Malays. Appl. Biol. (2006) 35(2): 81–85

RESEARCH NOTE

DIVERSITY AND TREE SPECIES COMMUNITY IN THE KRAU WILDLIFE RESERVE, PAHANG, MALAYSIA

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Rapid developments that occur in most tropical countries have resulted loss and fragmentation of tropical rain forests, which consequently threaten the biological diversity in these forests. In Malaysia, similar scenario is occurring, nevertheless, many conservation efforts, i.e. the *in-situ* and *ex-situ* conservations have been carried out by the relevant authorities to conserve the biodiversity. As for the *in-situ* conservation, various kinds of forests have been gazetted as National Parks, Wildlife Reserves, Virgin Jungle Reserves, etc., and it has been estimated that a total of 1.39 million ha (about 7.6%) of all type of the forests are set aside for these purposes (Latiff, 2005). The establishment of wildlife reserves for instance, is for protection, propagation and preservation of indigenous flora and fauna, whereby the reserves should be in a pristine condition and represent the natural indigenous state (Given, 1994). Changes or loss of biodiversity in the forest habitats should be supported by scientific data on the status of biodiversity, however, many forest areas in our country are understudied and therefore, a comprehensive base-line data are not available for the assessment of the losses to be made. Nevertheless, many research have been conducted in many forest areas (e.g. Kochummen et al. 1990; Mat-Salleh et al., 2003) with a view to evaluate the status of biodiversity in our country, and this may provide substantial evidence for the relevant authorities to take significant management actions.

The Krau Wildlife Reserve (originally called the Krau Game Reserve) is the second largest protected area in Peninsular Malaysia after the National Park. The wildlife reserve covers an area of 62,395 hectares, and was established on 9 June 1923 (Anon., 2000). The gazettement of this undisturbed lowland forest area as a protected area, allows studies on biodiversity to be carried out to enhance the scientific knowledge on the biodiversity, thus appropriate management actions can be taken for conservation of the biodiversity. Many research on the status of fauna species in this area have be conducted (e.g. Zubaid, 1993; Lim, 1999; Lopez, 2000), however detailed information about the flora is still lacking. Nevertheless, there are a few flora studies have been reported such as a brief inventory by the DWNP/DANCED (2001) and Thomsen (2000). This paper describes a detailed community structure of tree species in one hectare plot established in the Wildlife Reserve. The study objectives include to determine the diversity of tree species, and to describe the tree species composition of the study area. It is hoped that the findings from this study can contribute to the base line data for management purposes.

Krau Wildlife Reserve (3º 43'N, 102º 10'S) is located about 5 km from Kuala Krau in Pahang, and about 245 km east of Kuala Lumpur. It lies in the west central of Pahang with an approximate area of 62,000 ha. The Reserve comprises of lowland habitats mainly on the southern part, whilst submontane to montane terrains occur on the north part with the highest peak, the Gunung Benom, located at the north-west of the Reserve. These reflect various forest vegetation types ranging from lowland dipterocarp forest to montane forest. Payne (1978) and Lim (1999) identified six distinct habitat zones within the reserve which include the lowland riparian zone, lowland dipterocarp, hill dipterocarp, submontane dipterocarp, oak-laurel and montane zone.

A one-hectare permanent plot of 200 m x 50 m was established at the Bukit Rengit area in the Krau Wildlife Reserve. The plot was divided into 100 subplots of 10 m x 10 m each, enabling the data collection to be carried in a systematic

manner. All trees with 5.0 cm diameter at breast height (DBH) and above were tagged and manually measured using the diameter tape at 1.3 m above the ground. All specimens of each measured trees were collected for the preparation of voucher specimens and for species identification. The identification of the specimens was made possible using keys in the *Tree Flora of Malaya* (Whitmore, 1972, 1973; Ng, 1978, 1989). The voucher specimens were deposited in the Universiti Kebangsaan Malaysia Herbarium (UKMB).

