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The community structure of macroalgae in a low shore mangrove forest in Selangor, Malaysia

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Abstract

The macroalgal communities associated with pneumatophores, basal area of tree trunks and sediment surface in the mangrove forest at Sementa, Selangor consisted of nine main species. Biomass, frequency of occurrence and relative cover of the species along a belt transect, showed two major trends, a decrease in these parameters in the landward direction for *Colpomenia* sp. *Gracilaria blodgettii* and *Gracilaria crassa* and an increase in the landward direction for *Dictyota dichotoma*, *Catenella nipae*, *Rhizoclonium* sp. and *Bostrichia radicans*. Algal dominance varied with substratum. Pneumatophores were dominated by *Caloglossa lepreurii* and sediment surface by *D. dichotoma*. The 40 cm zone at the base of tree trunks was dominated by two algal species. The 0–20 cm region above the sediment surface was colonized by *C. nipae*, while the 20–40 cm region was dominated by *Rhizoclonium* sp. The study identified the importance of substrate in macroalgal colonization.

Introduction

Numerous accounts of mangrove fauna and flora have appeared since 1950 (Lugo & Snedaker, 1974), but mangrove algal communities have received little attention. Post (1963, 1964a & b, 1966; Lambert *et al.*, 1987) gave detailed descriptions of various macroalgal species and identified a bostrychietum as an association of algae comprising several macroalgae such as *Bostrychia*, *Caloglossa*, *Catenella* and *Murrayella*. The species composition and ecology of macroalgae in the mangroves of east Indonesia have been studied by Chihara & Tanaka (1988) and Tanaka & Chihara (1988). Benthic macroalgae were found to have a total gross primary productivity of 240 kg O_2 d^{-1}, which accounted for 12% of the total gross primary productivity of the mangroves in Shurat Arwashie, Israel (Dor & Levy, 1984). The trophic importance of algae in the food web of the mangrove ecosystem was demonstrated in the stable carbon isotope ratios of consumers. Deposit feeders assimilated significant quantities of carbon with the range of ratios of the macroalgae and diatoms examined (Rodelli *et al.*, 1984).

Beanland & Woelkering (1983) suggested frequency distribution of mangrove-associated algae in South Australia may be influenced by canopy cover. Thirty two macroalgae taxa were associated with pneumatophores of mangroves at the New South Wales coast (King & Wheeler, 1985). The mangroves of Spencer Gulf, South Australia, are the habitat for 49 macroalgal species including 10 Chlorophyta, 2 Cyanophyta, 9 Phaeophyta and 28 Rhodophyta (Beanland & Woelkering, 1982). Davey & Woelkering (1985) showed a decrease in occurrence, relative cover and biomass of algae towards the landward side in Western Port Bay, Victoria.

Few of the studies mentioned provide quantitative data on algal community structure, and have been concerned only with macroalgae attached to pneumatophores. The aim of this study is to determine the frequency of occurrence, relative cover and biomass of macroalgae on pneumatophores, tree trunks and sediment surface along a belt transect from the *Avicennia* forest near the mudflat to the seaward edge of the *Rhizophora-Bruguiera* mixed forest.

Methods

The study site was situated at Kapar Mangrove Forest Reserve, 6 km north of Port Klang, Selangor (Fig. 1). The forest was bordered by the Straits of Malacca on the western side and on the eastern side by a bund which prevents sea water from intruding into reclaimed land. Starting at the seaward edge and for a distance of about 300 metres to the bund the forest can be subdivided into three distinct zones:

(i) an *Avicennia* zone, comprising exclusively of *Avicennia alba*.
(ii) a *Sonneratia* zone, with *Sonneratia alba* intermingled with *Avicennia alba*; and
(iii) a mixed forest zone on the high shore near

Table 1. The percentage cover, frequency of occurrence and biomass of macroalgae on pneumatophores along the belt transect in the mangrove forest in Sementa, Selangor. Quadrat A is near the high shore.

