers and R.T. Moore) Kohlm. and Volkm.-Kohlm. (OM)	+	+	+	+
128	<i>Trimmatostroma</i> sp. (FM)	+	+	+	-
129	<i>Wardomyces papillata</i> Dickinson (FM)	+	-	-	-
130	<i>Z. varium</i> Anastasiou (OM)	+	+	+	+
131	<i>Zygosporium gibbum</i> (Sacc., Rouss. and Bomm.) Hughes (FM)	-	+	+	-

Andaman and Nicobar Islands far away from the mainland. Reports on marine fungi are available from Tamil Nadu<sup>14</sup> and Andhra Pradesh<sup>18</sup> and Andaman and Nicobar Islands<sup>11</sup>. The mangroves of Orissa (along Mahanadi river) and Sunderbans (West Bengal), however, remain largely unexplored for marine fungi. Altogether 131 manglicolous fungi belonging to 77 genera have been reported from the studies conducted so far, with majority belonging to Ascomycetes (102 species in 65 genera) followed by Anamorphic fungi (27 species in 20 genera) and only two Basidiomycetes. Of the 131 manglicolous fungi from Pichavaram of Tamil Nadu<sup>14</sup>, Godavari delta and Krishna delta of Andhra Pradesh<sup>18</sup> and Andaman and Nicobar islands<sup>11</sup>, only 22 species were found to be common to all the sites. Majority of fungi were recorded from specific site only. Thus 22 species were recorded only from Pichavaram, 17 from Andaman and Nicobar islands, 11 from Godavari and 5 only from Krishna deltaic mangroves. Upon close examination of affinities of fungal communities, sixteen species were found to be common to Godavari and Krishna deltaic mangroves. This is followed by 6 fungi common to Pichavaram and Andaman and Nicobar islands, 3 each common to Pichavaram and Godavari, Godavari and Andaman and Nicobar

islands and Pichavaram and Krishna deltaic mangroves. These numbers are in addition to the 22 fungi found common to all the 4 sites. The situation in the case of Godavari and Krishna deltas, where more number of fungi have been found to be common could be due to the proximity of the sites where similar environmental and other abiotic conditions exist. There were 11 fungi found to be common to Godavari, Krishna and Pichavaram mangroves than other combinations (Godavari, Krishna and Andaman and Nicobar islands or Pichavaram, Krishna and Andaman and Nicobar islands or Pichavaram, Krishna and Andaman and Nicobar islands). Of the 17 fungi reported only from Andaman and Nicobar islands fungi such as *Acrocordiopsis patilii*, *Antennospora salina*, *Biatriospora marina*, *Caryosporella rhizophorae*, *Coronopapilla mangrovei*, *Etheiophora blepharosporea*, *Halosarpheia viscidula*, *Massarina armatispora*, *Passeriniella savoryellopsis*, *Salsuginea ramicola*, *Savoryellopsis paucispora* and *Trematosphaeria striatispora* are typical mangrove fungi reported from South East Asia. Interestingly some of them were reported from west coast of India also<sup>13</sup>. The geographical proximities and directions of global water currents seem to play a role in the distribution of marine fungi<sup>21,22</sup>. In case of other

mangrove sites, where considerable number of fungi were reported from any one site only, they have been mostly terrestrial fungi and the local environmental conditions might have played a role in the occurrence of fungal communities in these mangrove sites.

