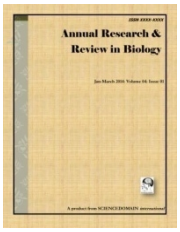

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A Comparison of Species Diversity in Two 1-ha Plots at Tekai Tembeling Forest Reserve, Pahang, Malaysia

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Authors' contributions

Author NE designed the study, performed the analysis, wrote the first draft of the manuscript. Authors KAK, MN and AGAN give a useful suggestion and recommendation to enriched the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The effects of commercial logging on tree species diversity in the Tekai Tembeling Forest Reserve (TTFR), Jerantut, Pahang is unknown. This article is focus on inventory of two forest plots having one ha area of each.
Study Design: This study based on inventory conducted within the forest area.
Place and Duration of Study: Tekai Tembeling Forest Reserve (TTFR), Pahang, Malaysia between 2008 and 2010.
Methodology: 100 quadrats of 10mx10m were established in each plot. Hundred percent inventory was applied to collect the data which were analyzed using Ecological Methodology Software to calculate species diversity, richness and composition. Accordingly, species richness, species composition, evenness and species dominance were compared between two plots.
Results: Altogether 34226 individuals were found in both plots which were belonging to 950 species under 321 genera and 107 plant families. Remarkably, 700 species were found in plot 2 while it was only 520 in plot 1. However, plot 1 comprised more stems than plot 2. The importance value index (IVI) value was found to be highest for *Shorea curtisii* among species group in plot 1 but in case of plot 2 it was highest for *Knema hookeriana*. So it can be concluded that these species were dominant species. In this study, individuals

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was all of the plants collected during inventory including trees, shrub, climbers, palm and so on while stand density only represent the number of plant with dbh at least 5cm. Total stand density and basal area were 1310 plants ha^{-1} and 27.52 m^2 ha^{-1} respectively in plot 1 while they were 316 plants ha^{-1} and 9.50m^2 ha^{-1} respectively in plot 2. Notably, Euphorbiaceae was the most diverse which was followed by Dipterocarpaceae plant family in both plots.

Conclusions: Species diversity in Plot 2 was more diverse compared to Plot 1. However Plot 1 was more dense than Plot 2 with 18752 individual trees compared to 15459 in Plot 2.

Keywords: Diversity; richness; importance value index (IVI); species accumulation curve.

1. INTRODUCTION

Biological diversity or popularly termed as biodiversity, is the total variety of life on earth [1]. Tropical rainforest is among the richest ecosystems in the world. The flora is very diverse compared to other types of forest [2]. Indo-Malesian rainforest has been considered by many botanist and ecologist as one of the most complex and richest terrestrial ecosystem in the world [3]. No other rainforest contains a greater number of different species growing together in discrete areas as the Indo-Malesian forest [4]. The forest in Malaysia is the example of one of the world's oldest rain forest. This is fourth biodiversity rich country in Asia after India, China and Indonesia [5]. Malaysian people enjoy to collect the food, spiritual needs and medicines from the forest. Besides, ecological services are other important attractive avenue for them. It is undeniable that the tropical rainforest of Malaysia constitute the core of biodiversity in Malaysia. The forests are a unique natural heritage which has evolved over 130 million years resulting in a very rich flora and fauna [6]. Diversity measurements are frequently seen as indicator of the well being of ecological ecosystems species diversity or 'heterogeneity' measures are the traditional way of quantifying biodiversity especially for flora assemblages [7]. According to [6], an inventory of flora and fauna biodiversity is an essential step towards the conservation of forest biodiversity. The objectives of inventory is to collect information about the forest vegetation which includes species composition, number of individual tree and non-tree, tree height, diameter at breast height (DBH) and other. The information collected enable foresters make better decision to ensure sustainable management of forest. Floristic inventories comprised of data from plots of various sizes and sampling intensities are widely used in botanical and ecological studies of tropical vegetation. At one extreme, detailed long term studies of forest are being carried out in large plots that aim to quantify forest dynamics and monitor change over time [8]. In Peninsular Malaysia, the production forests comprise about 2.8 million hectares of which more than 80% has already been logged [9]. Therefore, the structure, composition and productivity of the second growth forest are quite different from the virgin stands. This paper reports on comparison of species composition between two 1-ha plots of logged over hill forest.

