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Comparison of plant communities at six study plots in Penang forest reserves, Malaysia

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Abstract: An analysis of plant communities from six study plots within the Penang forest reserves, Malaysia, revealed 359 plant species with stems ≥ 2.0 cm diameter. More than 70 percent of trees were below 10 cm diameter at breast height (DBH). Total Above Ground Biomass (TAGB) and Basal Area (BA) varied between sites, with the highest value (631.15 t ha^{-1}) at Bukit Panchor Forest Reserve (Land) and the lowest (112.83 t ha^{-1}) at Bukit Panchor Forest Reserve (Swamp). Based on the species list, the study plot could be divided into two groups, the mainland and the island group. In general, intact forest haboured relatively higher number of woody species than the disturbed forest. The species composition was clearly different between island and mainland forests.

Resumen: Un análisis de las comunidades vegetales de seis parcelas de estudio en las reservas forestales Penang, Malasia, arrojó la cifra de 359 especies de plantas con tallos ≥ 2.0 cm diámetro. Más de 70 por ciento de los árboles tuvieron diámetros a la altura del pecho (DBH) < 10 cm. La biomasa aérea total (BAT) y el área basal (AB) variaron entre sitios, siendo el valor más alto (631.15 t ha^{-1}) el de la Reserva Forestal de Bukit Panchor (tierra) y el más bajo (112.83 t ha^{-1}) el de la Reserva Forestal de Bukit Panchor (pantano). Con base en la lista de especies, las parcelas de estudio se pueden dividir en dos grupos, el de tierra firme y el insular. En general, el bosque intacto albergó un número relativamente mayor de especies leñosas que el bosque perturbado. La composición de especies fue claramente diferente entre los bosques insulares y los de tierra firme.

Resumo: Uma análise das comunidades de plantas em seis parcelas de estudo no interior das reservas florestais de Penang, Malásia, revelou 359 espécies de plantas com troncos ≥ 2,0 cm de diâmetro. Mais de 70% das árvores apresentavam um diâmetro ao nível do DAP abaixo dos 10 cm. A biomassa aérea total (TAGB) e a área basal (BA) variou entre estações, com o valor mais alto (631,15 t ha^{-1}) na Reserva Florestal de Bukit Panchor (terra firme) e a mais baixa na Reserva Florestal de Bukit Panchor (Pântano). Com base na lista de espécies, a parcela estudada foi dividida em dois grupos: a continental e a insular. Em geral, a floresta intacta abrigava um número relativamente mais alto de espécies lenhosas do que a floresta perturbada. A composição das espécies era claramente diferente entre as florestas insulares e as continentais.

Key words: Basal area, forest type, forest reserve, Penang island, species composition, total aboveground biomass.

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Introduction

Tropical forests are rated as among the world's important biodiversity hotspots due to the occurrence of high number of species. Species richness is one of the most important measures of community structure and is one of the most crucial questions asked in the field of ecology. This is especially true in the tropical regions, such as Malaysia, where biodiversity is high (Laurance 2007).

The correlations between causes and effects of species diversity intrigued since long both naturalists as well as ecologists such as Darwin (1859) and Hutchinson (1959). Many studies have been conducted to examine the patterns of diversity at temporal scales ranging from seasonal changes to evolutionary time as well as spatial scales ranging from meter-square plots to latitudinal gradients (e.g. Crimmins *et al.* 2008; Halpern & Spies 1995; Leigh *et al.* 2004; Takyu *et al.* 2005). Global awareness on biodiversity also helps to guide the design, implementation and improvising existing policy on natural resources management (Harris 1984; Kessler *et al.* 1992), thus making the effort to quantify the species diversity as a major task for many scientists. Enumerations of species richness provide the very basis for research, conservation and management of the forest, although it is usually restricted relatively only to small portion of the forest system due to logistic and time constraints.

Forest studies on specific locations in Penang, Malaysia are limited (e.g. Raich & Turner 1990; Turner 1989, 1990), therefore, this study was undertaken to gather information particularly on plant communities in the five forest reserves in Penang. This paper will provide a basic ecological insight on the status of Penang forest reserves. Hopefully, this study would also initiate a more thorough and indepth study of these valuable forests.

