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Research Article

A study on Diversity of Fungi in Marine Ecosystem of East Coast areas of Kanyakumari District, Tamil Nadu, India.

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Abstract

The present study was confined to the Marine ecosystem in Kanyakumari District, Tamil Nadu comprising of Sanguthurai (S1), Chothavilai (S2), Vivekananda Rock (S3), Vattakottai Fort (S4) and Chinnamuttom (S5). Water, sediment, seafoams and natural substrates of mangrove plants were collected to isolate the fungi. The water and sediment sample were collected separately and analysed for temperature, pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand, salinity, alkalinity, dissolved carbohydrate, particulate organic carbon, total dissolved solids, ammonia, hardness and calcium on water and pH, alkalinity, total carbon, total organic matter, total phosphorus, salt concentration, N, P and K were also analyzed for sediment samples. A total of 135 fungal species were isolated and enumerated by plating, baiting and direct observations techniques. Among these, 67 species were represented in Sanguthurai (S1), 61 in Chothavilai (S2), 53 in Vivekananda Rock (S3), 63 in Vattakottai Fort (S4) and 56 in Chinnamuttom (S5). In this study, 98 species of fungi were recovered from sediment samples whereas water samples yielded 87 species and natural substrates with 66 species. From the sea foams, a total of 40 fungal species were recorded. Among the Hyphomycetes, *Aspergillus* was the common genus represented by 31 species followed by *Alternaria* (10 sp.), *Penicillium* (12 sp.) and *Curvularia* (12 sp.). At the species level, 68 species were found exclusively in post monsoon, 64 in summer, and 112 in pre- monsoon and 68 species in monsoon. Accordingly 31 species belonged to 100% frequency of occurrence followed by 14 sp. with 80%, 10 with 60%, 19 with 40% and 33 sp. were 20% observed in the mangrove eco- systems. Both Simpson and Shannon indices were highest at Vivekananda Rock (0.8702 and 5.1891). The Shannon evenness was least 0.0927 at Vattakottai Fort while it was 0.8264 at Vivekananda Rock and 0.7453 at Chothavilai. Similarity indexes of fungi in five sampling stations were also studied.

Keywords: Marine ecosystem, Fungal diversity, Physico-chemical analysis, Species richness, Diversity and similarity index

Introduction

Biological diversity refers the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystem and ecological complexes of which they are part. Biodiversity encompasses all life forms, ecosystems and ecological processes and acknowledges the hierarchy at genetic, taxon and ecosystem level. The petroleum industry is responsible for the generation

of high amounts of organic residues, as well as for the pollution of soils, rivers and seas. The potentiality of the microorganisms, pointed out in literature as agents of degradation of several compounds, indicates biological treatments as the most promising alternative to reduce the environmental impact caused by oil spills. It is known that the main microorganisms consuming petroleum hydrocarbons are bacteria and fungi. However, the filamentous fungi possess some attributes that enable them as good potential agents of degradation, once those microorganisms ramifies quickly on the substratum, digesting it through the secretion of extracellular enzymes.

Marine and estuarine habitats are oceans and ocean – associated smaller bodies of water that contain salt or brackish water, including river mouths, sounds, lagoon, tidal creeks, salinas, etangs and the like. Mangrove vegetation or "Mangle" is the tropical counter part of the tidal salt –marshes of temperate regions. In the sub- tropics, both types of communities may mingle. The "Mangle" is composed of the wide variety of shoreline trees and bushes belonging to numerous, often unrelated plant families and share the common ability to grown in estuarine and coastal environments. They are open systems with respect to energy and matter and thus couple upland terrestrial and coastal estuarine ecosystem (Lugo and Snedaker, 1974).

India has a vast coastline of about 5,700 km divided into east and west coasts. Mangroves as one of the coastal wetland ecosystems offer an ideal environment for fish farming. Several species of flora and fauna, native to mangrove environment, depend on the stability of this environment (Untawale, 1987). The biomass produced in mangrove is enormous and it is recycled by various organisms including wood borers, fungi and bacteria. This recycling of nutrients is essential for the sustenance and maintenance of this environment.

Indian peninsula comprises about 7000 sq km of mangroves, out of which 70.18 only (12%) are distributed in the East coast, Andaman – Nicobar Islands and West coast respectively (Krishnamurthy *et al*., 1987). Mangrove forests of India are dispersed in tropical as well as subtropical conditions. Unique conditions prevail in these habitats that are responsible for detritus generation, accumulation, processing and turnover. During heavy rainfall which results in flushing freshwater and sediments to mangrove habitats and leads to decline in salinity to zero. During post –monsoon until January, salinity increases up to about 50% (Sridhar and Kaveriappa, 1988). Such conditions are favorable for fresh water fungi to exploit mangrove substrata. Live and dead twigs of mangrove canopy harbour terrestrial fungi and addition of such substrata into mangrove waters in monsoon (Wafar *et al*., 1997) results in domination of terrestrial fungi for several months (Maria and Sridhar, 2003). Recent study of west coast mangroves revealed that nearly one –third of wood – inhabiting fungi belong to terrestrial group (Maria and Sridhar, 2003). Endophytic fungi of mangrove leaves, stem and roots consists of more terrestrial than marine fungi (Ananda and Sridhar, 2002; Kumaresan and Suryanarayanan, 2001). In mangrove habitats, atleast up to six months under low salinity, freshwater and terrestrial fungi are involved in litter conditioning. In summer, increased salinity supports the activity of mainly marine fungi on detritus. Core group fungi (frequency ≥ 10%) on woody debris between west and east coast of India largely due to difference in diversity of mangrove plant species (Maria and Sridhar, 2002; Sarma and Hyde, 2001).

Mangroves are open systems with respect to both energy and matter and can be considered "interface" ecosystems coupling upland terrestrial and coastal estuarine ecosystems. (Lugo and Snedaker, 1974). While terrestrial fungi and lichens occupy the aerial parts of mangrove plants, the marine fungi occur at lower parts where their trunks and roots are permanently or intermittently submerged in water. At the high tide mark there will be an interface and an overlap of marine and terrestrial fungi that occur (Kohlmeyer, 1969a; Kohlmeyer and Kohlmeyer, 1979). Mangrove forests generate considerable amount of detritus such as leaf litter, woody debris and infloresence (Wafar *et al*., 1997) and hence

constitute an ideal habitat for many detritus – dependant fauna and microbes.

Based on the necessary basic information obtained on marine fungi and marine ecosystem, the present study has been undertaken in the proposed study area in marine ecosystem of Kanyakumari, a oceanic habitat along the East coast of Bay of Bengal in Tamil Nadu. Water and sediment samples were collected to Isolate and identify the fungi from the sampling areas by plating techniques.

Materials and Methods

Study area

Totally five (5) sampling stations were selected. The five sampling stations are:

1. Sanguthurai (S1)
2. Chothavilai (S2)
3. Vivekananda Rock (S3)
4. Vattakottai Fort (S4)
5. Chinna Muttom (S5)

Collection of water and sediment samples for biological parameters and Physico – chemical analyses

Collection of water samples

Random sampling of water was carried out at various depths (within 0.5 m). In each sampling station, once in a season for a period of one year, between 6 to 9 a.m. totally, 250 ml of water sample was collected in each station in sterilized glass container and then transferred to sterilize polythene bags and properly sealed.

Collection of sediment

As similar to the water sampling, soil sediments were also collected from the surface layer in each sampling station once in a season for the entire study period. The sediment samples were collected manually wearing hand gloves, transferred to sterile polythene bags and sealed properly.

Collection of sea foams

In addition to water and sediment samples, clean surface scums and foams of the marine water were also collected near the edges of the land surface randomly in the study area of mangrove system by scopping them into sterilized bottles.

Isolation of fungi from water and sediment samples by plating technique

Water samples

After sampling, within 24 hrs the water samples from each station were subjected to appropriate dilutions (10^{-2} to10^{-5}) and 0.1 ml of sample was aseptically transferred into the plates containing Potato dextrose agar/ Czapek dox agar/Corn meal agar/Rose Bengal agar with addition of mixture antibiotics, Tetracycline and Penicillin (Spread plate method) The plates were incubated at room temperature (28°C) for 4-5 days. Control plates were also maintained. Sterilization of glasswares and preparations of media were carried out as per the method described by Booth (1971).

