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PHYTOSOCIOLOGICAL ANALYSIS OF MANGROVE VEGETATION IN NETRAVATHI-GURUPURA AND MULKI-PAVANJE ESTUARINE COMPLEXES OF DAKSHINA KANNADA, KARNATAKA

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ABSTRACT
Phytosociological and distribution pattern of eumangrove vegetation and associated flora in Netravathi-Gurupura and Mulki-Pavanje estuarine complexes of Dakshina Kannada district were investigated. A total of 29 mangrove patches were identified along the estuary. During the study, 10 species of eumangroves and 14 species of mangrove associates were recorded. Among the mangroves, *Avicennia officinalis* and *Rhizophora mucronata* were most frequently occurred eumangroves, whereas *Derris trifoliata* is most commonly found associate mangroves. The structural analysis revealed the highest frequency, density and abundance for *Avicennia* species, followed by *Rhizophora mucronata*. *Avicennia officinalis* was found to be dominant species in Netravathi-Gurupura estuarine complex with IVI value of 3135.93, whereas *Avicennia alba* was dominant species in Mulki-Pavanje with IVI value of 1021.29. *Rhizophora mucronata* was second dominant species in both estuaries with IVI values of 1377.95 and 1013.29, respectively. The present investigation will help to understand the regeneration and recruitment patterns of different species of mangroves and therefore, it is an important conservation tool for sustainable management of mangrove ecosystem and their resources.

KEYWORDS: Mangroves, Eumangroves, Mangrove associates, Phytosociological analysis, Importance Value Index.

INTRODUCTION

Mangroves are the salt tolerant halophytic plant species, provide a wide range of ecological and economic products, and support coastal and marine ecosystems (Chandran *et al*., 2012). Mangrove forest grows well along the river bank, estuaries and coastal areas with the presence of brackish waters. According to their habitats, mangroves are categorized into two groups *viz*. eumangroves (true mangroves) and mangrove associates. In Karnataka, about 14 mangrove species have been recorded, the dominant being *Rhizophora mucronata* followed by *Avicennia* sp and *Sonneratia* sp (Prajapati, 2010; Shaikh and Srivastav, 2011; Sulochanan, 2013). They have unique features and special adaptations like breathing roots, buttresses and above ground roots that allow and enable them to live and survive in anaerobic and high salt water conditions (Mastaller, 1997; Gandaseca *et al*., 2011). Mangrove forest is a type of wetland and is considered as one of the most productive ecosystem and a natural renewable resource (Kathiresan, 2003; Karami *et al*., 2009). It supports the conservation of biological diversity by providing habitats, roosting grounds, spawning and nurseries grounds and provide rich productivity for a number of fishes, shellfishes, animals and birds (Faridah-Hanum *et al*., 2012). They also act as a protective barrier to shores from strong waves and storms such as tsunamis (Wah *et al*., 2011). Nowadays, mangrove ecosystem is heavily influenced by sand mining, land filling, waste dumping, defoliation, extensive collection of mangrove resources and also infrastructure development which cause problems for mangrove biodiversity and its natural regeneration (Rahees *et al*., 2014). Hence, an attempt was made to study the distribution and abundance of mangrove vegetation and associated flora in the Netravathi-Gurupura and Mulki-Pavanje estuaries in the Dakshina Kannada district, Karnataka.

MATERIALS & METHODS

Study area

Dakshina Kannada is the southern coastal district of Karnataka State with an area of 4859 km^2. The district lies between 12°57' and 13°50'N latitude and 74°00' and 75°50'E longitude. It spreads from the Western Ghats towards the Arabian Sea to the west. It is characterized by excessive humidity (78%) during the greater part of the year. The average rainfall of the district is about 3789.9 mm received mainly during the south-west monsoon season extending from June to September.

The major rivers are Netravathi, Kumaradhara, Phalguni, Shambhavi, Pavanje and Payaswini which originates in the Western Ghats and forming estuaries in the Arabian Sea and form the important mangroves in Netravathi-Gurupura and Mulki-Pavanje estuarine complexes. Most mangroves are of the fringing type in linear formations along the estuarine banks.

