A Study of Forest Structure, Diversity Index and Above-ground Biomass at Tok Bali Mangrove Forest, Kelantan, Malaysia

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Abstract: - This paper attempts to give an information about the structure of mangrove distribution at Tok Bali, Kelantan in order to initiate for management and rehabilitation programme. A study was conducted in July to November 2006 to determine the species composition, diversity index and above-ground biomass in 15.8 ha Mixed Mangrove Forest. A transets forest profile length of 30 meter and 20 plots were established, a Diameter Breast Height (DBH) and height were measured and recorded, and also diversity index and above-ground biomass were determined. A total of 10 species consists nine exclusive and one non-exclusive mangrove were recorded. The common species found were *Sonneratia alba* (1,170 trees/ha, 330 saplings/ha and 22,680 seedlings/ha) followed by *Ceriops decandra, Excoecaria agallocha, Avicennia alba, Bruguiera cylindrica, B. sexangula, Rhizophora apiculata, Aegiceras corniculatum, Nypa fruticans* and *Derris trifoliata*. From the results an average of 595 trees/ha, 598 saplings/ha and 646 seedlings/ha represented a moderate good condition and regeneration potential. Total above-ground biomass was 2664.57 kg/ha and *S. alba* also recorded the highest because the of wide range of diameter and height. Mangrove trees showed total average of species richness (S) was 8.0, eveness (E) was 0.793 and diversity (H') was 1.603.
Key-Words: - Biodiversity, Mangrove, Distribution, Structure, Above-ground biomass

1. Introduction

The word 'mangrove' has been used to refer either to the constituent plants of tropical intertidal forest communities to the community itself [1]. Mangroves are woody plants that grow at the interface between land and sea in tropical and sub-tropical latitudes. Mangroves trees therefore grow in soil that is more or less permanently water-logged and in water those salinity fluctuates and may be as high as that of open sea [2]. Mangroves cover only 0.2% of total area occupied by terrestrial ecosystems in the New World. However, mangrove ecosystems hold a wide diversity of aquatic and terrestrial species of different taxonomic groups, and when all species are considered, mangrove ecosystems rival many other tropical habitats in alpha diversity [3].

A mangroves forest gives various functions as well as direct and indirect. Mangrove trees provide timber for construction, firewood and charcoal, fishing poles, pulp and tannin [4]. Mangrove also provides protection and as habitat suitable as breeding and nursery areas for many organisms [5], and provide important regulatory functions. They reduce coastal erosion and flooding, supply and regenerate nutrients and retard run-off [6]. Mangroves play an important role in water storage and trapping of sediments and carbon, contributing to the control of the quality and quantity of water, particles, and solutes discharged to the ocean [3].

Mangrove forest ecosystem support important wetland community of plants and animals, they are characterized by unique species of trees and shrubs that fringe the intertidal zone along sheltered coastal, estuarine and riverine areas in tropical and subtropical latitudes [7],[8]. The relatively high plant productivity and the active biological processes characteristic of mangrove ecosystems yield many goods and services of direct or indirect benefit to humans. They are also important to estuarine fisheries, because of the detritus and dissolved organic carbon contributed to estuarine food webs and the shelter their roots provide for juveniles.

The total mangrove area in Malaysia is approximately 645,852 ha or about 2 % of its total land area [9]. Malaysian mangrove is the third largest mangrove forest in the Asia-Pacific region after Indonesia and Australia. The Matang Mangroves is located on the west coast of Peninsular Malaysia in the state of Perak, is very well known as the largest mangrove area that being managed on sustainable basis with timber extraction and fishing activities taking place throughout the year [5].

In Malaysia it is become serious when Malaysia government allocate some fund under Natural Resources and Environment Ministry (NRE) for establishment replanting project namely National Tree Planting Program along Coastal Areas with suitable species along coastal area Peninsular Malaysia, Sabah and Sarawak and another technical committee on research and development for these suitable species under 9th. Malaysian Plan [10].

There is not much information related to mangrove forests at Tok Bali, Kelantan, thus, this study was done to provide information about species composition, diversity index and above-ground biomass in a mixed mangrove forest. For organizations involved with natural resource management, both monitoring and information reporting are necessary to promote learning, understanding and the application of management strategies. This information also will be useful in determining shifts or changes due to phenomena such as sea level rise, global climate change, and other catastrophic natural disturbances. Hopefully, all the data can help researchers and related agencies for their future study or management.