Sediment sample

One gram of the sediment was weighed and then dissolved in 99 ml of sterile seawater and then subjected to dilution serial as done for water samples. 0.1 ml of the sample was directly inoculated onto medium containing plates and incubated in the incubation chamber at 28ºC for further observation. In this technique, 10^{-2} to 10^{-5} dilutions were prepared and taken into account for plating.

Sea foams sample

The surface scums and foams were diluted with sterile seawater and dilution-plating technique was attempted to isolate mycoflora. The slides were prepared with the fresh seafoam and directly observed under the microscope. Furthermore, scums and foams centrifuged with 5 ml of sea water at 3000 rpm for 5 minutes and the residue of the samples were considered for direct observation

under the light microscopes under 10 X and 45 X magnification.

Besides these, dilution and direct plating method were also attempted to isolate fungi from the foam samples using Potato dextrose agar, Rose bengal agar and Corn meal agar containing plates. The plates were incubated at room temperature for 4-5 days and observed for fungal development.

Isolation of mycoflora by membrane filtration method

Through nitrocellulose membrane filter disc of 0.45 μm pore size (Sartorius) 100 ml of the water samples were filtered using membrane filtration unit. Then the discs were transferred aseptically into agar plates (Corn meal agar and Czapek dox agar) and incubated at room temperature (28°C) with appropriate control plates for further observation (Vrijmoed, 2000).

Isolation of fungi from natural substrates by plating technique

Wood substrates

The naturally occurring different wood substrates such as drift wood, and intertidal woods found in the crevices of rock along the banks of the estuary were collected (randomly in the study area) in sterile polythene bags and brought to the laboratory for further processing. In the laboratory the surface fouling organisms were gently scraped off and washed off by exposing under running tap water and the samples were again washed with sterile seawater. Then wood samples were cut into small pieces of different sizes and were again washed with sterile seawater and allowed to drain for 1 h. to remove excess surface waters (Vrijmoed, 2000). The samples were kept at 4˚C for further use (Kohlmeyer and Kohlmeyer, 1979). The wood samples were placed aseptically on surface of the agar media in the petriplates such as, Sabourard's dextrose agar, Corn meal agar and Czapek dox agar. The plates were incubated at 28^{o}C for 4-5 days and observed for the occurrence of fungal colonies.

Seaweeds and Seagrasses

Seaweeds *Amphiroa* sp.(green algae)and *Sargassam* sp. (brown algae) and sea grasses *Thalassia* sp.were collected from S1 and S5 sampling stations. These were rarely covered with fouling organisms and cleaned from sediments and other debris as processed for wood substrates.

The leaf and stem portion of these samples were cut into small pieces and transferred to agar medium with mixture of antibiotic and incubated at room temperature (28°C). The plates were regularly observed for the development of fungal colonies for 4-5 days period (Vrijmoed, 2000).

Mangrove plant root samples

The normal negatively geotropic respiratory roots (pneumatophores) of *Avicennia marina* (Forsk.) Vireh. and prop roots of *Rhizophora mucronata* L., were also collected in polythene bags and washed with sterile seawater in the laboratory to remove the sediment and adhering particles. The washed root samples were cut into small pieces and placed on the surface of sterile agar medium in the petriplates with Sabouraud's dextrose agar and Corn meal agar. All plates were incubated at 28°C to observe the development of fungal colonies.

Mangrove plant leaves

In addition to root samples, fresh and decomposed leaves of mangrove plant species *Avicennia marina, Excoecaria agallocha* and *Rhizophora mucronata* were also collected, washed thoroughly twice with sterile sea water to remove the debris and cut into small pieces, preferably the infected portion of the leaves (up to 1 cm) was then transferred to agar containing plates incorporated with antibiotics. The plates were incubated at 28˚C (room temperature) and observed for the development of fungal colonies.

Isolation of fungi from natural substrates by Baiting technique

Typical marine and mangrove fungi were isolated using Baiting technique. Wood samples were

collected from the study area and studied for isolation of marine fungi. All these individual specimens were kept in sterile polythene bag and aerosal was created inside the bags by spraying with sterile seawater. The bags were tightly covered and kept under illumination and subsequently transferred to dark conditions. This was carried out for the entire study periods to observe the colonization of fungi on these different natural substrates.

All the plant baits were regularly observed under aseptic condition using stereoscopic Dissection Microscope under 2 X and 4 X magnifications. The fungal spores observed on the natural substrates (baits) along with hyphae were picked up using sharp Nichrome wire mounted on needle holder, then these were transferred to agar containing plates to ensure the germination and development of the spores (Sarma and Vittal, 2004).

Isolation of fungi

The incubated plates were observed for the development of fungi from 3rd day onwards. The number of colonies in each plate was counted and compared with control. The data obtained were used for calculating the frequency of occurrence. In addition to this, cultural characters of the colonies [color and structure] were also observed and fungi were enumerated. The natural baits kept in the plates were observed directly under the Stereoscopic Binocular dissection Microscope from 5th day onwards.

The fungal frequency was calculated based on the fungi isolated by plating and baiting technique. All the isolated fungal cultures were subcultured in test tubes containing agar medium.

Presentation of data

The semi permanent slides of the isolated fungi were prepared using Lactophenol Cotton Blue Staining method (Dring, 1976) and sealed with DPX mountant. The fungal species were photographed using photo micrographic instrument (Nikon AFX II Microscope fitted with Nikon FX-35 camera, Tokyo, Japan).

Identification of fungi

The identification of fungal taxa was based on illustrated Genera of imperfect fungi (Barnett, 1965), Hyphomycetes (Subramanian, 1971), Dematiaceous Hyphomycetes and More Dematiaceous Hyphomycetes (Ellis, 1971, 1976), Marine Mycology (Kohlmeyer and Kohlmeyer, 1979), Micro fungi on land plants (Ellis and Ellis, 1985) Micro fungi on Miscellaneous substrate (Ellis and Ellis, 1988), Illustrated key to the filamentous higher marine fungi (Kohlmeyer and Volkman - Kohlmeyer, 1991) and Manual of soil fungi (Gilman, 1957, 1998).

Enumeration of Fungi

The distribution of fungal taxa was listed out and the nomenclature followed is based on the fungi: "**The Fifth Kingdom - Mycota (ed.) Kendrick. (1992)**. Each taxon is briefly described by its binomial followed by morphology (diagnostic features), frequency, abundance density and relative frequency distribution in relation to seasonal occurrence (four seasons) and finally technique by which the taxon was isolated.

Quantitative analysis

At the end of one year, the percentage of frequency of occurrence of fungi, density, abundance and Relative frequency were determined based on the number of stations from which the particular fungi was isolated and the total number of fungal isolation.

$$\text{Frequency of occurrence} = \frac{\text{Number of sampling stations where the species occurred}}{\text{Total number of sampling stations studied}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of the species}}{\text{Total number of sampling stations studied}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individuals of the species}}{\text{Number of sampling stations in which the species occurred}} \times 100$$

Relative Frequency (RF) = (N_{col} /N_{total}) × 100

Species richness, diversity, evenness and Similarity indices of fungi in five stations

The diversity of fungi in the mangrove samples of five sampling stations were assessed on the basis of diversity indices,

Simpson index $D' = \frac{1}{\sum (pi)^2}$,

And

Shannon index, $H' = -\sum (p_i \ln p_i)$,

Where *pi* is the proportion of individuals of that species; *i* contribute to the total (Magurran, 1988). The Shannon Evenness, J′, was expressed by:

$$J' = \frac{H'}{H'_{max}}$$

Where *H′* mark is the maximum value of diversity for the number of species present (Pielou, 1975).

Physico – chemical analyses of water and sediment samples

The water and sediment sample were collected separately and analysed for temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), salinity, alkalinity, dissolved carbohydrate, particulate organic carbon (POC) total dissolved solids (TDS), ammonia, Hardness and calcium on water (Venugopalan and Paulpandian,1989; Aneja, 2001; APHA, 1998) and pH, Alkalinity, Total carbon, Total organic matter, Total phosphorus, salt concentration, N, P and K were also analyzed on sediment samples (Muthuvel and Udayasoorian,1992; Jackson, 1973; Walkley and Black, 1947; Saxena, 1994).

