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A review on Biodiversity of marine and mangrove fungi

T.Sivakumar

PG and Research Department of Microbiology, Kanchi Shri Krishna College of Arts and Science, Kilambi, Krishnapuram, Kancheepuram -631 551, Tamil Nadu, India
Corresponding Author: *shiva.fungi@gmail.com*

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Abstract

Fungi play an important role in decomposition of natural substrates in mangrove ecosystem. The fungi isolated from mangroves are mainly used in enzyme technology, biochemical, agricultural, pharmaceutical, molecular biology and other applied research fields. Fungi are known to play vital roles either as decomposers, symbionts of plants and animals and also parasites on plants in different ecosystem. Out of 1.5 million species of fungi, many remain un-described. Fungi grow in every conceivable habitat/ substrate having organic carbon. Decomposition of plant remains is an essential process accomplished by the fungi in nature, which balance the continuous requirements of raw material for green plant. Decomposition of organic matter in river, marine and estuarine waters is brought about by diverse aquatic biota namely, bacteria, fungi, nematodes and worms. Aquatic fungi have been reported to improve the palatability and nutrient content of plant and animal remains. The survival and success of fungi as decomposers are largely depend on their ability to adapt to their environment immediately surrounding the substratum and to provide viable reproductive units. Along with nature of substrate, everchanging factors like light, temperature, oxygen and hydrogen ion concentration act either singly or in concert to influence substrate colonization, growth and reproduction of a fungus.

Introduction

Most early studies on fungi colonizing mangroves were taxonomic and confined mainly to cataloguing fungi and describing new taxa collected in a given area (Cribb and Cribb, 1955; Kohlmeyer and Kohlmeyer, 1964 – 1969, 1971, 1977; Kohlmeyer, 1966, 1969a, 1981, 1984, 1985; Kohlmeyer and Schatz, 1985). Until recently, there have been few ecological studies on manglicolous fungi. Recent studies on inertial mangrove fungi have provided information on (a) frequency of occurrence (b) vertical zonation, (c) host and substratum specificity, (d) succession, and (e) seasonal occurrence (Aleem, 1980; Jones *et al*., 1988; Hyde, 1988a, 1989c, 1990b, 1991; Leong *et al*., 1991; Poonyth *et al*., 1999). Of these, considerable effort has been spent investigating the frequency of occurrence of manglicolous fungi (Jones and Tan, 1987; Borse, 1988; Hyde, 1988a,b, 1989a,b,c; Hyde and Jones, 1988; Jones *et al*., 1988; Jones and Kuthubutheen, 1989; Tan *et al*., 1989; Tan and Leong, 1990,1992).

Early studies on marine fungi on mangroves have focused on taxonomy of marine fungi including descriptions of new species and new genera, lists of fungi and surveys. This includes the marine fungi occurring in mangrove environments. Excellent reviews and vast amounts of information on marine fungi have appeared in several texts. (Johnson and Sparrow, 1961; Jones, 1976; Moss, 1986; Hyde and Lee, 1995; Jones, 1995; Jones and Alias, 1996). For several accounts on various aspects of marine fungi the following works, among others, are referable (Chinnaraj, 1993a; Jones and

Tan, 1987; Hyde and Jones, 1988; Hyde, 1990a; Hyde *et al*., 1990; Ravikumar, 1991; Leong *et al*., 1991; Kohlmeyer and Kohlmeyer, 1979; and Kohlmeyer *et al*., 1995). Ecological studies on manglicolous fungi are relatively recent i.e. from late 1980s onwards. A wealth of information is now available on different ecological aspects of fungi in mangroves including frequency of occurrence, vertical distribution, substrate preference, succession, seasonal occurrence and host specificity. However these are mainly from South East Asia (Hyde and Lee, 1995; Jones and Alias, 1996).

There are umpteen literatures on the ecology and taxonomy of soil fungi Most of the reports relate to the study of fungal flora from cultivated agricultural soils, uncultivated soil, pasturelands and forest soils. However, little is known about the microbial ecology of mangrove swamps. During the past several years, considerable work has been done on the taxonomy and ecology of mangrove swamp fungi in India (Padhye *et al.*, 1967; Pawar, *et al*., 1963; 1965 and Rai and Tewari, 1963).

Earliest studies on the ecology of mangroves fungi Kohlmeyer (1969a) encountered 3 common species of marine fungi in the mangrove habitat, namely *Lulworthia* spp (20% of all collections) *Leptosphaeria australiensis* (15%) and *Phoma* species (10%). 100 Mangrove species; only 8 have been examined for the occurrence of marine fungi and the latest Island research was conducted in Bermuda and collected 15 marine Ascomycetes, 1 Basidiomycetes, and 6 Deuteromycetes (Kohlmeyer and Kohlmeyer, 1977). Aleem (1980) reported that the Ascomycetes; *Halosphaeria viscidula*, *Rosellinia* sp and *Torpedospora radiata* were frequent on mangroves in sierra Leone and also found that the Mitosporic taxa. *Cirrenalia macrocephala*, *C. pygmea, C. tropicalis, Periconia* and *Zalerion* spp were abundant on mangrove wood. Kohlmeyar (1984) also reported that *L. australiensis* was a common species of mangroves. Although mangrove fungi of the West coast of India have been well studied, there have been few studies on the East coast (Bay of Bengal), despite the fact that its mangroves are more extensive compared to the west coast. (Untawale, 1987). Hyde and Jones (1988) observed the some fungi tend to occur configuration at certain levels and also reported that the greater species diversity occurred at the mid – littoral level.

