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Comparative Analysis of Marine and Terrestrial Fungal Communities in Mangrove Ecosystems of Alibag Taluka of Raigad District: Diversity, Functional Roles, and Environmental Adaptations

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Abstract
To compare the diversity, distribution, and ecological roles of marine and terrestrial fungi in mangrove ecosystems, isolation and identification of marine and terrestrial fungi from different mangrove substrates was carried out as special objectives. The study was carried out at Amba river estuary, Dharamtar and Kundlika river creek, Revdanda in Alibag taluka of Raigad district to compare species diversity, richness, and community composition between marine and terrestrial fungal groups. Study was carried out all seasons throughout the year. Assessment of environmental factors like salinity, pH, moisture, tidal influence was also carried out which affect the fungal distribution. Adaptive traits that enable fungi to survive fluctuating mangrove conditions were also determined on the basis of composition of fungal species associated with mangrove ecosystems. Some of the common fungal species identified were from the groups Lulworthiales, Halosphaeriales, *Penicillium, Aspergillus* and *Fusarium* along with few species of Basidiomycota. Results of the research are presented in the paper in details.

Keywords: Marine fungi, Terrestrial fungi, ecosystem, adaptive, environmental factors.

1. Introduction

Mangrove ecosystems are dynamic intertidal environments that serve as critical ecological interfaces between marine and terrestrial systems. These ecosystems experience extreme and fluctuating conditions, including salinity variation, tidal inundation, oxygen limitation, and temperature stress. Fungi are among the most important yet understudied components of mangrove ecosystems, playing key roles in organic matter decomposition, nutrient cycling, and plant health.

Mangrove-associated fungi can be broadly categorized into marine fungi, which are adapted to saline and tidal environments, and terrestrial fungi, which colonize mangrove substrates during periods of exposure. Understanding how these two fungal groups coexist, interact, and function under mangrove conditions is essential for elucidating ecosystem processes and resilience under environmental change. Despite increasing interest in mangrove mycology, comparative studies integrating diversity, function, and environmental adaptation of marine versus terrestrial fungi remain limited, particularly in tropical regions. This study aims to fill this knowledge gap using an integrative approach combining classical taxonomy, molecular tools, functional assays, and environmental analysis. An attempt was made to study the Marine and Terrestrial Fungal Communities in Mangrove Ecosystems with reference to Diversity, and Environmental Adaptations at two mangrove ecosystems of the Alibag taluka in Raigad district of Maharashtra.

2. Literature Review

Previous studies have documented high fungal diversity in mangrove substrates such as decaying wood, leaf litter, and sediments. Marine fungi often exhibit morphological and physiological adaptations such as melanized cell walls and halotolerance, while terrestrial fungi contribute significantly to lignocellulose degradation during non-inundated periods. Some of the important relevant work is as follows:

Juliana Britto Martins de Oliveira *et al* (2025) while working on Fungi in Mangrove has proved that changes in temperature, salinity, and the chemical composition of sediments can drastically modify microbial and fungal

communities in these environments, influencing the resilience of the ecosystem. V.V. Sarma and B.P.R. Vittal (2021) identified 88 fungal species on examination of decaying mangrove materials belonging to 9 host plant species collected from Godavari and Krishna deltas (Andhra Pradesh), east coast of India from August, 1993 to November, 1995.

Marta Filipa Simões *et al* (2015) worked on Soil and Rhizosphere Associated Fungi in Gray Mangroves (*Avicennia Marina*) from the Red Sea shows that they are significantly richer.

Nicole Li Ying Lee (2020) investigated the fungal communities associated with the mangrove tree *Sonneratia alba* throughout Peninsular Malaysia and Singapore. Results show distinct fungal communities at each sampled location with further differentiation according to the plant part.

Javier Vanegas *et al* (2019), aimed to inventory fungal populations associated with the rhizosphere of *Avicennia germinans* in different salinity levels in a semi-arid mangrove in the Colombian tropics. This study highlights soil salinity as a determining factor in the composition of the fungal community in mangroves.