Results and Discussion

The results of the two year period of study in Marine ecosystem comprising of Sanguthurai (S1), Chothavilai (S2),Vivekananda Rock (S3), Vattakottai Rock(S4) and Chinnamuttom (S5) in Kanyakumari district are presented and discussed under three sections, *viz*.,

1.Enumeration of taxa
2.Ecology of fungi

Enumeration of taxa

The fungi belonging to different genera which were isolated by plating and baiting techniques were enumerated with morphological and ecological descriptions. The system of classification was based on "**The Fifth Kingdom - Mycota (ed.) Kendrick (1992)** for the arrangement of genera under their respective orders and families. The genera and species within each family are arranged in alphabetical order.

Ecology of fungi

Physico-chemical status of water and sediment samples with respect to fungal distribution

The 10 kilometers long marine stretch under investigation did not show any mix up of pollutants from neighboring land mass. However, the status of the water quality in estuarine system has a direct bearing on its physico-chemical nature. Hence, ten parameters *viz*. temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), salinity, alkalinity, dissolved carbohydrate, particular organic carbon, and total dissolved solids (TDS), ammonia, hardness and calcium of water samples were observed and recorded. Likewise the nature of the soil such as pH, alkalinity, total carbon, total organic matter, salt (NaCl), nitrogen (N), phosphorus (P), and potassium (K) for sediment samples is given in tables 1 - 4.

The distribution of fungi with reference to the above said physico-chemical conditions at four different seasons like monsoon, summer, pre monsoon and post monsoon were also investigated.

By holding the above physico-chemical data observation were also made on the marine

Table 1. Details of physico-chemical parameters of water and sediment in five stations in post-monsoon.

Parameters	Mean (n=5)
Water samples	
Temperature (° C)	30.4±1.26
pH	5.73±0.16
Dissolved oxygen (mg/l)	11.32±0.41
Biological oxygen demand (mg/l)	6.44±0.44
Chemical oxygen demand (mg/l)	13.2±3.63
Alkalinity (mg/l)	34.96±3.86
Salinity (%)	55.25±3.06
Dissolved carbohydrate (mg/l)	13.85±0.67
Particulate organic carbon (mg/l)	280.10±66.19
Total dissolved solids (mg/l)	230±110.9
Ammonia (mg/l)	4.58±0.71
Hardness (mg/l)	10655.8±324.07
Calcium (mg/l)	204±67.23
Sediment samples	
pH	8.52±0.57
Salt Concentration (Kg/ach)	7.53±3.71
Nitrogen (Kg/ach)	60.92±6.87
Phosphorus (Kg/ach)	5.48±0.9
Potassium (Kg/ach)	130.83±60
Alkalinity (mg/l)	20±5.82
Total Carbon (%)	5.186±2.25
Total organic Matter (%)	18.83±2.61
Total Phosphorus (%)	0.103±0.124

Table 2. Details of physico-chemical parameters of water and sediment in five stations in summer.

Parameters	Mean (n=5)
Water samples	
Temperature (°C)	30.2±0.12
pH	9.56±0.39
Dissolved oxygen (mg/l)	7.78±0.54
Biological oxygen demand (mg/l)	4.88±0.81
Chemical oxygen demand (mg/l)	30.32±3.62
Alkalinity (mg/l)	32.4±2.99
Salinity (%)	55.81±1.10
Dissolved carbohydrate (mg/l)	15.54±1.28
Particulate organic carbon (mg/l)	420.71±33.01
Total dissolved solids (mg/l)	308±53.44
Ammonia (mg/l)	2.31±0.64
Hardness (mg/l)	10510.2±412.26
Calcium (mg/l)	242±74.76
Sediment samples	
pH	9.80±0.36
Salt concentration (Kg/ach)	5.6±7.62
Nitrogen (Kg/ach)	55.34±7.64
Phosphorus (Kg/ach)	8.6±0.55
Potassium (Kg/ach)	190±41.82
Alkalinity (mg/l)	69.5±27.8
Total carbon (%)	14.48±1.05
Total organic matter (%)	13.48±4.83
Total phosphorus (%)	0.06±0.01

Table 3. Details of physico-chemical parameters of water and sediment in five stations in pre monsoon.

Parameters	Mean (n=5)
Water samples	
Temperature (° C)	33.79±0.75
pH	5.65±0.14
Dissolved oxygen (mg/l)	13.60±1.28
Biological oxygen demand (mg/l)	7.22±0.36
Chemical oxygen demand (mg/l)	27.01±3.71
Alkalinity (mg/l)	44.33±3.90
Salinity (%)	50.53±1.06
Dissolved carbohydrate (mg/l)	15.70±1.08
Particulate organic carbon (mg/l)	386.30±95.25
Total dissolved solids (mg/l)	489.99±105.74
Ammonia (mg/l)	1.39±0.30
Hardness (mg/l)	10766.59±413.32
Calcium (mg/l)	230.32±77.20
Sediment samples	
pH	11.88±0.03
Salt Concentration (Kg/ach)	7.106±0.81
Nitrogen (Kg/ach)	65.58±7.8
Phosphorus (Kg/ach)	5.06±0.91
Potassium (Kg/ach)	152.5±44.26
Alkalinity (mg/l)	40±13.6
Total Carbon (%)	7.18±2.89
Total organic Matter (%)	13.18±4.23
Total Phosphorus (%)	0.147±0.09

Table 4. Details of physico-chemical parameters of water and sediment in five stations in monsoon.

Parameters	Mean (n=5)
Water samples	
Temperature (° C)	29.06±0.64
pH	5.67±0.25
Dissolved oxygen (mg/l)	14.94±3.15
Biological oxygen demand (mg/l)	6.93±0.76
Chemical oxygen demand (mg/l)	30.46±7.95
Alkalinity (mg/l)	34.71±5.93
Salinity (%)	43.68±6.62
Dissolved carbohydrate (mg/l)	16.41±0.92
Particulate organic carbon (mg/l)	460.40±133.97
Total dissolved solids (mg/l)	552.66±73.43
Ammonia (mg/l)	1.64±1.55
Hardness (mg/l)	8075.99±690.24
Calcium (mg/l)	222.66±43.95
Sediment samples	
pH	9.45±0.45
Salt Concentration (Kg/ach)	7.45±4.72
Nitrogen (Kg/ach)	68.36±3.78
Phosphorus (Kg/ach)	5.72±0.65
Potassium (Kg/ach)	185.5±33.58
Alkalinity (mg/l)	35.5±14.7
Total Carbon (%)	5.85±1.24
Total organic Matter (%)	11.48±1.57
Total Phosphorus (%)	0.06±0.03

microorganisms. The terrestrial form of fungi in the estuarine water and sediments exhibited temperature tolerance and germination activity with increasing salinity where as, the species of marine fungi *Varicosporina ramulosa, Halosphaeria maritima, Didymosphaeria maritima* and *Pleospora aquatica* recorded from sea foams demonstrated their salinity tolerance in their habitats. This would suggest the effect of salinity and temperature on spore germination of terrestrial, fresh water and marine fungi. On the other hand the marine species were indicated high tolerance against salinity and temperature stress on that by earlier observations by Byrne and Jones (1975). However, from the standpoint of fungal ecology, the most important single factor that governs the fungal occurrence is capacity of water to store/release oxygen. The oxygen content is directly influenced by temperature and the former has a direct bearing on the metabolism and growth of aquatic populations (Cooke and Rayner, 1984).

Species diversity of fungi in the mangrove ecosystem

During the four month study period, a total of 135 fungal species were enumerated from five sampling stations S1, S2, S3, S4, and S5 by plating and baiting techniques and also direct observation of the fungal spores in the centrifuged sediment layer of the sea foams. Among these, 67 species were represented in S1, 61 in S2, 53 in S3, 63 in S4 and 56 in S5 . Maximum fungal diversity was observed in S1 with represented by 67 species and minimum of 53 species was isolated in S3 (Tables 5, 6).

In this study, 98 species of fungi were recovered from sediment samples whereas water samples yielded 87 species and 66 species were isolated from natural substrates. From the sea foams, a total of 40 fungal species were recorded (Table 7).

Among the Hyphomycetes, *Aspergillus* was the common genus represented by 31 species followed by *Alternaria* with 10 species, 12 species with *Penicillium*and *Curvularia* with 12 species. In addition to this C*ladosporium, Mucor,Rhizopus, Fusarium, Dreschlera* and *Helminthosporium* were the common genera found in this estuarine system.
Out of the total 135 species isolated, only 19 were of typical marine fungi, of which, 13 species of marine and mangrove fungi were isolated from mangrove substates (*A. marina*) and 4 species like *Varicosporina ramulosa, Halosphaeria maritima, Bicrouania maritima*and*Pleospora aquatica* were isolated from sea foams whileremaining 116 species were terrestrial fungi which have migrated to aquatic system. It is interesting that the marine fungi enumerated in this study were isolated exclusively from mangrove woody substrates and the centrifuged sedimental layer of the sea foams.