Booth (1971b) observed on occurrence and taxonomy of aquatic fungi in saline habitats. Hyde (1989a) reported that the lignicolous materials were collected from 5 marine locations in Brunei; a rocky head land, a sandy beach, a man – made brackish lake, a healthy mangrove and an oil - polluted mangrove. Higher marine fungi present were identified and their percentage occurrence noted. There were significantly less diversity and number of fungi in the oil-polluted mangrove when compared to the healthy mangrove. Most attention to data has concentrated on assessment of fungal diversity, physiology and biochemistry (Kohlmeyer and Kohlmeyer, 1993). Hyde and Lee (1995) suggested that the diversity of marine fungi is greater in the tropics and attributed this to mangrove tree species richness. Jones *et al*. (1999) recorded all marine fungi from Marine habitats can be designated as micro fungi the "micro habitat predictor " model appear to the applicable in the marine environments.

There have however been no efforts to study the marine fungi on mangroves until recently when systematic studies on manglicolous fungi in India were initiated. A detailed investigation of fungi on mangroves of west coast was made by Patil and Borse (1985a,b) and Chinnaraj (1993a,b). However vast tracts of mangroves on the east coast remained virtually unexplored except for the studies of Ravikumar and Vittal (1996).

Quantitative data on the occurrence of tropical marine fungi have been published by Raghukumar (1973); Koch (1986); Kohlmeyer (1984); Zainal and Jones (1984, 1986). However all of these reports were on driftwood in the sea, along with driftwood on the mangrove floor or panels belonging to various timbers submerged near jetties.

Marine fungi have been classified into three geographical groups by Kohlmeyer and Kohlmeyer (1979): i) cosmopolitan species; ii) temperate – water species and iii) species from tropical and subtropical waters. Mangrove fungi have been incorporated in biogeographical maps by Jones (1993), Kohlmeyer (1981, 1984), Kohlmeyer and Volkmann – Kohlmeyer (1987) and Volkmann - Kohlmeyer and Kohlmeyer (1993). Based on the distribution in Atlantic Ocean, Indian Ocean, South – East Asia and Pacific Ocean. Hyde and Lee (1995) revised geographical distribution of representative mangrove fungi (*Halosarphaeria fibrosa, H. marina, Lignincola laevis* and *Lulworthia grandispora*). Geographical and seasonal distribution of *Asteromycetes cruciatus, Stigmoidea marina* and *Varicosporina ramulosa* correlated with their growth patterns under different temperature regimes (Boyd and Kohlmeyer, 1982).

Predominantly mangrove species: the Ascomycetes *Dactylospora haliotrepha, Halorosellinia oceanica,* *Lignincola leavis, Lulworthia grandispora, Saagaromyces abonnis* and *Verruculina enalia*;the basidiomycete *Halocyphina villosa* and anamorphic fungi *Cirrenalia pygmea* and *Zalerion varium* (Kohlmeyer 1984; Jones and Alias, 1996; Sarma and Hyde, 2001; Abdel-Wahab and El- Sharouney, 2002; Jones and Abdel-Wahab, 2005). Other species are more characteristic of open ocean waters: *Antennospora quadricornuta, A. salina, Periconia prolifica, Torpedospora radiata*, or wood associated with sand: *Corollospora maritima, Trichocladium melhae*. Mangrove fungi of the east coast of India have been well studied, there have been few studies on the east coast (Bay of Bengal), despite the fact that its mangroves are more extensive compared to the west coast (Untawale, 1987).

The marine fungi of Hong Kong and Thailand have been studied intensively over the past 15 years, and include not only random collections of drift material, but also the exposure and recovery of bait samples (exposure of bait in Hong Kong (Vrijmoed *et al.*, 1986; Sadaba *et al.*, 1995; Abdel- Wahab, 2000; Thailand: Pilantanapak *et al.*, 2005), collection of drift and attached mangrove samples in Hong Kong (Abdel-Wahab and El-Sharouny, 2002; Jones and Vrijmoed, 2003), Thailand (Hyde *et al.*, 1993; Sakayaroj *et al.*, 2004). Schmidt and Shearer (2004) analysed the geographical distribution data published on lignicolous mangrove fungi, and found that different oceans supported varying numbers. The number of fungi at each site varied: Atlantic Ocean: 12-46 per site (14 sites: mean 25.6); Indian Ocean: 12-64 (14: 42.9) and the Pacific Ocean: 17-87 (16: 44). The Pacific Ocean has the highest recorded number of fungi, again the result of repeated collections over many years: Hyde (1988c) in Brunei; Jones and Kuthubutheen (1989), Alias *et al.* (1995), Tan *et al*. (1989) and Leong *et al.* (1991) in Singapore, and the greater diversity of mangrove tree species in this region. The paucity of marine fungi from the Atlantic has been attributed to low mangrove tree diversity, for example three in Florida mangroves and four in the Bahamas (Jones and Abdel-Wahab, 2005; Jones and Puglisi, 2006). However, more intensive collections yielded 81 species for Florida mangroves from 250 collected samples (previously only 28: Jones and Puglisi, 2006) and 112 for the Bahamas from 600 collected samples, where only 31 had previously been recorded (Jones and Abdel-Wahab, 2005).