Quadrat algae	A	B	C	D	E	F	G	H	I	J	Mean
Percentage cover											
Catenella nipae	5.2	4.7	4.3	7.1	–	–	–	–	–	1.0	2.23
Caloglossa lepreurii	4.7	4.0	5.65	2.4	2.05	0.2	5.0	2.2	9.6	2.1	3.79
Bostrichia radicans	8.3	1.8	3.5	1.5	0.9	–	0.2	–	0.2	–	1.64
Enteromorpha sp.	–	0.2	–	–	–	–	–	–	–	–	0.02
Cladophora	–	–	–	–	–	4.0	–	–	–	–	0.40
Gracilaria blodgettii	–	–	–	–	0.2	3.0	–	–	–	0.1	0.33
Caloglossa adnata	–	–	–	0.05	0.7	0.1	0.2	0.6	3.0	0.1	0.47
Colpomenia sp.	–	–	–	0.2	0.1	–	–	–	–	–	0.03
Rhizoclonium sp.	–	–	–	–	0.1	–	–	–	–	8.2	0.83
Dictyota dichotoma	–	–	–	0.2	–	–	–	–	–	–	0.02
Frequency of occurrence											
Catenella nipae	0.4	0.4	0.3	0.3	–	–	–	–	–	0.1	0.15
Caloglossa lepreurii	0.5	0.3	0.5	0.2	0.2	0.1	0.2	0.2	0.5	0.2	0.29
Bostrichia radicans	0.6	0.2	0.2	0.1	0.1	–	0.1	–	0.1	–	0.14
Enteromorpha sp.	–	0.1	–	–	–	–	–	–	–	–	0.01
Cladophora	–	–	–	–	–	0.1	–	–	–	–	0.01
Gracilaria blodgettii	–	–	–	–	0.1	0.1	–	–	–	0.1	0.03
Caloglossa adnata	–	–	–	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.10
Compomenia sp.	–	–	–	0.1	0.1	–	–	–	–	–	0.02
Rhizoclonium sp.	–	–	–	–	0.1	–	–	–	–	0.2	0.03
Dictyota dichotoma	–	–	–	0.1	–	–	–	–	–	–	0.01
Biomass (mg/cm^2)											
Catenella nipae	2.332	3.961	2.249	10.55	–	–	–	–	–	1.626	2.0718
Caloglossa lepreurii	2.579	0.569	0.500	1.143	0.222	0.050	1.162	0.623	1.745	0.073	0.8666
Bostrichia radicans	0.981	0.161	0.333	0.233	0.028	–	0.020	–	0.250	–	0.2006
Enteromorpha sp.	–	0.191	–	–	–	–	–	–	–	–	0.0191
Cladophora	–	–	–	–	–	–	–	–	–	–	–
Gracilaria blodgettii	–	–	–	–	0.608	10.883	–	–	–	0.233	1.1724
Caloglossa adnata	–	–	–	0.037	0.423	0.100	6.343	–	–	–	0.6903
Colpomenia sp.	–	–	–	0.707	0.032	–	–	–	–	–	0.0739
Rhizoclonium sp.	–	–	–	–	0.010	–	–	–	–	0.821	0.3831
Dictyota dichotoma	–	–	–	0.711	–	–	–	–	–	–	0.0711