2. MATERIALS AND METHODS

2.1 Study Site

This study was carried out at Tekai Tembeling Forest Reserve in the district of Jerantut, Pahang. This is a logged over hill dipterocarp forest. The fieldwork was carried out during

May – December 2008. Fig. 1 showed the location of Tekai Tembeling Forest Reserve in Peninsular Malaysia.

2.2 Data Collection

Two 1-ha plots were established at different elevation within the hill forest. Each of the 1-ha plot was divided into 100 of 10x10m quadrats. Plot 1 located at elevation of 520m above mean sea level (amsl) and plot 2 located at elevation 436m amsl. Plot 1 was logged over five years ago and plot 2 was logged over 2 years ago. Data were collected from all the quadrats and they were divided specifically into tree and non-tree category. Basically, plants having diameter at breast height (dbh) ≥5cm were categorized under tree group while rests were under non-tree group. Basically, species name, dbh and height of trees were recorded. The dbh of tree was measured at 1.37m from the ground level using D-tape. Simultaneously, height of trees was measured using laser hypsometer.

Fig. 1. Location of Tekai Tembeling Forest Reserve

2.3 Data Analysis

Data analysis involved the calculation of frequency, density and basal area per hectare. Comparison between the two plots was also done. Density was the number of individuals for species *i* and frequency was the number of subplot that species *i* emerge. Density, frequency and basal area of each species in each plot were calculated to seek importance value index (IVI). Vegetation analysis is the best way to study species composition and vegetation structure in one ecosystem and IVI calculated in vegetation analysis [10]. IVI is the sum of relative density, relative dominance and relative frequency for a species and is calculated as follows [11].

IVI of sp. i = relative density of sp. i + relative frequency of sp. i + relative dominance of sp. i

where:

relative density = (no. individual of species i / total individuals of all species) * 100
relative frequency = (frequency of species i / total frequency value of all species) * 100
relative dominance =(basal area of species i / total basal area of all species) * 100

Collected data were analyzed using Ecological Methodology Software [12] to calculate species diversity, richness and composition. Accordingly, species richness, species composition, evenness and species dominance were compared between two plots. The calculations are based on the following:

Species richness

Jackknife first-order estimate: $\hat{s} = s + (n - 1/n)k$

where; $\hat{s}$ = jackknife estimate of species richness
s = observed total number of species present in quadrats
n = total number of quadrats
k = number of unique species

Species diversity

Simpson's Index

$$\hat{D} = 1 - \sum Pi^2$$

where; $\hat{D}$ = Simpson's index
Pi = proportion of species i in the sample

Shannon-Weiner measure

$$H' = \sum_{i=1}^{s} (Pi)(\log Pi)$$

where; H' = information content of sample (bits/individual) and index of diversity
s = number of species
Pi = proportion of total sample belonging to species *i*

Species evenness

Simpson's measure of evenness

$$E_{1/D} = (1/\hat{D})/s$$

where; $E_{1/D}$ = Simpson measure of evenness
s = number of species in the sample
$\hat{D}$ = Simpson index

Smith and Wilson's index of evenness

$$E_{var} = 1 - \left[\frac{2}{\pi \arctan\left\{ \sum_{i=1}^{s} \left(\log_e(n_i) - \sum_{j=1}^{s} \log_e(n_j)/s \right)^2 / s \right\}} \right]$$

where E_{var} = Smith and Wilson's index of evenness
n_i = Number of individuals in species i in sample ($i = 1, 2, \ldots, s$)
n_j = Number of individuals in species j in sample ($j = 1, 2, \ldots, s$)
s = Number of species in entire sample