Diversity most simply can be expressed as species richness, that is the number of species (Magurran, 1988). However, since richness increase in direct relation to number of individuals, area and variety of habitats sampled. Ecological variation over the temporal and spatial dimensions of the sample may augment diversity because of the increased number of areas, habitats or seasons included. Hyde (1990c) recognized the different in the common species at study sites, a core group of fungi occurring in the mangrove ecosystem. The Majority of the species *Dactylospora haliotrepha*, *Leptosphaeria avicenniae* were also reported from Brunei and other tropical mangroves (Hyde 1989a). Alias *et al*. (1995) reported that more than 60 fungal species can be recorded as common to mangrove ecosystems of the West Indo Pacific region.

Chinnaraj (1993a,b) had earlier reported 63 species of higher marine fungi from the Andaman and Nicobar Islands, which are approximately 1000 km away from the mainland on the East coast. Ravikumar and Vittal (1996) reported 48 species belonging to 37 fungal genera on *Rhizophora apiculate* at Pichavaram.

As diverse vegetation exists in mangroves, it is considered as a major niche of fungal repository. Mangrove fungal diversity is dependent on the age of mangrove, diversity of mangrove plant species and the physicochemical features of mangrove habitat (temperature, salinity and tidal range) (Hyde and Jones, 1988; Jones, 2000). Twenty-eight mangrove tree species yielded 120 higher marine fungi (Hyde, 1990b). Fifty-five mangroves and their associates yielded about 200 higher marine fungi (Jones and Alias, 1996). *Rhizophora apiculata* among the mangrove tree species harboured a maximum of 63 higher marine fungi (Sarma and Vittal, 2000).

Among the different geographical locations; South East Asia has been sampled most thoroughly (Hyde and Lee, 1995; Jones and Alias, 1996). There seem to be no discernible difference between mangrove fungi reported in the subtropics as compared to those found in tropical areas. Among 900 known marine fungi, 358 are recorded from the mangrove ecosystem (Jones and Alias, 1996; Jones and Mitchell, 1996). Out of 54 mangrove tree species and 60 mangrove associate plant species, up to 55 species have been studied for fungi (Jones and Alias, 1996). Studies on mangrove fungi from the Indian Ocean are limited compared to the Atlantic Ocean and Pacific Ocean and South – East Asian region. Although the Indian peninsula possesses about 6700 km^2 of mangroves (Natarajan, 1998) only a few studies dealt with fungal richness and diversity in Gujarat (Borse *et al*., 2000; Patil and Borse, 2001), Maharashtra (Borse, 1988), Karnataka (Ananda and Sridhar, 2003), Tamil Nadu (Ravikumar and Vittal, 1996) and Andra Pradesh (Sarma and Vittal, 2000).

Chandralata (1999) and Raghukumar and Raghukumar (1998) reported adaptation and activity of terrestrial fungi under marine/ mangrove ecosystem as facultatives or indwellers or residents. Terrestrial fungi are common in mangrove water and mud (Chowdhery *et al*., 1982; Garg, 1983), mangrove leaves (Raghukumar *et al*., 1995), wood (Aleem, 1980), standing senescent stems (Sadaba *et al*., 1995), decomposing mangrove palm (*Nypa fruticans*) (Hyde and Alias, 2000). Terrestrial fungi in deep – sea region of Arabian Sea were recovered (Raghukumar and Raghukumar, 1998). Seawater, sea foam and beach soil of Arabian Gulf Coast, Saudi Arabia yielded terrestrial fungi, typical marine and freshwater fungi (Bokhary *et al*., 1992). Sampling of the leaf litter from the Nethravathi mangroves, India revealed the occurrence of many freshwater Hyphomycetes (Sridhar and Kaveriappa, 1988).

Sarma and Vittal (2000) investigated the fungal diversity of proproots, seedlings and wood of *Rhizophora apiculata* and wood, roots and pneumatophores of *Avicennia* spp in deltaic mangroves of Godavari and Krishna rivers in the east coast of India. The number of fungi recorded on proproots (61) was much greater when compared to wood (24) and seedling (21).

Prasannarai and Sridhar (2001) reported the diversity of marine fungi on intertidal wood collected from 13 locations in the West coast of India was assessed out of 3327 wood samples scanned, of which, 72%, posses sporulating fungi. Altogether 88 species belonging to 47 genera were uncounted. The species richness and diversity was highest in Islands than in beaches and harbour locations. It has been predicted that Islands adjacent to the West coast of India provide critical habitat for marine fungi.

Borse (2002) reported that the distribution and substratum range of 166 species (13 Labyrinthulomycota, 4 Chytridiomycota, 20 Oomycota, 1 excluded sp., 120 Ascomycota, 3 Basidiomycota and 23 mitosporic fungi) of marine fungi recorded so far from India on animal substratum, driftwood, intertidal wood, algae, mangroves, sea grasses, salt marsh plants and as propagules in the sea foams samples. Maria and Sridhar (2002) studied the richness and diversity of filamentous fungi on woody litter of mangrove along the West coast of India. Diversity of fungi in the roots of mangrove species of West coast of India (Ananda and Sridhar, 2002).

