PLANT DIVERSITY AND STRUCTURAL DYNAMICS OF MANGROVES IN THE SOUTHWEST COAST OF KERALA, INDIA

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Abstract. Mangroves are the plants adapted to strident environment with unvarying inundation of the soil and extremely diverse salinities, habitual in river banks, sand flats and coastlines of the tropics and subtropics of the world. Mangrove vegetation in six geographical regions of Kollam on the Southwest coast of India was selected to study the phytosociological characteristics and diversity indices. We analysed the pattern of mangrove species diversity, density and basal area and similarity parameters. Totally, 12 species of mangroves belonging to 8 genera and 6 families were identified; Rhizophoraceae and Avicenniaceae were the most dominant group represented. Highest density was recorded for *Avicennia officinalis* (3760stems/ha), followed by *Avicennia marina* (3721stems/ha). *Avicennia officinalis* is the most common mangrove counted with the highest Important value index (IVI) and Relative IVI; 64.19 and 21.40 respectively. Shannon- Weiner Index of diversity ranged from 2.002 to 3.11; species richness from 0.429 to 1.033 and the similarity in floral composition varied from 0.33 to 0.66. The sites selected were distinct from one another and the species diversity varied from one place to another; influenced by the climatic, biotic, anthropogenic stresses.
Keywords: *mangroves, floral diversity, Importance Value Index, Similarity Index, density*

Introduction

Mangrove ecosystems are found all over the world in tropical and subtropical regions along the land-sea interface, bays, estuaries, lagoons, backwaters and in rivers reaching upstream up where the water still remain saline (Qasim, 1998). Biodiversity is prevalent in the tropical estuaries, particularly in the intertidal dense vegetation known as mangroves (Mooney et al., 1995).The development and structure of mangrove forests result from an interaction of many physical factors and environmental variables (Hogarth, 2007; Lacerda et al., 2002). Mangrove plantations are one among the most productive ecosystem on this planet and serve as a nursery for marine and neptunian livelihood, they serve as guardian of their juvenile stock and form most valuable biomass (Odum, 1971).They all have usual assortment of adaptations that facilitate them to cope with regular tidal flooding, strong winds, waves and water currents, muddy soils, high levels of salts in the water, and oxygen deficient soils. In addition, they have an astonishing capability of carbon sequestration; suffice ability to serve as provenance and store sediments and nutrients for further near coastal marine habitats including coral reefs and seagrass beds (Polidoro et al., 2010). They are found between the Tropic of Cancer and the Tropic of Capricorn on all continents covering an estimated 75percent of the tropical coastline worldwide. The total area of terrestrial ecosystem in the world is occupied by only 0.2 percent mangrove lids. However, mangrove ecosystems hold a wide diversity of aquatic and terrestrial species of different taxonomic groups. When all species are considered, mangrove ecosystem rivals many

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other tropical habitats in alpha diversity (Peter, 1999). India has a total area of 4461 sq.km of mangroves; India is the fourth largest mangrove area in the world with 0.14% of country's total geographical area (Naskar and Mandal, 1999).The extent of mangrove of Kerala is 2502 ha out of which 1189 ha belongs to the state and 1313 ha is under private ownership, but various studies showed that the vegetation of mangroves in Kerala covers only 1095 ha (Kurien, 1984), Early study reported that out of the total 1671 ha of mangroves in Kerala, 1470 ha are with private ownership (Basha, 1991). Increase in population density of the Kerala coast has resulted stupendous pressure on the natural ecosystem, partially on the mangroves.

Mangrove vegetation in Kollam occur along the banks of estuarine water bodies and adjacent to the back water channels, in the form of narrow continuous belt or patches. Total of 15 pure mangroves and 33 semi mangroves had been recorded from entire costal area of Kerala, Kollam district contribute maximum percentage of private forest (73.3%) and only 26.7% under state ownership (Vidyasagaran and Madhusoodanan, 2014). When compared to other districts, Kollam has the second highest mangrove diversity (11 out of 15 pure species). Mangrove ecology are discoursed with undivided attention globally, since because as the result of their economic values in boosting profitable fisheries alone (Jayadev, 2012). Mangroves of south coastal region of Kerala have indigenous characteristics compare to the mangrove ecosystem of other region. Therefore, this study was carried out to identify the present status of mangroves forest in Kollam through investigating the plant species composition and diversity. Nonetheless no literature exists on mangroves of Kollam in any aspects. Hence, this is an attempt made to unlock the peach in mangrove ecosystems of Kollam through scrutinizing structural dynamics and diversity, which might help to provide guidance for conservation forethoughts and scientific management of the locations.