Materials and methods

Study sites

Six study sites have been established in January 2004, in five forest reserves of Penang Island and Seberang Perai, Malaysia (Table 1, Fig. 1). Annual rainfall varies from 2000 to 2500 mm and mean daily temperature ranges between 21 and 32ºC. A 20 x 20 m study plot was established in each site to census the vegetation. The sampling area was marked with PVC pipes for future reference. Plant censuses were conducted over a one year period between February 2004 and January 2005. All the six forest areas are shown in Fig. 1, and their locations, forest types, and most abundant species are listed in Table 1.

Table 1. Location details of six study plots distributed over five forest reserves in Penang, Malaysia. Names of the most abundant species, one for each site, are given in parantheses.

Area	Location	Forest Type
Pantai Acheh Forest Reserve (PAFR)	Penang Island 100º 11' 35.44" N 5º 27' 52.67" E	Coastal hill forest (*Shorea maxwelliana*)
Teluk Bahang Recreational Forest (TBFR)	Penang Island 100° 13' 55.79" N 5° 26' 56.88" E	Lowland forest (*Calophyllum wallichianum*)
Bukit Kerajaan Forest Reserve (BKFR)	Penang Island 100° 15' 25.14" N 5° 25' 31.25" E	Highland forest (*Syzygium bernardi*)
Bukit Mertajam Forest Reserve (BMFR)	Seberang Perai Tengah 100º 30' 13.91" N 5º 22' 10.19" E	Lowland forest (*Garcinia atroviridis*)
Bukit Panchor Forest Reserve (BPFR-L)	Seberang Perai Selatan 100° 32' 51.70" N 5° 09' 16.43" E	Lowland forest (*Macaranga trichocarpa*)
Bukit Panchor Forest Reserve (BPFR-S)	Seberang Perai Selatan 100° 33' 24.61" N 5º 08' 54.50" E	Swamp forest (*Pyrenaria acuminate*)

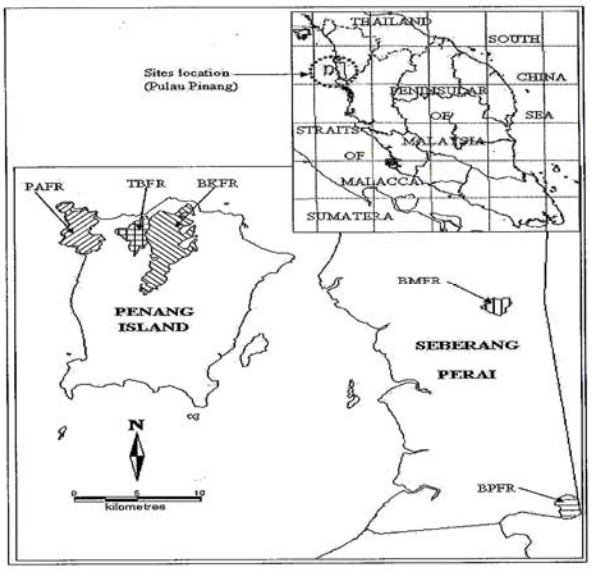

Fig. 1. Map showing the location of research plots in Penang State. See Table 1 for site acronyms.

Census method

The most effective and acceptable method to study and quantify species diversity and richness is plot sampling method (e.g. Condit *et al.* 1996; Shimida 1984). All free-standing woody plant species within the plots were sampled. All stems ≥ 2.0 cm diameter at breast height (DBH at 1.3 meter) were measured, tagged and mapped to possible nearest 0.01 meter for DBH, 0.5 meter for height (Condit *et al.* 1996; Hubbell & Foster 1983; Manokaran & Swaine 1994) and 0.1 meter for individual location. Leaves, fruits, barks and special characters (sap, latex and smell) of individual trees were collected / recorded for further identification when needed. Identification was based on Whitmore (1983) and Ridley (1967). Voucher specimens are deposited at the herbarium of School of Biological Sciences, Universiti Sains Malaysia (USM), for further reference.

Total above ground biomass (TAGB) was calculated from the formulae based on DBH (Kato *et al.* 1978) as below:

$$W_{S\,(stem)} = 0.313(D^2H)^{0.9733}$$

$$W_{B\,(branch)} = 0.136(W_S)^{1.070}$$

$$W_{L\,(leave)} = \frac{1.25(0.124W_S^{0.794})}{0.124W_S^{0.794} + 125}$$

$$TAGB = W_S + W_B + W_L$$

where, D = Diameter at breast height (DBH) in cm, H = Total height in m.