Occurrence of fungi in the estuarine water

In this study, totally 87 species of fungi were isolated and enumerated from the water samples by dilution-plating technique. Among the fungi isolated 2 species belonged to Chytridiomycetes; 5 belonged to Zygomycetes; 6 to Ascomycetes and 69 to Deuteromycotina. Of all these, *Aspergillus* were found to be dominate genus with 30 species, followed by *Curvularia* (6 species), *Penicillium* (11 species), *Alternaria* (3 species) and 5 species of *Cladosporium*

The above result was discussed with previous reports of Chandralata (1999) and Raghukumar and Raghukumar (1998) also 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).Seawater, seafoam and beach soil of Arabian Gulf Coast, Saudi Arabia yielded terrestrial fungi, typical marine and freshwater fungi (Bokhary *et al*., 1992).

Occurrence of fungi in the sediment samples

By employing the plating technique, 98 fungi were isolated from the mangrove sediment samples. Among these, 11 to Zycomycotina, 5 to Ascomycotina and 81 belonged to Deutromycotina . As like in the water samples, in sediments samples also the genus *Aspergillus* was also found to be

Table 5. Documentation of fungi isolated during the study period

otal number of species	=	135
True marine fungi	=	19
Terrestrial fungi	=	116

Stations wise,

In Sanguthurai	=	67
In Chothavilai	=	61
In Vivekananda Rock	=	53
In Vattakottai fort	=	63
In Chinnamuttom	=	56

Seasons wise,

During post-monsoon	=	68
During summer	=	64
During pre-monsoon	=	112
During monsoon	=	68

Substrate wise,

From water	=	87
From sediment	=	98
From sea foams	=	40
From natural substrares	=	66

Table 6. Fungi isolated from all the five sampling stations during the study period

Name of the fungi	S1	S2	S3	S4	S5
Mycota					
Chytridiomycota					
Allomyces arbusculus	+	+	-	-	-
Oomycota					
Achlya ambisexualis	-	-	+	-	-
Zygomycota					
Cunninghamella elegans.	+	-	-	-	-
Absidia spinosa	+	-	+	-	-
Mucor flavus	-	-	+	-	-
M. pusillus	+	+	-	+	-
Mucor sp.	+	+	-	+	+
Rhizopus arrhizus	-	+	-	-	+
Rhizopus oryzae	+	+	+	+	+
R. nigricans	+	+	+	+	+
R. stolonifer	+	+	+	+	+
Actinomucor elegans	+	+	-	-	+
Syncephalastrum racemosum	-	-	+	-	-
Ascomycotina					
Saccharomyces sp. 1	-	-	+	+	-
Saccharomyces sp. 2	-	+	-	+	+

Saccharomyces sp. 3	+	+	-	-	-
Saccharomyces sp. 4	+	-	-	+	+
Bicrouania maritima	-	-	-	-	-
Didymella avicenniae	-	-	-	-	-
Leptosphaeria peruviana	-	-	-	-	-
Leptosphaeria sp.1	-	-	-	-	-
Massarina armatispora	-	-	-	-	-
Massarina cystophorae	-	-		-	-
Ploespora aquatica	-	+	-	-	-
Quintaria lignatilis	-	-	-	-	-
Trematosphaeria lineolatisopsora	+	-	-	-	-
Verrculina enalia	-	-	-	-	-
Emericella nidulans	+	-	-	+	-
Chaetomium globosum	-	-	+	-	-
Thielavia terricola	-	-	-	-	+
Neurospora crassa	+	+	+	+	+
Arenariomyces trifurcatus	-	-	-	-	-
Halosphaeria maritima	-	-	-	-	-
Lophiostoma mangrovei	-	-	-	-	-
Lulworthia grandispora	-	-	-	-	-
Torpedospora ambispinosa	-	-	-	-	-
Basidiomycotina					
Phanerochaete chrysosporium	-	-	-	-	-
Deuteromycotina					
Aspergillus alliceus	-	+	-	-	+
Aspergillus candidus	+	+	+	+	+
A. carbonarius	+	+	+	+	+
A. castaneus	+	+	-	+	+
A. chevalieri	+	-	-	+	+
A. clavatus	+	+	-	+	+
A. conicus	+	+	+	+	+
A. erthrocephalus	+	+	-	+	+
A. flavus	+	+	+	+	+
A. fumigates	+	+	+	+	+
A. funiculosus	+	+	+	+	+
A.humicola	+	-	+	+	-
A. japonicas	-	-	+	+	-
A. luchuensis	+	+	-	+	+
A. nidulans	+	+	+	+	+
A. niger	+	+	+	+	+
A. ochraceus	+	+	-	+	+
A. oryzae	+	+	+	+	+
A. parasiticus	-	-	-	-	+
A. repens	+	+	+	+	-
A. ruber	+	-	-	-	-
A. sacchari	+	+	+	+	+
A. sparsus	-	-	-	-	+
A. sulphureus	+	+	+	+	+
A. sydowi	+	+	+	+	+
A. tamari			-		
A. terreus	+	+	+	+	+
A. terricola	+	+	-	+	+
A. ustus	+	+	+	+	+

A. versicolor	+	+	+	+	+
A. wentii	+	+	+	+	+
Botrytis bassiana	-	-	-	+	-
Cephalosporium acremonium	-	-	-	+	-
P. citrinum	+	+	+	+	+
P. digitatum	+	-	+	+	-
P. expansum	+	-	-	+	+
P. frequentans	-	-	-	+	+
P. funiculosum	-	-	-	-	+
P. griseum	+	+	-	-	-
P. janthinellum	+	+	+	+	+
P. lanosum	-	-	-	-	+
P. luteum	-	-	-	+	-
P. purpurrescens	+	+	+	-	-
P. restrictum	-	-	+	+	-
P. rubrum	+	+	-	+	+
Trichoderma viride	+	+	-	-	+
Varicosporina ramulosa	-	-	-	-	-
Verticillium luteo -album	+	-	-	+	-
Alternaria brassicola	+	-	-	+	+
A. cincerariae	-	-	+	-	-
A. citri	+	+	-	-	+
A. crassa	+	-	-	-	-
A. dennisii	-	-	-	-	-
A. humicola	+	-	-	-	-
A. petroselini	-	-	-	-	-
A. solani	-	-	-	-	-
A. triticicola	-	-	-	-	-
A. tenuissima	-	-	-	-	-
Bidenticula cannae	-	-	+	-	-
Bipolaris tetramera	-	+	-	-	-
Cercospora beticola	-	-	+	-	-
Cirrenalia tropicalis	-	-	-	-	-
Cladosporium apicale	+	+	-	+	+
C. britannicum	+	+	+	+	+
C. gallicola	-	-	+	+	-
C. herbarum	-	-	+	-	-
C. tenuissimum	+	+	-	+	-
C. uredinicola	+	+	+	-	+
Clavatspora bulbosa	-	-	-	-	-
Cochlibolus sativus	-	+	-	+	-
Curvularia andropogonis	-	-	-	-	-
C. geniculata		+	-	+	+
C. inaqualis	-	+	+	+	+
C. indica	+	-	-	-	-
C. lunata	+	+	+	+	-
C. pallescens	-	+	-	-	-
C. palmarum	-	+	+	-	-
C.richardiae	-	+	-	-	-
C. subulata	-	+	-	-	-
C. tritici	-	-	-	+	+
C. tuberculata	-	+	-	-	-
C. uncinata	-	-	+	-	-
Drechslera avenacea	-	-	+	-	+
D. indica	+	-	-	+	-
D. japonica	+	-	-	+	+

D. stenospila	-	-	-	+	-
D. tripogonis	-	-	+	+	-
H. velutinum	-	-	-	-	-
Nigrospora sphaerica	+	-	+	-	-
Periconia laminella	-	-	-	-	-
Scolecobasidium gyrocarpi	+	+	+	-	-
Tetraploa aristata	-	-	-	-	-
Fusarium moniliforme	+	-	+	-	-
F. oxysporum	+	+	+	+	-
F. semitectum	+	+	+	+	+
F. subulatum	+	-	-	-	-
Ascochyta vulgaris	-	-	+	-	+
Phoma humicola	-	+	-	-	-
Total no. of Fungi	**67**	**61**	**53**	**63**	**56**

(+) – Present; (–) - Absent

Table 7. List of Fungi isolated from various marine substrate samples collected in the study area.