All trees enumerated in the one hectare plot were summarized for the overall taxonomic composition and quantitative data were analysed to determine abundance. These include determination of basal area, as well as calculating the density and frequency of occurrence of each species. The basal area was calculated based on equation (Husch et al., 1982):

$$\text{Basal Area (BA)} = \frac{\pi D^2}{4} \text{ cm}^2$$

where

π = 3.1416

D = diameter at breast height (cm)

Several indices such as the Importance Value Index (IV_i) and Shannon-Wiener Diversity Index (H') were also calculated to determine species importance and species diversity of the study areas, respectively. The IV_i was calculated by summing up the values of relative density (*RD*), relative dominance (based on basal area) (*RB*), and relative frequency (*RF*) of each species or family; whilst the Shannon-Wiener Diversity Index (H') was calculated using formula as follows:

$$H' = -\sum_{i=1}^{s} = p_i \ln p_i$$

where

s = the number of species

p_i = the proportion of individuals or the abundance of the ith species expressed as a proportion of total abundance

ln = log base$_n$

A total of 1464 trees with diameter at breast height (DBH) of 5.0 cm and above were recorded in the one hectare study plot at the Bukit Rengit area of the Krau Wildlife Reserve. Identifications on all specimens revealed a total of 314 species and 151 genera from 56 families. The number of species per hectare found in this study agrees with the reports by Clark and Clark (1996) and Gentry (1990) who stated that the number of tree species in the tropical forests is extremely high, commonly passing 100 species per hectare. Based on the number of genera, the Euphorbiaceae comprises the highest number of 14 genera followed by Annonaceae and Leguminosae with a total of nine and eight genera, respectively. The largest family based on the species number was also represented by the Euphorbiaceae with a total of 34 species or 10.82% of total species number (Table 1). This was followed by the Myrtaceae with 23 species (7.32%) and the Dipterocarpaceae of 21 species (6.68%). Moreover, it is quite interesting to note that there are three families, i.e. Aquifoliaceae, Dracaenaceae and Proteaceae, represented by one genus, one species and one individual. These species are *Ilex macrophylla* (Aquifoliaceae), *Dracaena elliptica* (Dracaenaceae) and *Helicia attenuata* (Proteaceae) whereby the least abundance of the species perhaps is of conservation concern.

Tree species composition in tropical forest varies greatly from place to place mainly due to variation in biogeography, habitat and disturbance (Whitmore, 1998). For example, in a heath forest in Pulau Langkawi, Raffae (2003) reported a total of 210 species and 127 genera from 49 families in a 2.6 ha permanent at the Gunung Matchinchang forest area. The number reported by Raffae (2003) is far less than the number of taxa reported from this study which was conducted in a smaller plot size, thus the tree species richness in the Krau Wildlife Reserve, a pristine protected area, is obviously at a high number.

The tree communities in the study plot were dominated by small size of trees whereby 1072 individuals was found with diameter of 5.0-14.9

Table 1. Ten leading families with the highest number of species present in the study plot at the Krau WR

Famili	Genus	Species	No. of trees
Euphorbiaceae	14	34	209
Myrtaceae	2	23	93
Dipterocarpaceae	6	21	142
Lauraceae	7	18	44
Burseraceae	4	16	99
Guttiferae	4	16	81
Annonaceae	9	14	61
Myristicaceae	4	14	69
Leguminosae	8	12	35
Ebenaceae	1	11	23

cm (Figure 1). Thirty individuals fall in the largest diameter class of 55.0 cm and above. The largest tree was the *Shorea curtisii* (Dipterocarpaceae), with a diameter of 128.4 cm. The pattern of tree communities based on the tree sizes is similar with those other studies of various forest types (e.g. Appanah & Weinland, 1993; Kochummen, 1990) showing the inverse 'J' shape, whereby the number of trees declined as the DBH class increased.