Prasannaraj and Sridhar (2003) reported fungi from intertidal wood collected from four coastal locations of the West coast of India. Of the 59 taxa identified, 43 Ascomycetes, 3 Basidiomycetes and 13 anamorphic fungi.

Detritus and live parts of mangrove vegetation have surveyed for the occurrence of higher fungi. In recent – past (up to 2000), 625 fungi encompassing 279 Ascomycetes, 277 mitosporic fungi, 29 Basiomycetes, 3 Chytridiomycetes, 3 Myxomycetes, 14 Oomycetes, 9 Thraustochytris and 12 Zygomycetes have been reported from mangrove forests worldwide (Schmidt and Shearer, 2003). Maria and Sridhar (2003) studied fungal diversity on decomposing biomass of five mangrove plant species from the South West coast of India.

Typical marine fungi were not dominant in root endophytes of coastal sand dunes halophytes (Beena *et al*., 2000), roots of mangrove plant species (Ananda and Sridhar, 2002). The assemblage and diversity of filamentous fungi on leaf and woody litter accumulated on the floor of two mangrove forests (Nethravathi and Udyavara) in the South West coast of India. In their study, yielded 78 taxa belonging to 32 ascomycetes and 46 mitosporic fungi (Ananda and Sridhar, 2004). Sridhar (2005) attempted to deal with occurrence, distribution and diversity of filamrntous fungi in mangrove ecosystem.

Jones *et al.* (2006) reported marine fungal diversity of Thailand was investigated and 116 Ascomycota, 3 Basidiomycota, 28 anamorphic fungi, 7 Stramenopiles recorded, with 30 tentatively identified. These species have primarily been collected from driftwood and attached decayed wood of mangrove trees. The holotype number of 15 taxa is from Thailand and 33 are new records from the country.

Hyde and Sarma (2006) Biodiversity and ecology of higher filamentous fungi on *Nypa fruticans* in Brunei were examined during 1999. Forty-six taxa were recorded including 33 ascomycetes and 13 anamorphic taxa in 25 genera. *Linocarpon* was the most species genus (6 species) followed by *Aniptodera* and *Astrosphaeriella* (4 each). More diversity was found on fronds than on leaves. *Linocarpon appendiculatum*, *L. bipolaris*, *Neolinocarpon globosicarpum* and *Oxydothis nypae* were more frequently recorded on fronds than other fungi, while *Linocarpon bipolaris* (13.5%), *Astrosphaeriella striatispora* (12.2%), *Trichocladium nypae* (8.1%) and *Linocarpon appendiculatum* (8.1%) were more frequently recorded on leaves.

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). 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 (Vittal and Sarma, 2006).

Sridhar and Maria (2006) studied that the pattern of colonization and diversity of filamentous fungi on naturally deposited and deliberately introduced *Rhizophora mucronata* Lamk. wood during monsoon and summer in a mangrove of southwest India and compares overall occurrence with three species co-occurrence. Among 17 core-group fungi (≥10 %), *Aigialus mangrovei, Cirrenalia pygmea, Lignincola laevis, Lulworthia grandispora, Passeriniella mangrovei, Trichocladium linderi, Tirispora* sp., *Zalerion maritimum* and *Z. varium* were highly dominant (≥20 %). On wood showing co-occurrence of three fungi, *A. mangrovei, Cirrenalia tropicalis, L. grandispora* and *T. linderi* were highly dominant core-group fungi. Even though *A. mangrovei*, *C. pygmea*, *C. tropicalis, Halosarpheia cincinnatula*, *L. grandispora, P. mangrovei, Verruculina enalia* and *Z. maritimum* are typical marine or mangrove fungi, they were core-group fungi on deliberately introduced wood in monsoon season indicates their high colonization activity on wood even under low salinity. Several terrestrial mitosporic fungi (*Alternaria, Arthrobotrys, Aspergillus, Penicillium, Phoma* and *Tetracrium*) were found particularly in monsoon season, but none of them belonged to core-group.

The distribution of fungi in Muthupettai mangroves along the East coast of Tamil Nadu, India was studied in terms of species diversity, seasonal variation, and frequency of occurrence in five sampling stations at two different seasons. In this study, total of 118 species of fungi isolated, of which maximum 94 species from sediment samples followed by water with 83 species. Among the fungal isolates *Aspergillus* was the common genus followed by *Penicillium, Curvualria* and *Alternaria* (Sivakumar *et al*., 2006).

Fungal biodiversity in freshwater, brackish and marine habitats were estimated based on reports in the literature. The taxonomic groups treated were those with species commonly found on submerged substrates in aquatic habitats: *Ascomycetes* (exclusive of yeasts), *Basidiomycetes, Chytridiomycetes,* and the non-fungal *Saprolegniales* in the Class *Oomycetes*. Based on presence/absence data for a large number and variety of aquatic habitats, about 3,000 fungal species and 138 saprolegnialean species have been reported from aquatic habitats. The greatest number of taxa comprise the *Ascomycetes*, including mitosporic taxa, and *Chytridiomycetes*. Taxa of *Basidiomycetes* are, for the most part, excluded from aquatic habitats. The greatest biodiversity for all groups occurs in temperate areas, followed by Asian tropical areas (Shearer *et al*., 2007).