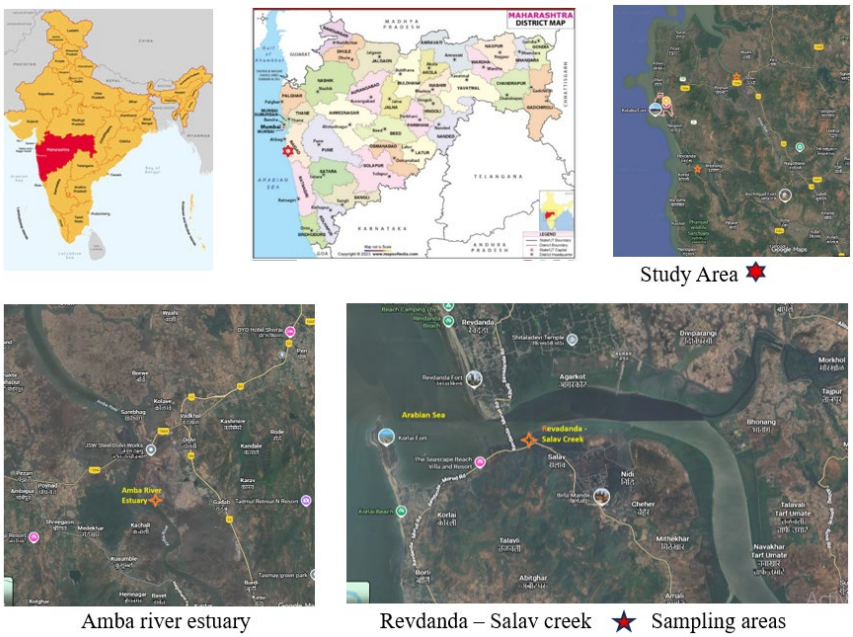
The first marine fungus from Indian mangroves was reported from east coast by Raghu Kumar (1973). There have however been no efforts to study the marine fungi on mangroves until recently when systematic studies on manglicolous fungi in India were initiated. The mycota of several of the tropical and subtropical mangrove substrata has been documented. Apart from isolating several interesting fungi, information was also gathered on the biogeography and ecology of these fungi (Hyde and Lee, 1995; Jones and Alias, 1997). Kohlmeyer (1969) classified fungi collected on mangrove plants into “marine" and "terrestrial" depending on their occurrence in relation to the position of the plant. According to him 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 and Kohlmeyer, 1979). Vertical zonation studies (Sarma, 1998) showed that most of the terrestrial fungi recorded in the study present above the tidal level except for few records where they were also recorded at the intertidal level. But, based on the fact that the aerial parts in mangroves are exposed to salt spray (Kohlmeyer and Kohlmeyer, 1979), these fungi can be said to have salt-tolerances.

A detailed investigation of fungi on 24 mangroves of west coast was made by Patil and Borse (1983, 1985a, b), Borse (1988a, b), Borse and Hyde (1989), Chinnaraj and Untawale (1992), Chinnaraj (1993a, b). However vast tracts of mangroves on the east coast remained virtually unexplored except for the studies of Ravikumar (1991) and Ravikumar and Vittal (1996).

3. Methodology

3.1 Study Area

This research was carried out in two mangrove ecosystems of Revadanda-Salav creek and Amba river estuary at Dharamtar. These mangrove ecosystems represents different tidal regimes with three zones as into intertidal, mid-tidal, and supratidal zones.



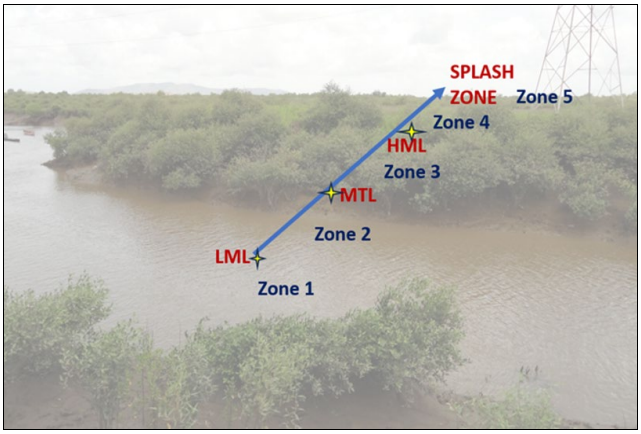
A. Revdanda-Salav Creek: (Alibag Taluka; 180 33’N& 730 00’E) Revdanda is one of the oldest historical port along with Chaul situated at the boundary of Alibag & Murud Taluka. Salav creek extends to Revadanda and then merges into the Arabian sea. Bank of creek is having a good mangrove vegetation consists of *Sonneratia, Avicennia, Aegiceras* and other species.