The mixed mangrove forest type is not dominated by any specific species. The formation is a catch all for mangrove forest types containing the three or more mangrove species in varying levels of dominance. The class generally represents mangrove forest found inland of the fringe.

1.1 Forest Stand Structure

Forest stand structure is defined as "the physical and temporal distribution of trees in a stand" and include within the description the distribution of species, vertical and horizontal spatial patterns, size of trees or tree parts, tree age, or combinations [11]. Descriptions of forest stand structure are commonly based on the aggregation of individual plant measures such as density, tree diameter at breast height distribution. In addition to zonation, mangrove forests are also characterized by attributes such as species richness, canopy height, basal area, tree density, age or size class distribution, and understory development [12].

1.1.1 Diameter

One of the simplest forms of stand characterization is the measurement of tree diameter. Diameter is usually measured with a tape at 1.3 above ground level and this measurement is referred to as dbh. An important exception however, concerns the mangroves with stilts-roots, such as *Rhizophora* spp, where the diameter measurement should be taken at 30 cm above [13]. Diameter is closely related to stand development and can easily be converted to basal area [14].

1.1.2 Tree height

The height is also useful criterion in forest stand classification. In mangroves forest, stand height can be divided into three or four classes. Stand height at 0 – 9 m considered as regeneration while stand height at 10 – 19 m considered as young stand. Lastly, when a stand height reaches at > 20 m, it considered as old stand [13].

1.1.3 Basal area

Basal area is the space covered or area occupied by a trees stem. The basal area of a stand is the sum of the individual basal areas of all trees greater than a certain diameter per unit ground area. It is a good measure of the overall stand development and can be related to wood volume and biomass [14].

1.2 Diversity index

The term diversity is usually synonymous with "variety" and is simply an indication of the number of different thing present. Diversity index provides a quantitative estimate of the closeness of training and predictions set points in the descriptor space. Also, provides an estimate of the diversity of the training set. The concept of diversity has two facets. They are richness or the number of items, and evenness or equality in the abundances of each item. Diversity indices provide a summary statistic of the diversity of a community. Species diversity is most often measured as species richness, the number of species in a given locality. In studies that experimentally manipulate species diversity [15], it is also most often species richness that is varied among treatments. Several indices of species diversity

incorporate information about the relative abundances of species in a locality, with higher diversity indicated by a more even distribution of abundance among species – higher evenness [16].

1.3 Mangroves Biomass

Mangroves and mangrove habitats contribute significantly to the global carbon cycle. Mangrove forest biomass may reach 700 t ha^{-1} [17] and estimate the total global mangrove biomass to be approximately 8.7 gigatons dry weight. Accurate biomass estimates require measuring volumes of individual trees abundances of each item using PC-ORD statistical program.

1.3.1 Above-ground Biomass

Above-ground biomass is the amount of standing organic matter per unit area at a given time. The amount of standing biomass stored in a forest is a function of the systems's productivity, age and organic matter allocation and exportation strategies. Biomass data for mangrove forests are scarce. There are two main approaches to biomass determination, clear cut and allometric techniques. Clear cutting is only recommended in young or scrub stands. Allometric measurement is preferred for all forests. The development of regressions of biomass on structural measurement of harvested trees allows estimation of standing biomass from easily measured parameters, such as DBH and height. Allometric biomass estimation is non-destructive, once samples have been taken and regression equations calculated.

2.0 Methodology

2.1 Study area

The study area is at the estuary of Semerak River, Tok Bali (06°52.0'N 102°30.5'E) in the district of Pasir Puteh, Kelantan in the northernmost of Peninsular Malaysia bodering to Thailand. The northeast monsoon and southeast monsoon influence the climate in Kelantan with an average temperature 27.2°C.The relative humidity average is 88.2% and the rainfall recorded as 2647 mm per year, where the daily rainfall is 148 mm (Malaysia Meteorology Central Kelantan, 1999). There are three mixed mangrove areas that cover 15.8 ha in Tok Bali. Two areas are on the left of the river and one is on the right river this area might not be influenced by tides everyday. Soils of the area are trade up of sand, silt and clay.