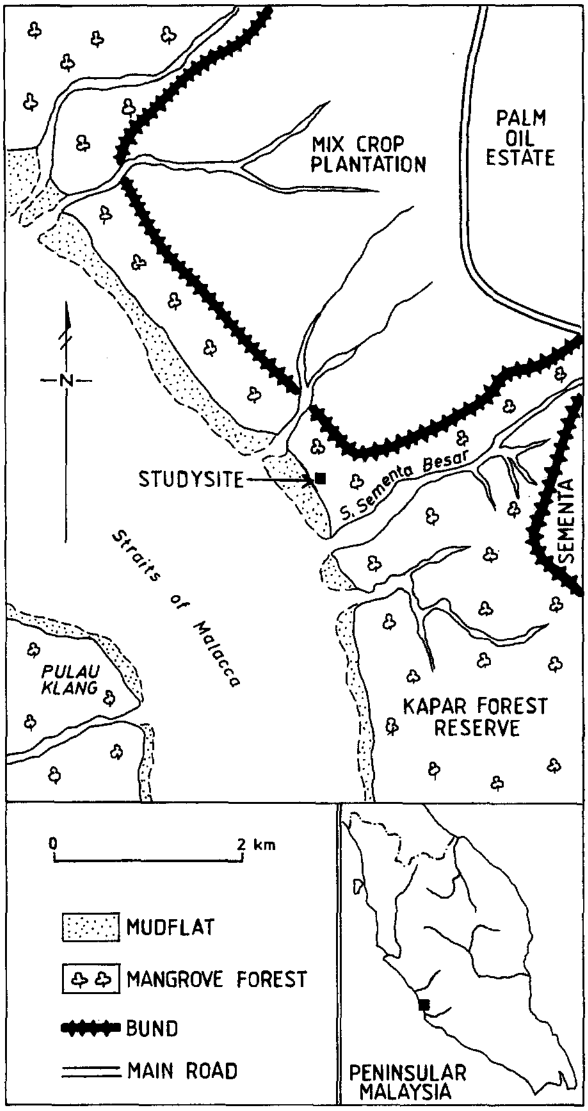

Fig. 1. Map of the study site in the Kapar Forest Reserve, Selangor.

the bund, predominantly comprised of *Bruguiera parviflora* and *Rhizophora mucronata.*

The tides are semi-diurnal and at extreme low tide (0 metre on the Chart Datum) exposes a mudflat seaward of the mangrove foreshore for about 300 m. The extreme highs of 5.3 m reaches the top of the bund.

The study site proper was a transect of 100 m long and 10 m wide, which began just above the mudflat in the *Avicennia* forest and ended at the landward edge of the mixed forest of *Sonneratia* and *Avicennia*. This did not include the landward mixed forest of *Rhizophora* and *Bruguiera*.

Three parameters were considered: biomass, cover and frequency of occurrence. All these measurements were obtained for macroalgae on pneumatophores, tree trunks (from sediment level up to a height of 40 cm) and sediment surface. Dry weight biomass was obtained by picking the algae into aluminium foil 'boats', removing any flecks of barks, then drying at temperature of 70 °C for two days. Biomass has been expressed as algal weight per unit area of the sample (mg cm^{-2}). Frequency of occurrence was obtained by counting the total number of occurrences for each species divided by the total number of samples. Cover data represent the total area occupied by algae as a percentage of total area sampled in each quadrat. Pneumatophores were considered as cylinders of 1 cm diameter for calculation of their surface area.

Along its length the transect was divided into quadrats of 10 m × 10 m, identified as A through J from the landward to the seaward end. Ten pneumatophores were taken from each quadrat and the algae were collected from 20 random square areas (0.5 m on a side) of the sediment. Also in each quadrat samples were taken from five trees of greater than 5 cm DBH. For these samples a knife was used to peel off 5 cm × 5 cm squares of the bark at 10 cm heights upward from the sediment to a maximum of 40 cm. Taking such peelings in equal numbers from the seaward and landward side of the trunks provided eight samples. All samples from the sections were preserved in 4% formalin for later analyses.

The distances from the sediment surface to the water level as noted on the three trunks was measured at both ends of the transect on a relatively high tide. With this information and the Chart Datum as a reference, it was determined that the seaward end of the transect was 3.0 m above (CD) while the landward end was 4.1 m above. In other words the sediment surface sloped upward 1.1 m toward the landward end (Fig. 2b).

Table 2. The percentage cover, frequency of occurrence and biomass of macroalgae on lower tree trunks (up to a height of 40 cm) along the belt transect in the mangrove forest in Sementa, Selangor. Quadrat A is near the high shore.