2.2. Fungi in Marine, Mangrove water and sediment

Single species isolated from mangrove soils, for example, that by Stolk (1955) on an *Emericellopsis* and *Westerdykellaornata* from East Africa and the paper by Swart (1970) on a *Pencillium* from Australia. The thraustochytrids comprise 7 genera and 31 species of marine fungoid protists has been found in estuarine, Littoral, and oceanic waters and sediments around the world. (Gaertner 1967a, 1968a,b; Bahnweg and Sparrow, 1974). Most fungi recorded from marine sediments use collected from coastal regions and are typical soil fungi, which are terrestrial in origin (Borut and Johnson, 1962; Vrijmoed and Hughes, 1990). Ulken (1970, 1972) studied occurrence and physiology of lower fungi from marine sediment in Brazil.

Studied on fungi of soil in mangrove vegetation and investigations on Indian mangal soil were conducted by Pawar and Thirumalachar (1966), Padhye *et al*. (1967), Rai *et al*. (1969), and Rai and Chowdhery (1975, 1976). In India single species isolated from mangrove soil by Rai and Tewari (1963) on *Preussia* isolates, by Pawar *et al*. (1963) on a *Monosporium*, by Pawar *et al*. (1965) on a *Cladosporium* and by Pawar *et al*. (1967) on *Phoma* species. Pawar and Thirumalachar (1966) compared the growth of pure cultures of marine and terrestrial isolates of the same species of soil fungi and concluded that most of the marine isolates grew batter on sea water agar, then on a distilled water medium whereas, the terrestrial isolates of the same specie showed the reverse reaction.

Ulken (1970, 1972, 1975) isolated Phycomycetes from mangrove sediments in Brazil and Hawaii, and Lee and Baker (1972a,b, 1973) investigated soil micro fungi from a Hawaiian mangrove swamp. Nya (1976) revealed qualitative composition of marine fungi from 3 biotopes, water at different depths, bottom sediments, and Macrophytes and the classes of Phycomycetes, Ascomycetes and Deuteromycetes were recorded and the total of 116 species of 41 genera with the greatest variety of species observed in the bottom sediments. The Macrophyte mycoflora comprised 67 species of 28 while in water 64 species of 27 general were found. Kohlmeyer and Kohlmeyer (1979) maintained that most of these fungi are isolated " from dormant propagules and not from actively growing fungi and that isolation methods excluded almost all true marine inhabitat's.

The arenicolous or sand – inhabitating (Kohlmeyer and Kohlmeyer, 1979) draw nutrients from a discrete organic base in the sediment and produce a profusion of hyphae which spread out and grow on the surface of sand grains producing ascocarps strongly adding to them and this space – invading mode of life is one of the characteristics of mycelial fungi and is well known among fungi in terrestrial soils. Kirk (1983) reported that the flotation were devised for the qualitative and quantitative study of marine higher fungi on sandy beach communities. Sample of the water, surface layer, sea foam, and sandy substrates and nearly fresh water body were examined marine fungi were readily demonstrated in the water column and in Neurton screen samples of the ocean surface, as well as sea foam and sand extracts.

Hyde *et al.* (1987) reported the techniques for obtaining sporulation of marine fungi, 65 Ascomycotina, 24 Deuteromycotina, ad 3 Basidiomycotina known to sporulating culture. Jones (1993) revealed the marine fungi appear to be distributed in relation to seawater temperature; arctic, temperate tropical; although others grew equally well over a range of temperature. Christopherson *et al*. (1999) reported that a total of 227 marine isolates of ubiquitous fungi were cultivated on different media and fungi were isolated include 18 different fungal species from 8 Ascomycetes genera from animals, plants and sediments of Venezuelan waters (0 – 10m) including mangroves and lagoon areas.

Occurrence of fungi on different substrata / tissue specificity (wood/twig, pneumatopores, seedlings, leaves and roots

Soft rot in terrestrial known since the middle of nineteenth century and this type of wood decay was later described and illustrated for fungi of marine habitats (Kohlmeyer, 1958). Ritchie (1959) has shown that common terrestrial fungi exist there on submerged wood and other similar substrates. Kohlmeyer (1969a) observed that among large collections, several fungi were encounted only in roots and stems of living *Avicennia* or *Rhizophora* and appear to be host specific. Terrestrial fungi develop on roots and branches above the high – tide line and on over lapping between marine and terrestrial species may occur at the water – air interface (Kohlmeyer, 1969b). Lee and Baker (1973) demonstrated some of the isolated fungi derived from dormant propagules of terrestrial species.

Johnson (1967) noted that the lignicolous fungi collected in the Neuse – Newport estuary were predominantly of terrestrial origin (73%) and majority of these were from water of less than 18% salinity (81%) while only 12% were recovered from whole estuary i.e. 0- 34 %. Kohlmeyer and Kohlmeyer (1971) listed 51 marine Deuteromycetes and 36 of these are lignicolous and the majority belongs to terrestrial genera (*Alternaria*, *Camerosporium*, *Dedryphiella*, *Diplodia*, *Humicola*, *Monodictys*), while other exclusively marine (*Cirrenalia*, *Orbimyces* and *Zalerion*).