From a quick glance on these studies it is noticed that the samples examined belonged mainly to *Rhizophora* spp. and *Avicennia* spp. although lesser number of samples of other hosts was also examined. This could be for obvious reasons, i.e. less intensive distribution of the other hosts or they were not thoroughly sampled. For example, in the study conducted in Godavari and Krishna deltas, on examination of 9 host plants, 88 manglicolous fungi were recorded<sup>18</sup>. Of these, more number of fungi (64) were recorded on *Rhizophora apiculata* Blume (fam. Rhizophoraceae), followed by *Avicennia officinalis* L. (fam. Avicenniaceae) (55) and *A. marina* (Forsk.) Vierh. (fam. Avicenniaceae) (45). On other hosts, the number of fungi recorded was less than 12. Samples belonging to these 3 hosts (*R. apiculata* and *Avicennia* spp.) have been taken up for their ecological studies from January 1994 to November 1995, at bimonthly intervals<sup>20</sup>. More number of samples collected belonging to these hosts (for their ecological studies) may be one of the reasons for recording more number of fungi on these hosts. Other hosts although collected occasionally did not yield rich diversity. Some of the fungi were recorded only on a particular host. Only a few species recorded in the present study had a wide range of hosts. For example, *Hypoxylon* sp., *Lulworthia* sp., *Trichocladium achrasporum*, *Lophiostoma mangrovei*, *Lulworthia grandispora*, *Halorosellinia oceanica* and *Hysterium* sp. were recorded on 6 or 5 hosts. *Verruculina enalia* was the only fungus that has been recorded on all the hosts. On the contrary 18 species were recorded only on *R. apiculata*, 9 on *A. officinalis* and 2 on *A. marina*. While host specificity can be attributed to some species, for example, *Saccardoella rhizophorae*, *Pedumispora rhizophorae*, *Lineolata rhizophorae*, *Rhizophila marina* and *Cryptospaheria mangrovei* specific to *Rhizophora*, for other fungi it was difficult to interpret definitely until further studies are conducted on other hosts and at other sites.

The diversity reported for Godavari and Krishna deltas of Andhra Pradesh showed that some diatrypalean fungi namely, *Eutypa bathurstensis*, *Cryptovalsa* sp. and *Cryptosphaeria mangrovei* also were present in mangroves<sup>18</sup> in addition to a

hypocrealean (*Hypocrea* sp.), a hysteriaceous (*Hysterium* sp.) and a tubeufiaceous fungus (*Tubeufia setosa*). This showed that upon examination of new hosts and new areas of mangroves one could expect more number of non-halosphaeralean fungi. Sarma & Vittal<sup>18</sup> reported that 36 of the 65 ascomycetes recorded had active spore dispersal mechanism of which 26 had fissitunicate asci and 10 with asci bearing an apical ring or pore. They further reported that the mycota mainly reflected the salinity (most of the time low to moderate) and annual rainfall (55-60 days per annum) prevailing in the Godavari and Krishna deltaic mangroves. Seventy-two species reported in the study can be recognized as obligate marine fungi as these belong to those genera that were hitherto recorded commonly from marine environments and hence are regarded as typically marine. The remaining 16 species viz., *Anthostomella leptospora*, *Anthostomella* sp., *Hypocrea* sp., *Gnomonia* sp., *Hysterium* sp., *Lecanidion atratum*, *Tubeufia setosa*, *Alveophoma* sp., *Corynespora cassicola*, *Dictyosporium* sp., *Epicoccum purpurascens*, *Phomopsis* sp., *Ellisembia vagum*, *Trimmatostroma* sp., *Zygosporium gibbum* and an undetermined Ascomycete can be said to be typical terrestrial fungi but adapted to mangrove environment<sup>2</sup>.

### Frequency of occurrence

Frequency of occurrence is calculated based on the overall percentage occurrence of fungi and they are further classified into different frequency groupings viz. very frequent (above 10 %), frequent (5-10 %), infrequent (1 < 5 %) and rare (less than 1 %). Such calculations were widely used to discuss fungal communities in mangroves<sup>20,23-27</sup>. From the east coast of India it was found that *Verruculina enalia* is the very frequently occurring fungus in all the 4 mangroves sites studied so far (Table 2). As Table 2 is self-explanatory, individual fungi are not repeated here but suffice to say that differences could be observed in the next most frequently occurring fungi and their percentage occurrence even while being recorded in all the sites. It should be mentioned here that only few hosts *Rhizophora apiculata* and *Avicennia* spp. have been taken up for frequency of occurrence studies in most cases<sup>14-19</sup>. However, if other mangrove hosts, in the respective sites, are sampled more intensively for ecological observations, probably, slightly a different picture might emerge. The fungi reported from west coast of India are

Table 2 — Frequently occurring marine fungi on mangroves of Bay of Bengal region.

