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Profiles of Species Composition and Aboveground Biomass in a Mangrove Forest, Matang, Peninsular Malaysia

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Abstract

To analyze the sustainability and carrying capacity of a mangrove forest, we studied the profiles of species composition and biomass from the riverside to inland. A belt transect (25× 180 m) divided into 9 plots was established in compartment 46, in the Matang Mangrove Forest Reserve, Perak, Peninsular Malaysia. Five tree species were distributed in the transect. *Rhizophora apiculata* showed the highest density, followed by *Bruguiera parviflora, B. sexangula, R. mucronata* and *Avicenia alba*. From the riverside to inland, the structure changed from pure R. apiculata stands to mixed Rhizophora-Bruguiera stands. The mean aboveground biomass of all the plots was 316 Mg ha^{-1}. The largest and smallest volumes for biomass were 558 Mg ha-1 on the riverside and 144 Mg ha^{-1} inland, respectively. The values tended to be higher in *R. apiculata-dominant* stands. If a larger productive area could be set up where R. apiculata would predominate, i. e. an area at a lower ground level, a larger sustainable amount of biomass for firewood and charcoal use could be produced. The annual dead biomass, which is supplied to the forest floor as nutrients for aquatic life, was 5.1 Mg ha-1. While stocked biomass is more valuable to a local economy than the dead biomass, the contribution of the fallen trees (dead biomass) to habitats and nutrients for aquatic life must be evaluated exactly in the future.

Discipline: Forestry and forest products
Additional key words: *Rhizophara, Bruguiera*, brackish water, sustainable management

Introduction

The Matang mangrove forest in Perak, Peninsular Malaysia covers a land area of approximately 40,711 ha[1,3]. The productive forest accounts for 85% of the area and has been appropriately managed under a working plan since the beginning of the 19th century. Moderate harvesting of firewood and wood for charcoal has supported the livelihood of the local people working in forestry. Meanwhile, the floor of mangrove forests and surrounding brackish water areas have supplied habitats enabling aquatic animals, i.e. crabs, shrimps and fish, to grow and breed. In other words, the people engaged in fisheries harvest the benefits of the forest.

The brackish water mangrove project has been carried out jointly by Japan International Research Center for Agricultural Sciences, Fisheries Research Institute, University of Malaya and Forest Research Institute of Malaysia for 5 years (FY 1995–1999). It aimed at obtaining new findings and information to analyze the sustainability and carrying capacity of the mangrove ecosystems. Under the project, the forest biomass stocked as living trees (wood resources), and released as litter (nutrients for aquatic life) was analyzed. The aboveground biomass had been estimated for several forests of the same species[4,5,9]. However, the differences among micro-sites and the total amount of litter (biomass of dead trees) are still unknown. In this study, we report the changes in species composition and aboveground bio-

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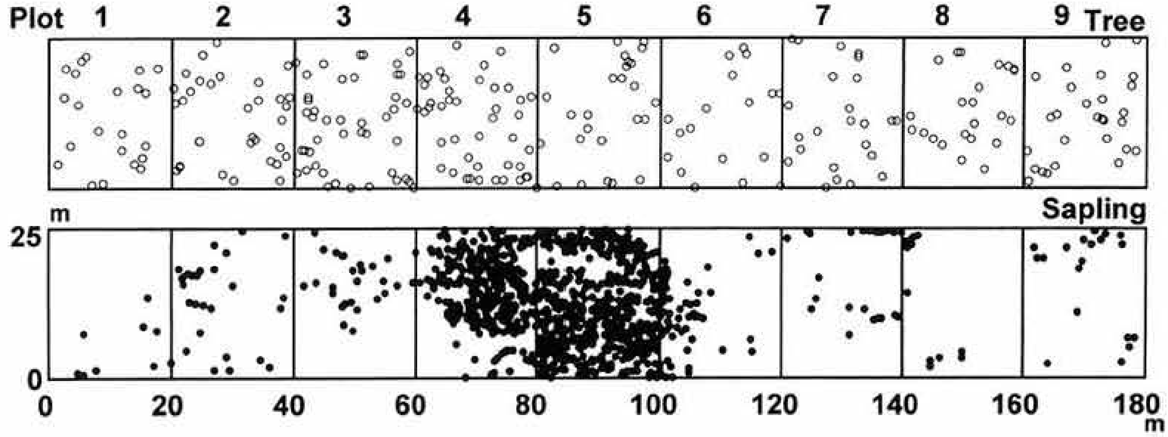

Fig. 1 Spatial distribution of trees (upper) and saplings (lower) in a belt transect (Compartment 46, Matang mangrove forest)

Plots numbered 1 to 9 are located on a transect extending from the riverside to inland.