Ritchie (1968) submerged wood of 8 tropical trees in the Panama canal zone and examined wood sections and found green heart (*Ocotea rodiaei*) and red mangrove (*Rhizophora mangle*) preactically fungus – free after about 6 weeks of exposure and one marine fungi *Lulworthia* species in addition to some 20 Deuteromycetes of terrestrial origin was isolated Kohlmeyer (1969b) reported that the ascocarps of *Keissleriella blepharospora* develop between cork cells of roots or submerged seedling of *Rhizophora* spp. Fell and Master (1973) reported that the senescence of leaf materials, they support a very different fungal community, which are responsible for their degradation.

Rai *et al.* (1969) tested wood decaying potential of twenty-two species of mangrove swamp fungi. The classified these fungi into groups based of on weight loss; above 31% strong, between 28 and 37% - moderate and below 28% weak. Ravikumar and Purushothaman (1998) studied on lignicolous marine fungi in the Vellar estuary, Tamil Nadu and recorded 1 species of Ascomycetces fungus *Corollospora intermedia* which are a new, recorded from India. Few reports of endophytic fungi on substrates collected from the marine environment and these include leaves and droppers of mangrove plants (Suryanarayanan *et al*., 1998; Abdel – Wahab *et al*., 1999; Kumaresan and Suryanarayanan, 1999). Mitosporic fungi and frequent inhabitants of leaves and it is common to find non – marine species such as *Cladosporium cladosporiodes* and *Pestalotiopsis* species in the early stages of incubation and *Pencillium* species and *Trichoderma* species.

The only extensive study of the terrestrial colonization of mangrove seedlings is that by Newell (1973, 1976) investigated the succession of fungi on submerged seedlings of *Rhizophora mangle*. Accordingly the marine fungi encountered in the mangrove habitat live on roots, stems, and twigs submerged in water and their terrestrial counterparts inhabit leaves, stems, branches and upper parts of the roots above the water surface (Kohlmeyer 1974; Kohlmeyer and Kohlmeyer, 1979). Kohlmeyer and Kohlmeyer (1977) examined host plants of *Avicennia germinans* (L.,), *Conocarus erecta* L., *Salicornia virginica* L., *Tamarix gallica* L., *Thalassia testudinum* Koenig and the collections include 15 Ascomycetes, 1 Basidiomycetes and 6 Deuteromycetes which are new records for the Bermuda Islands.

Byrne and Jones (1975) reported that the 28 microfungi which grew on wood blocks of beach (*Fugues sylvatica*) and Scots pine (*Pinus sylvestris*) submerged in seawater at Port Erin, Langstone harbour and Newton Farers were recorded. Schneider (1971) observed 23 species of fungi with the greatest number occurring on beach wood, which also offered the best conditions for rapid development. Quantitative data on the occurrence of tropical marine fungi have been published by Kohlmeyer (1984) and Zainal and Jones (1984, 1986), however all of their reports were on driftwood in the sea along with driftwood on the mangrove floor.

Marine fungi like *Leptosphaeria* species, *Mycosphaerella* species, and *Cirrenalia macrocephala* were for the first time recorded only by direct microscopic observation of the pneumatopores of *Avicenia officinalis* from Indian mangrove habitat by Garg (1982). Hyde (1989c) reported that the decayed archids *Acrostichum speciosum* (Mangrove fern) were collected from Kampong Kapok mangrove, Brunei and examined for higher marine fungi (A new bitunicate ascomycete, *Massarina acrostichi).* Hyde *et al*. (1990) investigated the distribution of fungi on *Sonnertia griffithi* and showed that some fungi were common on pneumatophores (*Aigialus grandis* and *Massarina velatospora*) while others were common on twigs (*Saccarcloella mangrovei* and *Savoryella longispora*).

Kohlmeyar and Vittal (1986) studied marine fungi of the mangal in Belize and India, encountered indepandtly a common Ascomycete (*Lophiostoma* sp.) growing at the upper intertidal level on bark ad wood of mangrove trees. Mouzouras *et al*. (1988) reported the ability of microorganisms to decay wood submerged in the sea and 42 marine fungi, belonging to the Asomycotina and Deuteromycotina have been shown to cause soft - rot decay of wood while 3 Basidiomycotina caused white rot - decay. Pena *et al*. (1996) reported that the first contribution to the knowledge of lignicolous marine fungi from Mardal plata, Argentina .10 species were collected from submerged wood panels, intertidal wood and driftwood.

Studies on marine and mangrove fungi of Indian ocean is quite recent and has been less well explored compared to the Atlantic and Pacific Oceans (Koch, 1986; Borse, 1988, Zainal and Jones; 1986; Hyde, 1988a; Steinke and Jones, 1993). Although Indian sandy beaches, mainland mangroves and some islands have been studied for mangrove and marine fungi, there are few quantitative studies (Borse, 1988; Ravikumar and Vittal, 1996; Prasannarai and Sridhar, 1997, 2000-2001, 2001; Sarma and Vittal, 2000, 2001; Sarma *et al*., 2001; Maria and Sridhar, 2002). Sarma and Hyde (2001) have reviewed factors affecting the frequency of occurrence of fungi in mangroves. A few studies are available on the impact of incubation of lignocellulosic materials collected from different habitat on the occurrence of fungi (Hyde, 1992b; Prasannrai and Sridhar, 1997).