Identification of mangrove patches

The data collected on mangrove species, distribution and actual area was determined. The mangroves patches were estimated using Google earth map and fixed with the help of a Global Positioning System (GPS 72H). The identified mangrove patches are shown in the Map (Fig. 1).

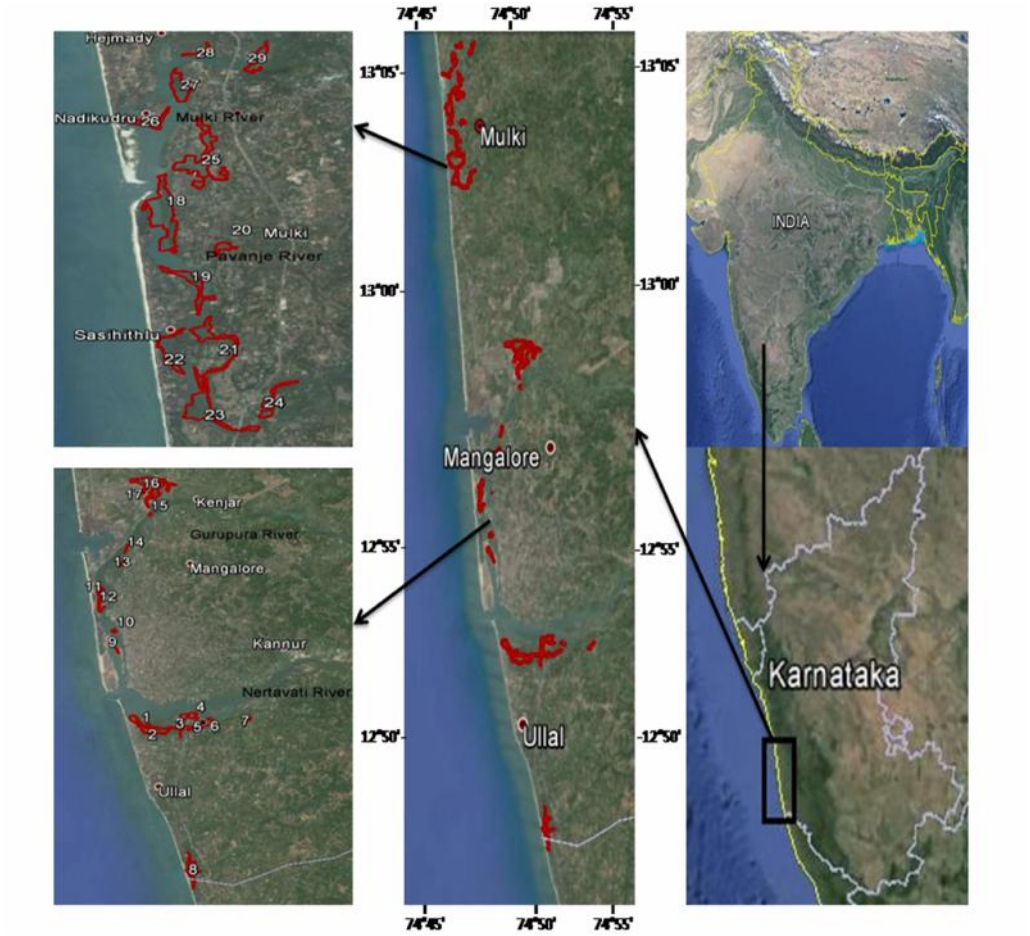

FIGURE 1: Map showing the study mangove patches.

Phytosociological analysis

The species of mangrove flora were identified with the help of standard manuals and available literatures (Rao and Suresh, 2001; Sanjappa *et al*., 2011; Chandran *et al*., 2012; Ram and Shaji, 2013). Distribution patterns of mangroves were studied by following quadrat method. The study area was divided into three quadrats of each 10×10 m size and analysis was carried out. Frequency, density, abundance and their relative values and Importance Value Index (IVI) for major mangrove species were calculated using standard formulae (Mueller-Dombois and Ellenberg, 1974).

