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PLANT DIVERSITY AND BIOMASS OF MARUDU BAY MANGROVES IN MALAYSIA

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Abstract

The mangroves of Marudu Bay in the state of Sabah is situated at the tip of Borneo Island, and at the southern limit of the Coral Triangle whose waters hold the highest diversity of corals, fish, molluscks, crustaceans and marine plant species in the world. The ecosystem shows a deterioration due to unsustainable fishing, pollution and encroachment, and these are impacting the Marudu Bay coastal communities economically. Fishing is the major economic activity here. Realising the importance of conserving the mangroves to uplift the socio-economic livelihood of the coastal community, a resource inventory of the mangroves and its productivity study were carried out. A total of 16 plant species in 12 genera and 9 families were identified. It was also found that 0.7 ha is capable of capturing all the species in the mangrove forest. The mangrove forests of Marudu Bay are dominated by *Rhizopora apiculata* and *R.mucronata*. The highest Importance Value index (IVI) was given by *Rhizophora mucronata*. Total Above Ground Biomass (TAGB) for 1^{-ha} of mangrove forest in Marudu Bay was estimated to be 98.4 t/ha. It was found in other parallel studies that the mangroves of Marudu Bay are productive ecosystems that provide valuable habitats, nurseries and spawning grounds for various commercially important species of fish and invertebrates such as shrimp besides many species of wildlife. The mangroves at Marudu Bay are not only aesthetically attractive but provide opportunities for ecotourism activities that can be undertaken by the local community inhabiting the area to uplift their meagre income, These activities include mangrove cruising, recreational fishing, educational tourism and mangrove honey production, amongst others. This way, the degradation of the mangrove in Marudu Bay can be halted and reversed.

Introduction

The largest mangrove area in the world is in Southeast Asia with 6.8 million hectares. The largest areas of mangrove are found in Indonesia, Malaysia, Myanmar, Papua New Guinea and Thailand, respectively. Mangrove forest is one of sixteen forest types found in Malaysia. Malaysia harbours approximately 12% of Southeast Asia's mangrove area and occurs mainly along the coasts of Sabah (57%), Sarawak (26%) and Peninsular Malaysia (17%). Marudu Bay and the northeast coast of Sabah, contain significant global biodiversity. The area constitutes Malaysia's second biggest concentration of coral reefs and hosts other significant habitats such as nationally rare sea grass beds and extensive mangrove forests with a large component of *Rhizophora* species. Mangroves occur both in estuaries and along open coastlines in Marudu Bay covering Kudat, Kota Marudu and Pitas dictricts. Kota Marudu has approximately 9550 ha of mangroves. The fisheries sector is an important source of employment for the local people at Kota Marudu. They are very dependent on the fisheries sector and the mangrove forest as a source of food, shelter and others.

Mangroves are highly productive ecosystems that provide valuable habitat for fish and shorebirds. Mangroves support the conservation of biological diversity by providing habitats, spawning grounds, nurseries and nutrients for a number of animals. A wide range of commercial and non–commercial fish and shellfish also depends on these coastal forests. The role of mangroves in the marine food chain is crucial. According to Kaspetsky (1985), the average yield of fish and shellfish in mangrove areas is about 90 kg per hectare, with a maximum yield of up to 225 kg per hectare. Fish in Malaysia is an important source of protein. When mangrove forests are destroyed, a decline in local fish catches often results. This can affect the needs of the local community. Fishing is the major economic activity here. Realising the importance of conserving the mangroves to uplift the socio-economic livelihood of the coastal community, a multidisciplinary study was undertaken through a top-down Ministry of Science and Innovation funding since 2009. This paper describes the Kota Marudu mangrove plant diversity and forest productivity, commonly measured in terms of biomass. It will form the basis for discussion of other parallel studies conducted together in this area especially on fish, other fauna and economic valuation of both tangible and intangible benefits of the Marudu Bay mangroves, to be dealt with in other papers.

Methodology: This study was conducted in Kota Marudu Mangrove Forest in Marudu Bay, Sabah. The district of Kota Marudu has an area of 1,917 Km^2 and located between the latitude of 6° 15" to 6° 45" N and the longitude of 116° to 117° E. Five rivers were selected for the establishment of the study plots viz: Bandau River, Bungon River, Sepitan River, Petogor River and Tandek River. One hundred (100) sample plots of size 10m x 10m totalling 1-hectare were established along the transect lines of the identified rivers at a distance of 100-250 metres between them. Only trees in the plot with diameter at breast height (dbh) > 1-cm and above were enumerated, measured and identified.