2.2 Materials

Several materials have been used along this data collection. Tape measurement for plot and transets establishment, diameter tape for DBH measurement, and compass for guide the pathway, Global Positioning System (GPS) for coordinate recorded and Laser Ace 300 for height measurement.

2.3 Sampling

2.3.1 Plots design

Several transects lines were created basically for proportioning a known area among various types of classifications, such as forests, cultivated fields, and urban uses. Each transect line consist 2 – 5 plots, depends to the area of the island. A circular plots (adult tree) were setup with radius 5.64 m, and sub plot 1(sapling) with radius 4m inside the main plot. Five square sub plot 2 (seedling) with size 0.5 x 1 m distribute around main plot (Fig. 1). All transects lines will be made at 25m from shore and the length between plot is 15 – 20m. The transect line might be changed depend on the area where the study done. The total area for main plot is 100 m^2 , 50m^2 for subplot 1 and 2.5 m^2 for subplot 2. By this approach, every possible combination of sampling units has an equal and independent chance of being selected.

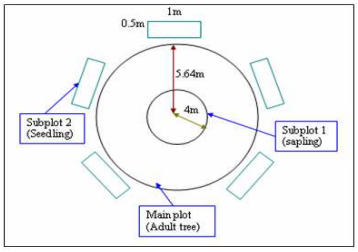

Fig. 1: Sampling plot unit

2.3.2 Data analysis

The data gathered were types of species, DBH, height, crown form and stem category. Mean of tree diameter, basal area and DBH size class distribution were calculated for each mangrove tree species found in the study area. While ecological approach such as species diversity, species richness or the number of items and species evenness equality in the abundances of each item using PC-ORD statistical program. Above-ground biomass was analyzed by the Diameter Breast Height (DBH) and height data. One allometric equation will be used to calculate the above-ground biomass. The equation from

Komiyama *et al.,* in 1988[18] is above-ground biomass = 116.6 $[(DBH)^2 H]^{0.8877}$).

3.0 Results

3.1 Mangrove Existence in Mixed Mangrove Forest, Tok Bali

Ten species from 10 genera and seven families were identified in Mixed Mangrove Forest at Tok Bali (Table 1). A total of 20 were established in this study area. Eight species were recorded for trees, nine species for sapling and seven species for seedling.

Table 1: Mangrove species found in Tok Bali, Kelantan

No	Family	Species	Group
1	Rhizophoraceae	*Ceriop decandra*	E
2	Rhizophoraceae	*Rhizophora apiculata*	E
3	Rhizophoraceae	*Bruguiera sexangula*	E
4	Rhizophoraceae	*B. cylindrica*	E
5	Sonneratiaceae	*Sonneratia alba*	E
6	Euphorbiaceae	*Excoecaria agallocha*	E
7	Avicenniaceae	*Avicennia alba*	E
8	Myrsinaceae	*Aegiceras corniculatum*	E
9	Arecaceae	*Nypa fruticans*	E
10	Fabaceae	*Derris trifoliata*	NE

Notes: E=Exclusive; NE=Non-exclusive

3.2 Existence, number of mangrove trees, sapling and seedlings

3.2.1 Trees

Figure 2 showed that *S. alba* was the most abundant tree with 1,165 trees/ha followed by *A. alba* (430 teees/ha), *E. agallocha* (170 trees/ha), *B. cylindrica* (95 trees/ha), *R. apiculata* (75 trees/ha), *B. sexangula* (45 trees/ha) and *A. corniculatum* (10 trees/ha).

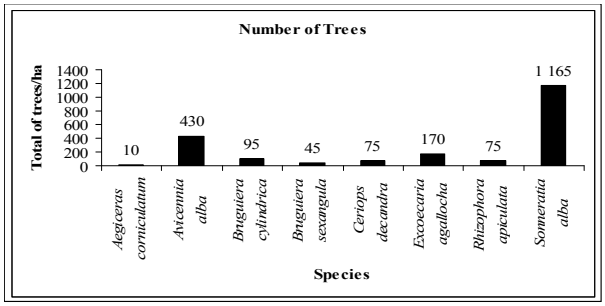

Fig. 2: Number of trees per ha

3.2.2 Saplings

Ceriops decandra sapling showed the highest dispersal followed by *B. cylindrica*, *A. alba, S. alba, A. corniculatum, R. apiculata, E. agallocha, B. sexangula* and *N. fruticans* (Fig. 3).