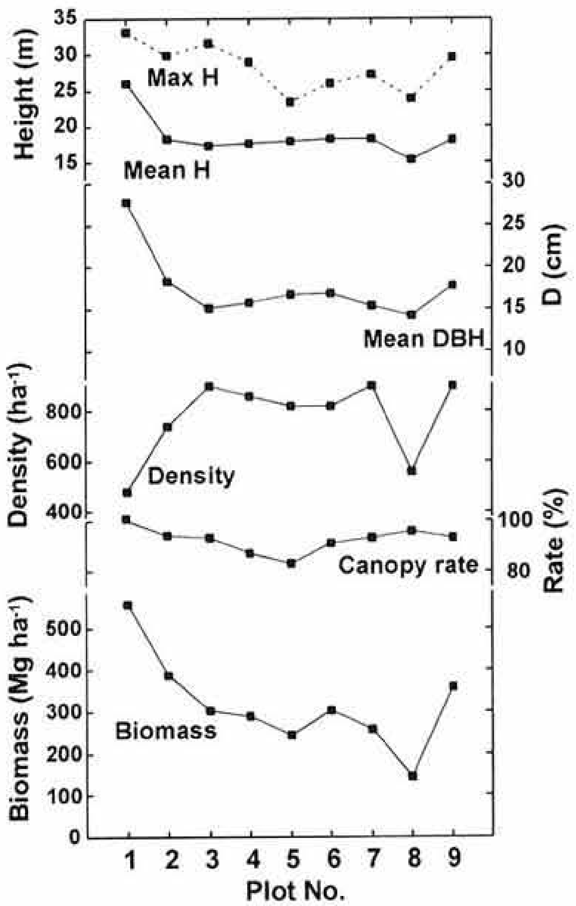

Fig. 2 Changes in values of trees along a transect from Plot 1 (riverside) to Plot 9 (inland), Matang mangrove forest

Each point shows the value calculated for trees (DBH ≧ 5 cm).

Canopy rate = 100 (plot area, %) – gap area (%).

mass from the riverside to inland and the dead biomass in a typical natural forest dominated by *Rhizophora* and *Bruguiera* species.

Methods

The experimental site established in compartment 46, Matang, Perak, Peninsular Malaysia (4°47'52"N, 100°38'49"E), consists of a belt transect extending from the riverside to inland with a size of 25×180 m. The transect was divided into 9 plots (25×20 m each), Plots 1–9, starting from the riverside. The edge of Plot 1 was separated by a distance of about 10 m from the riverside. The arrangement of the plots was described in previous reports[6,7].

For all the live trees more than 1.2 m in height, we measured the diameter of the stem at the 1.2 m height (D), as well as the height (H) and determined the location. When the position of the highest prop root was higher than 1.2 m, we measured D at 20 cm above the prop root. In this study, trees corresponded to a stem with $D \geq 5$ cm and saplings to a stem with $H \geq 1.2$ m and $D < 5$ cm. Gap was defined as the area under a canopy opening, which is equivalent to the canopy gap defined by Runkle[10]. Location and area of the gap were also determined. The dead trees of 1 year were recorded in the following year.

The volume of each tree ($D^2 \times H$) was used to calculate the biomass (dry matter weight of aboveground organs). To estimate the biomass, we used the coefficients of allometric equations of Kusmara et al.[5].

Results

Five species were recorded in the transect. *Rhizophora apiculata* showed the highest density, followed by *Bruguiera parviflora*, *B. sexangula*, *R. mucronata* and *Avicenia alba*. While the trees showed a random distribution in space, the saplings showed a contiguous distribution (Fig. 1). Gaps existed in all the plots except in Plot 1, but the larger ones were concentrated in Plots 4, 5 and 6.