Materials and Methods

Study Area

Kollam district encompasses with highest extent of mangroves among southern Kerala (Vidyasagaran and Madhusoodanan, 2014). To assess the location of structures that might influence the occurrence of mangroves and to recognize the extent of area covered by mangroves, each site was assessed and mapped using the Global Positioning System. All through the year humidity is higher during morning hours and during monsoon periods, Kollam receives an annual average rainfall of 2,555 millimeters and average temperature ranges 25° Celsius to 35° Celsius (Jayadev, 2012). The investigation was carried out among six stations: Ayiramthengu (N 09° 06' 59.8'' E 76° 28' 52.5''), Azhikkal (N 08° 07' 36.4'' E 76° 28' 14''), Asraamam (N 08° 53' 41.4'' E 76° 35' 8.6''), Shaktikulangara (N 08° 56' 23.44'' E 76° 33' 9.88''), Cherikadavu (N 08° 59' 47.2'' E 76° 35' 4.4''), Munroe Island (N 08° 58' 57.5'' E 76° 36' 59.2'') (*Fig. 1*). All these sites had a mangrove distributional area of two hectares and above. The sites were widely separated, had dissimilar sediment characteristics and were influenced highly by monsoon (Cintron et al., 1980).

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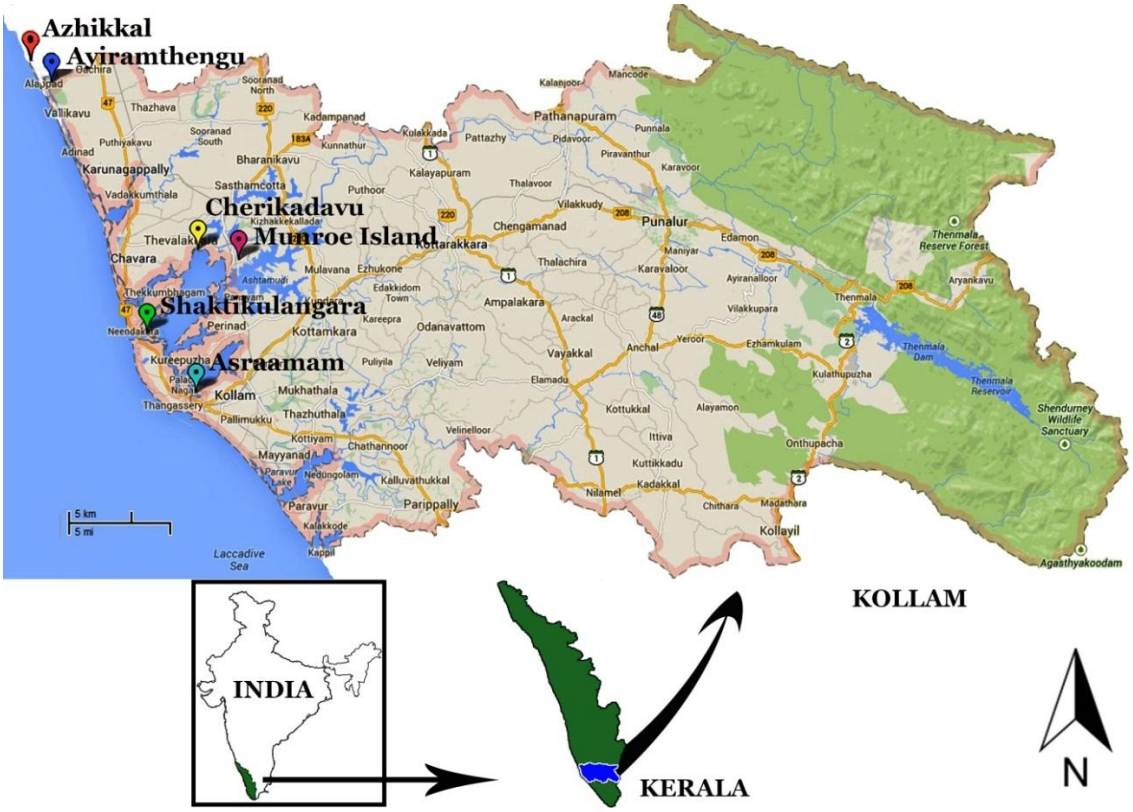