Important Value Index (IVI) which indicates the structural importance of a species within a stand of mixed species were as follows: IVI = RD + RF + RDo, where:

$$\text{RD (relative density)} = \frac{\text{No. of individuals of a species}}{\text{Total no. of individuals of all species}} \times 100$$

$$\text{RDo (relative dominance)} = \frac{\text{Total basal area of a species}}{\text{Basal area of all species}} \times 100$$

$$\text{RF (relative frequency)} = \frac{\text{Frequency of species}}{\text{Total frequency of all species in different plots}} \times 100$$

The volume of each tree (D^2xH) was used to calculate the biomass (dry matter weight of above-ground organs). To estimate the biomass, the following coefficients of allometric equations of Kusmana *et al*., (1992) were used: $Wx = b\ (D^2H)^a$**,** where Wx is the dry weight of the compartment x (x is s for stem, b for branches, I for leaves, f for flowers and fruits, and pr for prop-roots) while Wx indicates leaf area when Wx is LA and stem volume when Wx is Vs; D diameter at breast-height (DBH), H is total length of the tree stem above ground level; and a and b are constants.

Results and Discussion

Plant composition: The mangroves of Kota Marudu can be grouped into well marked communities which are nipah, bakau/bangkita, nipah mixed, other mixed species, non-commercial, transitional forest and beach forest (Fig. 1). Bakau/bangkita dominates more than 40% of the mangrove area, followed by other mixed species (19%) and nipah (8%). The remaining one-third of the mangrove area has been converted to other land uses such as rubber and oil palm (Fig. 2).

Mangroves can be divided into two groups: exclusive and non-exclusive. Exclusive mangroves are confined to intertidal areas and non-exclusive mangroves are not restricted to the typical mangrove environment but also found within drier areas in Kota Marudu (Fig. 2). The exclusive zone is dominated by *Rhizophora apiculata* and *R. mucronata.* Among the species that dominate the non-exclusive zone are *Bruguiera parviflora* and *Ceriops decandra*. Mangroves in Southeast Asia are the most diverse in the world with a total of 268 plant taxa that covers various habits which are trees, shrubs, herbs, climbers and epiphytes of these, 52 species are confined to the mangrove habitat only. In many mangroves, different species dominate certain zones.

Genera such as *Avicennia* and *Sonneratia* which are regarded as light demanding taxa are found in more exposed areas while *Rhizophora* spp. (*above*) are found in deep muddy areas. Species of *Rhizophora* are the primary mangrove colonist here. In Kota Marudu mangroves, there are 16 species in 12 genera and 9 families in 1^{-ha} ($\geq$1 cm dbh) (Table 1). The largest family is represented by Rhizophoraceae with five species which are *Rhizophora apiculata, R. mucronata, Bruguiera parviflora, B. gymnorrhiza* and *Ceriops decandra.* The diversity of the mangrove forest in Kota Marudu is lower when compared to the Matang Mangrove Forest in Peninsular Malaysia with 28 species in 15 genera and 12 families. According to Anon., (2007), there are 41 plant species from the mangrove forests throughout Malaysia.

Factors that may influence the distribution of mangrove species include the response to tides and frequency of inundation, soil type, drainage, age and degree of exposure. Within these communities are either extensive stands of mangrove species or many pockets of mixed species. The mix of species is also partly determined by the physiological tolerances of individual species to physical conditions such as like tidal inundation and high salinity, but may also be influenced by other factors such as predation of plant seedlings.

Table 1. Plant composition in 1^{-ha} Marudu Bay mangrove forest.