3. RESULTS AND DISCUSSION

3.1 Species Area Curve

Logging reduced tree density and the number of tree species per ha for both large and small trees. Fig. 2 shows the graph of species area curve. Plot 1 fell well below plot 2. The cumulative number of species is higher in plot 2 compared to plot 1. Plot 1 probably had greater number of total trees and non-trees but in term of number of species, plot 2 was more diverse than plot 1. As the area increases, the cumulative number of species also increases. According to [13], species accumulation curves plotted to estimate visually whether the curve has asymptotically approach some ceiling which indicates the sampling has been sufficient as well as the total richness. Study conducted by [14] on plant species diversity at Pasir Tengkorak Forest Reserve, Langkawi, Malaysia, showed that the slope of species accumulation curve for one ha study site rised as sample area increase but did not approach an asymptote. The increase of the number of species as a function of area is one of the laws of ecology [15]. Both plot 1 and plot 2 species accumulation curves did not approach an asymptote condition. Thus indicates, the sampling is not sufficient to cover the number of species exist in study area.

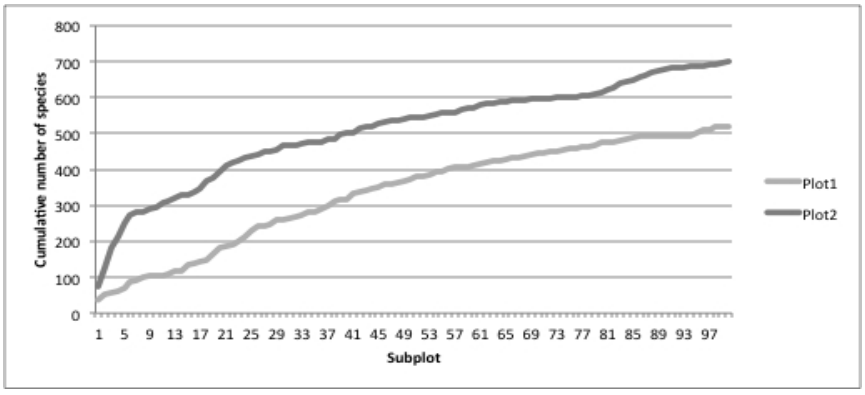

Fig. 2. Species area curve

3.2 Vegetation Composition

The result showed that, total number of stems were 34226 which were from 950 species under 321 genera and 107 plant families. Most of the stems conquered by non-trees because both of the plots were logged over within 2-5 years ago, so it has less number of large trees. Some of the species only emerge in one plot such as, *Adiantum sp.*

(Adiantaceae) and *Alseodaphne sp.1* (Lauraceae) were found only in plot 1 while *Amischotolype griffithii* (Commelinaceae) and *Aglaonema sp.* (Araceae) was reported only in plot 2. The five most diverse families collected across all categories were Euphorbiaceae, Dipterocarpaceae, Palmae, Melastomataceae and Rubiceae. Many of these families were represented by only one genus and many species. These five families represent about 16.7% of the total species recorded in the study area. In terms of individuals, the study area was dominated by five most abundance species, namely *Melastoma malabathricum* (Melastomataceae)*, Croton argyratus* (Euphorbiaceae)*, Henckelia sp1.* (Gesneriaceae)*, Trema orientalis* (Ulmaceae) *and Globba sp.* (Zingiberaceae). However, if only trees with dbh≥5cm were considered, in terms of basal area the site was dominated by *Lithocarpus sp14.* (Fagaceae) in plot 1 and *Dillenia sp.* (Dilleniaceae) in plot 2. In Perak, Malaysia 348 species was recorded by [16] for the study on vascular plant in coastal hill forest. Meanwhile, study conducted by [17] showed that 86 species was recorded in the study of tree taxa inventory in Ayer Hitam Forest Reserve, Selangor along six new trails at the base camp.

The average number of taxa across all categories on a per ha basis for plot 1 and plot 2 is also shown in Table 1 for comparison. The number of family, genera, species and individual are obviously different. Number of individuals combined both trees and non trees. This result indicates plot 1 has the higher number of individual than plot 2, but the number of species in plot 1 lower than plot 2. In short, most of the plants in plot 1 consist of many similar species while in plot 2, most of plants comprise from different family, genus and species.