Figure 1. *Map of Kollam district showing different study locations*

Ecological data analysis

The distribution patterns of mangroves were studied using species area method and quadrat analysis with in each locations (Michael, 1998) fifteen quadrats each of 5×5m size were taken on the basis of data obtained. Density, frequency, basal area and their relative values and importance value index (IVI) of mangrove species were calculated by following standard Phytosociological methods (Curtis and Mclntosh, 1951). The IVI for the species was determined as the sum of the relative frequency, relative density and relative dominance (Curtis, 1959). Girth of trees exceeding 10cm diameter at breast height (dbh, at 1.37m above the ground) was measured. In order to determine the quantitative relationship between the plant species, the subsequent parameters were determined.

$$\text{Density} = \text{Number of individuals}/_{\text{ha}} \quad \text{(Eq. 1)}$$

$$\text{Frequency} = \frac{\text{No.of quadrates in which a species occurs}}{\text{Total no.of quadrates}} \times 100 \quad \text{(Eq. 2)}$$

$$\text{Abundance} = \frac{\text{Total no.of individuals of a species in all quadrates}}{\text{Total no.of quadrates in which the species occur}} \quad \text{(Eq. 3)}$$

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$$\text{Basal area} = \frac{G^2}{4\pi} \quad \text{(Eq. 4)}$$

G = girth at breast height (1.37m)

$$\text{Relative Basal Area} = \frac{\text{Basal area}}{\text{Total Basal area}} \times 100 \quad \text{(Eq. 5)}$$

$$\text{Relative density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100 \quad \text{(Eq. 6)}$$

$$\text{Relative Frequency} = \frac{\text{No.of occurrence of a species}}{\text{No.of occurrence of all species}} \times 100 \quad \text{(Eq. 7)}$$

$$\text{IVI} = \text{R. Basal Area} + \text{R. Density} + \text{R. Frequency} \quad \text{(Eq. 8)}$$

$$\text{RIVI} = \frac{\text{IVI}}{3} \quad \text{(Eq. 9)}$$

Species Richness

Species richness is describing the overall range of species in an area, on a macroscalic level, a distinct relationship between an areas locations and its number of species is recognizable. The species richness was calculated using Margalef's Index (Margalef, 1958):

$$\text{Margalef Richness Index (d)} = \frac{S-1}{In\ N} \quad \text{(Eq. 10)}$$

Where, S = total number of species, N = basal area of species ($m^2.ha^{-1}$).

α Diversity analysis

Measure of diversity is frequently seen as indicators of the well-being of any ecosystem, the following indices were worked out to assess and compare the range and distribution of plant species in different locations.

a) The species diversity was calculated using Shannon- Wiener Index (Shannon and Weaver, 1963).

Shannon Index was calculated as,

$$H' = 3.3219[log_{10}N - (\sum Nilog_{10}Ni/N)] \quad \text{(Eq. 11)}$$

Where, ni was the total number of species i and N was the total number of all the species. The factor 3.3219 was used to convert the index value to log2.

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b) Concentration of dominance was measured by Simpson Index (Simpson, 1949).

$$Cd = 1 - \Sigma\left(\frac{Ni}{N}\right)^2 \quad \text{(Eq. 12)}$$

Where, N_i and N were the same as explained above.

c) Equitability (e) was calculated following (Pielou, 1966):

$$e = H'/H_{max} \quad \text{(Eq. 13)}$$

Where, $H_{max} = 3.3219\log_{10}S$, S = Total no. of species and H' = Shannon index.