Quadrat algae	A	B	C	D	E	F	G	H	I	J	Mean
Percentage cover											
Rhizoclonium sp.	0.1	19.15	25.75	30.55	36.65	20.75	4.95	8.45	21.4	–	16.76
Caloglossa adnata	3.0	8.85	15.25	7.0	3.95	4.2	3.05	14.3	6.8	1.47	6.78
Caloglossa lepreurii	0.15	2.25	–	0.55	0.05	0.3	–	–	–	–	0.33
Bostrichia radicans	6.6	32.30	28.5	39.7	30.2	2.05	3.05	6.75	1.05	–	14.97
Catenella nipae	44.75	29.7	11.6	15.3	4.25	0.5	10.0	4.35	0.05	–	12.05
Cladophora	–	–	–	–	–	–	0.3	–	0.05	4.6	0.39
Colpomenia sp.	–	–	–	–	–	–	0.45	–	–	–	0.4
Dictyota dichotoma	–	–	0.16	–	0.5	–	–	–	–	–	0.06
Frequency of occurrence											
Rhizoclonium sp.	0.05	0.6	1.35	1.35	0.9	1.05	0.85	0.95	1.1	–	0.90
Caloglossa adnata	0.2	0.5	0.9	1.50	0.3	0.4	0.45	0.65	0.2	0.1	0.56
Caloglossa lepreurii	0.05	0.15	–	0.15	–	0.10	–	–	–	–	0.04
Bostrichia radicans	0.45	0.90	1.45	1.60	0.6	0.7	0.2	0.2	0.1	–	0.63
Catenella nipae	0.6	0.85	1.05	0.75	0.15	0.15	0.25	0.20	0.05	–	0.41
Cladophora	–	–	–	–	–	–	0.05	–	0.05	0.15	0.02
Colpomenia sp.	–	–	–	–	–	–	0.15	–	–	–	0.01
Dictyota dichotoma	–	–	0.05	–	0.05	–	–	–	–	–	0.01
Biomass (mg/cm^2)											
Rhizoclonium sp.	0.060	11.980	12.044	21.472	24.428	6.064	1.016	3.692	9.692	–	9.0448
Caloglossa adnata	0.780	2.484	3.968	2.376	0.936	1.316	1.400	4.736	1.516	1.928	2.1450
Caloglossa lepreurii	0.020	1.092	–	0.028	0.240	0.336	–	–	–	–	0.1716
Bostrichia radicans	0.900	5.128	7.100	7.032	5.028	1.036	0.732	1.640	0.104	–	2.8144
Catenella nipae	51.092	32.172	25.112	17.604	4.660	–	11.328	3.092	0.068	–	14.6583
Cladophora	–	–	–	–	–	–	–	–	–	–	–
Colpomenia sp.	–	–	–	–	–	–	0.240	–	–	–	0.0240
Dictyota dichotoma	–	–	0.180	–	0.440	–	–	–	–	–	0.0620

Results

The distribution of macroalgae along the transect varied in the three parameters investigated, *viz.*, frequency of occurrence, percentage cover and biomass. Changes in the parameters occurred gradually.

Macroalgae on pneumatophores: The most abundant alga on the pneumatophores was *Caloglossa lepreurii* with the highest frequency of occurrence and percentage cover (Table 1).

Catenella nipae, *Caloglossa lepreurii* and *Bostrichia radicans* were more abundant and frequent at the landward quadrats A, B and C. A11 these algae occurred in low frequencies on pneumatophores throughout the transect (Table 1).

Macroalgae on tree trunks: Macroalgae were found growing mostly below the 40 cm mark (Table 2 & Fig. 2) on tree trunks in the region just above the sediment surface. The most dominant macroalgae species on the lower tree trunks was *Rhizoclonium* sp., with the highest percentage cover and frequency of occurrence, while *Catenella nipae* had the highest biomass (Table 2).

Macroalgal distribution on the sediment surface: *Dictyota dichotoma* and *Rhizoclonium* sp. increased in abundance towards the landward section of the transect while *Colpomenia* sp. and