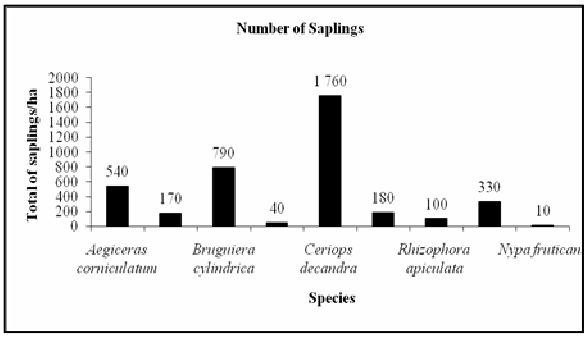

Fig.3 Number of sapling per ha

3.2.3 Seedlings

Fig. 4 showed *S. alba* was the highest dispersal followed by *B. cylindrica, C. decandra, A. alba, A. corniculatum, D. trifoliata* and *B. sexangula*.

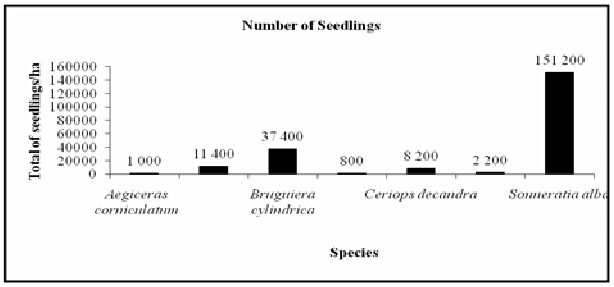

Fig 4: Number of seedling per ha

3.3 Forest Profile

The forest profile gave more than 73 indivuduals (31 trees, 42 saplings and seedlings). Most of seedling were found at 10 to 14 m length of the transects (Fig. 5).

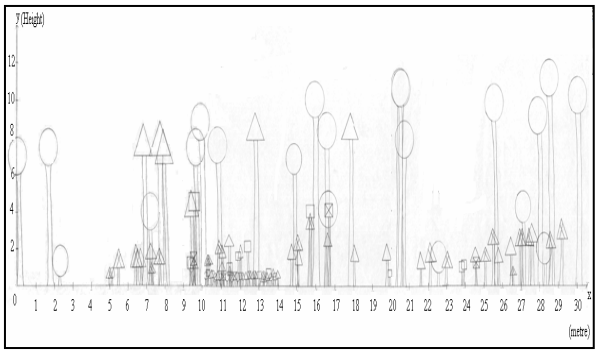

Fig. 5: Forest profile in Mixed Mangrove Forest at Tok Bali, Kelantan

4.2 Community structure

The highest total basal area was *Sonneratia alba* with 13.83 m^2 ha^{-1} followed by 5.316 m^2 ha^{-1} *Avicennia alba* (Table 2). *S.alba* also be the dominance species in this study area with 13.8295 m^2 h^{-1}. While the lowest total of dominance recorded by *Aegiceras corniculatum.* Total density for this study area was 2070. Meanwhile, total for important value for this study area was 299.99 with *S.alba* be the highest total of important value.

Table 2: Community structure of Mixed Mangrove Forest

Species	Basal Area(m^2/ha)	Density	frequency	Importance value
Sa	13.83	1170	0.85	146.86
Cd	0.23	75	0.35	15.62
Ea	1.14	170	0.20	19.75
Aa	5.31	430	0.90	73.42
Bs	0.18	45	0.15	7.72
Ra	0.31	75	0.35	16.01
Ag	0.04	10	0.05	2.23
Bc	0.61	95	0.35	18.38
Total	**21.68**	**2070**	**3.20**	**299.99**

4.4 Diversity index

Table 4 shows that *A.alba* trees have the highest species diversity among eight species recorded at Tok Bali. Follow by, *S.alba* and *Rhizophora apiculata*. Most of the plot will existed with all these eight trees species. Maximum number of trees recorded was 27 trees.