Table 1. Number of taxa by categories

Plot	No. of family	No. of genera	No. of species	No. of trees/ha
plot 1 (5 years after logging)	84	190	520	18752
plot 2 (2 years after logging)	103	296	700	15474

3.3 Size Class Distribution

Fig. 3 shows the distribution of tree in different dbh classes. This graph distribution conformed to a reverse 'J' shape curve. About 87.64% of trees having dbh between 5cm-24.9cm; 1248 trees from plot 1 and 269 trees from plot 2. The number of trees with diameter greater than 50cm was 11 in plot 1 and 6 in plot 2, totaling 0.98% of total trees. A few number of trees having >50cm dbh resulted from logging activities 2-5 years ago need much time to recover to get its previous form. Although only larger trees were harvested, the immediate effect of logging was reducing the number of species per plot mostly for small tree (5cm-24.9cm). Compared to plot 2, plot 1 had higher ratios for both large trees and small trees. Even though the number of trees in plot 2 was smaller than plot 1, Fig. 2 illustrated the number of cumulative species was greater than plot 1. It proved that plot 1 had many trees but most of them are repeated species or came from same species while in plot 2 the number of trees are less but the number of new species emerges in each subplot were high (combined of trees and non-trees). In short, plot 2 was more diverse than plot 1. The diversity of each plot was not influenced by the number of trees. [18] conducted a study of biomass and floristics of Sayap-Kinabalu Park, Sabah and found 101 individuals having dbh between 5cm and 10cm and 4 individuals having dbh greater than 50cm. Also, a research carried out in a few recreational forests in Malaysia by [19] recorded that the plants with 1-10cm dbh were dominant at lower elevation compared to higher elevation, thus,

indicates a high disturbances from easy accessibility by public. In TTFR, elevation did influence the distribution of dbh, however most of the large trees have been cut off during logging. Most of the trees found in range 5-25cm which may take a few decades for recovery.

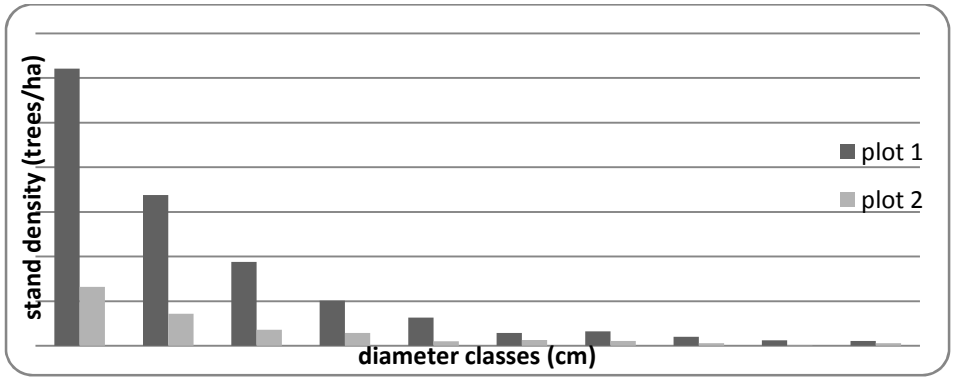

Fig. 3. Distribution of tree in different size classes

3.4 Importance Value Index (IVI)

A total of 241 dominant species were observed in plot 1. The dominant and co-dominant species were *Shorea curtisii* (Dipterocarpaceae) and *Mallotus kingii* (Euphorbiaceae), showing their IVI values 10.7 and 7.25 respectively, whereas, the highest value of density was also recorded for *Shorea curtisii* (Dipterocarpaceae, 53 plantsha^{-1}). Their contributions to the plot 1 were 8% of the total density, 6.64% of frequency, 3.29% of basal area and 5.98% of IVI. For trees in plot 2, a total of 163 tree species were recorded. Amongst the trees the highest value of density (14 plants ha^{-1}) and IVI (8.53) was recorded for *Knema hookeriana* (Myristicaceae). The co-dominant species of the site was *Croton argyratus* (Euphorbiaceae) which showed their values of IVI (6.04) and density (10 plants ha^{-1}). Their contributions were 7.6% of the total density, 6.27% of frequency, 0.7% of basal area and 4.86% of IVI.