β Diversity

β diversity estimates the species turnover or the similarity index. Jaccard's index was used to quantify the extent to which family and species compositions overlapped between sample sites (Jaccard, 1908). The Jaccards cluster diagram or dendrogram was fabricated with similarity matrix by simple coefficient of distance working on Biodiversity professional (version 2) (McAleece et al., 1997), using unweighted pair group method with arithmetic Mean (UPGMA) (Sneath, 1973).

$$J_{ab} = 1 - [c/(a + b - c)] \quad \text{(Eq. 14)}$$

Where, J_{ab} = Jaccard's Index, a = number of species present in one location, b = number of species present in another location, c = number of species that are common to both locations.

Result and Discussions

Species Composition

Floristic study of different sites in Kollam revealed the occurrence of 12 species belonging to six families (*Table 1*). Among the families, *Rhizophoraceae* was the most frequent genera having five species, followed by *Avicenniaceae* and *Sonneratiaceae* with two species each. Among the location Shaktikulangara recorded the highest number of species (11species) abided by Ayiramthengu (9 species) and the least was recorded in Cherikadavu (5 Species). Distribution of mangrove at different site indicates that *Avicenna marina, Rhizophora mucronata, Excoecaria agallocha* were noticed in the entire study site. *Avicennia officinalis* occur found in five sites; these species were found as dominant species across the study sites. *Bruguiera cylindrica, Aegiceras corniculatum, Rhizophora apiculata* were found in four sites whereas *Bruguiera gymnorrhiza and Sonneratia caseolaris* were noticed in three sites. *Luminitzera racemosa, Ceriops tagal, Sonneratia alba* were rare species, which was confined only in single sites, In wetlands an increase in the number of the plant species is indicative of ecosystem health, but in case of mangroves, their distribution of species is determined

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by salinity, competition and other physical factor (Hogarth, 2007). The species composition and the agent causing maximum destruction are related to the difference in localities (Rao, 1986). Apart from the noted sites, Kollam have many other small mangrove patches which are under serious threats of degradation. Extensive land filling has affected the mangrove vegetation of some area in a drastic manner. The existing mangrove patches in Kerala with high diversity are mangroves of Kumarakom, Kannamali, Mangalavanam, Chettuva, Nadakkavu, Edakkad, Pappinisseri and Kunjimangalam, Veli, which have been singled out for conservation and rehabilitation (Suma, 1995).

Table 1. *Occurrence of different mangrove species at different sites*

True Mangrove species	Family	Ayiram thengu	Azhik-kal	Asraa-mam	Shaktikul-angara	Cherik-adavu	Munroe island
Aegiceras corniculatum	Myrsinaceae	+	+	–	+	+	–
Avicennia marina	Avicenniaceae	+	+	+	+	+	+
Avicennia officinalis	Avicenniaceae	+	–	+	+	+	+
Bruguiera cylindrica	Rhizophoraceae	+	+	–	+	–	+
Bruguiera gymnorrhiza	Rhizophoraceae	–	–	+	+	–	+
Ceriops tagal	Rhizophoraceae	–	–	–	+	–	–
Excoecaria agallocha	Euphorbiacea	+	+	+	+	+	+
Lumnitzera racemosa	Combretaceae	+	–	–	–	–	–
Rhizophora apiculata	Rhizophoraceae	+	+	–	+	–	+
Rhizophora mucronata	Rhizophoraceae	+	+	+	+	+	+
Sonneratia alba	Sonneratiaceae	–	–	–	+	–	–
Sonneratia caseolaris	Sonneratiaceae	+	–	+	+	–	–

Vegetation Structure and Importance Value

Vegetative composition is important in defining a wetland because vegetation affects its hydrology (Brinson, 1993). Phytosociology is the study of characteristics, classification, relationship, and distribution of plant communities, via different measures the dynamics of each species as well as their relation among each other in a community can be analyzed with a sufficient number of samples as database. This study is important for understanding the functioning of community, implies knowledge of structure and composition of the component species. Various parameters on the basis of which the present Phytosociological investigation has been done, the parameters include frequency (*Fig. 2*), relative frequency, density, relative density, abundance, basal cover and important value index (Cottom and Curtis, 1956). The density values (*Table 2*) shows that, *Avicenna officinalis* has the highest stem density (3760 stems/ha) among the