$$\text{Frequency of a species} = \frac{\text{Total number of quadrats in which species occurred}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Density of the species/quadrat} = \frac{\text{Total number of individuals of the species}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individuals of species occurring}}{\text{Total number of quadrats in which species occurred}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequency of all species}} \times 100$$

$$\text{Relative density} = \frac{\text{Density of a species}}{\text{Sum of density of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total stand basal cover of species}}{\text{Total stand basal cover of all the species}} \times 100$$

Importance Value Index (IVI) = Relative frequency + Relative density + Relative dominance

RESULTS & DISCUSSION

A total of 29 mangrove patches were identified along the Dakshina Kannada coast. Among 29 patches, 17 patches were distributed in Netravathi-Gurupura estuarine complex and 12 patches in Mulki-Pavanje estuarine complexes (Table 1).

TABLE 1: Mangrove patches along the Netravathi-Gurupura and Mulki-Pavanje estuarine complexes, Dakshina Kannada district, Karnataka.

Netravati-Gurupura estuarine complexes			Mulki-Pavanje estuarine complexes		
Patch code	Latitude	Longitude	Patch code	Latitude	Longitude
MGR-1	12°50'02.36"N	74°50'10.44"E	MGR-18	13°4'34.37"N	74°46'48.36"E
MGR-2	12°49'36.54"N	74°50'31.24"E	MGR-19	13°3'35.18"N	74°46'53.78"E
MGR-3	12°50'05.04"N	74°51'32.03"E	MGR-20	13°3'49.32"N	74°47'23.90"E
MGR-4	12°50'04.36"N	74°51'38.73"E	MGR-21	13°3'00.95"N	74°47'16.95"E
MGR-5	12°49'42.75"N	74°51'39.26"E	MGR-22	13°2'54.94"N	74°47'03.18"E
MGR-6	12°50'01.48"N	74°52'07.01"E	MGR-23	13°2'05.35"N	74°47'11.59"E
MGR-7	12°49'54.46"N	74°53'02.63"E	MGR-24	13°2'25.96"N	74°47'58.02"E
MGR-8	12°45'51.96"N	74°51'54.62"E	MGR-25	13°4'41.59"N	74°46'55.71"E
MGR-9	12°52'21.82"N	74°49'25.42"E	MGR-26	13°5'15.06"N	74°46'27.66"E
MGR-10	12°52'41.95"N	74°49'26.27"E	MGR-27	13°5'46.74"N	74°46'48.22"E
MGR-11	12°53'59.93"N	74°49'02.79"E	MGR-28	13°6'01.97"N	74°46'51.47"E
MGR-12	12°53'47.85"N	74°49'26.09"E	MGR-29	13°6'09.02"N	74°47'32.56"E
MGR-13	12°54'54.25"N	74°49'33.34"E			
MGR-14	12°55'12.49"N	74°49'32.86"E			
MGR-15	12°56'28.19"N	74°50'06.46"E			
MGR-16	12°57'31.95"N	74°50'14.96"E			
MGR-17	12°57'38.01"N	74°49'34.59"E			

Distribution of eumangroves in Netravathi-Gurupura and Mulki-Pavanje estuarine complexes of Dakshina Kannada district shown in Table 2. A total of 10 species of eumangroves *viz. Acanthus ilicifolius*, *Aegiceras corniculatum*, *Avicennia alba*, *A. officinalis*, *Bruguiera gymnorrhiza*, *Excoecaria agallocha*, *Kandelia candel*, *Rhizophora mucronata*, *Sonneratia alba* and *S. caseolaris* were recorded during the study period. The occurrence and distribution of eumangrove species such as *Rhizophora mucronata, R. apiculata, Acanthus ilicifolius, Avicennia alba, A. marina, A. officinalis, Bruguiera cylindrica, B. gymnorrhzia, Lumnitzera racemosa, Excoecaria agallocha, Kandelia candel, Sonneratia alba, S. caseolaris, Aegiceras corniculatum* and *Ceriops decandra* along the estuaries of Karnataka were reported by Rao and Suresh (2001) and Chandran *et al*. (2012).

TABLE 2: Distribution of eumangroves in Netravati-Gurupura and Mulki-Pavanje estuarine complexes of Dakshina Kannada district.