No.	Family	Species	Vernacular name
1.	Avicenniaceae	*Avicennia alba*	Api-api putih
2.	Avicenniaceae	*Avicennia marina*	Api-api jambu
3.	Rhizophoraceae	*Bruguiera gymnorrhiza*	Tumu
4.	Rhizophoraceae	*Bruguiera parviflora*	Lenggadai
5.	Rhizophoraceae	*Ceriops decandra*	Tengar
6.	Euphorbiaceae	*Excoecaria agallocha*	Bebuta
7.	Sterculiaceae	*Heritiera littoralis*	Dungun
8.	Leguminosae	*Intsia bijuga*	Merbau Ipil
9.	Rhizophoraceae	*Rhizophora apiculata*	Bakau minyak
10.	Rhizophoraceae	*Rhizophora mucronata*	Bakau kurap
11.	Sonneratiaceae	*Sonneratia alba*	Perepat
12.	Meliaceae	*Xylocarpus granatum*	Nyireh Bunga
13.	Meliaceae	*Xylocarpus malaccensis*	Nyireh Batu
14.	Pteridaceae	*Acrostichum speciosum* *	Piai lasa
15.	Pteridaceae	*Acanthus ilicifolius* *	Jeruju Putih
16.	Palmae	*Nypa fructicans* *	Nipah

* Not included for analyses of stand density, basal area, IVI and biomass estimation