B. Amba River Estuary: (Tal Roha; 180 30’N 730 05’N)- Amba River traversed from Pali- Nagothane and then Joined to Dharamtar creek on North of Nagothane. In the intertidal region of Amba- River and Dharamtar creek there is a long estuary holding the mangrove vegetation dominated by Sonneratia.

3.2 Sampling Design

Sampling was done throughout the year covering all three seasons. To study the true marine fungi and terrestrial fungi horizontal distribution of manglicolous fungi was studied along the bank of creeks in the mangrove stands. Depending on the expanse of the species permanent transects were marked from the centre of the creek towards the bank. Extent of marking of transect was from the lower mean tide level to higher mean tide level. With reference to the tidal amplitude of the Raigad district inter tidal region was marked horizontally in the five zones.

Zone 1- 0 to 1 mt.: Low mean tide level
Zone 2- 1 to 2 mt.: Mean tide level
Zone 3- 2 to 3 mt.: High mean tide level
Zone 4- 3 to 4 mt.: Splash zone
Zone 5- above 4mt.: Beyond the tide level



Diagrammatic representation of horizontal zonation in the creek

For understanding the horizontal distribution of marine fungi four regions from mean sea level up to the transition zone where the terrestrial flora takes over the mangroves. Sampling of fungal species were done from the bark, leaves, fruits and pneumatophores of the various mangrove species growing in tidal zone and intertidal zone.

Various mangrove species found growing along the transect extending from mean sea level to the transition zone were recorded. In the intertidal zone and beyond the tidal zone samples of the fungal species was done in the form of drifted wood, pneumatophores, decaying logs, fruits, flowers, roots and other plant originated substrates.

Monthly collections were made at each zone and 25 samples were obtained from each zone. Samples were examined by direct microscopic observations method.(Hyde and Jones 1988) Samples were also incubated further in the moist chambers for 7 to 10 days and observed periodically for sporulating fungal species.

3.3 Culture Technique

To study the detail of some of the fungal species and for the identification and confirmation of the species at taxonomic level some of the fungal species are studied by culture techniques.

Plant tissues collected were excised into one cm. length pieces and washed in sterile distilled water. The tissue pieces were aseptically plated on malt extract agar medium (1.5%) amended with tetracycline (250 mg/ liter) similarly processed tissue segments were surface sterilized using 95% ethanol (1min), 6% sodium hypochlorite (5 min) and 95% ethanol (0.5 min) followed by 3 rinses of water. (Distilled water) Tissues were plated on antibiotic amended malt extract agar medium. The plates were incubated at 23 + 2o c up to four weeks at 12hr light and dark regime.

Periodically the tissues were screened for the sprouts of mycelia or discrete colonies on the mycellial portions were transferred to fresh antibiotic free malt extract medium and identified based on the colony characterizations, sporulation and spore morphology using monographs and taxonomic keys.

3.4 Environmental Parameter Measurement

Following Environmental parameters were also studied by testing soil and water at both the sites under study. Salinity, pH, Temperature, Organic matter content

3.5 Fungal Identification

Identification of the fungal species was carried out with the help of manuals and monographs on marine fungi based on Morphological features of mycelium, growth colonies, microscopic examination of spores and reproductive structures.