Eumangroves	Patches (MGR)																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Acanthus ilicifolius	+	+	-	-	+	-	-	-	-	-	+	-	+	-	-	+	+	+	+	+	-	-	+	+	+	+	+	-	-
Aegiceras corniculatum	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-	-
Avicennia alba	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	-	-	+	+	+	-	-
A. officinalis	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
Bruguiera gymnorrhiza	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Excoecaria agallocha	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	+	-	-	-	-
Kandelia candel	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	+	-	-
Rhizophora mucronata	+	+	+	+	-	-	-	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sonneratia alba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	-	+	-	-
S. caseolaris	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	+	+	-	+	-	-	-	-

TABLE 3: Associate species of mangroves in Netravati-Gurupura and Mulki-Pavanje estuarine complexes of Dakshina Kannada district.

Mangrove associates	Patches (MGR)																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Acrostichum aureum	+	-	+	+	+	+	+	+	+	-	+	-	+	-	+	+	+	-	-	+	-	-	-	-	+	-	-	-	-
Cerebra odollam	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-
Clerodendrum inerme	+	+	+	+	+	-	+	+	-	-	+	+	+	+	-	-	-	-	-	-	-	-	+	+	+	-	-	+	+
Derris scandens	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D. trifoliata	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	-	-	+	+
Cyperus malaccensis	+	-	+	+	-	-	+	+	-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	+	+	-	+	-	-
Fimbristylis ferruginea	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+
Morinda citrifolia	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pandanus fascicularis	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Pongamia pinnata	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Porterisia coarctata	+	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-
Premna serratifolia	+	-	+	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-
Sesuvium portulacastrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Thespesia populnea	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-

TABLE 4: Frequency, density, abundance and their relative values and Importance Value Index (IVI) of mangrove species of Netravati-Gurupura and Mulki-Pavanje estuarine complexes along Dakshina Kannada coast

Patches (MGR)	Species	Frequency	Density	Abundance	Relative Frequency	Relative Density	Relative Dominance	IVI
Netravati-Gurupura estuarine complexes								
1	*Avicennia officinalis*	100.00	2300.00	2300.00	37.50	58.97	45.48	141.96
	Rhizophora mucronata	66.67	1366.67	2050.00	25.00	35.04	10.48	70.52
	Kandelia candel	66.67	166.67	250.00	25.00	4.27	12.94	42.21
	Sonneratia caseolaris	33.33	66.67	200.00	12.50	1.71	31.08	45.29
2	*Avicennia officinalis*	100.00	1600.00	1600.00	50.00	58.54	70.27	178.81
	Rhizophora mucronata	66.67	1000.00	1500.00	33.33	36.59	14.12	84.04
	Kandelia candel	33.33	133.33	400.00	16.67	4.88	15.61	37.15
3	*Avicennia officinalis*	100.00	966.67	966.67	50.00	67.44	74.09	191.54
	Rhizophora mucronata	100.00	466.67	466.67	50.00	32.56	25.93	108.49
4	*Rhizophora mucronata*	33.33	666.67	2000.00	25.00	24.10	20.73	69.82
	Avicennia officinalis	100.00	2100.00	2100.00	75.00	75.90	79.27	230.17
5	*Avicennia officinalis*	100.00	1733.33	1733.33	100.00	100.00	100.00	300.00
6	*Avicennia officinalis*	100.00	1033.33	1033.33	100.00	100.00	100.00	300.00
7	Nil	-	-	-	-	-	-	-
8	*Rhizophora mucronata*	100.00	2966.67	2966.67	50.00	80.18	16.22	146.40
	Avicennia officinalis	100.00	733.33	733.33	50.00	19.82	83.76	153.58
9	*Avicennia officinalis*	100.00	1266.67	1266.67	60.00	82.61	79.19	221.79
	Rhizophora mucronata	66.67	266.67	400.00	40.00	17.39	20.82	78.22
10	*Rhizophora mucronata*	100.00	4200.00	4200.00	100.00	100.00	100.00	300.00
11	*Avicennia officinalis*	100.00	1966.67	1966.67	50.00	56.19	80.89	187.08
	Rhizophora mucronata	100.00	1533.33	1533.33	50.00	43.81	19.14	112.95
12	*Rhizophora mucronata*	100.00	1200.00	1200.00	50.00	80.00	20.45	150.45
	Avicennia officinalis	66.67	233.33	350.00	33.33	15.56	64.03	112.91
	Bruguiera gymnorrhiza	33.33	66.67	200.00	16.67	4.44	15.55	36.66
13	*Avicennia officinalis*	100.00	1733.33	1733.33	50.00	55.91	80.00	185.91
	Rhizophora mucronata	100.00	1366.67	1366.67	50.00	44.09	20.00	114.08
14	*Avicennia officinalis*	100.00	1100.00	1100.00	75.00	91.67	76.12	242.79
	Rhizophora mucronata	33.33	100.00	300.00	25.00	8.33	23.87	57.20
15	*Avicennia officinalis*	100.00	1200.00	1200.00	100.00	100.00	100.00	300.00
16	*Avicennia officinalis*	100.00	2266.67	2266.67	75.00	97.14	57.04	229.19
	Sonneratia caseolaris	33.33	66.67	200.00	25.00	2.86	42.94	70.80
17	*Avicennia officinalis*	100.00	2100.00	2100.00	42.86	65.63	51.72	160.20
	Sonneratia alba	33.33	66.67	200.00	14.29	2.08	37.66	54.03
	Rhizophora mucronata	100.00	1033.33	1033.33	42.86	32.29	10.63	85.78
Mulki-Pavanje estuarine complexes								
18	*Sonneratia alba*	33.33	100.00	300.00	16.67	4.48	36.38	57.52
	Avicennia alba	100.00	1700.00	1700.00	50.00	76.12	46.91	173.03
	Rhizophora mucronata	66.67	433.33	650.00	33.33	19.40	16.72	69.46
19	*Rhizophora mucronata*	100.00	933.33	933.33	37.50	30.43	15.41	83.34
	Avicennia alba	100.00	1966.67	1966.67	37.50	64.13	34.66	136.29