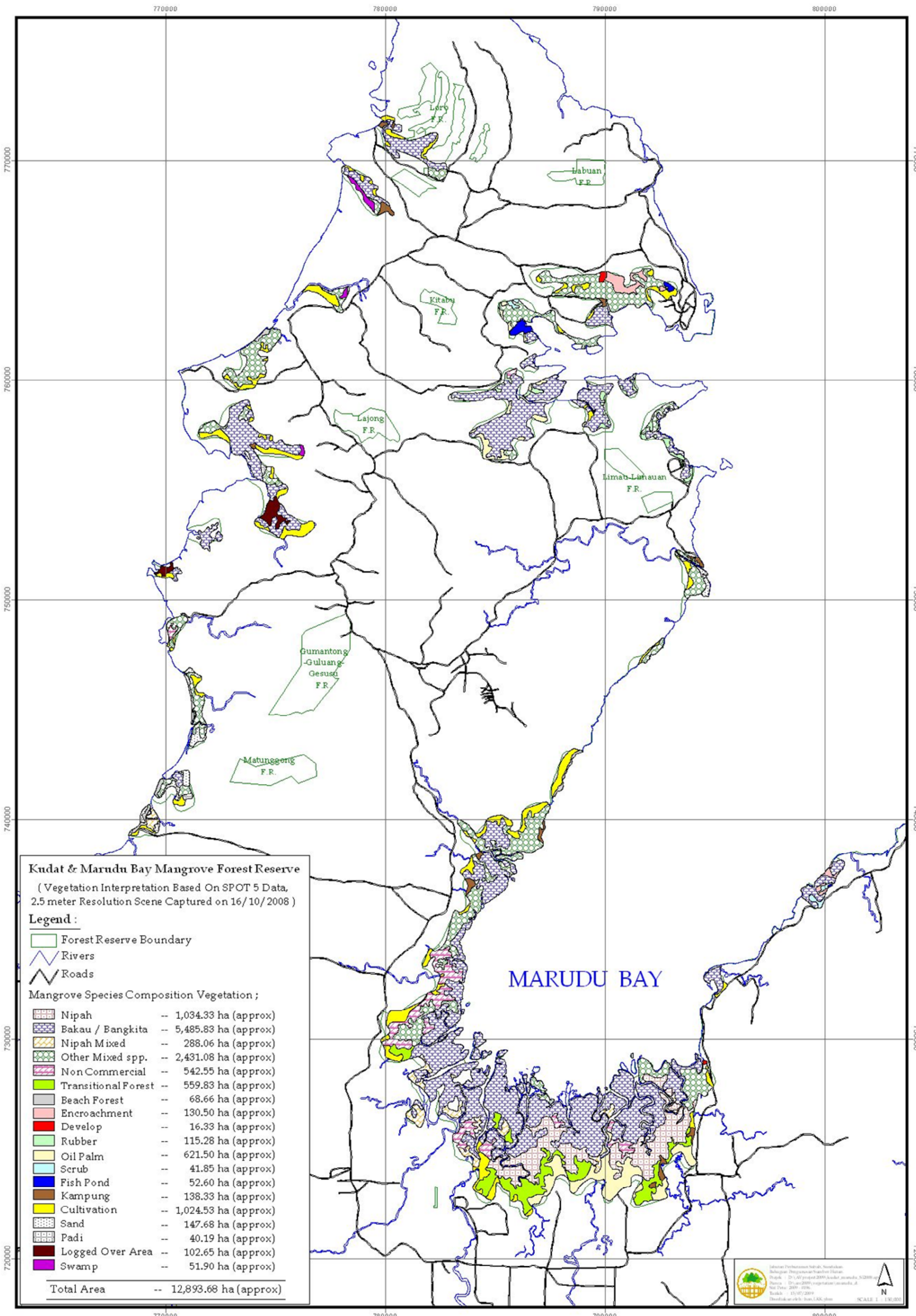

Fig. 1. Mangrove communities in Marudu Bay.

Exclusive and non-exclusive areas in mangrove forests, Marudu, Sabah

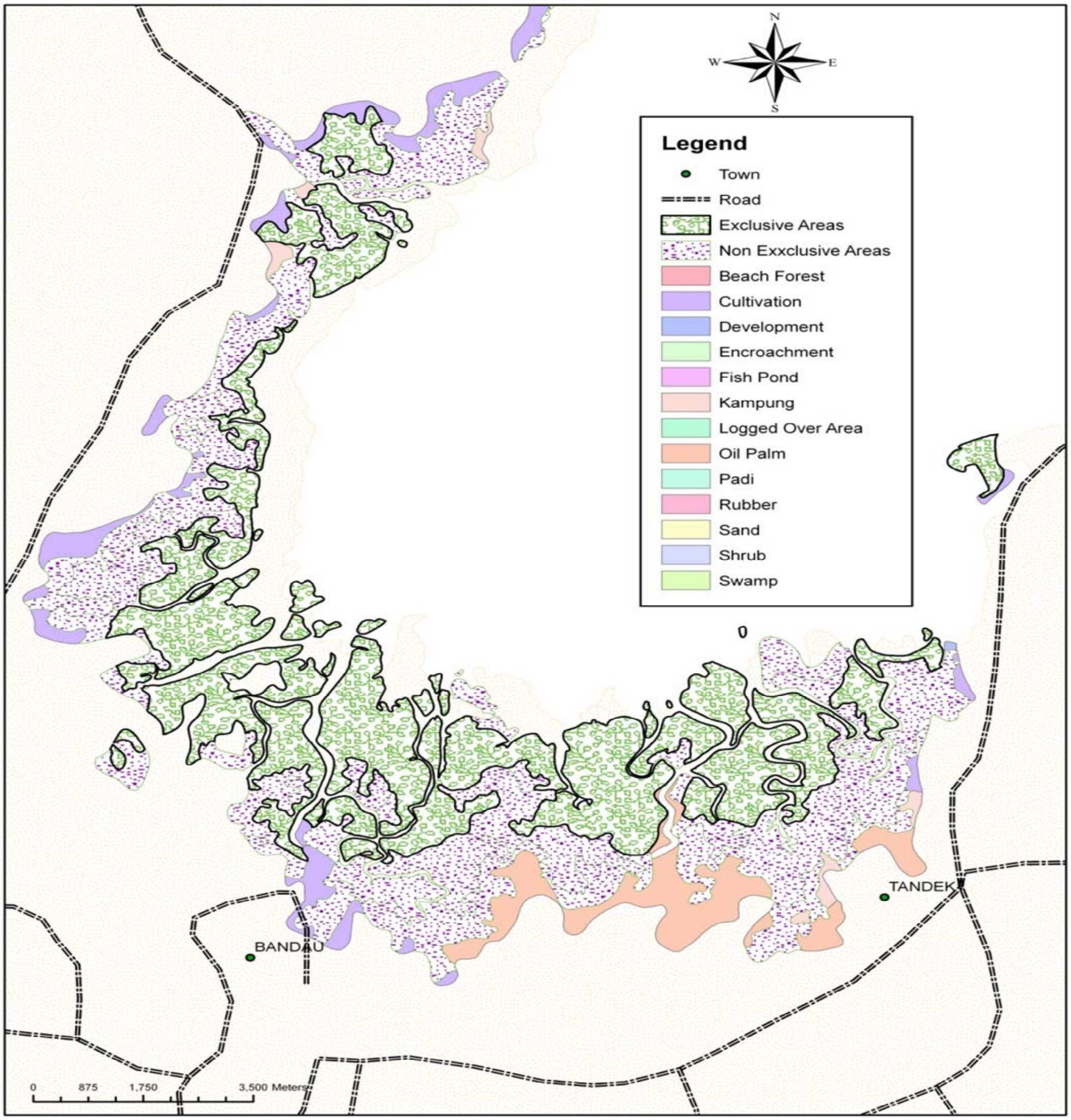

Fig. 2. Zonation of mangrove based on exclusiveness and non-exclusiveness.