Basal area (BA) and tree density were also calculated for the most dominant species for each sampling plot. From the data collected, a species diversity analysis using statistical software MVSP (Multi Variate Statistical Programme) ver 13.3d by Kovach Computing Services (2002) was conducted. The Simpson's unbiased index, Shannon's diversity and evenness indices were also calculated from the species diversity results using the same MVSP software. To increase normality, data for species occurrences were log transformed (Krebs 1989).

Results

A total of 729 individuals from 359 different species have been sampled with mean density of standing trees calculated at 3051 stems ha^{-1}. Based on species occurrence, thirteen most common plant families were recorded from all six plots although the number varied from one plot to another. In terms of family occurrence, most common is Euphorbiaceae whilst Lauraceae, Fagaceae, Polygalaceae are among the least common families. Anacardiaceae is a major family, though relatively confined to coastal forests namely PAFR and TBFR (Table 2).

The highest number of species per plot was recorded in BKFR (74 species), and the lowest (40 species) in BMFR. Number of species per plot for the remaining study sites ranged from 57 to 66 species (Fig. 2). As for the number of standing trees, we recorded the highest number (161 trees per plot) in BKFR and the lowest in BMFR (56 trees per plot).

Table 2. Three most important plant families from each of the research plots. Site names as in Table 1.

Research sites	Families
BKFR	Myrtaceae, Lauraceae and Fagaceae
BMFR	Euphorbiaceae, Clusiaceae and Rubiaceae
BPFR(L)	Euphorbiaceae, Fabaceae and Myristicaceae
BPFR(S)	Theaceae, Euphorbiaceae and Polygalaceae
PAFR	Anacardiaceae, Dipterocarpaceae and Moraceae
TBFR	Anacardiaceae, Clusiaceae and Myrtaceae

Smaller sized plants (< 10 cm DBH) were more abundant in all study sites (Fig. 3) than the bigger sized trees, reaching to almost 95% of total tree population in BKFR. The TAGB for BPFR-L was highest (Fig. 4) despite the small number of bigger sized trees (> 10 cm DBH) recorded at this site. The proportion of standing trees under 10 cm DBH for all the study plots was more than 70% and their contribution to overall TAGB was very low. In addition, the BA was also highest for trees > 10 cm DBH (Fig. 5) suggesting that for some reasons, timber trees in BPFR were not logged in the past.

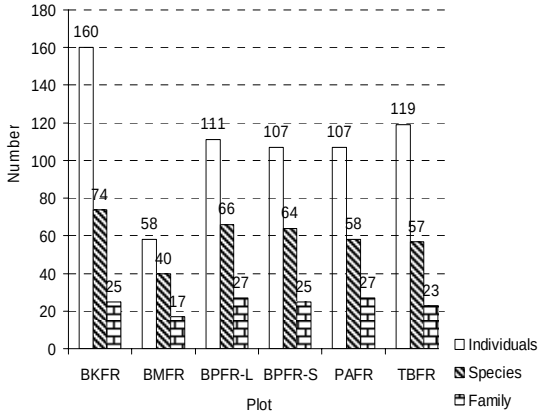

Fig. 2. Relation between species number and family count for the study plots. Individual tree count is highest in Bukit Kerajaan Forest Reserve (BKFR), located on the Penang Island, than Bukit Mertajam Forest Reserve (BMFR) in the mainland. In general, number of families across all study sites fluctuates between 17 to 27 . See Table 1 for site acronyms.

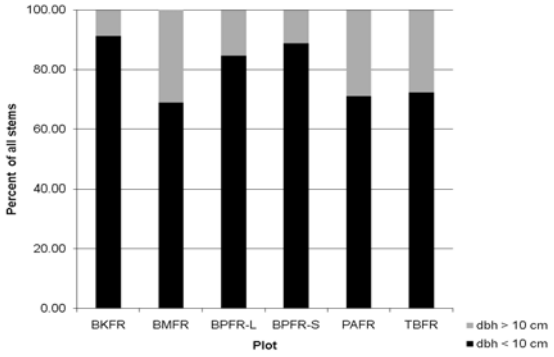

Fig. 3. Percentage of trees in different dbh classes. The impact of previous logging activities is clearly shown in Bukit Kerajaan Forest Reserve study plot. The percentage of bigger size trees (dbh>10 cm) at this forest reserve is the lowest in comparison with other forest reserves. See Table 1 for site acronyms.