Some values among the plots showed distinct differences (Fig. 2). The maximum H of trees ranged from 33.2 m (Plot 1) to 23.4 m (Plot 5). Although the mean H of trees was similar among the 7 plots, the values in Plot 1 (26.0 m) and Plot 8 (15.3 m) were considerably higher and lower than those in the other plots, respectively. The mean D values in Plots 1 and 8 were largest (27.8 cm) and smallest (14.2 cm), respectively among the plots. The smaller the values of H and D, the higher the density. The canopy rate, which is defined as the plot area (100%) minus gap area (%), ranged from 100% in Plot 1 to 83% in Plot 5. The largest and smallest values for biomass were 558 Mg ha^{-1} in Plot 1 and 144 Mg ha^{-1} in Plot 8, respectively. The mean biomass of all the plots was 316 Mg ha^{-1}.

The tree species showed some features in their height distribution, i.e. the structural profile along the transect (Figs. 3 and 4). For trees, there were 4 species which differed in their distribution and density. *R. apiculata* formed a canopy in all the plots, and it was the most abundant species in each plot except in Plot 8; in particular, it occurred in the canopy layer contiguously in Plot 1. *B. parviflora* was distributed in most plots, except in Plots 1 and 6, and was mainly observed in the sub- or under-canopy layer. *B. sexangula* formed the canopy in Plots 5, 8 and 9. *R. mucronata* was found only in the canopy layer of Plot 9.

There were 4 species of saplings (Figs. 3 and 4). *B. parviflora* was the most abundant species and was distributed contiguously in Plots 4 and 5, followed by *B.*

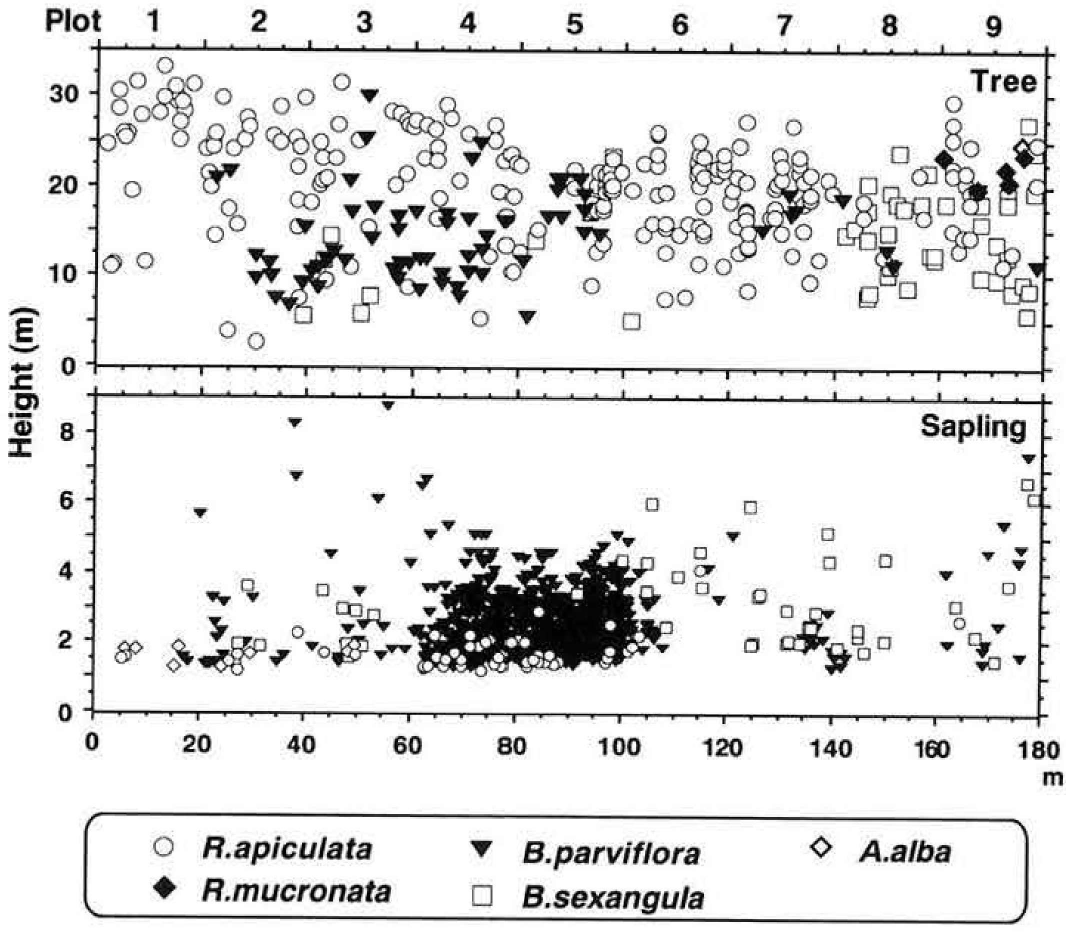

Fig. 3. Height distribution of trees and saplings along a transect (20×180 m) from Plot 1 (riverside) to Plot 9 (inland), Matang mangrove forest