Abundance parameters such as density, frequency and basal area are important parameters to describe the forest structure. The density and size distribution of trees contribute to the structural pattern characteristic of rain forests. The factors controlling tree density include the effects of natural and anthropogenic disturbance and soil condition (Richards, 1952). From the total of 1464 trees censused in the one hectare plot, the Euphorbiaceae indicates the highest number of individuals with a density of 209 trees/ha, followed by the Dipterocarpaceae and the Burseraceae with a density of 142 trees/ha and 99 trees/ha, respectively. Species wise, *Anisophyllea corneri* (Anisophylleaceae) shows the highest density of 73 trees/ha, whilst the second and third highest density indicates by *Mallotus penangensis* (Euphorbiaceae) and *Gymnacranthera forbesii* (Myristicaceae), respectively (Table 2). In comparison to a logged over forest of Bangi Permanent Forest Reserve, in Selangor, Lajuni (1996) found a total of 1018 trees in her one hectare plot; similar to this study, the Euphorbiaceae showed the highest density with a total of 200 trees/ha, which was not far different from the study in Krau. Based on this brief comparison, a high number of trees found in this study agree with the statement of Richards (1952) regarding factor of disturbances that control tree density in a rain forest.

Frequency of occurrence for any particular species can be used as a crude analysis of distribution pattern, whereby the highest frequency value reflects a widespread distribution of the species in the study plot. The species *Anisophyllea corneri* shows the highest frequency of 47%, whereby this species was found in 47 subplots of 100 subplots in the study area (Table 2); *Mallotus penangensis* indicates the second highest frequency of 33%, whilst the *Gymnacranthera forbesii* showed a frequency value of 29%.

Basal area for all trees in the study plot was calculated and the total basal area was estimated at 43.46 m^2/ha. The Dipterocarpaceae dominated the plot area with a total basal area of 12.00 m^2/ha (Table 2). This was followed by the Leguminosae and Euphorbiaceae whereby its total area were far less than the Dipterocarpaceae of 3.91 m^2/ha and 3.32 m^2/ha, respectively. This is not surprising because most large trees with DBH of more than 55 cm are dipterocarp trees, and this contributes to the large basal area of this family. As for species, *Shorea curtisii* indicates the largest basal area with a total of 4.30 m^2/ha, whilst *Koompassia malaccensis* and *Dipterocarpus cornutus* represent the second and third largest area with estimation of 2.07 m^2/ha and 1.58 m^2/ha, respectively.

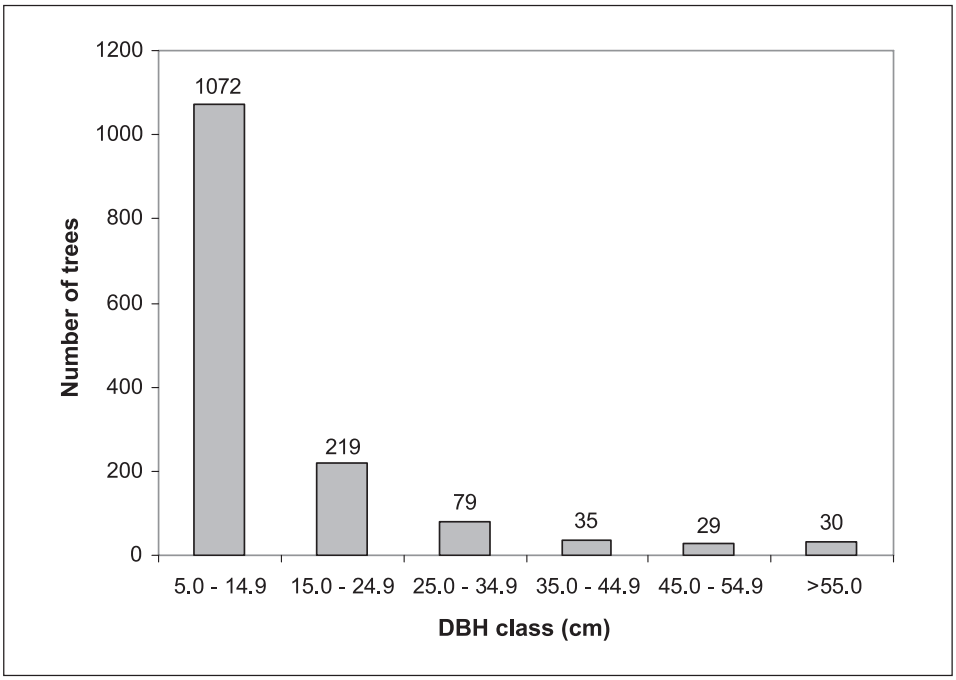

Fig. 1. Number of trees in each diameter class in the one hectare plot at Krau WR.