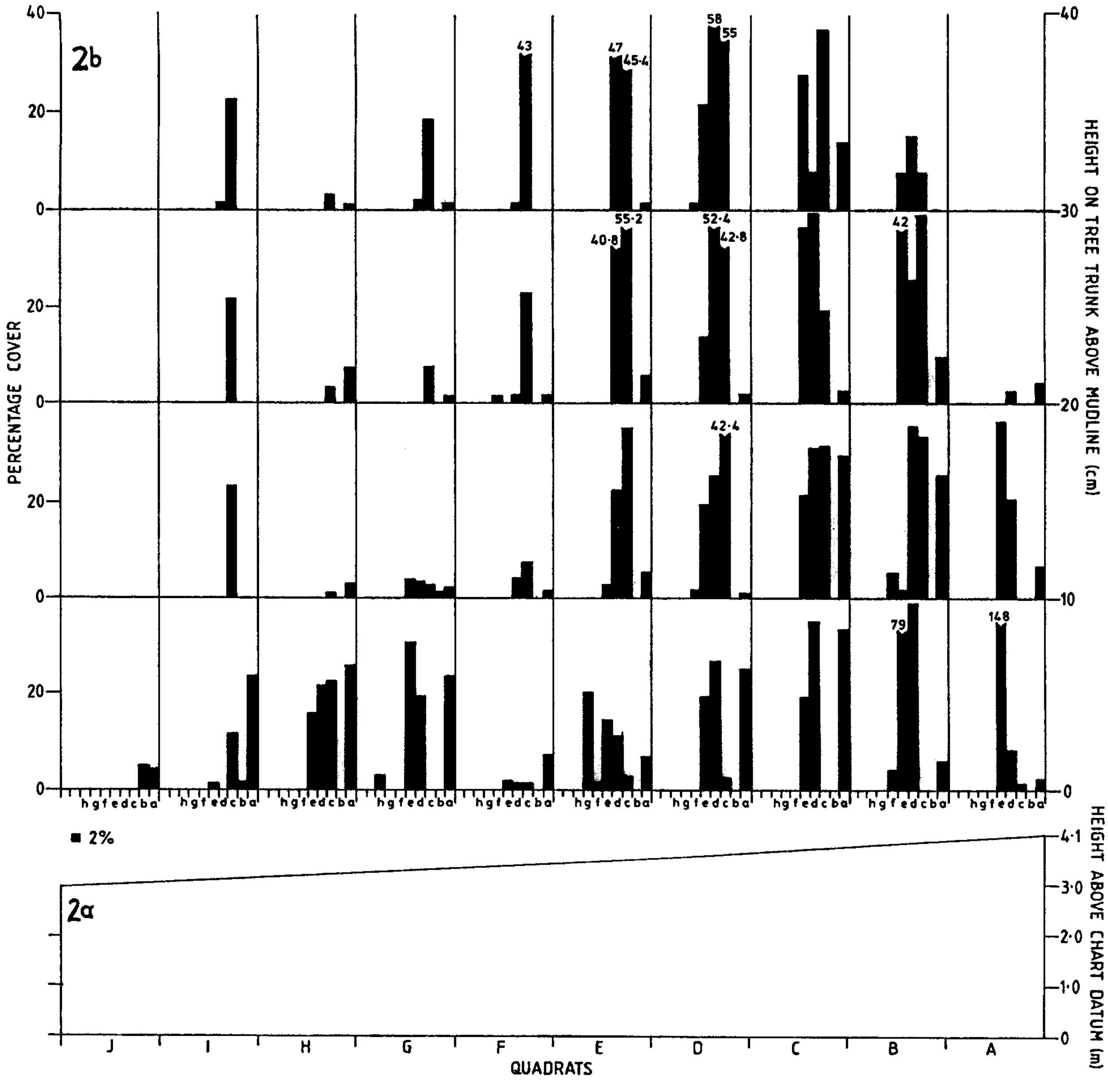

Fig. 2. (a) Diagram shows the percentage cover of macroalgae on the tree trunks upto a height of 40 cm above the sediment level along the 100–metre transect. Key for lowercase letters: a = *Caloglossa adnata*; b = *Cladophora* sp.; c = *Rhizoclonium* sp.; d = *Bostrichia radicans*; e = *Catenella nipae*; f = *Caloglossa lepreuii*; g = *Dictyota dichotoma*; h = *Colpomenia* sp. (b) Diagram indicates shore profile and location of belt transect sections A to J in relation to diagram (a).

Gracilaria blodgettii showed the opposite trend, increasing seawards (Table 3). This pattern was persistent for all the parameters measured. *Gracilaria crassa* was found only in tide pools at the edge of the forest, close to the mudflat.

Dictyota dichotoma, *Catenella nipae*, and *Gracilaria blodgettii* increased in biomass, cover and frequency of occurrence landwards while *Colpomenia* sp., *Gracilaria crassa* and *Gracilaria blodgettii*, however, showed a decrease in biomass, cover

Table 3. The percentage cover, frequency of occurrence and biomass of sediment macroalgae along the belt transect in the mangrove forest in Sementa, Selangor. Quadrat A is near the high shore.