4. Observation

List of higher Marine Fungi with Reference to the Zonal Distribution

Table 1: Zonal Distribution of marine fungi at Amba river estuary

Sr. No.	Name of the fungal species	No. of fungal species occurred in				Frequency of occurrence of species			
		Zone I	Zone II	Zone III	Zone IV	Zone I	Zone II	Zone III	Zone IV
Ascomycota									
1.	Aniptodera chesapeakensis	05	09	09	-	11.36	3.81	3.94	0.0
2.	Aniptodera mangrovei	02	06	08	-	4.54	2.54	3.50	0.0
3.	Aniptodera sp.	02	17	04	01	4.54	7.20	1.75	1.75
4.	Ascocratera manglicola	-	09	07	-	0.0	3.81	3.07	0.0
5.	Clavatospora bulbosa	-	12	18	11	0.0	5.08	7.89	19.25
6.	Corollospora maritima	-	04	02	01	0.0	1.69	0.87	1.75
7.	Cryptosphaeria mangrovei	01	02	12	-	2.27	0.84	5.26	0.0
8.	Dactylospora haliotrepha	-	03	03	01	0.0	1.27	1.31	1.75
9.	Halorosellina oceanica	03	04	01	-	6.81	1.69	0.43	0.0
10.	Hysterium Sp	01	01	09	11	2.27	0.42	3.94	19.25
11.	Kallichroma tethys	-	08	14	-	0.0	3.38	6.14	0.0
12.	Lignicola sp.	06	09	15	-	13.63	3.81	6.57	0.0
13.	Lophiostoma mangrovei	-	17	04	-	0.0	7.20	1.75	0.0
14.	Lulworthia grandispora	04	16	18	02	9.09	6.77	7.89	3.5
15.	Savoryella paucispora	-	09	18	-	0.0	3.81	7.89	0.0
16.	Verruculina enalia	08	19	07	-	18.18	8.05	3.07	0.0
17.	Zopfiella sp.	02	04	-	02	4.54	0.84	0.0	3.5
Hyphomycetes									
18.	Alternaria sp.	-	19	17	06	0.0	8.05	7.45	10.52

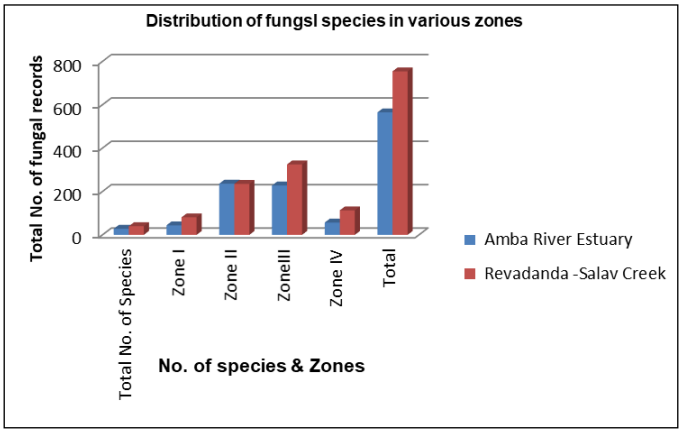
19.	Chladosporium chladosporious	04	09	07	04	9.09	3.81	3.07	7.00
20.	Cirrenalia basiminuta	-	12	15	07	0.0	5.08	6.57	12.25
21.	Cirrenalia tropialis	-	07	03	-	0.0	2.96	1.31	0.0
22.	Fusarium oxysporum	-	17	12	06	0.0	7.20	5.26	10.52
23.	Monodictys pelagica	03	01	-	-	6.81	0.42	0.0	0.0
24.	Periconia prolifica	01	02	03	-	2.27	0.84	1.31	0.0
25.	Trichoderma sp.	02	02	14	05	4.54	0.84	6.14	8.75
26.	Trimmatostroma sp.	-	-	06	-	0.0	0.0	2.63	0.0
27.	Zalerion varium	-	02	02	-	0.0	0.84	0.87	0.0
Coelomycetes									
28.	Phoma sp.	-	16	-	-	0.0	6.77	0.0	0.0
		44	236	228	57				