	Avicennia officinalis	66.67	166.67	250.00	25.00	5.43	49.92	80.35
20	*Rhizophora mucronata*	66.67	400.00	600.00	33.33	20.34	11.24	64.91
	Avicennia alba	100.00	1466.67	1466.67	50.00	74.58	41.28	91.28
	Avicennia officinalis	33.33	100.00	300.00	16.67	5.08	47.48	69.23
21	*Rhizophora mucronata*	66.67	833.33	1250.00	25.00	28.74	9.36	63.10
	Avicennia alba	100.00	1766.67	1766.67	37.50	60.92	29.10	127.52
	Excoecaria agallocha	33.33	166.67	500.00	12.50	5.75	8.88	27.12
	Avicennia officinalis	33.33	66.67	200.00	12.50	2.30	30.87	45.66
	Sonneratia alba	33.33	66.67	200.00	12.50	2.30	21.81	36.61
22	*Rhizophora mucronata*	100.00	866.67	866.67	33.33	28.57	8.34	70.24
	Avicennia alba	100.00	1933.33	1933.33	33.33	63.74	25.97	123.04
	Avicennia officinalis	66.67	200.00	300.00	22.22	6.59	40.58	69.39
	Sonneratia alba	33.33	33.33	100.00	11.11	1.10	25.11	37.32
23	*Rhizophora mucronata*	100.00	1266.67	1266.67	30.00	31.67	9.39	71.06
	Avicennia officinalis	100.00	2200.00	2200.00	30.00	55.00	48.59	133.59
	Bruguiera gymnorrhiza	33.33	166.67	500.00	10.00	4.17	8.03	22.10
	Sonneratia caseolaris	33.33	33.33	100.00	10.00	0.83	20.43	31.26
	Kandelia candel	33.33	166.67	500.00	10.00	4.17	6.78	20.95
	Excoecaria agallocha	33.33	166.67	500.00	10.00	4.17	6.78	20.95
24	*Rhizophora mucronata*	100.00	1233.33	1233.33	30.00	30.83	9.46	70.30
	Avicennia officinalis	100.00	2466.67	2466.67	30.00	61.67	47.20	138.87
	Bruguiera gymnorrhiza	33.33	66.67	200.00	10.00	1.67	16.82	28.49
	Kandelia candel	66.67	133.33	200.00	20.00	3.33	12.88	36.22
	Excoecaria agallocha	33.33	100.00	300.00	10.00	2.50	13.63	26.13
25	*Excoecaria agallocha*	66.67	133.33	200.00	22.22	4.08	9.54	35.84
	Avicennia officinalis	33.33	200.00	600.00	11.11	6.12	31.78	49.01
	Rhizophora mucronata	66.67	1700.00	2550.00	22.22	52.04	9.54	83.80
	Avicennia alba	100.00	1200.00	1200.00	33.33	36.73	28.39	98.46
	Sonneratia caseolaris	33.33	33.33	100.00	11.11	1.02	20.76	32.89
26	*Avicennia alba*	100.00	1400.00	1400.00	37.50	33.07	66.04	136.61
	Rhizophora mucronata	100.00	2666.67	2666.67	37.50	62.99	16.51	117.00
	Kandelia candel	66.67	166.67	250.00	25.00	3.94	17.472	46.40
27	*Avicennia alba*	100.00	2400.00	2400.00	42.86	52.94	39.26	135.06
	Rhizophora mucronata	66.67	1900.00	2850.00	28.57	41.91	8.96	79.44
	Sonneratia alba	33.33	33.33	100.00	14.29	0.74	40.45	55.47
	Kandelia candel	33.33	200.00	600.00	14.29	4.41	11.34	30.03
28	*Rhizophora mucronata*	66.67	1266.67	1900.00	40.00	42.22	20.46	102.68
	Avicennia officinalis	100.00	1733.33	1733.33	60.00	57.78	79.53	197.30
29	*Rhizophora mucronata*	100.00	3400.00	3400.00	50.00	63.35	24.61	137.96
	Avicennia officinalis	100.00	1966.67	1966.67	50.00	36.65	75.36	162.00