Marine substrata support different fungal assemblages, for example the mangrove palm *Nypa fruticans* and woody tissue of mangrove trees such as *Rhizophora apiculata* and *Avicennia marina*. Typical fungi on *N. fruticans* included *Astosphaeriella striatispora, Linocarpon appiculata, L. nypae, Oxydothis nypae* and *Trichocladium nypae*, taxa never recorded from mangrove wood (Hyde and Nakagiri, 1989; Hyde, 1992a; Hyde and Alias, 2000; Pilantanapak *et al.*, 2005).

Hyde (1991) reported *Phomopsis mangrovei*, coelomycetous fungus on proproots of *Rhizophora apiculata* from Ranong mangrove, Thailand. Kohlmeyer and Kohlmeyer (1993) revealed the comparison of the marine mycota of recently introduced *Rhizophora* species (Hawaii and Moorea) with that of long established *Rhizophora* stands from the Caribbean (Belize) and 43 species are known from *Rhizophora* in Belize and only 7 and 21 species were collected from Moorea and Oahu respectively.

Ravikumar and Vittal (1996) reported on the fungi colonizing different substrata of *Rhizophora apiculata* and *R. mucronata* from Pichavaram mangroves of Tamil Nadu, East coast of India and concluded that different substrata of the same host plant are colonized by different frequently occurring fungi. According to Hyde *et al*. (1990b) bark was an important factors in determing the mycota present on *Rhizophora apiculata* particularly when small diameter roots were examined. Young roots surrounded by bark were invariably colonized by

Leptosphaeria sp., *Lulworthia grandispora, Massarina ramunculicola, phomopsis* sp. and *Rhizophila marina*.

Poonyth *et al*. (1999) revealed split wood blocks of *Bruguiera gymnorrhiza* and *Rhizophora mucronata* were submerged in the intertidal zone of 5 mangrove sites in Maritrius of the blocks over regular intervals and *Cirrenalia pygmea* and *Lulworthia* species were more common as early colonizer. A relatively high percentage of the fungi colonizing the test blocks were mitosporic fungi. Seasonal occurrence and colonization of intertidel wood and introduced teak wood panels by marine fungi was investigated in mangrove Harbour (West coast of India) of the 33 taxa encountered 29 taxa were found on intertidal wood and 15 species on teak. The most frequently collected species on intertidal wood were *Trichocladium* species, *Zalenion varium*, and *T. alopallonellum.* Sarma and Vittal (2001) recorded the number of fungi on prop roots of *R. apiculata* (61) was much greater when compared to wood (24) and seedlings, 21 from the developing substrate collected from the deltaic mangrove of Godavari and Krishna rivers in the East coast of India.

Borse *et al*. (2000) reported that the higher marine fungi in foam and intertidal wood and dead submerged wood of *Avicennia marina* from Daman coast. In this study 13 species of higher marine fungi (10 Ascomycetes,3 Deuteromycetes) were recorded. Borse (2000) studied that the 83 species (62 Ascomycetes, 3 Basidiomycetes, 18 Deuteromycetes) of higher marine fungi from Maharashtra Coast (The Arabian sea) including 19 species as new records for the fungi of Maharashtra from the substrates include driftwood, intertidal wood harbour timber and dead submerged parts of the mangroves.

Sarma and Vittal (2001) examined the decaying mangrove materials belonging to a host plants species collected from Godavari and Krishna deltas, East coast of India include, 65 Ascomycetes (74%), 1 Basidiomycetes and 22 Mitosporic fungi (25%) (Including 6 Coelomycetes and 16 Hyphomycetes).

Fungi on Seaweeds and Seagrasses

Some of the leaf – inhabiting saprobes occur on rhizomes of the same host as well; for instance, *Lulworthia* species, on rhizomes of *Zostera marina* (Kohlmeyer, 1963) and *Thalassia testudrinum*, (Kohlmeyer and Kohlmeyer 1971). Tubaki and Asano (1965) recorded 16 imperfect fungi on seaweeds most of them as saprophytes like *Dendryphiella qrenaria*, *D. salina*, *Alternaria maritima* and *Monodictys austrina*. *Leptosphaeria* sp., *Pleospora* sp., and *Sphaerulina pedicellata* are all very common on *Spartina* culms by Johnson and Howard (1968). The sporadic occurrence of algicolous fungi may be explained by antibiotic substances produced by healthy algae (Sieburth, 1968).

Meyers (1969) has described a second species of *Lindra* from *Thalassia* species, namely *Lindra marinera* and suggests it may be active in the degradation of *Thalassia* leaves. Meyers *et al*. (1970) suggest that yeast my be active in the degradation of *Spartina* as well as a number of fungi imperfect like *Fusarium*, *Phoma*, and *Nigrospora* sp. Kohlmeyer and Kohlmeyer (1971) have reported *Varicosporina ramulosa, Halocyphina villosa*, from *Spartina alterniflora*, *Loisel,* from decaying leaves of *Claviceps purpurea.* Jones (1976) and Kohlmeyer and Kohlmeyer (1979) have revised the occurrence of marine fungi on algae and seaweed though these substrates have not been studied as intensively as fungi on wood tissue. Stanley (1991). Recent reviews of litereature on algicolous fungi have been published by Andrews (1976), Jones (1976) and Kohlmeyer (1974). Kohlmeyer and Kohlmeyer (1979) reported that the *Lindra thalassiae* is the most indiscriminate species of all, as it occurs in leaves of a spermatophyte (*Thalassia)* as well as in air vesicles of *Sargassum* sp.