	Very frequent	Frequent
Godavari delta <sup>20</sup>	<i>Verruculina enalia</i> (20.6%)	<i>Lophiostoma mangrovei</i> (6.5%)
	<i>Eutypa bathurstensis</i> (10.1%)	<i>Cirrenalia pygmaea</i> (6.3%)
		<i>Rhizophila marina</i> (5.9%)
		<i>Cryptosphaeria mangrovei</i> (5.1%)
Krishna delta <sup>20</sup>	<i>Verruculina enalia</i> (15.6%)	<i>Dactylospora haliotrepha</i> (8.7%)
		<i>Eutypa bathurstensis</i> (7.9%)
		<i>Lulworthia</i> sp. (6.5%)
		<i>Halosarpehia abonnis</i> (5.4%)
Pichavaram <sup>14</sup>	<i>Verruculina enalia</i> (27.8%)	<i>Dactylospora haliotrepha</i> (7.9%)
	<i>Lophiostoma mangrovei</i> (11.8%)	<i>Leptosphaeria australiensis</i> (6.7%)
		<i>Aigialus grandis</i> (5.5%)
		<i>Lophiostoma mangrovei</i> (9.9%)
Andaman & Nicobar Islands <sup>11</sup>	<i>Verruculina enalia</i> (12%)	<i>Halorosellinia oceanica</i> (9.6%)
	<i>Halocyphina villosa</i> (10.2%)	<i>Lulworthia grandispora</i> (9.2%)
		<i>Ascocratera manglicola</i> (7.7%)
		<i>Trichocladium achrasporum</i> (6.9%)
		<i>Dactylospora haliotrepha</i> (6.7%)

somewhat different from the east coast<sup>13</sup>. Sarma & Hyde<sup>27</sup> have discussed in detail the factors responsible for frequency of occurrence of fungi in mangroves that included, among others, host specificity, plant parts collected, site of collection of samples in a vertically zonated pattern and different seasons. Two mangroves on east coast viz. Mahanadi (Orissa) and Sunderbans (West Bengal) still remain largely unexplored and a complete picture on the frequency of occurrence of fungi from east coast would emerge only after intensive studies are conducted from these 2 important mangrove formations.

### Substratum preference

Different parts of mangrove plants harbour different fungal communities. In a study on substrate preference, Ravikumar & Vittal<sup>15</sup> maintained separate records on the number of samples supporting sporulating fungi on decaying wood, seedlings and prop roots of *Rhizophora apiculata*. They found that the prop roots of *R. apiculata* supported more number

of fungi than the other 2 substrata. Similar observations were made by Sarma & Vittal<sup>17</sup> who reported that on *Avicennia* spp. the number of species recorded on wood (61) was much greater when compared with pneumatophores (14) and roots (17). *Verruculina enalia* was very frequent on all the three plant parts but its percentage occurrence on wood (24.4 %) was slightly more when compared with roots (22.9 %) and pneumatophores (18.9 %). *Lulworthia* sp. that was very frequent on pneumatophores (13.6 %) and roots (11 %) was only infrequent on wood (4.1 %). *Leptosphaeria australiensis* occurred very frequently on pneumatophores (11.7 %), frequent on roots (5.1 %) and rare on wood (0.6 %). Such differences in percentage occurrence were noticed with respect to other fungi common to all the 3 substrata of *Avicennia* spp. On *Rhizophora apiculata* the number of fungi recorded on prop roots (61) was much greater when compared with seedlings (21 species) and wood (24 species). The fungus recorded very frequently on all the 3 substrata of *R. apiculata* was *Verruculina enalia*. However, its percentage occurrence was more or less equal on seedlings (23.8 %) and wood (23.4 %) but was much less on prop roots (13.1 %). *Dactylospora haliotrepha* which was very frequent on wood (12.5 %) was frequent on prop roots (5.5 %) and rare on seedlings (3.3 %). *Lophiostoma mangrovei* that was frequent on wood (9.4 %) and seedlings (8.1 %) was rare on prop roots (1.5 %). *Saccardoella rhizophorae* (17.6 %) and *Phomopsis mangrovei* (18.3 %) that were very frequent on seedlings were absent on wood. However, the former was infrequent (4.7 %) and the latter rare (0.8 %) on prop roots. Such differences were observed in the case of other fungi on different substrata of *Avicennia* spp. and *R. apiculata* (Table 3). In this study more fungal taxa were recorded on prop roots of *R. apiculata* and wood samples of *Avicennia* spp. when compared to other substrata viz., seedlings, roots or pneumatophores of the respective hosts. The reasons could be that the number of samples of these two substrata of the respective hosts was available in plenty when compared to other substrata mentioned above. Alternatively and probably the latter substrata do not support a rich diversity.