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12 true mangrove species, followed by *Avicenna marina* (3721 stems/ha). *Rhizophora mucronata* ranked third based on the stems density (1938 stems/ha), the lowest density was recorded for *Sonneratia caseolaris* (267 stems/ha). Relative density of the species ranged from 1.46% to 20.57% (*Table 2*). *Avicenna officinalis* has the highest basal area (29.70 m^2ha^{-1}) followed by *Avicennia marina* (19.64 m^2ha^{-1}) and *Rhizophora mucronata* (14.11 m^2ha^{-1}), it is seen that the mangroves on sea fronts generally have high basal area. The frequencies of different species revealed the degree of dispersion of individual species in an area and are expressed in terms of percentage occurrence (*Table 2*). Relative frequency was highest for *Avicenna marina* (21.35%) whereas, *Avicennia officinalis* (16.29%) even it has higher density and basal area. Analysis of the abundance of species shows that *Lumnitzera racemosa* has the least (4.83%) followed by *Sonneratia caseolaris* (5%) and *Bruguiera cylindrica* (5.91%). *Avicenna officinalis* shows highest abundance and relative abundance (12.16%) and (14.51%).

Species dominance is calculated based on the Important Value Index and was calculated every species found in each study sites. It is usually practiced in ecological scrutinies; IVI indicates the ecological importance of a species in a specified ecosystem which can be used for computing species conservation and management through which species having low IVI value require soar protection preference (Kacholi, 2013). The IVI for a species was calculated as the sum of its relative basal area, relative frequency, relative density and often to describe and compare the species dominance of the sites (*Fig. 3*). In Kollam, the highest IVI and RIVI value were recorded for *Avicennia officinalis* (64.19 and 21.40) and was found to be the dominant species owing to high values of Relative density and Relative frequency, followed by *Avicenna marina* (59.78 and 19.93), *Rhizophora mucronata* and *Sonneratia alba* (*Table 2*). *Rhizophora mucronata* was the foremost dominant mangrove based on the species important value index in Kannur, Kerala (Vidyasagaran et al., 2011). The results indicate that *Sonneratia caseolaris, Lumnitzera racemosa* and *Ceriops tagal* are the least dominant mangrove species of Kollam region, the lowest IVI and RIVI were recorded for *Sonneratia caseolaris* (4.60 and 1.53) revealing the rarity and sporadic distribution of those species.

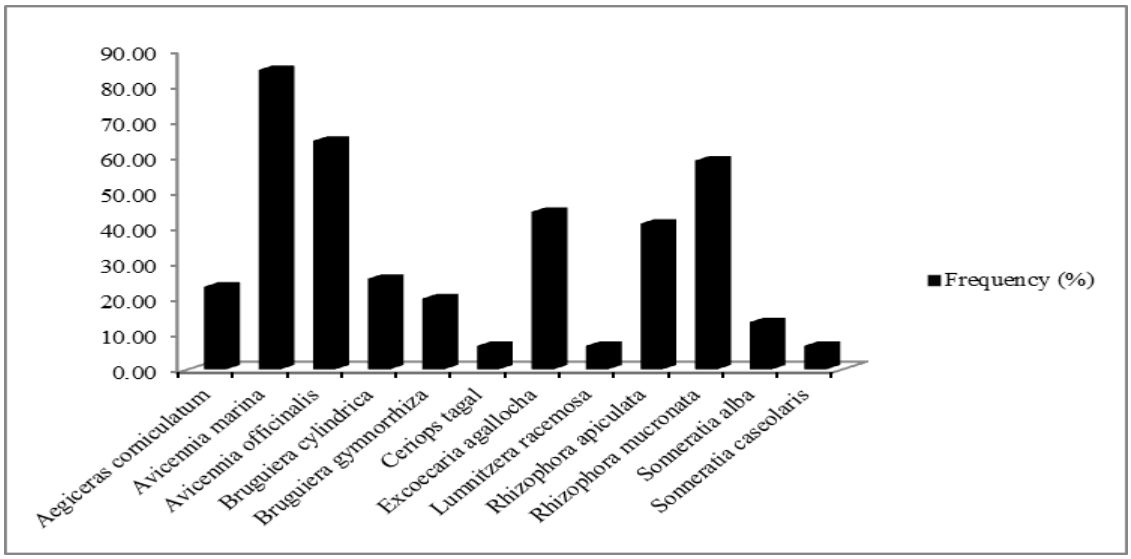

Figure 2. *Frequency distribution of mangrove species recorded in the present study*