Table 2 shows the stand density was 2368 trees/ ha. *Rhizophora apiculata* contributed 32% of the total number of trees but smaller in basal area (5.4 m^2/ ha) than *R. mucronata* (8.2m^2/ha).

Table 3 shows the summary of Important Value Index (IVI) by species in the plot. Although the density of *R. mucronata* was lower than *R. apiculata*, the basal area of the former species was larger than *R. apiculata* which contributed to the highest IVI (Important Value Index). Importance value index (IVI) is the sum of relative abundance, relative dominance and relative frequency attributable to each species for which data were obtained in a study plot. It 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 asymptote for the species accumulation curve in this study has yet to be reached (Fig. 3). However at the 17^{th} plot (0.7 ha), the graph has started to level off and it was not until the 25^{th} plot (1 ha) that the graph showed an increment of one species only. The increment of one species is probably not worthwhile to consider increasing the sampling area when taken into account the time and cost for the establishment of the additional subplots (0.3 ha). Roberts-Pichette and Gillespie (2001) stated that sampling is sufficient when no or very few species are added with each successive quadrat that is sometime after the curve starts to flatten. Seaby & Henderson (2007) also stated that when a species accumulation curve approaches an asymptote, it shows that sampling is adequate to collect most of the species present; the asymptotic value is a measure of the total species complement. It is thus assumed here that 0.7 ha is capable of capturing all the species in the mangrove forest at Marudu Bay. If sampling effort increases, more of the species found in a habitat can be captured until eventually only the rarest species or occasional ones remain unrecorded, thus additional effort will not increase the number of species recorded.

Table 2. Stand density in 1^{-ha} plot.

Species	Stand density (no. stems/ha)	Percentage (%)
Rhizophora apiculata	757	32
Rhizophora mucronata	511	22
Xylocarpus granatum	449	19
Bruguiera parviflora	348	14
Avicennia alba	175	7
Ceriops decandra	84	4
Heritiera littoralis	13	0.5
Sonneratia alba	11	0.5
Avicennia marina	10	0.5
Excoecaria agallocha	7	0.5
Bruguiera gymnorrhiza	1	0.5
Intsia bijuga	1	0.5
Xylocarpus malaccensis	1	0.5
	2368	**100**

Table 3. Summary of IVI by species in 1^{-ha} plot.

Species	IVI
Rhizophora mucronata	82.25
Rhizophora apiculata	75.08
Xylocarpus granatum	43.22
Bruguiera parviflora	41.08
Avicennia alba	25.69
Ceriops decandra	18.32
Sonneratia alba	4.43
Excoecaria agallocha	2.63
Heritiera littoralis	2.53
Avicennia marina	1.76
Xylocarpus malaccensis	1.02
Intsia bijuga	1.00
Bruguiera gymnorrhiza	1.00

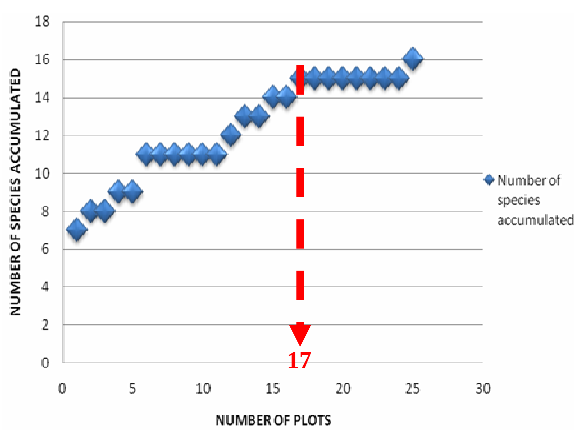

Fig. 3. Species accumulation curve of a mangrove forest at Marudu Bay, Sabah.