Table 4: Mean values and univariate measures of trees from 20 plots.

tree tok bali

Summary of 8 sp N = 20 plot

Num.	Name	Mean	Stand.Dev.	Sum	Minimum	Maximum	S	E	H`
1	Sa	11.700	8.968	234.000	.000	27.000	17	.934	2.647
2	Cd	.750	1.333	15.000	.000	5.000	7	.908	1.767
3	Ea	1.700	4.520	34.000	.000	17.000	4	.790	1.095
4	Aa	4.300	2.515	86.000	.000	8.000	18	.963	2.782
5	Bs	.450	1.146	9.000	.000	4.000	3	.966	1.061
6	Ra	.750	1.251	15.000	.000	4.000	7	.928	1.807
7	Ag	.100	.447	2.000	.000	2.000	1	.000	.000
8	Bc	.950	1.820	19.000	.000	6.000	7	.855	1.663
AVERAGES:		2.588	2.750	51.750	.000	9.125	8.0	.793	1.603

Notes : S: Richness, E: Evenness, H: Diversity

4.5 Aboveground Biomass

Table below (Table 5) shows the overall result above-ground biomass for eight trees species. *S. alba* recorded the highest above-ground biomass with 665.73 kg ha^{-1}. Meanwhile, *A.alba* contributed second highest above-ground biomass. Lowest total for above-ground biomass recorded was *Aegiceras corniculatum*.

Table 5: Shows above-ground biomass for eight trees species in Mixed Mangrove Forest at Tok Bali.

Species	Above-ground biomas (kg ha^{-1})
Sonneratia alba	665.73
Ceriops decandra	147.92
Excoecaria agallocha	345.14
Avicennia alba	583.94
Bruguiera sexangula	216.96
Rhizophora apiculata	232.52
Aegiceras corniculatum	105.92
Bruguiera cylindrica	366.44
Total	**2664.57**

4.0 DISCUSSION

The plant species richness of the Mixed Mangrove Forest, Tok Bali is lower compare with Sematan mangrove with 28 species, including 18 considered true mangroves. It should be more by sampling at different times and over a larger area, the diversity obtained will almost certainly be higher. The plots studied in Tok Bali were mature as well as diverse.

An average tree basal area of 2.71 m^2 ha^{-1} was recorded, with maximum values of 13.83 m^2 ha^{-1} and the highest for a single species, *S.alba.* The abundance of saplings and seedlings gives an indication of the natural regeneration occurring. The highest total of saplings recorded was 176 for *C. decandra* while 756 seedlings for *S.alba.* From this data, total number of seedling per hectare showed a good regeneration potential [19]. The tree sapling and

seedling similarity matrices were positively correlated and tree species number and seedling richness were positively correlated suggesting that species were abundant in the presence of their mother trees.

The reasons for mangrove seedling remaining close to their mother trees could include poor dispersal of seedling (e.g. weak tidal movement and canopy shape) and the presence of a suitable environmental habitat. Number of non-exclusive mangrove was negatively correlated with the tree, sapling and seedling. This suggests that they were found in different habitats. The environmental conditions required by mangrove seedlings and saplings or the non-exclusive mangrove in some way inhibit or out compete the mangroves.

Basal area is the cross-sectional area of a single tree stem, including bark, measured at breast height, or sum of the cross-sectional areas of all stems in a stand measured at breast height and expressed per unit of land area. From the result, *Sonneratia alba* was the highest total basal area. The total basal area for the study site is 21.6840 m^2 ha^{-1}. This total basal area is higher than total basal area in Rhizophora-Avicennia forest type (17.1162 m^2 ha^{-1}). Highest total basal area showed the species has wide range of diameter. If the diameter of tree wider, total basal area also will increase. The lowest total basal area was recorded by *A. corniculatum*. This species only occur in one plot and low of distribution.

Density is defined as the number of plants or specific plant parts per unit area of ground surface. The counting plant on sample plots of a known area is a simple means of deriving density estimates. For this study area, *S.alba* will be dominance species because of high total number tree estimation per hectares (1,170 trees). 2,070 trees estimates will be grown in one hectares area. Density does not give an indication of the size of the individuals unless counts are made and recorded by size classes.