Among mangroves, the species of *Avicennia officinalis* and *Rhizophora mucronata* were most frequently observed eumangroves and recorded in 26 and 25 patches, respectively. The species of *Avicennia alba*, *Excoecaria agallocha*, *Kandelia candel*, *Sonneratia alba* and *S. caseolaris* were sparsely distributed in Netravathi-Gurupura estuarine complex but frequently observed in Mulki-Pavanje estuarine complex. Occasionally species of *Bruguiera gymnorrhiza* were observed. The distribution of mangrove species are influenced by many physico-chemical factors of water and soil such as response to tides, frequency of inundation, temperature, soil type, drainage, age and degree of exposure (Chapman, 1975; Faridah-Hanum *et al*., 2012). The eumangroves such as *Rhizophora apiculata* and *Avicennia marina* are found in high salinity zones (>15 ppt), while *Aegiceras corniculatum* prefer medium salinity zones (5 to 15 ppt), *Rhizophora mucronata*, *Avicennia officinalis*, *Sonneratia alba*, *Kandelia candel* and *Excoecaria agallocha* are found in high and medium salinity zones. The species *Acanthus ilicifolius* was present in all salinity zones, but *Sonneratia caseolaris* was present in medium to very low salinity zones (< 0.5 ppt) conditions. In contrast to this, the species of *Acanthus ilicifolius*, *Kandelia candel* and *Sonneratia caseolaris* were observed in low salinity zones. Similar kind of distribution of eumangroves was observed by Chandran *et al*. (2012).

The distribution of mangrove associates in Netravathi-Gurupura and Mulki-Pavanje estuarine complexes in Dakshina Kannada district are shown in Table 3. A total of 14 species of mangrove associates viz. *Acrostichum aureum*, *Cerebra odollam*, *Clerodendrum inerme*, *Derris scandens*, *D. trifoliata*, *Cyperus malaccensis*, *Fimbristylis ferruginea*, *Morinda citrifolia*, *Pandanus fascicularis*, *Pongamia pinnata*, *Porterisia coarctata*, *Premna serratifolia*, *Sesuvium portulacastrum* and *Thespesia populnea* were recorded. The species of *Derris trifoliata* was most commonly found climber associate in both the estuaries during study period. The dense patches of salt tolerant freshwater fern, *Acrostichum aureum* (Rao *et al*., 1973) were seen in Netravathi-Gurupura compared to Mulki-Pavanje estuarine complex. This fern grows in colonies in swampy and marshy places where the tidal force is minimum and salinity at low concentration (Chandran *et al*., 2012). Dense formation of *Clerodendrum inerme* and *Cyperus malaccensis* were observed in few patches in both the estuarine complexes along Dakshina Kannada coast.