The IVI showed that, *Shorea curtisii* was the dominant species in Plot 1 and *Knema hookeriana* was the dominant species in Plot 2. These results influenced by the density and size of trees in each plot. The species composition of the logged over forest have been altered with a significant reduction in the composition of dipterocarps, thus indicating that the logging practice had a negative impact of changing species composition. It is illustrated that second growth forests have much greater proportion of volume of non-dipterocarps. This is due to the dipterocarps in the second growth are comparatively smaller hence they occupied less growing space. Even though the number of dipterocarps species were large in both plots, but it represented by small trees. Mostly have a dbh less than 5cm.

It was found that, the abundant species dipterocarps are being replaced by other species. *Macaranga*, *Stemonurus* and *Trema* are more dominant in plot 2 in comparison to plot 1. The logging activities provide sufficient space for light demanding species and fast growing species. This indicate that creation of large gaps in the previous logging activities provides sufficient space of these light demanding and fast growing species to colonized the areas. In plot 1, the dipterocarps species start dominate the area because it is already five years

logged over, so there were many large trees and the improvement of canopy layer caused the pioneer species hard to receive light. Thus it gave an opportunity for dipterocarp species more growing space. There were a numbers of species which found only in one plot. For an example, *Gynotroches axillaris* (Rhizophoraceae) only found in plot 1 while *Combretum sundaicum* (Combretaceae) only emerge in plot 2. Total stand density and basal area for trees ≥5cm dbh were, respectively, 1310 trees ha^{-1} and 27.517m^2ha^{-1}in plot 1 and 316 trees $ha^{-1}$and 9.498m^2ha^{-1} in plot 2.

Tables 2 and 3 showed the ten most dominant species in each plot. *Shorea curtisii* and *Knema hookeriana* were the most dominant species which comprise highest IVI in Plot 1 and Plot 2 respectively. Study conducted in Tranum Forest Reserve, Raub, Pahang, Malaysia indicates the dominant species within the study area was *Xanthophyllum palembanicum* with IVI value 6.552 [11]. In West Java, [20] studied the density of tree communities in Mount Patuha and found out that the most dominant species was *Cichona pubescens* with IVI 56.93. Meanwhile, in Perak, Malaysia, [16] found that the most dominant species was *Agrostistachys longifolia* with IVI 12.45. The various results indicate that type of dominant species varied for every type of forest. According to [21], species with high IVI value need less priority for conservation while those with low IVI need high conservation effort.

3.5 Species Diversity

Table 4 shows that the Jackknife method estimated 644.8 species present in plot1 and 866.3 species present in plot2. This method gives overestimation of the actual number of species observed in both plots. The Simpsons index diversity shows that both plots have high diversity; 0.98 for plot 1 and 0.99 for plot 2. The species diversity in plot1 and plot2 of Tekai Tembeling Forest Reserve calculated using Shannon-Weiner (H') gave value of H'= 6.99 and H'=8.00, respectively. Comparison between the two plots showed higher species diversity index in plot2. Shannon-Weiner index (H') was one of the most common indices used in evaluating structural diversity of forest stands. It was often used to compare the diversity of different habitats, especially when a number of replicates were considered. The higher value of Shannon-Weiner's index indicates high species richness. The H' value was related to species richness and was influenced by underlying species abundance distribution. Many study in Malaysia rainforest indicates high value of diversity indices that exceeds the usual range 1.5-3.5 such as Pulau Pangkor Forest Reserve, Perak, H'=4.26 [16], Gunung Matchincang Forest Reserve, Kedah, H'=4.33 [14] and Pulau Timun, Langkawi, H'=3.60 [22]. Result also showed the Simpson's measure of evenness is 0.09 in plot1 and 0.18 in plot2. While Smith and Wilson's index of evenness in plot 1 and plot 2 were 0.24, 0.29 respectively. This suggests that the diversity is high but evenness is low in both plots because there were overlap in vegetation composition and structure. Evenness index ranges from 0 to 1.0 with 1.0 representing a situation in which all species are equally abundant [23]. [12] suggested that range below 0.5 is considered as low evenness.