Table 2: Zonal Distribution of marine fungi at Revadanda –Salav creek

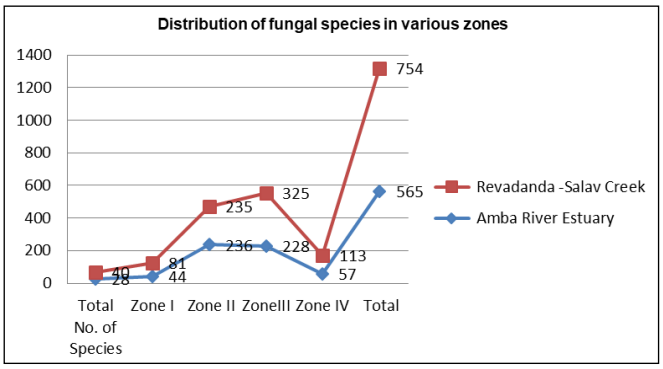
S. No.	Name of the fungal species	No. of fungal species occurred in				Frequency of occurrence of species			
		Zone I	Zone II	Zone III	Zone IV	Zone I	Zone II	Zone III	Zone IV
Ascomycota									
1.	Aigialus grandis	02	09	05	-	2.46	3.78	1.5	0.0
2.	Aigialus mangrovei	01	02	-	-	1.23	0.84	0.0	0.0
3.	Aniptodera chesapeakensis	-	04	04	06	0.0	1.68	1.2	5.28
4.	Aniptodera haispora	-	-	07	-	0.0	0.0	2.10	0.0
5.	Aniptodera mangrovei	03	04	05	-	3.69	1.68	1.5	0.0
6.	Aniptodera sp.	-	12	04	08	0.0	5.04	1.2	7.04
7.	Ascocratera manglicola	01	05	08	-	1.23	2.10	2.4	0.0
8.	Aspergillus flavus	09	08	02	14	11.07	3.36	0.6	12.32
9.	Aspergillus wentii	-	-	17	-	0.0	0.0	5.1	0.0
10.	Caryosporella rhizophorae	-	06	09	03	0.0	2.52	2.7	2.64
11.	Ceriosporopsis cambrensis	02	04	08	-	2.46	1.68	2.4	0.0
12.	Clavatospora bulbosa	02	-	04	07	2.46	0.0	1.2	6.16
13.	Corollospora maritima	02	03	06	-	2.46	1.26	1.8	0.0
14.	Cryptosphaeria mangrovei	-	06	08	-	0.0	2.52	2.4	0.0
15.	Dactylospora sp	01	03	05	-	1.23	1.26	1.5	0.0
16.	Eutypa bathurstensis	02	12	16	03	2.46	5.04	4.8	2.64
17.	Halosarpheia marina	-	02	09	01	0.0	0.84	2.7	0.88
18.	Halosarpheia minuta	-	-	05	09	0.0	0.0	1.5	7.92
19.	Halosarpheia ratnagiriensis	04	08	15	02	4.92	3.36	4.5	1.76
20.	Hysterium Sp	-	12	04	-	0.0	5.04	0.0	0.0
21.	Kallichroma tethys	-	09	04	07	0.0	3.78	2.1	6.16
22.	Leptosphaeria australiensis	02	01	10	06	2.46	0.42	3.0	5.28
23.	Lulworthia grandispora	02	05	09	-	2.46	2.10	2.7	0.0
24.	Marinosphaera mangrovei	-	09	08	01	0.0	3.78	2.4	0.88
25.	Rhizophilla marina	03	04	01	-	3.69	1.68	0.30	0.0
26.	Savoryella lignicola	02	09	15	-	2.46	3.78	4.5	0.0
27.	Zopfiella sp.	01	16	06	02	1.23	6.72	1.8	1.76
Basidiomycota									
28.	Halocyphina villosa	-	-	14	09	0.0	0.0	4.2	7.92
Mucoromycotina									
29.	Cunninghamella elegans	-	12	09	04	0.0	5.04	2.7	3.52
30.	Rhizopus stolonifer	05	08	12	06	6.15	3.36	3.6	5.28
Hyphomycetes									
31.	Cirrenalia tropialis	04	06	13	-	4.92	2.52	3.9	0.0
32.	Curvularia lunata	09	09	-	-	11.07	3.78	0.0	0.0
33.	Fusarium oxysporum	-	13	17	09	0.0	5.46	5.1	7.92
34.	Monodictys pelagica	02	04	12	-	2.46	1.68	3.6	0.0
35.	Periconia prolifica	09	04	05	-	11.07	1.68	1.5	0.0
36.	Trichocladium achrasporum	-	03	08	09	0.0	1.26	2.4	7.92
37.	Trichoderma sp.	04	06	16	05	4.92	2.52	4.8	4.40
38.	Zalerion maritimum	-	-	09	02	0.0	0.0	2.7	1.76
Coelomycetes									
39.	Phoma sp.	09	07	04	-	11.07	2.94	1.2	0.0
40.	Phomopsis sp	-	10	12	-	0.0	4.20	3.6	0.0
		81	235	325	113				

Table 3: Distribution of fungal species in various zones at two locations under the study.