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Table 2. *Phytosociological parameters of mangroves in Kollam*

Name of the species	Frequency (%)	Density (Stems/ha)	Basal Area (m^2/ha)	Abundance	Rel. Frequency	Rel. Density	Rel. Basal Area	Rel. Abundance	IVI	Rel. IVI
Aegiceras corniculatum	23.33	1007	4.39	7.19	5.90	5.51	4.04	8.58	15.44	5.15
Avicennia marina	84.44	3721	19.64	11.01	21.35	20.36	18.07	13.13	59.78	19.93
Avicennia officinalis	64.44	3760	29.70	12.16	16.29	20.57	27.33	14.51	64.19	21.40
Bruguiera cylindrica	25.56	907	3.81	5.91	6.46	4.96	3.51	7.05	14.93	4.98
Bruguiera gymnorrhiza	20.00	1183	4.76	7.39	5.06	6.47	4.38	8.82	15.92	5.31
Ceriops tagal	6.67	987	4.60	6.17	1.69	5.40	4.23	7.36	11.32	3.77
Excoecaria agallocha	44.44	1294	7.13	7.28	11.23	7.08	6.56	8.68	24.87	8.29
Lumnitzera racemosa	6.67	560	1.59	4.83	1.69	3.06	1.46	5.76	6.22	2.07
Rhizophora apiculata	41.11	1640	10.30	6.70	10.39	8.97	9.48	7.99	28.84	9.61
Rhizophora mucronata	58.89	1938	14.11	7.02	14.89	10.60	12.98	8.37	38.48	12.83
Sonneratia alba	13.33	1013	7.07	3.17	2.37	5.54	6.51	3.78	15.42	5.14
Sonneratia caseolaris	6.67	267	1.58	5.00	1.69	1.46	1.45	5.96	4.60	1.53
TOTAL	395.55	18277	108.67	83.83						

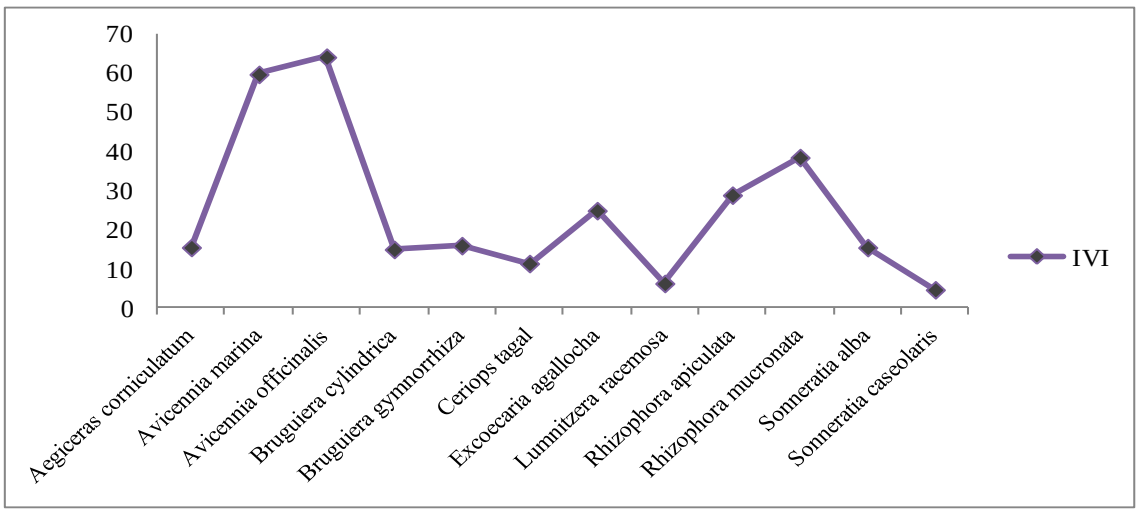

Figure 3. *Importance Value Index of different mangrove species at Kollam*

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Diversity Indices and Species Richness