Figure 4 shows the distribution of diameter class. From the total number of trees found in 1^{-ha}, 97% was represented by trees less than 30 cm diameter at breast height (dbh) and the remaining 3% was from the dbh class greater than 30 cm. The distribution of trees by diameter class follows the Reverse-J curve. It shows the number of larger trees decreasing in number with larger diameter class. Reverse-J pattern of this area is said to be similar to the pattern of inland forest. This happens because the growth rate of seedlings and juvenile trees is higher than matured trees (Hitimana *et al*., 2004). According to Hitimana *et al*., (2004), mixed uneven-aged tropical rain forests have diameter distributions representing all age classes in typical reverse-J shaped curve. This model, however, can be modified by some environmental factors such as tree cutting, competition for resources between species or between mother trees and seedlings, regeneration patterns, differences in topography or soils, irregular or seasonal climatic events (Brunig, 1983; Denslow, 1995). Hence, diameter distributions are often used to assess the disturbance effect within forests (Hett & Loucks, 1976; Davis & Johnson, 1987; Denslow, 1995) and to detect trends in regeneration patterns (Poorter *et al*., 1996). Tree density distribution across different diameter classes also shows how well the growing forest is utilizing the site resources.

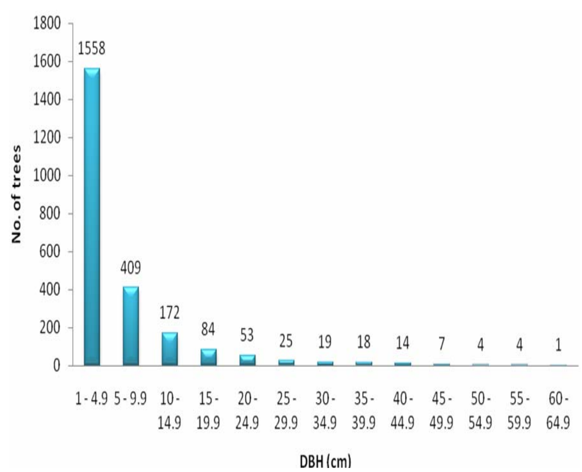

Fig. 4. Number of trees by diameter class (dbh) of 1^{-ha} of Marudu Bay mangrove forest, Sabah.

Biomass estimation: Total above ground biomass (TAGB) for 1^{-ha} of mangrove forest in Marudu Bay was estimated to be 98.4 t/ha. The highest biomass was given by *Rhizophora mucronata* which was ca. 50% TAGB; its basal area was higher than other species (Table 4). According to Suzuki & Tagawa (1983), TAGB is greatly affected by density, basal area, and height. The TAGB value of Marudu Bay is almost the same as several other mangrove forest in Nagura estuary - Ishigaki Island, Southern Japan (94.8 t/ha) and Talidendang Besar, Riau, East Sumatra (94.98 t/ha). TAGB at Marudu Bay was, however, lower than Matang mangrove forest in Peninsular Malaysia which was about 150 t/ha (Ong, 1993). According to Komiyama *et al*., (2007), the above-ground biomass in mangrove forests was less than 100 t/ha in most secondary forests or concession areas. Based on the estimation of above-ground biomass obtained, the estimated carbon sequestered by the mangroves at Kota Marudu is ca. 49 t C/ha. This value was obtained by assuming 50% of the estimated biomass was carbon sequestered by the forests (Brown & Lugo 1982). Pidgeon (2009) stated that mangrove forest sequester as much as 50 times the amount of carbon in their soil per hectare as tropical forest. Thus, the long-term sequestration of carbon by one square kilometer of mangrove area is equivalent to that occurring in fifty square kilometres of tropical forest. So, while relatively small in area, the mangroves in Marudu Bay are extremely valuable for their long-term carbon sequestration capacity.

Table 4. Above ground biomass of trees 1cm and above by species in 1^{-ha} mangrove forest at Marudu Bay, Sabah.