Table 2. Summary on abundance parameters for five leading species in the one hectare plot at the Krau WR

Parameter	Species	Family	Value
Density (trees/ha)	1. *Anisophyllea corneri*	Anisophylleaceae	73 trees/ha
	2. *Mallotus penangensis*	Euphorbiaceae	38 trees/ha
	3. *Gymnacranthera forbesii*	Myristicaceae	32 trees/ha
	4. *Shorea macroptera*	Dipterocarpaceae	29 trees/ha
	5. *Elateriospermum tapos*	Euphorbiaceae	25 trees/ha
Frequency (%)	1. *Anisophyllea corneri*	Anisophylleaceae	47%
	2. *Mallotus penangensis*	Euphorbiaceae	33%
	3. *Gymnacranthera forbesii*	Myristicaceae	29%
	4. *Shorea maxwelliana*	Dipterocarpaceae	22%
	5. *Shorea lepidota*	Dipterocarpaceae	20%
	Gironniera parvifolia	Ulmaceae	20%
	Calophyllum pulcherrimum	Guttiferae	20%
Basal Area (m^2/ha)	1. *Shorea curtisii*	Dipterocarpaceae	4.30 m^2/ha
	2. *Koompassia malaccensis*	Leguminosae	2.07 m^2/ha
	3. *Dipterocarpus cornutus*	Dipterocarpaceae	1.58 m^2/ha
	4. *Anisophyllea corneri*	Anisophylleaceae	1.51 m^2/ha
	5. *Irvingia malayana*	Irvingiaceae	1.23 m^2/ha
Importance Value Index (IV_i)	1. *Anisophyllea corneri*	Anisophylleaceae	4.01%
	2. *Shorea curtisii*	Dipterocarpaceae	3.34%
	3. *Gymnacranthera forbesii*	Myristicaceae	2.00%
	4. *Mallotus penangensis*	Euphorbiaceae	1.97%
	5. *Elateriospermum tapos*	Euphorbiaceae	1.84%

The study plot indicates that *Anisophyllea corneri* was the most important species with an IV_i of 4.01%, followed by the *Shorea curtisii* and *Gymnacranthera forbesii* with values of 3.34% and 2.00%, respectively (Table 2). From these values, none of the species can be considered to have absolute dominance in the community, because Curtis and Macintosh (1951) stated that species with IV_i of more than 10% can be considered as having absolute dominance in a particular community. Relatively, *A. corneri* was the most dominant species in the plot compared to other species, and its dominance is due to high density and frequency of this species in the study plot.

Diversity of tree species in the study plot calculated using the Shannon-Wiener diversity index (H') shows a value of 5.19 (H'_{max} = 5.74). The value is considerable high and since the Krau Wildlife Reserve is a protected area of virgin forests, hence the high tree species diversity is not surprising. As suggested by Magurran (1988) that the Shannon Index value consists of measurements of two components, i.e. species richness and relative abundance (evenness or unevenness), it is apparent that the richness and evenness of the tree community in this study is high, and most species are represented by more or less similar number of individuals. In comparison, a similar study in a protected forest at the Lesong Virgin Jungle Reserve in Pahang, Suhaili (2004) reported the Shannon index value of 4.96, and a high diversity in the Krau Wildlife Reserve should be an interesting point to note for management plans in the area.

ACKNOWLEDGEMENTS

The authors would like to thank the Department of Wildlife and National Parks (DWNP) and DANCED for financial supports granted throughout the study.

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