Name of the fungi	Water	Sediment	Sea foams	Natural substrates
Mycota				
Chytridiomycota				
Allomyces arbusculus	+	-	-	+
Oomycota				
Achlya ambisexualis	+	-	-	+
Zygomycota				
Cunninghamella elegans	-	+	-	+
Absidia spinosa	+	+	-	-
Mucor flavus	-	+	+	-
M. pusillus	+	+	-	-
Mucor sp.	+	+	+	+
Rhizopus arrhizus	+	+	-	-
R. oryzae	+	+	-	+
R. nigricans	+	+	+	-
R. stolonifer	+	+	-	-
Actinomucor elegans	+	+	-	-
Syncephalastrum racemosum	-	+	-	-
Ascomycotina				
Saccharomyces sp. 1	+	-	-	+
Saccharomyces sp. 2	+	+	-	-
Saccharomyces sp. 3	-	+	-	-
Saccharomyces sp. 4	+	-	-	-
Bicrouania maritime	-	-	-	+
Didymella avicenniae	-	-	-	+
Leptosphaeria peruviana	-	-	-	+
Leptosphaeria sp.1	-	-	-	+
Massarina armatispora	-	-	-	+
Massarina cystophorae	-	-	-	-
Ploephora aquatica	+	-	-	-
Quintaria lianatilis	-	-	-	+
Trematosphaeria lineolatisopsora	-	-	-	+

Verrculina enalia	-	-	-	+
Emericella nidulans	+	+	-	+
Chaetomium alobosum	-	+	-	+
Thielavia terricola	+	+	-	-
Neurospora crassa	+	+	-	+
Arenariomyces trifurcates	-	-	+	-
Halophaeria maritima	-	-	+	-
Lophiostoma mangrovei	-	-	-	+
Lulworthia grandispora	-	-	-	+
Torpedospora ambispinosa	-	-	-	+
Basidiomycotina				
Phanerochaete chrysosporium	-	-	-	
Deuteromycotina				
Aspergillus alliceus	+	-	-	-
Aspergillus candidus	+	+	-	+
A. carbonarius	+	+	-	+
A. castaneus	+	+	-	-
A. chevalieri	+	+	+	+
A. clavatus	+	+	-	+
A. conicus	+	+	+	+
A. erthrocephalus	+	+	+	+
A. flavus	+	+	-	+
A. fumigates	+	+	+	+
A. funiculosus	+	+	-	+
A. humicola	+	+	-	-
A. japonicas	-	+	-	-
A. luchuensis	+	+	-	+
A. nidulans	+	+	+	+
A. niger	+	+	+	+
A. ochraceus	+	+	-	+
A. oryzae	+	+	+	+
A. parasiticus	+	+	-	+
A. repens	+	+	-	-
A. ruber	+	+	-	-
A. sacchari	+	+	-	+
A. sparsus	+	+	-	-
A. sulphureus	+	+	+	+
A. sydowi	+	+	+	+
A. tamari	+	+	-	-
A. terreus	+	+	+	+
A. terricola	+	+	-	+
A. ustus	+	+	-	+
A. versicolor	+	+	+	+
A. wentii	+	+	+	+
Botrytis bassiana	-	-	+	-
Cephalosporium acremonium	+	+	-	-
P. citrinum	+	+	+	+
P. digitatum	+	+	-	+
P. expansum	+	+	-	-
P. frequentans	+	+	-	+
P. funiculosum	+	+	+	-
P. griseum	+	+	-	-
P. janthinellum	+	+	-	+
P. lanosum	-	+	-	-

P. luteum	+	+	-	-
P. purpurrescens	+	+	+	-
P. restrictum	+	+	-	-
P. rubrum	+	+	-	+
Trichoderma viride	+	+	-	+
Varicosporina ramulosa	-	-	+	-
Verticillium luteo-album	+	+	-	+
Alternaria brassicola	+	+	-	-
A. cincerariae	-	+	+	-
A. citri	+	+	-	+
A. crassa	-	-	-	-
A. dennisii	-	-	+	-
A. humicola	+	+	-	-
A. petroselini	-	-	+	-
A. solani	-	-	+	-
A. triticicola	-	-	+	-
A. tenuissima	-	-	+	-
Bidenticula cannae	+	+	-	+
Bipolaris tetramera	-	+	-	-
Cercospora beticola	+	+	-	+
Cirrenalia tropicalis	-	-	-	+
Cladosporium apicale	+	+	-	+
C. britannicum	+	+	-	+
C. gallicola	+	+	-	-
C. herbarum	+	+	-	-
C. tenuissimum	+	+	-	+
C. uredinicola	+	+	-	-
Clavatspora bulbosa	-	-	-	+
Cochliobolus sativus	-	+	+	-
Curvularia andropogonis	-	-	-	-
C. geniculata	-	+	+	+
C. inaqualis	+	-	-	-
C. indica	+	-	+	-
C. lunata	+	+	-	+
C. pallescens	-	+	+	-
C. palmarum	+	+	-	+
C. richardiae	-	+	+	-
C. subulata	+	+	+	+
C. tritici	+	-	-	-
C. tuberculata	-	+	+	-
C. uncinata	-	+	-	-
Drechslera avenaea	-	+	-	-
D. indica	+	+	+	-
D. japonica	+	+	+	-
D. stenospila	+	+	-	-
D. tripogonis	-	+	-	-
H. oryzae	+	+	-	-
H. velutinum	-	-	-	-
Nigrospora sphaerica	+	+	-	+
Periconia laminella	-	-	-	-
Scolecobasidium gyrocarpi	-	+	+	-
Tetraploa aristata	-	-	+	-
Fusarium moniliforme	+	+	-	-
F. oxysporum	+	+	-	+
F. semitectum	+	+	+	+

F. subulatum	+	+	-	-
Ascochyta vulgaris	-	+	-	-
Phoma humicola	-	+	-	-
Total No.of Fungi	**87**	**98**	**40**	**66**

(+) – Present (–) - Absent

dominant (represented with 30 species), followed by *Curvularia* (8 species), *Penicillium* (12 species) *Drechslera* (5)and *Alternaria* (4 species), Cladosporium (6 species).

With the above-presented results while, assessing the species diversity of fungi in the estuarine waters and sediments, the fungal genera, *Aspergillus, Penicillium, Curvularia, Alternaria, Cladosporium* and *Drechslera* were found to be dominant members of this system. This well agreed with the findings of Garg (1982), Rai and Chowdhery (1978), Raper and Fennell (1965) and Roth *et al*. (1964). According to their findings Aspergilli dominated over Mucorales and Penicillia in the mud of mangrove swamps of Sunderband. Nicot (1958) recorded the dominance of Aspergilli and Penicillia in the coastal soils of France. Further more, Raper and Fennell (1965) have also suggested that certain non-osmophilic species of *Aspergillus* may grow luxuriantly under halophytic conditions. Although terrestrial fungi are found in coastal environments frequently as part of the spore population, only species adapted to saline environments appear to be able complete their life cycles fully in coastal and marine environments (Jennings 1986). Sparrow (1934, 1936) reported that the presence of *Aspergillus* and *Penicillium* species in the marine sediments. Satio (1952) investigated the mycoflora of a salt marsh and observed that the species of *Penicillium* and *Trichoderma vignorum* were the common forms encounted in the surface mud. This well correlates with the findings made by Garg (1983) in which, he came comecross highest number of fungi from surface layer of the Sunderban mangrove mud.

Ito *et al.* (2001) have reported the mycobiota of mangrove forest soils from the rhizosphere of eight mangrove species collected at the Ranong Research Center (Kasetsart University) and Phang-Nga. Two methods were used to isolate the fungi: incubation at 45ºC and the standard dilution plate method. Forty-two fungal strains were documented from soil samples, all typical soil taxa, with *Penicillium* sp., *Trichoderma harzianum* and an unidentified strain were the most commonly isolated strains. Further, mangrove soil fungi have been reported by Wongthong (2001), Kongamol (2001) and Sriswadskulmee (2002).

Isolation of *Aspergillus* species in greater number and frequency is due to the high nutrient level in the mangrove eco-system. These species prefer a medium with high osmotic concentration and therefore, compete more easily with other forms in the mangrove eco-system.