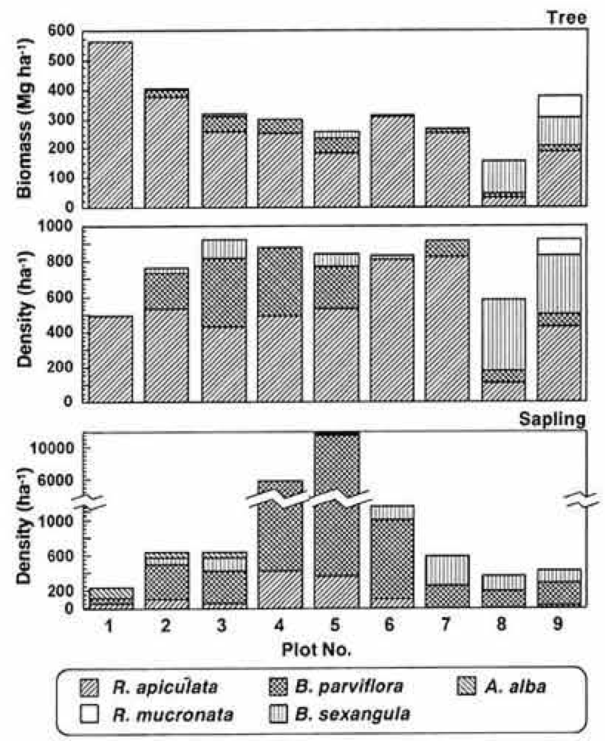

Fig. 4. Profile of biomass and density along a transect from Plot 1 (riverside) to Plot 9 (inland), Matang mangrove forest

sexangula which was distributed from Plots 2 to 9. *R. apiculata* was observed in the lower layer at around 1.2 to 3.0 m and was concentrated in Plots 4 and 5. No *R. mucronata* saplings were detected in the transects, and in the case of *A. alba*, there were no trees but saplings in the lower height layer.

Table 1. Aboveground biomass and biomass supplied as debris in each plot

Plot	Aboveground biomass (Mg ha^{-1})	Supplied biomass (Mg ha^{-1} yr^{-1})*	Ratio (%)
1	557.8	0.0	0.0
2	387.8	1.2	0.3
3	302.4	15.2	5.0
4	289.0	4.2	1.5
5	244.4	15.4	6.3
6	301.8	0.0	0.0
7	257.4	4.8	1.9
8	143.9	5.0	3.5
9	359.1	0.0	0.0
Mean	315.9	5.1	1.6

* Value refers to dead aboveground biomass in a year.

R. apiculata accounted for 83% of the total aboveground biomass, followed by *B. sexangula*, *B. parviflora* and *R. mucronata* with 8, 6 and 3% of the total, respectively. Percentages of tree density for *R. apiculata*, *B. sexangula*, *B. parviflora* and *R. mucronata* were 65, 14, 20, 1%, respectively. *R. apiculata* accounted for a larger biomass rate than the density rate in most plots, except in Plots 8 and 9 (Fig. 4). The profiles of densities of saplings showed different patterns compared with trees (Figs. 3 and 4). The densities were extremely high in Plots 4 and 5, and the composition rate of the species was different. For *R. apiculata* the density of saplings was lower than the density of trees, and the value was lower in plots where the species was predominant in terms of tree biomass and density, e.g. Plots 1, 2 and 6. Conversely in the case of *B. parviflora* the tree biomass and density were not the highest in all the plots, but the density of the saplings was predominant in most plots.

The mean value of aboveground biomass that produces debris (large litter) on the forest floor in a year was 5.1 Mg ha^{-1} (Table 1). The biomass corresponded to the dry weight of the trees which had died in a year. The values ranged from 0 to 15.4 Mg ha^{-1} among the plots and the rates to the living biomass were 0 to 6.3%.