Quadrat algae	A	B	C	D	E	F	G	H	I	J	Mean
Percentage cover											
Dictyota dichotoma	2.2	1.93	0.05	–	0.1	2.95	1.43	0.09	0.22	–	0.89
Rhizoclonium sp.	2.0	1.55	0.05	–	–	–	–	–	–	–	0.36
Gracilaria blodgettii	0.1	–	–	–	0.18	3.5	0.4	0.4	2.52	3.0	1.01
Gracilaria crassa	–	–	–	–	–	–	–	–	0.5	2.0	0.25
Colpomenia sp.	–	0.05	–	–	0.04	0.03	0.05	0.18	0.14	1.38	0.18
Bryopsis sp.	–	–	–	–	–	–	–	–	0.55	1.03	0.15
Frequency of occurrence											
Dictyota dichotoma	0.4	0.45	0.1	–	0.1	0.4	0.15	0.1	0.1	–	0.18
Rhizoclonium sp.	0.3	0.5	0.05	–	–	–	–	–	–	–	0.08
Gracilaria blodgettii	0.05	–	–	–	0.1	0.1	0.1	0.05	0.25	0.4	0.10
Gracilaria crassa	–	–	–	–	–	–	–	–	0.1	0.05	0.01
Colpomenia sp.	–	0.05	–	–	0.1	0.05	0.1	0.2	0.2	0.5	0.12
Bryopsis sp.											
Biomass (mg/cm^2)											
Dictyota dichotoma	0.1174	0.0644	0.0263	–	0.0015	0.1106	0.0265	0.0067	0.0137	–	0.0367
Rhizoclonium sp.	0.0689	0.3051	0.0074	–	–	–	–	–	–	–	0.0381
Gracilaria blodgettii	0.0133	–	–	–	0.0016	0.6236	0.0427	0.0061	0.2355	9.2526	1.0165
Gracilaria crassa	–	–	–	–	–	0.0108	–	–	0.0809	12.7657	1.2857
Colpomenia sp.	–	0.0041	–	–	0.0017	0.0054	0.0062	0.0025	0.0015	0.1957	0.0217
Bryopsis sp.	–	–	–	–	–	–	–	–	0.1371	9.0145	0.9151

and frequency landwards. No sediment macroalgae was found on the sediment in quadrat D which appeared to be the boundary where seaward dominant algae increased in abundance and landward dominant algae began to decline (Table 3).

Discussion and conclusion

Algal dominance in the mangrove forest was related to their substratum. Algal communities on trees are subjected to less tidal inundation compared to those on sediment. The morphological structure of the substratum would also affect macroalgal growth. Macroalgae communities on pneumatophores were similar to those on tree trunks. Similar substratum promoted the growth of similar macroalgae. Macroalgae on the sediment, however, grow on the mud substrate where their rhizoids are not easily dislodged by the mild wave action typical of the mangrove shore.

Macroalgae do not only compete amongst themselves for space, but also with barnacles. Barnacles attach to almost any firm structure within reach of tidal waters. Some algal species such as *Rhizoclonium sp.* are capable of growing among barnacles while other such as *Colpomenia sp.* and *Dictyota dichotoma* are unable to do so. Fewer algal species were found on *Sonneratia* trunks and pneumatophores as their bark peeled off easily.

The difference in tidal cover at both the ends of the transects caused variations in algal dominance. Sea front quadrats, J and I seemed to have promoted macroalgal growth which required frequent tidal cover, presence of tidal pools and gullies. Landward fringe quadrats on the other hand, supported algal species that are probably more adapted to withstand desiccation. They probably tolerate lower salinities as frequent rains affected the landward edge of the transect. *Bostrichia radicans* and *Rhizoclonium sp.* were common species landwardly as they have resilient cell-walls which prevent desiccation (Chapman, 1973). The mid quadrats of the transect supported more species compared with those quadrats on landward and seaward portions of the transect (Fig. 2a). Thus, it appears changes in the surrounding environment and the morphological structure of macroalgae determine the community structure. Macroalgae are ubiquitous in the mangrove environment and are important as food for deposit feeders and grazers.

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