It can be inferred from above studies that each substratum, when seen individually, had its own very frequent, frequent and infrequent fungi appearing on them<sup>17</sup> and hence it can be concluded that fungi colonizing mangrove substrata often show preference

Table 3 — Very frequent and frequent fungi occurring on different plant parts (substrata) of *Rhizophora apiculata* and *Avicennia* spp.<sup>17</sup>

Name of the plant	Substrate (part)	Very frequent	Frequent
<i>Rhizophora apiculata</i>	Wood	<i>Verruculina enalia</i> (23.4) <i>Dactylospora haliotrepha</i> (12.5) <i>Hysterium</i> sp. (10.4)	<i>Lophiostoma mangrovei</i> (9.4) <i>Epicoccum purpurascens</i> (6.8) <i>Trichocladium achrasporum</i> (5.2)
	Prop roots	<i>Verruculina enalia</i> (13.1) <i>Rhizophila marina</i> (11.7)	<i>Cirrenalia pygmaea</i> (8.7) <i>Cryptosphaeria mangrovei</i> (6.2) <i>D. haliotrepha</i> (5.5)
	Seedlings	<i>Verruculina enalia</i> (23.8) <i>Phomopsis mangrovei</i> (18.3) <i>Saccardoella rhizophorae</i> (17.6)	<i>Lophiostoma mangrovei</i> (8.1)
<i>Avicennia</i> spp.	Wood	<i>Eutypa bathurstensis</i> (25.9) <i>Verruculina enalia</i> (24.6)	<i>Lophiostoma mangrovei</i> (9.4)
	Pneumato-phores	<i>Verruculina enalia</i> (18.9) <i>Camarosporium roumeguerii</i> (17.1) <i>Lulworthia</i> (12.6)	<i>Bathyascus avicenniae</i> (8.1) <i>Zopfella latipes</i> (7.2) <i>Halocyphina villosa</i> (5.4)
	Roots	<i>Leptosphaeria australiensis</i> (11.7) <i>Verruculina enalia</i> (22.8) <i>Lulworthia</i> sp. (11.0) <i>Lophiostoma mangrovei</i> (10.2)	<i>Lulworthia grandispora</i> (5.4) <i>Hypoxyton</i> sp. (9.3) <i>Halorosellinia oceanica</i> (8.5) <i>Halocyphina villosa</i> (5.9) <i>L. australiensis</i> (5.1) <i>Dactylospora haliotrepha</i> (5.1)

among different substrata of the same host<sup>15</sup>. Thus it is important to sample all parts of a plant to study the fungal communities particularly when frequency of occurrence of fungi is considered<sup>27</sup>.

### Seasonal occurrence

Observations on seasonal occurrence of manglicolous fungi were studied by Sarma & Vittal<sup>16</sup> from Godavari and Krishna deltas, Andhra Pradesh, east coast of India. The above study showed that only few fungi occurred throughout the sampling period of 2 years (total 12 samplings) from January 1994 to December 1995 where bimonthly samplings were conducted. The occurrence of few fungi throughout the year or in all the seasons is a common phenomenon for other organisms also. Sarma & Vittal<sup>16</sup> reported that at Godavari delta, *Rhizophila marina*, *Verruculina enalia*, *Cryptosphaeria mangrovei*, *Lophiostoma mangrovei*, *Lulworthia* sp. and *Saccardoella rhizophorae* on *Rhizophora apiculata* and *Eutypa bathurstensis*, *Lophiostoma mangrovei*, *Verruculina enalia*, *Halorosellinia oceanica* and *Hypoxyton* sp. on *Avicennia* spp. occurred in most of the samplings. Some of these fungi also had high overall percentage occurrence on respective hosts and a few are host specific also e.g. *Saccardoella rhizophorae*, *Cryptosphaeria mangrovei* and *Rhizophila marina* on *Rhizophora apiculata* and *Eutypa bathurstensis* on *Avicennia* spp. (Table 4). These fungi may be said to be tolerant to a wide range of habitats and temperature in addition to other abiotic