Isolation of fungi from sea foams

From the sea foams, totally 40 fungal species were isolated, of which, 18 species were isolated by dilution-plating technique. Where as, spores of 28 fungal species were directly observed in the centrifuged sedimental layer of the sea foams. Among the fungi 3 species belong to Zygomycotina, 3 species to Ascomycotina, 34 species to Deuteromycotina. As similar to water and sediment samples in sea foams, *Aspergillus* (11 species) was the dominant, among the isolated fungi, followed by *Drechslera* (2 sp.),*Penicillium* (3 sp.), *Alternaria* (6 sp.),*Curvularia* (6 sp.)(Table 8)**.** Where as, in the centrifuged sedimental layer of the seafoams, spores of *Alternaria* consists 7 species, *Curvularia* with 7 species were found abundantly than the spores of other genera. Conidial fungi associated with foam and submerged leaves play significant role in processing aquatic litter, energy flow and productivity (Manoharachary and Galaiah, 1987).

Isolation of fungi from estuarine water attempted with membrane filtration technique

As similar to dilution-plating technique fungi were also isolated by membrane filtration technique. Totally 27 species of fungal flora were isolated and enumerated.

Of which, Zygomycotina represented with 4 species, followed by Ascomycotina (2 species) and Deuteromycotina represented with 21 species**.** Among the isolated fungi, *Aspergillus* occurred predominantly and was represented by 14 species followed by *Penicillium* (4 species).

This membrane filtration technique result was correlated with earlier article by Vrijmoed (2000) who reported that the estuarine water and oceanic water can be used for isolation of fungi by employing membrane filtration technique to water samples with a low seawater load.

Distribution of fungi in relation to mangrove vegetation and their substrates

The fungi in the estuarine system were studied by plating and baiting techniques at certain specific sampling stations where, the mangrove vegetation was dense and varied. Because of the thick and varied mangrove vegetation, plenty of plant baits were available in these regions. The baits used decayed plant materials, driftwood, aerating roots, proproots, intertidal woods, seagrasses and seaweeds.

Totally, 66 species of fungi belong to different groups were enumerated from the natural substrates attempted with direct plating techniques (Table 8). In this, 6 speices with Zygomycotina, 15species with Ascomycotina and 45 speices with Deuteromycotina. *Aspergillus* was found to be more predominant fungi, *A. flavus, A. fumigatus, A. luchuensis, A. terreus, A. nidulans*, followed by *Penicillium* sp**.** Of which, 22 species of fungi were isolated from fresh leaves of *A. marina* and decomposed leaves of *A. marina* yielded 12 species

Fungi helps in litter decomposition, in break down of organic matter and energy flow, thus making the environment more favorable for the growth and succession of microorganisms was reported by Harvey (1952). Mangrove vegetation play an important role in the distribution of fungi in the aquatic system, since they contribute to the leaf litter which harbor mycoflora as pointed out by Cunnell (1956). Fungi which occur on driftwood, intertidal wood, manalia rope and other lignocellolic substrates in marine and estuarine environments have been reported by Johnson and Sparrow, (1961), Hughes (1960), Kohlmeyer and Kohlmeyer (1979). The relationship observed between bank and bed vegetation fungal distribution pointed out the intermediary role played by aquatic fungi in the decomposition process between the leaf litter and lower invertebrates and thereby enhancing the palatability of the former as pointed out by Barlocher and Kendrick (1974,1976). Sadaba *et al.* (1995) studied the vertical distribution of fungi on *Acanthus ilicifolius* in Hong Kong and most of the fungi, they encounted were typical terrestrial (fungi 34, out of 44) vertical zonation studies by Sarma (1998) showed the most of the terrestrial fungi recorded in the above tidal level. The fungal diversity of proproots, seedlings and wood of *Rhizophora apicualta* and wood and pneumatophores of *Avicennia* sp. were investigated by Sarma and Vittal (2000).

Enumeration of facultative and mangrove marine fungi from Natural substrates by baiting technique.

Totally, 42 species of fungi were isolated from natural substrates of mangrove plants by baiting technique. In this, 24 terrestrial fungi were isolated by baiting technique. Among the isolates, *Aspergillus* was the common genera represented by 10 species. Besides these, 18 species of typical marine and mangrove fungi were isolated from wood substrates of by employing baiting technique.

A detailed investigation of fungi on mangroves of west coast was made by Patil and Borse (1985a,b), Chinnaraj and Untawale (1992), Chinnaraj (1993a,b). However, vast tracts of mangroves on the east coast remain vitually-unexplored wxcept for the studies of Ravikumar and Vittal (1996) and Sarma and Vittal (2001). The present study a survey of the fungi on mangroves at Cauvery delta, Muthupet mangroves in Tamil Nadu (East coast of India) that have not been previously investigated was therefore initiated.

Table 8. List of total number of fungi isolated in all the four seasons

Name of the fungi	Post monsoon	Summer	Pre monsoon	Monsoon
Mycota				
Chytridiomycota				
Allomyces arbusculus	+	+	+	+
Oomycota				
Achlya ambisexualis	-	+	+	+
Zygomycota				
Cunninghamella elegans.	+	-	+	-
Absidia spinosa	-	-	+	-
Mucor flavus	-	-	+	-
M. pusillus	+	-	+	-
Mucor sp.	+	+	+	+
Rhizopus arrhizus	-	-	+	+
R. oryzae	+	+	+	+
R. nigricans	-	+	+	+
R. stolonifer	+	+	+	+
Actinomucor elegans	+	-	+	+
Syncephalastrum racemosum	+	-	+	-
Ascomycotina				
Saccharomyces sp. 1	-	+	+	+
Saccharomyces sp. 2	+	-	-	+
Saccharomyces sp. 3	-	+	+	-
Saccharomyces sp. 4	-	-	+	+
Birouania maritime	-	-	+	-
Didymella avicenniae	-	-	+	-
Leptosphaeria peruviana	-	-	+	-
Leptosphaeria sp.1	-	-	+	-
Massarina armatispora	-	-	+	-
Massarina cystophorae	-	-	+	+
Pleospora aquatica	-	-	+	+
Quintaria lignatilis	-	-	+	-
Trematosphaeria lineolatisopsora	-	-	+	-
Verrculina enalia	-	-	+	-
Emericella nidulans	+	-	+	-
Chaetomium globosum	-	-	-	+
Thielavia terricola	-	-	+	+
Anthostromella sp.	-	-	+	
Neurospora crassa	+	+	+	+
Arenariomyces trifurcates	-	+	-	-
Halosphareia maritima	-	+	+	-
Lulworthia grandispora	-	-	+	-
Torpedospora ambispinosa	-	-	+	-

Basidiomycotina				
Phanerochaete chrysosporium	-	-	+	+
Deuteromycotina				
Aspergillus alliceus	+	-	+	-
A. candidus	+	+	+	+
A. carbonarius	+	+	+	+
A. castaenus	-	-	+	+
A. chevalerii	-	+	+	-
A. clavatus	+	+	+	+
A. conicus	+	+	+	+
A. erthrocephalus	+	+	+	+
A. flavus	+	+	+	+
A. fumigates	+	+	+	+
A. funiculosus	+	+	+	+
A. humicola	-	-	+	+
A. japonicas	+	+	-	-
A. luchuensis	+	+	+	+
A. nidulans	+	+	+	+
A. niger	+	+	+	+
A. ochraceus	+	+	+	+
A. oryzae	+	+	+	+
A. parasiticus	-	-	+	+
A. repens	+	-	+	-
A. ruber	-	-	+	-
A. sacchari	+	+	+	+
A. sparsus	-	-	+	-
A. sulphureus	+	+	+	+
A. sydowi	+	+	+	+
A. tamari	+	-	+	-
A. terreus	+	+	+	+
A. terricola	+	+	+	+
A. ustus	+	+	+	+
A. wentii	+	+	+	+
Botrytis bassiana	+	-	-	-
Cephalosporium acremonium	-	-	+	-
P. citrinum	+	+	+	+
P. digitatum	+	-	-	-
P. expansum	-	-	+	+
P. frequentans	-	+	+	+
P. funiculosum	-	+	-	-
P. griseum		+	+	-
P. janthinellum	+	+	+	+
P. lanosum	+	-	-	-
P. luteum	-	-	+	+
P. purpurrescens	-	+	+	+
P. restrictum	-	-	+	+
P. rubrum	+	+	+	+
Trichoderma viride.	-	-	+	+
Varicosporina ramulosa	-	+	-	-
Verticillium luteo - album	-	+	+	+
Alternaria brassicola	-	+	+	-
A. cincerariae	+	+	+	-
A. citri	+	+	+	-
A. crassa	-	-	+	-