Discussion

The study plots in the transect appeared to reflect the structure of the Matang forest reserve. The forest is widely dominated by *R. apiculata* associated with *R. mucronata*, *B. parviflora* and *B. sexangula*[3]. *R. apiculata* was distributed and formed a canopy layer all over the transect (Figs. 3 and 4). *R. apiculata* trees were the only trees in some plots, and they tended to grow taller with a large biomass near the riverside. Nakamura et al.[6] reported that *R. apiculata* showed a unimodal D distribution in Plot 1 in the area closest to the riverside. Moreover, the density of individuals in the understory and the sapling layer was low and the mortality of the seedlings (H < 1.2 m) was higher than in the other species. Therefore, they suggested that *B. sexangula* and *B. parviflora* that occurred as saplings and seedlings with a lower mortality might replace *R. apiculata*. Other plots also showed this tendency. The seedling density of *R. apiculata* was higher than that of *B. sexangula* and *B. parviflora* in Plot 1[6]. Moreover, the ratios of *R. apiculata* and 2 *Bruguiera* species showed an opposite trend for the values on the riverside (Plot 1) and inland (Plot 9). For *R. apiculata,* the riverside is a suitable site for seedling establishment, but not for growth and survival. In any case, in all tree species, the seedlings can not survive under closed canopy[6]. Therefore, in Plot 1 with a 100%

canopy rate (see Fig. 3) light conditions are unfavorable for recruiting the seedlings to the sapling stage, suggesting that light rather than topographical factors affects the recruitment.

The profile of the species composition from the riverside to inland showed species-specific changes (Figs. 3 and 4). While the *R. apiculata* biomass largely predominated on the riverside, mixed stands with 3 to 4 species were observed inland. The fact that the density rates of *B. parviflora* and *B. sexangula* for trees, and especially for saplings, were higher inland suggests that forests change to a *Bruguiera* spp. forest with increasing distance from inland. Fujimoto et al.[2] also indicated a similar change in profile in Japan: *Rhizophora* species became predominant with decreasing ground level toward the seaside. A *Rhizophora–Bruguiera* mixed forest was established at higher ground level (inland). Haron Abu Hassan[3] reported that *Rhizophora* and *Bruguiera* species were the major trees and shared the main habitat in the Matang mangrove forest. Therefore, it is important to analyze the dynamics and biomass of the 2 genera to determine the sustainability and carrying capacity of the forest.

The total biomass at the study site was 316 Mg ha^{-1} (Table 1), a value lower than that in the protected stands with a mean of 409 Mg ha^{-1} in Matang[9] and showed comparable values to those of *R. apiculata* forests in Indonesia (356 Mg ha^{-1})[4]. Kusmana et al.[5] pointed out that a large biomass of more than 200 Mg ha^{-1} is produced in an area where the annual temperature and precipitation exceed 25°C and 2,000 mm, respectively. The Malay Peninsula where the study area is located is under such climatic conditions. Moreover, the lack of wind disturbance mainly associated with typhoons contributes to the growth of taller trees[9], and consequently higher trees produce a large biomass[11]. In this study, pure stand of *R. apiculata* (Plot 1) had a large biomass with a value (dry matter, 558 Mg ha^{-1}) presumably higher than the biomass values reported in the literature. Sites with an extremely high or low biomass occur patchily in natural forests. Most of the pure stands of *R. apiculata* (Plots 1, 2 and 7, Figs. 2 and 3) display a larger biomass than the stands where *Rhizophora* and *Bruguiera* species grow together. Wood of *Rhizophora* species has a higher quality as fuel compared with that of *Bruguiera* species[3]. For the production of larger amounts of sustainable biomass for firewood and charcoal, it is important to secure a larger productive area where *R. apiculata* can predominate easily, i.e. areas at a lower ground level.

The annual dead biomass, which is supplied to the forest floor as nutrients for aquatic life, amounted to 5.1 Mg ha^{-1}. However, since this value was only recorded for 1 year and there are no other reports on dead biomass, further studies should be carried out. The balance between dead and growth mass in a year is 0 in a well-matured forest. Based on the biomass in a stand whose age was recorded exactly in Malaysia, the annual growth was 7.9 Mg ha^{-1}[8]. Although we can not simply compare the value[8] with the dead mass in our stands, the forest under study must be still growing and preserving organic matter as live biomass. Moreover, it remains to be determined when the respective organs (leaf, branch and stem) fall to the floor after dying. It will be necessary to clarify the process whereby dead standing trees produce debris to determine the effect of fallen trees (dead biomass) on habitats and nutrients for aquatic life.

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