factors. Other fungi e.g. *H. oceanica*, *Hypoxyton* sp., *Lulworthia* sp., *Halocyphina villosa*, *Dactylospora haliotrepha*, *Trichocladium achrasporum* although present in most of the samplings were not abundant in terms of their overall percentage occurrence. The mangrove areas in this study experience two monsoons viz. south west monsoon during June to September and North East monsoon during October to December. From January to May end it will be a dry period. The major observations of the above study were that more number of fungi were recorded during July, September and November samplings in both years. This shows that the mangrove fungi prefer more dampness and low to moderate temperature and salinity (rains during monsoon season bring freshwater surge). Some fungi that appeared on one host were absent on other hosts in any particular sampling. We do not know the particular reasons for this. In fact such a situation complicates the aspect of seasonality of individual fungi in mangroves. Other than the above generalizations it seems that it is necessary to conduct a multiple year study to find out the seasonality of individual fungi. This is an area for further studies on mangrove fungi.

### Vertical distribution

There is only one report that is available on vertical distribution of mangrove fungi from east coast of India<sup>19</sup>. In this study preliminary observations were made on fungi colonizing prop roots of *R. apiculata* at Krishna delta. Three vertical levels were divided

artificially of which level I (30 cm-90 cm) represented submerged samples, level II (90 cm-150 cm) represented intertidal samples and level III (150 cm-210 cm) represented the high tide samples. The results in this study showed that the middle region (level II) representing the intertidal zone had more number of fungi appearing followed by submerged region (level I) and finally the level III. This is more or less similar to other studies conducted on this host<sup>28-30</sup>. The results also indicated that while some fungi have their occurrence throughout the tidal range, for example, *Hysterium* sp., *Dactylospora haliotrepha*, *Massarina* sp., *Periconia prolifica*, *Phoma* sp. and *Monodictys* sp. (although differences were found in their percentage occurrence) several fungi have an affinity

to a particular level, thus, for example, *Lulworthia* sp. (15 %), *C. pygmaea* (9.5 %) and *H. villosa* (6.9 %), at submerged level, *Halosarpheia* sp. (13.5%), *L. australiensis* (8.2%) and *H. ratnagiriensis* (4.9 %) at intertidal level and *Epicoccum purpurascens* (35.7 %) and *Trimmatostroma* sp. (28.6 %) at high tide level were recorded in more numbers at the respective vertical levels (Table 5). The major observations of the study were that hyphomycetous fungi and bitunicate fungi occur at level III while unitunicate fungi and other bitunicate fungi with or without mucilaginous sheaths prefer first or second vertical levels. This also shows that Ascomycetes with immersed or semi-immersed fruit bodies occur in the water inundated niches. The movements of upfilling