Diversity indices can be used to characterize the species abundance relationship in a community. Shannon's diversity index is a simple measure to seek out species diversity. The species diversity indices revealed that Kollam had a high species diversity and better evenness figure. In the present study, disclosed that Kollam had total Shannon index as 3.266 (*Table 3*), it rewarded highest value in Shaktikulangara (3.112) and lowest in Cherikadavu (2.002). It indicates that sites with higher Shannon – Weiner had comparatively maximum number of species. An ecosystem with H' value greater than 2 has been treated as medium to high diverse in terms of species (Barbour et al., 1999). Thus Kollam has rationally high species diversity. The present study indicates, Simpson index of diversity of mangroves for whole Kollam as 0.879, Simpson value of species was found to be higher (0.858) at Shaktikulangara abide by Ayiramthengu (0.825) and least at Azhikkal (0.674) followed by Cherikadavu (0.796). The species evenness (Pielou's evenness) or equitability ranged from 0.902 to 0.791 (*Table 4*). The intact species richness worth of mangroves at Kollam revealed as 3.276, the species richness of various locations fluctuated between 1.022 and 0.429. Relatively higher value was recorded in Shaktikulangara and lower value in Cherikadavu (0.429) followed by Azhikkal (0.536) and Asraamam (0.539), the estimated species richness values of different site are bestowed in *Table 4*.

Table 3. *Diversity indices of different mangrove sites of Kollam*

Name of the locality	Shannon Index(H')	H max	Equitability(e)	Simpson´s Index(Cd)	Species richness(d)
Ayiramthengu	2.763	3.170	0.872	0.825	0.819
Azhikkal	2.044	2.585	0.791	0.674	0.536
Asraamam	2.200	2.585	0.851	0.741	0.539
Shaktikulangara	3.112	3.461	0.899	0.858	1.033
Cherikadavu	2.002	2.323	0.862	0.706	0.429
Munroe Island	2.460	2.808	0.876	0.778	0.623
Entire Kollam District	3.266	3.585	0.911	0.875	1.121

Similarity Indices

Compared to α-diversity, however, knowledge of β-diversity in the marine ecosystem context is more limited (Gray, 2000). This index depends on the number of species shared by two assemblages and the number of species unique to each of them. The results presents in Table 4 revealed that the highest value of β-diversity was registered between Azhikkal- Asraamam (0.66) abided by Shaktikulangara-Cherikadavu (0.55) which is comparatively higher than Cherikadavu- Munroe Island (0.50). The reduced level of similarity (0.33) was recorded between Ayiramthengu-Azhikkal and Ayiramthengu- Shaktikulangara (0.33). The higher similarities for

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mangroves in internal and central sites are due to the better organic carbon content of soil while, fringe areas uphold low plant growth diversity due to less organic carbon content of soil and high variations (Brahmaji, 1998). (*Fig. 4*) Dendrogram results the hierarchical clustering using the UPGMA algorithm (Odum, 1969). The resulting dendrogram display the level of similarity in percentage among different sites of Kollam and to obtain the natural grouping of different species along different sites. Locations in same groups shows much similarity than locations in disimilar groups, dendrogram also revealed that various grouped locations indicate distinction on species composition and abundance. It shows Cherikadavu- Asraamam, Munroe-Shaktikulangara and Azhikkal-Ayiramthengu are similar and are naturally grouped.

Table 4. *Similarity Index in species composition among study sites*

Locations	Ayiramthengu	Azhikkal	Asraamam	Shaktikulangara	Cherikadavu	Munroe Island
Ayiramthengu	—	0.33	0.50	0.33	0.44	0.40
Azhikkal		—	0.66	0.45	0.43	0.38
Asraamam			—	0.45	0.43	0.38
Shaktikulangara				—	0.55	0.36
Cherikadavu					—	0.50
Munroe Island						—