The rhizoid of Phycomycetous fungi and the ectoplasm that elements of Thraustochytrids penetrate the host cells and draw nutrients and they may also be endoparasites (Chandralata, 1986, 1987). Recent work on *Juncus roemerianus* (Kohlmeyer and Kohlmeyer, 1995, 1996; Kohlmeyer *et al.,* 1995, 1996, 1997) and on *Phragmites australis* (Poon and Hyde, 1998) have resulted in the discovery of a number of species new to science.

Fungi on Sea foams

Kohlmeyer (1966) found that the fungal spores in foam, which is a good indication of the mycota present in the sand of a particular beech. Kohlmeyer (1966) reported that the propagules of marine fungi contained in foam are deposited by the waves on washed – up substrates, such as seagrasses, algae or animal remains. Appendaged Ascospores and Basidiospores , and tetra radiate conidia, are regularly found in sea foam along sandy beaches, mostly together with algae and protozoa (Schlichting, 1971). Kohlmeyer (1966) examined 5 Ascomycetes, one Basidiomycates, and 9 fungi Imperfecti from foam samples collected along shores.

Conidial fungi on sea foams and leaves have been explored from various parts of the world by Bandoni (1972), Barlocher and Kendrick (1977), Crane (1968), Conway (1969), Descals *et al*. (1977), Dudka (1974), Durrieu (1970), Dyko (1978), Gonczol (1975), Greathead (1961), Ingold (1975), Iqbal and Webster (1973,1977), Iqbal (1974), Marvanova (1972), Marvanova *et al*. (1967), Nilsson (1958) and Nawawi (1973, 1975). Presence of fungal spores in foam in aquatic environments has long been recognized by Kohlmeyer and Kohlmeyer (1979), Kirk (1983) and also systematic investigation fungi in sea foam was carried out on a sandy beach in Viginia.

Recently, Bandoni (1972) reported the occurrence of some of these conidial fungi in terrestrial habitats and 40 conidial fungi were identified and assigned to 20 genera. Kirk *et al*. (1973) reported that the collection ,identification of ecological groups of lignicolous, arenicolous, graminicolous and endocommansalic fungi within the sea foam ,wood and marsh grass plants. The role of conidial fungi in processing of an aquatic litter, energy flow, productivity and experimental aspects of these fungi have been worked out by Barlocher and Kendrick (1974, 1976), Suberkropp and Klug (1976) and Suberkropp and Thomas (1984). Ingold (1975) reported that conidia of most of them accumulate in foam, which acts as a spore trap, and " the examination of a foam samples can very quickly give a picture of the species present in a particular stream above the point of collection". The ecological studies of concerning conidial fungi have emphasized their role in processing litter, energy flow, and productivity in aquatic ecosystems (Suberkropp and Klug, 1976). Conidiogenesis has been worked thoroughly in some conidial fungi colonizing submerged leaves and foam by Descals *et al*. (1977) and Ingold (1975).

Seafoam generally contains the highly distinctive spores of *Corollospora* sp., C*arbosphaerella* sp., *Varicosporina ramulosa* in tropical and *Asteromyces cruciatus* in temperate areas, *Alternaria* and other terrestrial and marine fungi depending upon climate and local conditions, (Kohlmeyer and Kohlmeyer, 1979; Boyd and Kohlmeyer, 1982). Microscopic counts of fungi, algae, protozoa and in liquefied sea foam demonstrated the potential of the simple and direct approach information of the ecological roles, seasonal and geographic distribution of marine microorganisms (Kohlmeyer and Kohlmeyer, 1979).

New geographical limits for several species, the seasonal distribution of tropical *V. ramulosa* and the vertical zonation of *Corollospora* species, deposited by sea foam were less active physiologically than geo fungi and calcicolous marine species in the upper 30cm of the strand line. (Kirk, 1983). A new marine Ascomycte, *Lindra obtusa* and its anamorph, *Anguillospora marina* isolated from sea foam samples on some shores of Japan and appear to be adapted to marine habitats was described by Nakagiri and Tubaki (1983).

Murthy and Manoharachary (1981), Manoharachary and Madhusudhan Rao (1983), Madhusudhan Rao and Manoharachary (1984), Sridhar and Kaveriappa (1982) and Subramanian and Bhat (1981) have studied the conidial fungi associated with foam and submerged leaves. Sridhar and Kaveriappa (1982) have studied the conidial fungi associated with foam and submerged leaves. Mahusuhan Rao and Manocharachary (1984) have reported the association of conidial fungi on diversified submerged leaves.

Patil (2003) reported that the submerged leaves of *Memmeaylon umbellaun* and *Mangifera indica* were colonized by species of *Alastospora*, *Beltrana*, *Flagellospora*, *Ingolidiella*, *Lemonniera*, *Lunulospora*, *Monosporella* and *Triselophorus* along with these fungal forms of species of *Actinospora*, *Angiullospora*, *Cameroporium*, *Caluariopsis*, *Spelroplis*, *Tetrachacum* and *Tetraploa* are also isolated in foam samples. These conidial fungi play important role in processing aquatic litter, energy flow and productivity.

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