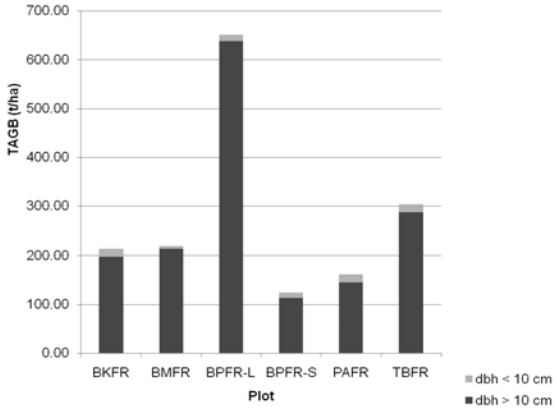

Fig. 4. Comparison of total above ground biomass (TAGB) for six study plots of five forest reserves in Penang, Malaysia. Data suggested that standing trees in lowland forest of Bukit Panchor Forest Reserve (BPFR(L)) are bigger in size than other study plots. See Table 1 for site acronyms.

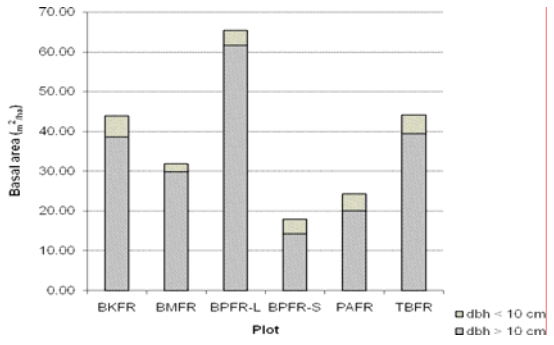

Fig. 5. Comparison of basal area (BA) for the study sites. Data from study plots in both Bukit Kerajaan Forest Reserve (BKFR) and Teluk Bahang Forest Reserve (TBFR) suggested that basal area for standing trees is comparatively the same. See Table 1 for site acronyms.

Two distinct groups could be identified using the UPGMA dendogram (Fig. 6) differentiating the mainland and the island forests. Sorensen's coefficients for species similarities are less than 0.2 for all study plots suggesting that these plots contain many different species as shown in Fig. 6. Unlike the species similarity coefficients, the family clusters are separated into 3 groups, and BPFR-S and BPFR-L show the highest similarities at about 0.7 even though the sites are situated in a different area (Fig. 7). Two coastal forest reserves,

namely TBRF and PAFR are distinctively grouped together implying possible unique characteristics of these forests to harbour trees of certain families.

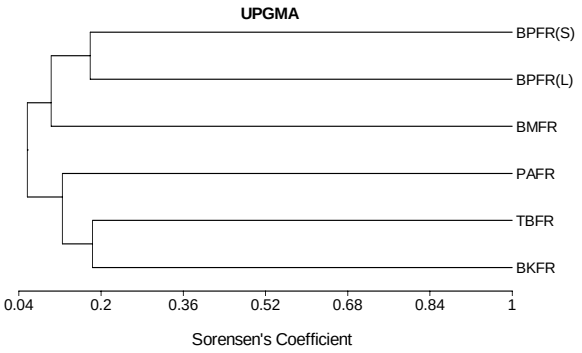

Fig. 6. Dendrogram showing the species similarities between the study sites. Two separate groups can be distinguished, group (a) BPFR (S & L) and BMFR, and (b) PAFR, TBFR and BKFR, as lowland-mainland forest and coastal-island forest, respectively. See Table 1 for site acronyms.

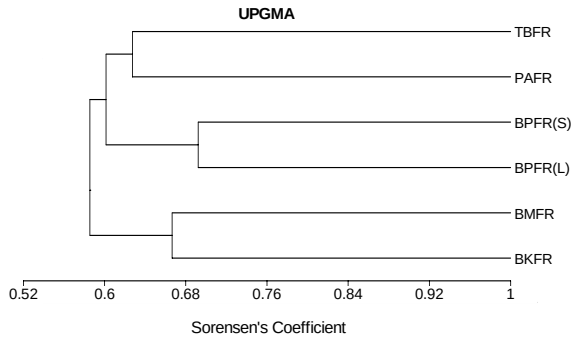

Fig. 7. Dendrogram showing the family comparison between the study sites based on Sorensen's coeffiecients. Three groups can be distinguished; (a) TBFR and PAFR, (b) BPFR (L) and BPFR (S), and (c) BMFR and BKFR.