Phytosociological data on mangrove flora of Netravathi-Gurupura and Mulki-Pavanje estuarine complexes, Dakshina Kannada, Karnataka are presented in Table 4.The structural analysis of mangroves revealed that highest frequency, density and abundance of species of *Avicennia* in most of the patches, followed by *Rhizophora mucronata*. *Avicennia officinalis* was densely distributed species and present in patches MGR-1, 2, 3, 4, 5, 6, 9, 11, 13, 14, 15, 16, 17, 23, 24 and 28, whereas *A. alba* in MGR-18, 19, 20, 21, 22 and 27. The dominance of *Rhizophora mucronata* observed in MGR-10, 12, 25, 26 and 29. The high density of *Avicennia* species and *Rhizophora mucronata* observed in these estuarine complexes may be due to their adaptive characters for reproduction and survival with efficient mechanism of persistence by producing widely dispersed propagules (Tomlinson, 1986; Vidyasagaran *et al*., 2011; Ram and Shaji, 2013).

The relative density of *Avicennia officinalis* ranged from 2.30 (MGR-21) to 100% (MGR-5, 6 and 15), *A. alba* 33.07 (MGR-26) to 76.12% (MGR-18) and *Rhizophora mucronata* 8.33 (MGR-14) to 100% (MGR-10). While, the other species such as *Bruguiera gymnorrhiza*, *Excoecaria agallocha*, *Kandelia candel*, *Sonneratia alba* and *S. caseolaris* were recorded lower relative density values. The pure formation of *Avicennia officinalis* (Relative frequency=Relative density=Relative dominance= 100%) was observed in MGR-5, 6 and 15, whereas monospecies of *Rhizophora mucronata*was seen in MGR-10. In MGR-7, however true mangroves were totally absent but only mangrove associates such as *Acrostichum aureum*, *Clerodendrum inerme*, *Derris trifoliata*, *Cyperus malaccensis* and *Pandanus fascicularis* were observed towards the river side. The dominance of *Avicennia* species were supported by their high Importance Value Index (IVI) in all the patches except MGR-10. The values of IVI indicates the contribution that a species makes to the community with respect to the number of plants within the quadrats (abundance), its influence on the other species through its competition, shading or aggressiveness (dominance) and its contribution to the community *via.,* its distribution (frequency) (Gibbs, 1996). The structural analysis of the mangrove communities at different estuarine formations revealed that there is site specific domination of species which in turn supported by the adaptability of the species to specific site conditions (Cottom and Curtis, 1956; Rahees *et al*., 2014).

Important Value Index of each mangrove species are presented in Figure 2. *Avicennia officinalis* was found to be more dominant species in Netravathi-Gurupura estuarine complexes with IVI value of 3135.93 (Fig. 2a), followed by *Rhizophora mucronata*, *Sonneratia caseolaris*, *Kandelia candel*, *Sonneratia alba* and *Bruguiera gymnorrhiza* with IVI values of 1377.95, 116.09, 79.36, 54.03 and 36.66, respectively. *Avicennia alba* was dominant in Mulki-Pavanje estuarine complexes with IVI value of 1021.29 (Fig. 2b), followed by *Rhizophora mucronata* and *Avicennia officinalis* with IVI values of 1013.29 and 945.40, respectively. The other species such as *Sonneratia alba*, *Kandelia candel*, *Excoecaria agallocha*, *Sonneratia caseolaris* and *Bruguiera gymnorrhiza* exhibited low IVI values (186.92, 133.60, 110.04, 64.15 and 50.59, respectively). Mohanan (1997) reported that *Avicennia* species was found to be the early colonizer followed by *Rhizophora*, *Derris* and *Acanthus* species.

The present investigation helps to understand the regeneration and recruitment patterns of different species of mangroves and therefore, it is an important conservation tool for sustainable management of mangroves and its natural resources.