Table 4 — Seasonal occurrence of some selected fungi<sup>16</sup>

		Most common	Common
Godavari delta	<i>Rhizophora apiculata</i>	<i>Verruculina enalia</i> (11) <i>Rhizophila marina</i> (11) <i>Lophiostoma mangrovei</i> (10) <i>Cryptosphaeria mangrovei</i> (10) <i>Lulworthia</i> sp. (10)	<i>Dactylospora haliotrepha</i> (9) <i>Halocyphina villosa</i> (9) <i>Epicoccum purpurascens</i> (9) <i>Halorosellinia oceanica</i> (8) <i>Cirrenalia pygmaea</i> (8) <i>Trichocladium achrasporum</i> (8) <i>Phoma</i> sp. (8)
	<i>Avicennia</i> spp.	<i>Verruculina enalia</i> (12) <i>Eutypa bathurstensis</i> (12) <i>Lophiostoma mangrovei</i> (12) <i>Halorosellinia oceanica</i> (11) <i>Hypoxylon</i> sp. (10)	<i>Halocyphina villosa</i> (9) <i>Lulworthia</i> sp. (7) <i>Savoryella lignicola</i> (7)
Krishna delta	<i>Rhizophora apiculata</i>	<i>Verruculina enalia</i> (12) <i>Dactylospora haliotrepha</i> (12) <i>Saccardoella rhizophorae</i> (12) <i>Lulworthia</i> sp. (11) <i>Phoma</i> sp. (11)	<i>Rhizophila marina</i> (9) <i>Epicoccum purpurascens</i> (9) <i>Hysterium</i> sp. (8) <i>Aigialus grandis</i> (7) <i>Leptosphaeria australiensis</i> (7) <i>Massarina</i> sp. (7) <i>Halocyphina villosa</i> (7)
	<i>Avicennia</i> spp.	<i>Verruculina enalia</i> (12) <i>Eutypa bathurstensis</i> (12)	<i>Dactylospora haliotrepha</i> (12) <i>Lulworthia</i> sp. (9) <i>Halocyphina villosa</i> (9)

(Numbers in parenthesis indicate the actual number of samplings in which the fungus was recorded as against total number of 12 samplings).

Table 5 — Vertical distribution of fungi on mangroves at Krishna delta<sup>19</sup>

	Very frequent	Frequent
Submerged	<i>Rhizophila marina</i> (23.3%) <i>Lulworthia</i> sp. (15%)	<i>Cirrenalia pygmaea</i> (9.5%) <i>Saccardoella rhizophorae</i> (7.8%) <i>Verruculina enalia</i> (6.6%) <i>Dactylospora haliotrepha</i> (5.2%) <i>Halocyphina villosa</i> (6.9%)
Intertidal	<i>Dactylospora haliotrepha</i> (15.4%) <i>Halosarpheia</i> sp. (13.5%) <i>Rhizophila marina</i> (12.6%)	<i>Leptosphaeria australiensis</i> (8.2%) <i>Saccardoella rhizophorae</i> (5.3%)
High tide	<i>Epicoccum purpurascens</i> (35.7%) <i>Trimmatostroma</i> sp. (28.6%) <i>Hysterium</i> sp. (10.7%)	<i>Bactrodesmium linderii</i> (6%)

and receding waters during high and low tides and the associated abrasions wash away the conidia of hyphomycetes or prevent formation of superficial fruit bodies, mostly. However, successful fungi would either have long and coiling hyphal attachments to the conidia (e.g. *Cirrenalia pygmaea*, *Zalerion varium*) or have a gummy substance in the fruit bodies that stick firmly to the substratum (e.g. *Dactylospora haliotrepha* and *Lecanidion atratum*). Most of the studies on vertical distribution of fungi in mangroves are from *Rhizophora* spp. The added advantage of this host is that the standing prop roots are either dead or in various stages of decomposition. This makes the investigators to collect the samples easily and study them. The prop roots of *Rhizophora* spp. fixed into the soil or hanging downwards but not separated from the host makes available a conducive environment for fungi to form deeply seated fruit bodies. This condition is more seen in completely inundated parts of prop roots of *R. apiculata* where they are exposed to longer duration. In the intertidal zone, however, both unitunicates and bitunicates appear and have either semi-immersed or superficial fruit bodies<sup>28</sup>. In order to understand the phenomenon of vertical distribution of fungi in mangroves other hosts also have to be studied thoroughly. This is an area for future studies. Here again, since it is not easy with other hosts where hanging and fringing parts will be missing the only alternative remaining seems to be to leave the poles of other hosts in mangroves (cut them into equal size) and fix them in intertidal waters in mangroves.

Based on the studies already conducted it is obvious that mangrove litter colonized by diverse group of fungi emphasizing the need to undertake similar studies on the fungal diversity of mangroves of Mahanadi and Sunderbans, which remain largely unexplored. A complete picture on fungal diversity on mangroves of Bay of Bengal region would emerge only after these two mangrove sites are studied.

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