Meanwhile, frequency is the number of plots on which species occurs divided by the total number of plots sampled. Frequency data are used to detect changes in plant abundance and distribution on a range site over time or to identify differences in species responses to varying management practices. Selection of the proper plot size is extremely important for estimating frequency, and more than one plot size may be needed for varying plant species and plant distribution. Frequency data are easily obtained, but numerous sample plots must often be evaluated before reliable estimates can be derived. Most species in Mixed Mangrove Forest give frequency above 0.05. This indicates that all plot samples found mangrove species. Most of the plot will dominate with *S.alba* because this species showed the highest total of frequency (0.85).

S.alba indicated the highest total of the important values compared to the other seven mangrove species which was derived from the total relative density, relative dominance and relative frequency. If the species showed a higher important value indicated that species was abundance and can be found diversely in the study area as pioneer species.

Diversity indices can be measured by Species Richness (R), Evenness (E) and Diversity (H). The species richness approach to assessing biodiversity examines the distribution of all resident terrestrial. The analysis of species richness involves identifying the vegetation and land cover types in which a given species can be expected to occur. While, species evenness is a measure of biodiversity which quantifies how equal the populations are numerically. Diversity is the total range of plant species features in an area.

For this study, each diversity indices were obtained from PC-ORD analysis. Species richness for *A.alba* was higher because this species have more number of species and low of species evenness. Species richness for Rhizophora-Avicennia forest type reached to 3.041 by *R.apiculata*. This is due to the *R.apiculata*'s high in species diversity (23). A community that has more species will have a greater diversity index than a community of similar evenness with fewer species. A community with greater evenness will also have a larger diversity index than a community same richness with lower evenness. Since diversity entails both richness and evenness, it is the possible community is richer, whereas the other community is more even.

The amount of standing biomass stored in a forest is a function of the system's productivity, age and organic matter allocation and exportation strategies. The total above-ground biomass for Mixed Mangrove Forest, Tok Bali was 2,664.57 kg ha^{-1}. *S. alba* recorded the highest total above-ground biomass because of wide range of diameter and height. Total above-ground biomass for Rhizophora-Avicennia forest type is 18662 kg ha^{-1} [20]. This total number of above-ground biomass is higher than above-ground biomass at Mixed Mangrove forest type. Different

total of above-ground biomass influence by trees diameter. Most of trees in Rhizophora-Avicennia forest type have wide range of diameter.

5.0 CONCLUSION AND RECOMMENDATION

The mangrove forest is a valuable coastal resource in Tok Bali in terms of its biodiversity and ecology. This study was focus on Mixed Mangrove forest type. A total of 10 species from 10 genera and seven families were identified in Mixed Mangrove Forest at Tok Bali. *S.alba* has dominated this study area with 234 trees recorded. While, *A. corniculatum* showed very low number with only two trees recorded. This forest type has a potential regeneration because of the very high total number of seedling per hectare (5,305). Among the sampled plots, species composition of the mangroves was more diverse in plot 20. In Tok Bali, assemblage was characterized by low species diversity if compared with Sematan (28 species) mangrove forest. Although this mangrove forest type is a mixed mangrove, the diversity of mangrove species was low. The total above-ground biomass for this forest type was 2,664.57 kg ha^{-1}. Total tree basal area for this study area is 21.68 m^2ha^{-1}.

It is recommended that there is an urgency to develop a comprehensive management plan for mangrove resources in Malaysia. Despite the various regimes, mangroves are still being degraded for its resources. Matang Mangrove Forest Reserves (MMFR) is one of the most well-managed mangrove forests. The question arises whether mangrove management be intensified, adapting the management plan of MMFR. Even though other mangrove forests use these guidelines, there is a need for a national plan for sustainable use of all mangrove forests. There is a need for a national plan for sustainable land use and look at long-term people's welfare simultaneously. Scientific community should conduct research on priority management issues. It is often argued that the ecologists fail in communicating their knowledge to decision makers and therefore have limited influence. It is important to link science to management in order to have effective and efficient mangrove management. Absence of proper evaluation on mangrove forests results in the undervaluation of the mangrove forests. Therefore, there is need for proper valuation of the forests for the society to know the actual economic value of the mangroves.

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