Discussion

This study provides a comprehensive estimate of presently available TAGB of Penang Forest Reserves. The key conclusion is that the biomass of these forests, ranging from 112.83 t ha^{-1} to 637.15 t ha^{-1}, is considered a high value for such a small area, compared to the other tropical areas (Ng & Low 1982). Our result is similar to the findings reported by Aiken & Leigh (1992) and Turner (1989) from their studies. In Malaysia, many species of trees can occur within a relatively small area. The lowest number of species recorded in a forest reserve (i.e. BMFR) can be related to geographical condition of the study plot or evidence of anthropogenic activities (e.g. logging). We strongly suggest that the human intrusion factor has played a major role leading to the low species count of this research plot rather than geographical condition.

Although the TAGB for BPFR-L was comparatively high, results from the six research plots are still within the range of TAGB values reported by Kato *et al*. (1978) in their studies of Malaysian forests. This suggests that most Malaysian forests contain almost the same range of TAGB. Between the study sites, we found that the TAGB varied and did not show any specific pattern. The high number of smaller trees suggests that these forests are indeed rich in juvenile trees, which is a good sign of a healthy and a continuously growing forest, because matured forests usually contain a low number of small trees (Aiken & Leigh 1992; Shuttleworth 1981).

The BA for the study plots is related to the TAGB, hence any changes in individual tree data will result in the change of overall BA and TAGB. The lowest BA and TAGB recorded from BPFR (S) could be due to the location, as the site is situated in swampy area and is often submerged under water in the rainy season. It is very likely that due to this constant waterlogged condition, overall trees here are smaller in size (see Fig. 3) and shorter in height due to poor nutrient supply. Furthermore, the substrate structure here is not suitable for the growth of big trees, as it is boggy and consists mainly of decomposed organic matter and plants can easily be uprooted by strong wind (Zimmerman *et al.* 1994).

Distinct grouping of study plots (Fig. 7) indicates that, plants in Malaysian tropical forests are more or less concentrated around a few main and big families such as Dipterocarpaceae, Fabaceae, Anacardiaceae and Sapotaceae (Corner 1988). BMFR and BKFR are examples of a situation where species similarity is low but they share a high family similarity.

Referring to the Shannon's index value (species count), we can imply that all the six plots have uniformally high diversity and evenness (all the values ranged from 0.9 to 1.0 for Evenness and from 1.6 to 1.8 for Diversity index) (Table 3). There are two possible reasons as to why Bukit Kerajaan ecological plot shows a higher diversity index

value; (i) the long term effects of past logging activities, and (ii) the minimal human intrusion at current time in this area compared to other research plots. Logging activities create gaps and encourage regeneration phase, and combine with minimal anthropogenic disturbance, the secondary regrowth will contribute to higher species diversity in these disturbed areas. These findings show that the Bukit Kerajaan study plot is the least disturbed and it is also remarkably untouched by logging activities (logging activities have ceased since more than 70 years in BKFR). The finding coincides with the fact that Bukit Kerajaan Forest reserve was once logged, in the early colonial time in early 30's.

Table 3. Diversity and Evenness indices for the study sites, base on species and family count. Site names as in Table 1.

Research sites	Shannon's Diversity (Species Count)	Evenness (Species Count)	Shannon's Diversity (Family Count)	Evenness (Family Count)
BKFR	1.815	0.929	1.172	0.828
BMFR	1.607	0.956	1.114	0.871
BPFR(L)	1.759	0.953	1.275	0.890
BPFR(S)	1.689	0.929	1.185	0.847
PAFR	1.703	0.943	1.216	0.840
TBFR	1.714	0.960	1.229	0.903

Conclusions

The six study plots distributed over five forest reserves harbour rich plant communities and reflect the high plant biodiversity in this tropical area. Although the species composition differed among surveyed sites, the overall pattern was similar which is high species and family diversity. Apparently the intact and relatively pristine forests such as BKFR have high species diversity when compared with a relatively disturbed forest like BMFR. It is also clearly shown from this study that forest species community composition are different between the island and mainland, however, the family similarities did not follow the species grouping pattern. Lastly, we suggest that the number of plots and their size should be increased in future research to get a better perspective as well as conclusive data on forest ecology of island and inland lowland forests.

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