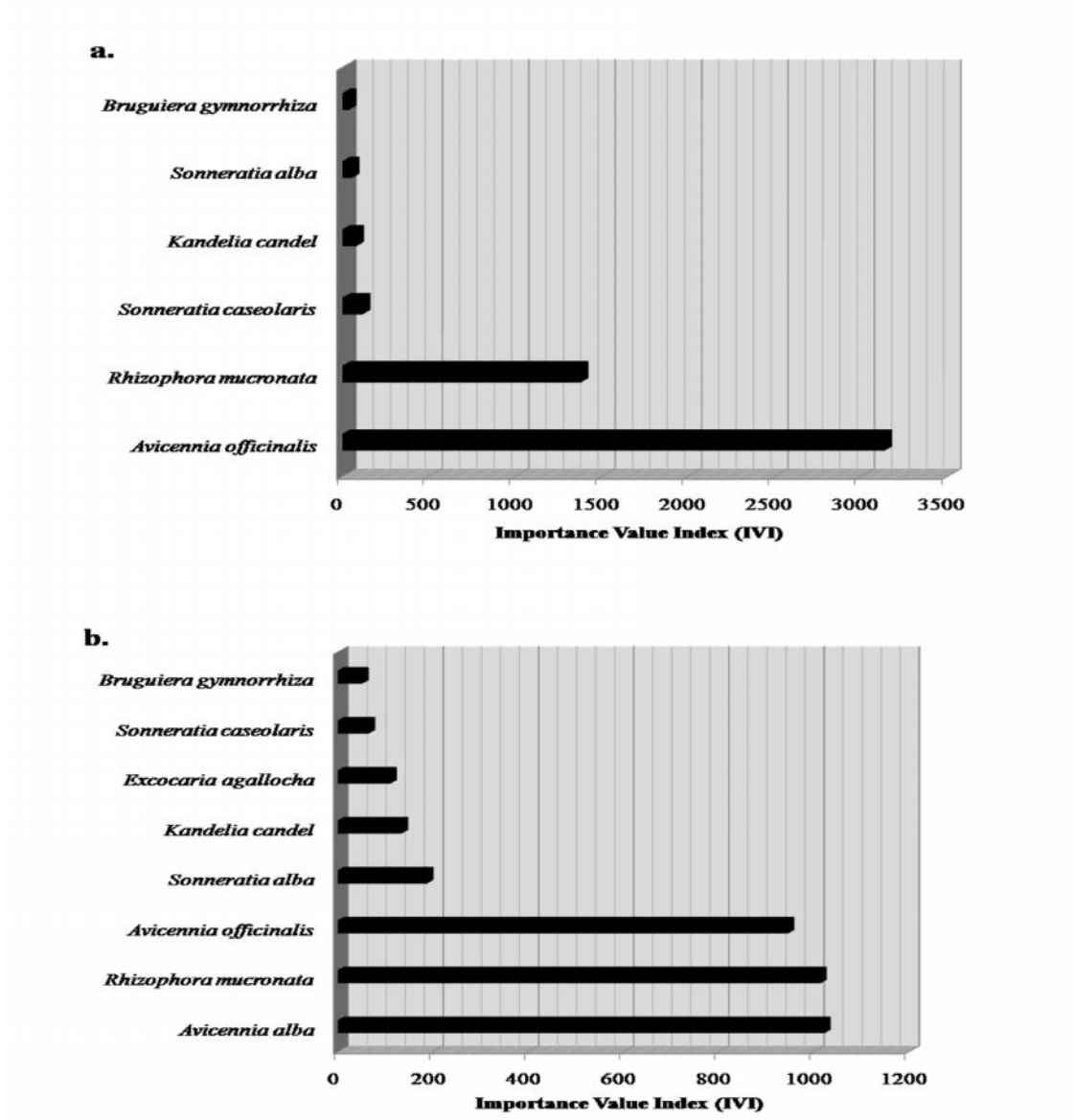

FIGURE 2: Importance Value Index of mangrove species of Netravathi-Gurupura (a) and Mulki-Pavanje (b) estuarine complexes.

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