Species	Biomass (t/ha)
Rhizophora mucronata	46.7
Rhizophora apiculata	28.8
Avicennia alba	11.4
Bruguiera parviflora	6.6
Xylocarpus granatum	2.8
Sonneratia alba	0.8
Excoecaria agallocha	0.3
Ceriops decandra	0.3
Avicennia marina	0.3
Heritiera littoralis	0.1
Xylocarpus malaccensis	0.1
Intsia bijuga	0.1
Bruguiera gymnorrhiza	0.1
	98.4

Conclusions

The mangroves at Kota Marudu are not only aesthetically attractive but provide many nooks and corners for activities that can be undertaken by the local community inhabiting the area to uplift their meagre income. Amongst them are mangrove cruising, recreational fishing, edu-tourism and honey production. Mangroves are also ecologically linked with other coastal ecosystems such as coral reefs, mudflats, rocky shores, seagrass bed and sandy beaches. Degradation and destruction of the mangroves can thus damage these coastal ecosystems and impact the Kota Marudu coastal communities economically. In order for the Kota Marudu community to enjoy in perpetuity the benefits of the mangrove forests, it is important to conserve its biodiversity and use these resources sustainably. Besides providing many services to mankind, mangroves also provide recreation and opportunities for ecotourism, education and also scientific research.

References

Brown, S. and A.E. Lugo. 1982. A comparison of structural and functional characteristics of saltwater and freshwater wetlands. In: *Wetlands Ecology and Management*. (Eds.): B. Gopal, R. Turner and R. Wetzel. pp. 109-130. Jaipur: International Scientific Publishers.

Brunig, E.F. 1983. Vegetation structure and growth. In: *Tropical Rainforest Ecosystems: Structure and Function.* (Ed.): F.B. Golley pp. 49-76. Amsterdam: Elsevier.

Davis, L.S. and K.N. Johnson. 1987. Forest Management*.* New York: McGraw-Hill.

Denslow, J.S. 1995. Disturbance and diversity in tropical rain forests: the density effect. *Ecol. Appl*., 5(4): 962-968.

Anonymous. 2007. The world's mangroves 1980-2005. FAO forestry paper 153. Rome: FAO.

Gibbs, J.G. 1966. Studies of the importance of plant species in vegetation above timber-line on North-West Slopes Adjoining Bruce Road, Mt. Ruapehu, Tongariro National Park. *Tuatara*, 14(1): 25-29.

Hett, J.M. and O.L. Loucks. 1976. Age structure models of balsam fir and eastern hemlock. *J. Ecol*., 64: 1029-1044.

Hitimana, J.H., L.K. James and T.N. Joseph. 2004. Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon Moist Lower Montane Forest, Western Kenya. *Forest Ecology and Management*, 194: 269-291.

Kapetsky, J.M. 1985. Mangroves, fisheries and aquaculture*.* FAO Fisheries Report 338. Rome: FAO.

Komiyama, A., J.E. Ong and S. Poungparn. 2007. Allometry, biomass, and productivity of mangrove forests: A review. *Aquatic Botany*, 89: 128-137.

Kusmana, C., S. Sabiham, K. Abe and H. Watanabe. 1992. An estimation of above ground tree biomass of a mangrove forest in East Sumatra, Indonesia. *Tropics*, 11: 243-257.

Ong, J.E. 1993. Mangroves—a carbon source and sink. *Chemosphere*, 27: 1097-1107.

Pidgeon, E. 2009. Carbon sequestration by coastal marine habitats: Important missing sinks. In: *The Management of Natural Coastal Carbon Sinks*. (Eds.): D. Laffoley and G. Grimsditch. pp. 47-51. Gland: IUCN.

Poorter, L., F. Bongers, R.S.A.R. Rompaey and M.D. Klerk. 1996. Regeneration of canopy tree species at five sites in West African moist forest. *For. Ecol. Manage.,* 84: 61-69.

Roberts-Pichette, P. and L. Gillespie. 2001. Terrestrial vegetation biodiversity monitoring protocols. EMAN occasional paper series, Report No. 9. Burlington: Ecological Monitoring Coordinating Office.

Seaby, R.M.H. and P.A. Henderson. 2007. SDR-IV Help: Measuring and understanding biodiversity. Lymington: Pisces Conservation Ltd.

Suzuki, E. and H. Tagawa. 1983 . Biomass of a mangrove forest and a sedge marsh on Ishigaki Island, South Japan . *Jap. J . Ecol*., 33: 231-234.

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