Location under study	Total No. of fungal species recorded	Total No. of fungal records				
		Zone I	Zone II	Zone III	Zone IV	Total
Amba River Estuary	28	44	236	228	57	565
Revdanda Salav Creek	40	81	235	325	113	754



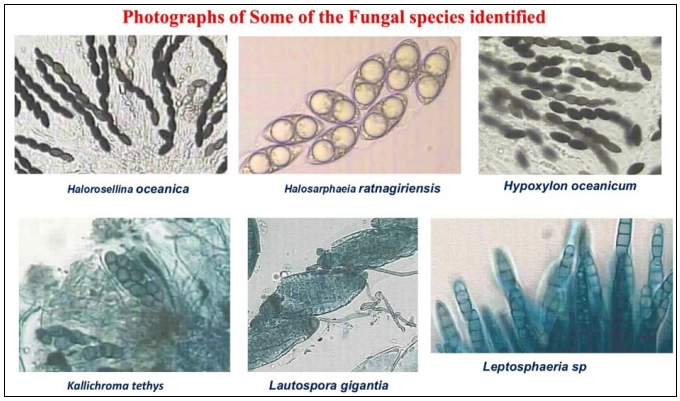
Graph 1



Graph 2

Amba river estuary at Dharamtar

Revadanda-Salav creek with mangrove vegetation



Photographs of some of the fungal species identified

Aegicerus stem

Avicennia wood log

Kandellia stem / *Sonneratia leaf*

Portion of Radicle

Avicennia branch

Sonneratia stem

Photographs of some of the plant parts and drifted organs of mangrove plants showing the growth of Marine and Terrestrial fungi

Conclusions

The occurrence of a greater number of fungal species at Revdanda –Salav creek (40) than that of Amba river estuary (28) may be concerned with the type of ecosystem. Amba river is an estuarine ecosystem receiving the saline water as per the tidal levels while the Revdanda-Salav creek is an open to sea type of ecosystem. Tidal levels at Amba river estuarine ecosystem varies from day to day, it was highest o full moon day and on new moon day while it gradually decreases in the successive days. The outermost zone (Zone IV) is receiving the tidal waters for very few days of the month. Open sea type of ecosystems receives the saline water daily. The span of tidal level and period of dryness in absence of tidal water may be the cause of higher number of fungal records at Revdanda-Salav creek. (754) than that of Amba river estuary (565).

At both the locations the number of fungal records was always higher at zone –II and zone III. This was the intertidal area receiving the tidal water every day and mangroves are get flooded every day by the tidal water or tidal splashes. Though zone –I is having plenty of water throughout, the conditions may not be very suitable for the colonization of the fungal species and therefore the number of fungal records at zone was always low. At zone IV at Amba river estuary the total number of fungal records were 57 while at Revdanda –Salav creek it was 113. The number of fungal records at Revdanda- Salav creek was highest in zone III which was the most active zone and while at Amba-river estuary the zone II and zone III was quite similar active as it didn't show much difference in the number of records.

It is interesting to note that though the number of fungal records were low at zone –IV and highest at zone –III the number of fungal species with highest frequency of occurrence was more at zone –IV(18) and lowest at zone-III (11). Large number of occurrence of fungal species with more frequency of occurrence (7 at Amba river estuary and 11 at Revdanda –Salav creek respectively) indicates that the fungal species colonizing here may be adapted to comparatively dry situations and the conditions are more favourable for their growth. At Amba river estuary the no. of fungal species with high frequency occurrence at all the zones was higher than that of Revdanda –Salav creek except for the zone –IV.