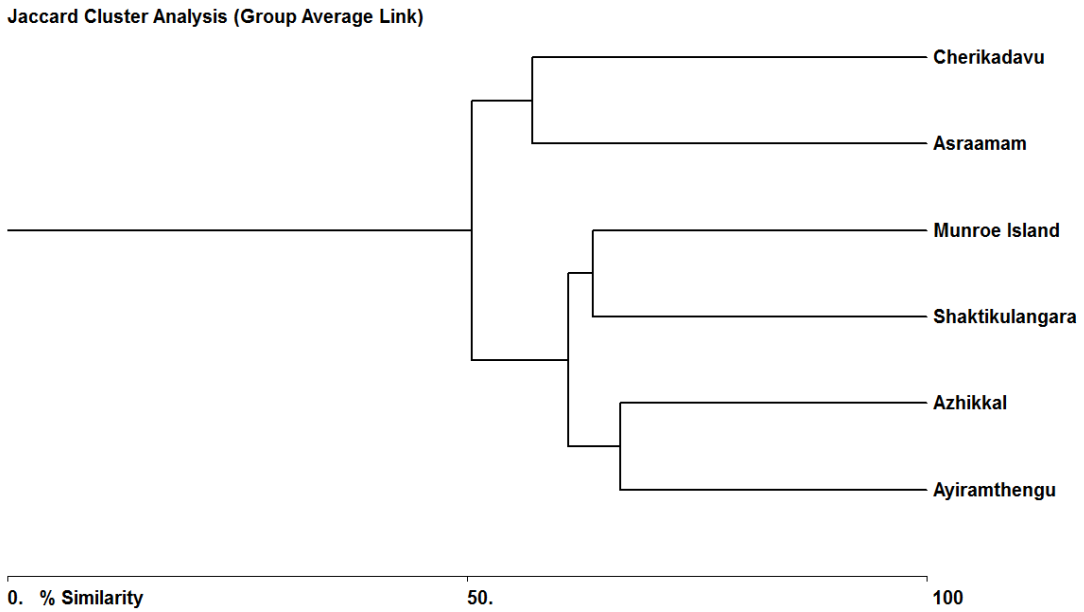

Figure 4. *Dendrogram of Kollam mangroves showing grouping of stations sampled during the study period*

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Conclusion

This study concentrates Mixed Mangrove forest in Kollam, a total of 12 species of mangroves belonging to six families were identified. The result shows that family Rhizophoracae is the largest family in Kollam region followed by Avicenniaceae and Sonneratiaceae. The sequences of distribution of each station were erratic and vegetation was diverse. *Avicennia marina, Excoecaria agallocha* and *Rhizophora apiculata* were found distributed in all six stations followed by *Avicennia officinalis* in five stations. Almost all stations were dominated by *Avicennia officinalis* followed by *A. marina, Lumnitzera racemosa and Ceriops tagal* are least diverse species in Kollam. The diversity of *Ceriops tagal* is proscribed to Shaktikulangara region in Kerala, no other studies shows the diversity of the species in Kerala. High species diversity indicates the maturity of an ecosystem (Odum, 1969).The Simpson index diversity of mangroves of Kollam (0.875) is comparatively similar to the values of diversity in Kannur, Kerala (0.821 and 0.854) (Jose, 2003). Existence of variation in species richness in mangroves of different locations was reported by several workers, the species richness always influenced by variation in rainfall, temperature, anthropogenic pressure and edaphic factors (Parthasarathy and Sethi, 2001). Almost every mangrove species in Kollam are of conservation and importance value. Extensive land fillings has affected the mangrove vegetation in a drastic manner, human population have major impact on the diversity, structure of forest ecosystems (Kacholi, 2013), In our study we also noted that mangroves are negatively compact by human development, they are mainly ditched to several industrial developments, housing etc. Early studies results that mangrove forests are under immense pressure from clear cutting, land use change, hydrological alternation, chemical spill and climate change (Blasco, 2001) The similarity indices also revealed the similar trend like that of evenness index, Highest similarity indices between the sites in the present study are attributed to the formation of common species into dense thickets; similar results are observed earlier (Banerjee and Gosh,1998). Seen a widespread overlap and similarity between all the sites through ordination visualization and direct comparison, thus comparisons of mangrove factors to richness, diversity and similarity indices was performed for Kollam as a whole. Trees basal area is another physical measurement that can be used to compare and characterize trees (Cris, 1999). As a recommendation, by considering the importance of mangroves and its associates in coastal ecosystem, the respective authority should enforce the regulation in order to protect and conserve the mangrove patches in Kollam.

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APPENDIX

Electronic Appendix 1: Basic Research Data

Electronic Appendix 2: Images

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