Table 2. Quantitative analysis of 10 most dominant species in Plot 1

No.	Species	Density (stem/ha)	Frequency (%)	Basal area (m^2ha^{-1})	RD (%)	RF (%)	RBA (%)	Mean height (m)	IVI (%)
1	*Shorea curtisii*	53	36	8.430	4.046	3.462	3.192	13.847	10.699
2	*Mallotus kingii*	52	33	0.268	3.969	3.173	0.103	9.583	7.246
3	*Swintonia floribunda*	49	31	0.116	3.740	2.981	0.048	12.531	6.769
4	*Syzygium sp7.*	40	26	0.416	3.053	2.500	0.208	12.123	5.762
5	*Lithocarpus sp14.*	2	2	0.528	0.153	0.192	5.302	18.500	5.647
6	*Swintonia schwenkii*	34	27	0.335	2.595	2.596	0.198	13.685	5.389
7	*Knema sp1.*	35	26	0.106	2.672	2.500	0.061	8.549	5.232
8	*Mallotus sp11.*	30	28	0.143	2.290	2.692	0.096	10.157	5.078
9	*Garcinia rostrata*	34	22	0.272	2.595	2.115	0.161	9.509	4.872
10	*Knema hookeriana*	33	22	0.275	2.519	2.115	0.167	9.427	4.802

Table 3. Quantitative analysis of 10 most dominant species in Plot 2

No.	Species	Density stem/ha	Frequency (%)	Basal area (m^2ha^{-1})	RD (%)	RF (%)	RBA (%)	Mean height (m)	IVI (%)
1	*Knema hookeriana*	14	11	0.180	4.430	3.833	0.264	8.52	8.527
2	*Shorea leprosula*	5	5	1.167	1.582	1.742	4.784	21.18	8.109
3	*Endospermum diadenum*	2	2	0.643	0.633	0.697	6.597	20.00	7.927
4	*Dillenia sp.*	2	1	0.643	0.633	0.348	6.597	17.00	7.579
5	*Croton argyratus*	10	7	0.214	3.165	2.439	0.439	8.85	6.042
6	*Calophyllum sp4.*	2	2	0.388	0.633	0.697	3.979	12.50	5.308
7	*Santiria sp5.*	6	6	0.278	1.899	2.091	0.951	7.83	4.940
8	*Etlingera sp.*	3	3	0.410	0.949	1.045	2.801	16.33	4.796
9	*Elateriospermum tapos*	7	5	0.276	2.215	1.742	0.808	11.20	4.766
10	*Hopea sp1.*	1	1	0.197	0.316	0.348	4.043	25.00	4.708

Table 4. Diversity indices of Plot 1 and Plot 2

Diversity indices	Plot 1	Plot 2
Species richness (S)	644.8	866.3
Simpson's diversity index (D)	0.98	0.99
Shannon-Weiner diversity index (H)	6.99	8.00
Simpson's evenness index (E)	0.09	0.18
Smith & Wilson's evenness index	0.24	0.29

4. CONCLUSION

There were 950 species, 321 genera and 107 family found from two ha study plot. Species diversity in Plot 2 was more diverse compared to Plot 1. However Plot 1 was more dense than Plot 2 with 18752 individual trees compared to 15459 in Plot 2. Variations in number of individual trees, families, vegetation composition and basal area may be due to differences between the logging periods which influenced the plants growth. Until all species of TTFR are known from future inventories, the potential of TTFR for *in situ* conservation of all flora has yet to be determined.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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