Clavatospora bulbosa, (19.25) *Hysterium* sp. (19.25) at Amba river estuary were the species with highest frequency of occurrence found in zone –IV. At Revdanda –Salav creek the fungal species with highest frequency of occurrence were restricted to the zone –I. *Aspergillus flavus* (11.07), (at zone-IV with frequency of occurrence 12.32), *Curvularia lunata, Periconia prolifica*, and *Phoma* sp. It indicates that these all-fungal species are more zones specific.

Comparatively very low number of fungal species with high frequency of occurrence in zone II & III, which shows higher fungal records in contradiction in the zone II & III did not allow the colonization of fungal species for longer period or in multiple seasons; but one species may be replaced by others accordingly to changing environmental and water conditions.

Fungal species like *Aniptodera* sp, *Hysterium* sp. *Lulworthia grandispora, Cladosporium chladosporious, Trichoderma* sp., *Aspergillus flavus, Eutypa bathurstensis, Halosarpheia ratnagiriensis, Leptosphaeria australiensis, Zopfiella* sp., *Rhizopus stolonifer* were found to be distributed in all four zones, indicating their wide ecological amplitudes. Fungal species like *Aspergillus wentii*, (zone-III), *Phoma* sp. (zone-II), *Trimmatostroma* sp. (zone-III) were restricted to only one zone. These fungal species might be not tolerating dry situations.

Analysis of the fungal species with reference to the mangrove host plants along the transect as a sample study indicates that the number of fungal species and fungal records were always higher on the plants and plant parts which usually get flooded during the high tide. Fungal species from the group of Hyphomycetes were found to be high in number with high frequency of occurrence. This was the first attempt in this region to study the zonal (horizontal) distribution of fungal species and therefore a basic data is contributed in this field.

5. Discussions

Comparative Marine and Terrestrial Fungal Communities in Mangrove ecosystems

Marine and terrestrial fungal communities in mangrove ecosystems differ in composition, ecological roles, physiological adaptations, and spatial distribution, largely due to contrasting exposure to salinity, tidal inundation, and oxygen availability.

1. Community Composition

Marine Fungi are dominated by obligate and facultative marine taxa. Common fungal groups recorded were Ascomycota (e.g., Lulworthiales, Halosphaeriales), Some Basidiomycota often show high host and substrate specificity. Many species are unique to mangrove wood and submerged debris. Terrestrial Fungi are Mostly cosmopolitan soil and plant-associated fungi which were dominated by Ascomycota (e.g., *Penicillium, Aspergillus, Fusarium*), Basidiomycota, less substrate-specific and with broader ecological niches

Zone	Marine Fungi	Terrestrial Fungi
Intertidal	Dominant	Rare
Mid-tidal	Co-exist	Co-exist
Supratidal	Rare	Dominant

2. Spatial Distribution

A spatial distribution among the fungal species was observed in various zones as represented below.

Marine fungi dominate regularly inundated zones while terrestrial fungi colonize exposed sediments, roots, and leaf litter with Overlapping in transition zones.

3. Environmental Tolerance and Adaptations

Marine Fungi were with high halotolerance or halophily and adapted to fluctuating salinity, low oxygen (anoxic sediments), UV exposure.

Structural adaptations were also noticed in the form of Melanized cell walls, Thick-walled spores, Appendaged spores for water dispersal.

Terrestrial Fungi were with Lower salinity tolerance, require stable moisture conditions, Aerobic conditions and were found to be adopted favourably with soil and plant colonisation.

4. Functional Roles

Marine Fungi were Early colonizers of submerged wood and litter degrading cellulose and hemicelluloses contributing to initial stages to decomposition.

Terrestrial Fungi are usually efficient lignin degraders dominant in later stages of decomposition which includes Saprotrophs, Endophytes and Pathogens.

5. Seasonal Dynamics

Marine fungi show greater stability year-round while Terrestrial fungi fluctuate with Rainfall, Temperature, Exposure time.

6. Ecological Significance

Marine fungi drive nutrient cycling in submerged zones on the contrary Terrestrial fungi enhance soil formation and plant health. Together, they ensure ecosystem resilience and productivity. This study and comparison highlight how mangroves are hotspots of fungal diversity, integrating marine and terrestrial processes into a single ecosystem.

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