A. dennisii	+	+	+	-
A. humicola	-	-	+	+
A. petroselini	+	+	-	-
A. solani	-	-	+	-
A. triticicola	-	+	+	-
A. tenuissima	-	-	+	-
Bidenticula cannae	-	-	+	-
Bipolaris tetramera	-	+	-	-
Cercospora beticola	+	-	+	-
Cirrenalia tropicalis	-	-	+	-
Cladosporium apicale	+	+	+	+
C. britannicum	+	+	+	+
C. gallicola	+	+	-	+
C. herbarum	+	-	+	-
C. tenuissimum	+	+	+	-
C. uredinicola	+	+	-	-
Clavatspora bulbosa	-	-	+	-
Curvularia andropogonis	+	-	+	-
C. geniculata	+	-	+	-
C. inaqualis	-	+	-	-
C. indica	-	-	+	-
C. lunata	+	+	+	+
C. pallescens	-	-	-	+
C. palmarum	+	+	+	+
C. richardiae	+	+	-	-
C. subulata	+	+	+	+
C. tritici	+	-	-	-
C. tuberculata	-	+	+	+
C. uncinata	-	-	+	-
Drechslera avenacea	+	-	+	-
D. indica	-	-	+	+
D. japonica	+	-	+	-
D. stenospila	+	-	+	-
D. teres	+	-	-	+
H. oryzae	-	+	-	+
H. velutinum	+	+	-	-
Nigrospora sphaerica	-	-	+	+
Periconia laminella	-	-	-	+
Scolecobasidium gyrocarpi	-	-	-	+
Tetraploa aristata	-	+	+	+
Fusarium moniliforme	+	-	+	-
F. oxysporum	-	-	+	+
F. semitectum	+	+	+	+
F. subulatum	+	-	+	-
Ascochyta vulgaris	-	-	+	-
Phoma humicola	+	-	+	-
Total No. of Fungi	**68**	**64**	**112**	**68**

(+) – Present (–) - Absent

Table 9. Frequency of occurrence isolated fungi by plating/baiting/direct observation during the study period.

Name of the fungi	FO	DENSITY	ABUNDANCE	RF
Mycota				
Chytridiomycota				
Allomyces arbusculus	20	0.8	4.0	0.68
Oomycota				
Achlya ambisexualis	20	0.6	3.0	0.68
Zygomycota				
Cunninghamella elegans	20	0.8	4.0	0.68
Absidia spinosa	40	1.0	2.5	1.37
Mucor flavus	20	1.4	7.0	0.68
M. pusillus	80	4.4	5.5	2.73
Mucor sp.	100	12.0	12.0	3.42
Rhizopus arrhizus	40	1.0	2.5	2.0
R. oryzae	100	6.0	6.0	3.42
R. nigricans	100	14.2	14.2	3.42
R. stolonifer	100	5.6	5.6	3.42
Actinomucor elegans	60	1.6	2.66	2.05
Syncephalastrum racemosum	20	0.6	3.0	0.68
Ascomycotina				
Saccharomyces sp. 1	40	2.6	6.5	1.37
Saccharomyces sp. 2	80	2.8	3.5	2.73
Saccharomyces sp. 3	20	0.6	3.0	0.68
Saccharomyces sp. 4	80	1.8	2.25	2.73
Bicrouania maritima	0	0	0	0
Didymella avicenniae	0	0	0	0
Didymosphaeria sp.	0	0	0	0
Leptosphaeria peruviana	0	0	0	0
Leptosphaeria sp.1	0	0	0	0
Massarina armatispora	0	0	0	0
Massarina cystophorae	0	0	0	0
Pleospora aquatica	20	0.4	2.0	0.68
Quintaria lignatilis	0	0	0	0
Trematosphaeria lineolatisopsora	0	0	0	0
Verrculina enalia	0	0	0	0
Emericella nidulans	40	1.8	4.5	1.37
Chaetomium globosum	0	0	0	0
Thielavia terricola	20	0.6	3.0	0.68
Neurospora crassa	100	6.8	6.8	3.42
Arenariomyces trifurcatus	0	0	0	0
Halosphaetia maritima	0	0	0	0
Lophiostoma mangrovei	0	0	0	0
Lulworthia grandispora	0	0	0	0
Torpedospora ambispinosa	0	0	0	0
Basidiomycotina				

Phanerochaete chrysosporium	0	0	0	0
Deuteromycotina				
Aspergillus alliceus	40	1.4	3.5	1.37
A. candidus	100	15.6	15.6	3.42
A. carbonarius	100	13.6	13.6	3.42
A. castaenus	60	1.8	3.0	2.05
A. chevalieri	60	1.6	3.0	0.68
A. clavatus	100	19.2	19.2	3.42
A. conicus	100	6.0	6.0	3.42
A. erthrocephalus	100	20.6	20.6	3.42
A. flavus	100	26.8	26.8	3.42
A. fumigatus	100	21.8	21.8	3.42
A. funiculosus	100	17.4	17.4	3.42
A. humicola	40	3.6	9.0	1.37
A. japonicus	40	3.6	9.0	1.37
A. luchuensis	100	16.8	16.8	3.42
A. nidulans	100	17.0	17.0	3.42
A. niger	100	32.2	32.2	3.42
A. ochraceus	100	29.4	29.4	3.42
A. oryzae	100	27.2	27.2	3.42
A. parasiticus	20	0.4	2.0	0.68
A. repens	80	11.0	9.25	2.73
A. ruber	20	1.2	5.0	0.68
A. sachari	100	16.0	16.0	3.42
A. sparsus	20	0.4	2.0	0.68
A. sulphureus	100	19.2	19.2	3.42
A. sydowi	100	14.0	14.0	3.42
A. tamarii	20	0.8	4.0	0.68
A. terreus	100	29.8	29.8	3.42
A. terricola	100	11.8	11.8	3.42
A. ustus	100	13.0	13.0	3.42
A. versicolor	100	10.8	10.8	3.42
A. wentii	100	13.6	13.6	3.42
Botrytis bassiana	20	0.4	2.0	0.68
Cephalosporium acremonium	20	0.6	3.0	0.68
P. citrinum	100	9.4	9.4	3.42
P. digitatum	80	6.2	7.75	2.73
P. expansum	80	7.8	9.75	2.73
P. frequentans	80	5.6	9.33	2.05
P. funiculosum	20	2.2	11.0	0.68
P. griseum	40	2.8	7.0	1.37
P. janthinellum	100	6.6	6.6.	3.42
P. lanosum	20	0.6	3.0	0.68
P. luteum	40	1.4	3.5	1.37
P. purpurrescens	60	3.6	6.0	2.05
P. restrictum	40	1.6	4.0	1.37
P. rubrum	100	10.4	10.4	3.42
Trichoderma viride	60	3.0	5.0	2.05
Varicosporina ramulosa	0	0	0	0
Verticillium luteo-album	40	1.2	3.0	1.37
Alternaria brassicola	40	1.0	2.5	1.37
A. cincerariae	20	0.6	3.0	0.68
A. citri	60	5.6	9.33	2.05
A. crassa	0	0	0	0

A. densissi	0	0	0	0
A. humicola	20	1.0	5.0	0.68
A. petroselini	0	0	0	0
A. solani	0	0	0	0
A. triticicola	0	0	0	0
A. tenuissima	20	0.8	4.0	0.68
Bidenticula cannae	20	0.8	4.0	0.68
Bipolaris tetramera	20	0.6	3.0	0.68
Cercospora beticola	20	0.6	3.0	0.68
Cirrenalia tropicalis	0	0	0	0
Cladosporium apicale	80	4.6	4.6	2.73
C. britannicum	100	3.2	3.2	3.42
C. gallicola	80	5.2	6.5	2.73
C. herbarum	40	1.4	3.5	1.37
C. tenuissimum	80	9.0	11.25	2.73
C. uredinicola	80	9.0	11.25	2.73
Clavatspora bulbosa	0	0	0	0
Curvularia andropogonis	0	0	0	0
C. geniculata	60	1.6	2.66	2.05
C. inaqualis	80	3.0	3.75	2.73
C. indica	20	0.6	3.0	0.68
C. lunata	80	5.8	9.75	2.73
C. pallescens	20	1.0	5.0	0.68
C. palmarum	60	3.0	5.0	2.05
C. richardiae	20	1.0	5.0	0.68
C. subulata	60	3.0	5.0	2.05
C. tritici	0	0	0	0
C. tuberculata	20	0.8	4.0	0.68
C. uncinata	20	0.8	4.0	0.68
Drechslera avenacea	20	0.6	3.0	0.68
D. indica	40	1.8	4.5	1.37
D. japonica	40	1.4	5.0	0.68
D. stenospila	20	1.0	5.0	0.68
D. tripogonis	40	1.2	3.0	1.37
H. oryzae	40	2.4	6.0	1.37
H. velutinum	0	0	0	0
Nigrospora sphaerica	60	5.4	9.0	2.05
Periconia laminella	20	1.2	6.0	0.68
Scolecobasidium gyrocarpi	20	0.4	2.0	0.68
Tetraploa aristata	0	0	0	0
Fusarium moniliforme	40	1.6	4.0	1.37
F. oxysporum	80	5.4	6.74	2.73
F. semitectum	100	7.6	7.6	3.42
F. subulatum	20	0.6	3.0	0.68
Ascochyta vulgaris	20	0.4	2.0	0.68
Phoma humicola	40	1.4	3.5	1.37

FO - Frequency of Ocurrence
RF - Relative Frequency

(+) - Present
(–) - Absent

Table 10. Species richness, diversity and evenness of fungi recovered from five stations

Sampling stations	Species richness	Diversity indices		
	Species Recovered	Simpson (D′)	Shannon (H′)	Shannon Evenness (J′)
Sanguthurai (S1)	74	0.7696	3.0152	0.0826
Chothavilai (S2)	72	0.8764	3.0504	0.7453
Vivekananda Rock (S3)	91	0.8702	5.1891	0.8264
Vattakottai Fort (S4)	79	0.0927	3.2070	0.8426
Chinnamuttom (S5)	71	0.8760	4.8129	0.8371
Mean ± S.D	5.4±6.65	0.8786±0.0016	3.0693±0.0514	0.7364±0.052

Table 11. Similarity indexes of fungi isolated from all the five sampling stations.

(a). Mori_Horn Index and shared species

Stations	**S1**	**S2**	**S3**	**S4**	**S5**
S1	2	0.981	0.852	0.971	0.952
S2	57	2	0.78	0.701	0.8
S3	56	54	2	0.99	0.947
S4	56	52	57	2	0.991
S5	46	51	48	48	2

(b). Jaccard classic and shared species

Stations	**S1**	**S2**	**S3**	**S4**	**S5**
S1	2	0.702	0.595	0.456	0.485
S2	55	2	0.403	0.410	0.438
S3	56	57	2	0.580	0.541
S4	54	50	55	2	0.565
S5	48	51	48	46	2

(c). Sorenson classic and shared species

Stations	**S1**	**S2**	**S3**	**S4**	**S5**
S1	2	0.852	0.763	0.814	0.745
S2	55	2	0.775	0.575	0.769
S3	56	56	2	0.767	0.713
S4	55	50	55	2	0.535
S5	48	51	50	48	2

Seasonal variation of species

At species level of the total 135 species recorded, 68 species were found exclusively in post monsoon, 64 in summer, and 112 in Pre- monsoon and 68 species in monsoon . In summer, there was a decreased in the species diversity (64 species) which could be related to reduce water flow in the rivers, increased water temperature and low DO level (Table 8).

The high fungal diversity in pre-monsoon (112 species) could be related to increase in dissolved oxygen (DO), total dissolved carbohydrate, particulate organic carbon in water level and increase in the level of N, and P concentration in the sediments. It could be due to the increase in nutrients in the water system brought by the inflow of the marine water into the estuarine system and soil leachates as reported by Cooke (1963) in riverine system. In the present study, the maximum fungal species diversity was observed during the pre-monsoon which well agreed with the earlier ecological studies carried out by Dayal and Tandon (1962) and Manoharachary (1974) in fresh water ponds, muds and soils of Hyderabad district.

The presence of non-aquatic fungi in the estuarine system could be attributed to the entry of air-borne fungal spores and the fungi from the soils, which are constantly added to the aquatic system. These are termed as "immigrants" or "extra aquatic inhabitants" is agreed with the earlier studies of seasonal variation and distribution of fungi in fresh water ponds by Manoharachary and Ramarao (1981). Aleem (1980) observed that mangrove fungi display a seasonal periodicity with greater diversity and growth in density in the wet (May – November) seasons. The fungal species were found to the more frequent in mangroves towards the end of rainy season (Sep – Oct.) and similar observation was made in India by Sarma and Vittal (2001). Rossman *et al*., (1998) reported a comparative study of fungal communities during the dry season as compared to the wet season.

Frequency of occurrence, density, abundance and relative frequency of fungi in all the five sampling stations

The fungal frequency of occurrence, density, abundance and relative frequency in the five sampling stations was calculated (in percentage). Accordingly 31 species belonged to 100% of frequency of occurrence followed by 13 sp. with 80%, 10 with 60%, 19 with 40% and 32 sp. were 20% observed in the mangrove eco- systems (Table 9)**.**

The fungal densities was highest for *Aspergillus niger* (32.2) followed by *A. terreus* (29.8), *A. ochraceus* (29.4), *A. oryzae*(27.2), *A. fumigatus* (21.8).*A. flavus* (26.8), *A. erythrocephalus*(20.6), *A. funiculosus* (17.4), *A. clavatus* (19.2), *A. sulphureus* (19.2), *A. nidulans* (17.0). The lowest fungal density was observed in *Aspergillus sparsus, A. parasiticus, Botrytis bassiana, Ascochyta vulgaris, Pleospora aquatica* with represented by 0.4% .

The fungal abundance was maximum for *A. niger* (32.2) followed by 29.8 for *A. terreus*, 29.4 for *A. ochraceus*, 27.2 for *A. oryzae*, 26.8for *A. flavus*, 20.6for *A. erythrocephalus*, 19.2 for *A. clavatus*. The minimum fungal abundance was observed in *Aspergillus sparsus, A. parasiticus, Penicillium parvum, Botrytis bassiana, Ascochyta vulgaris, Pleospora aqautica* (0.2%). When analyzing the relative frequency, 31 species (3.42) followed by 11 sp. (2.73), 11 sp. (2.05), 17 sp. (1.37) and 34 sp. (0.68) of relative frequency.

It is well agreed with previous findings by Sarma *et al*. (2001), Aleem, 1980, Leong *etal*. (1991), Poonyth *et al*. (1999) and Hyde (1990a, 1991) have studied the fungal distribution in intertidal mangroves and provided information on (a) frequency of occurrence (b) vertical zonation (c) host and substratum specificity (d) succession and (e) seasonal occurrence. It is noted at here, that the percentage occurrence as an expression of the frequency of collections of fungi gives in indication of the more common fungi within the mangrove

ecosystem (Hyde and Jones, 1988; Alias *et al*., 1995).

Species richness, diversity, evenness and similarity index of fungi in five stations

The species richness and diversity of fungi at five mangrove stations was determined using Simpson and Shannon indices. Both Simpson and Shannon indices were highest at Vivekananda rock (0.8702 and 5.1891). The Shannon evenness was least (0.0927) at Vattakottai fort while it was 0.8264 at Vivekananda rock and 0.7453 at Chothavilai (Table 10). Species richness and diversity of fungi in all the five stations during two seasons is in conformity with the diversity studies of Maria and Sridhar (2002). Ananda and Sridhar (2004) studied diversity of filamentous fungi on decomposing leaf and woody litter of mangrove forests in the south east coast of India.

Mori_horn index, Jaccard classic, Sorenson classic and Bray-curtis with shared species were analysed for all the sampling stations (Table 11). The shared species was maximum observed in between S1 to S2 and S3 to S4 with 57 species and minimum shared species was observed in between S1 to S5 and S4 to S5 with represented by 46 species**.** Mori_horn index and shared species analysis, the highest similarity of species were observed in between S1 and S3 with 0.981 and lowest at between S3 and S5 with 0.947.

When analyzing the Jaccard classic and shared species, the maximum similarity was observed between S1 and S2 represented by 0.702 and minimum of similarity of species 0.541 was observed in between S3 and S5**.** Sorenson classic and shared species, the highest similarity of species was showed in between S1 and S2 (0.852) and least in between S3 and S5 (0.535).

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