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CONTENTS

Front cover: Giant caterpillar of *Suana concolor*, a defoliator of *Acacia mangium* (Photo: Chey Vun Khen)

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Some wood properties of *Xylia xylocarpa* planted in Sabah

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Abstract. Five 9-year-old trees of planted *Xylia xylocarpa* were extracted from a small plot at Luasong, Tawau, Sabah. Wood specimens for the physical and mechanical tests were prepared according to the International Standard Organisation (ISO) standard from three height levels, bottom, middle and top, at the inner and outer radial positions of the stem. The variations of wood properties of the species were analysed by analysis of variance (ANOVA). The mean basic density, oven-dry density and green moisture content (MC) were 0.72 g/cm^3, 0.78 g/cm^3 and 49.8%, respectively. The total shrinkage from green to oven-dry conditions for the radial and tangential directions were 3.35% and 5.76%, respectively. The means for modulus of rupture (MOR), modulus of elasticity (MOE), compression parallel to grain, radial shear, tangential shear, radial hardness and tangential hardness were 134.8 N/mm^2, 12861 N/mm^2, 68.3 N/mm^2, 18.95 N/mm^2, 23.38 N/mm^2, 7.86 kN and 7.4 kN, respectively. Within-tree, the wood density decreased from the bottom to the top, and increased from inner to the outer part of the stem. The moisture content increased with height, and decreased from the inner to outer part of the stem. Shrinkage was higher at the outer part of the stem, and decreased from the bottom to the top of the stem. Generally, the mechanical properties of the species decreased with height, and increased from the inner to outer part of the stem. Overall, the wood properties of planted *X. xylocarpa* were almost comparable to a number of more mature local popular heavy hardwood species, indicating its suitability for heavy construction uses. However, more samples from different sites and different growth rates have to be studied for drawing general conclusions of the wood properties of the species. Further research to investigate the wood quality indicators such as wood durability, seasoning characteristics and wood machining properties is necessary for promoting the species for various uses.

Keywords: mechanical properties, physical properties, wood properties, wood quality, *Xylia xylocarpa*

INTRODUCTION

At present, most of the traditional slow-growing tropical species used for heavy construction purposes such as Selangan Batu (*Shorea* spp.), Resak (*Vatica* spp.), Merbau (*Intsia palembanica*) and Belian (*Eusideroxylon zwageri*) are fast depleting from the natural forest of Sabah. On the other hand, fast growing species such as *Acacia mangium*, *Paraserianthes falcataria*, *Gmelina aborea*, and *Araucaria* spp. which are being planted extensively generally produce timbers of low to medium density, with inferior mechanical strength properties. A fast growing tree such as *Xylia xylocarpa* with a denser wood suitable for structural end uses is therefore highly desired. The species belongs to the family Leguminosae and occurs naturally in India, Indo-China, Myanmar and Thailand. It is reported to grow fairly fast and yield a hard and durable wood used for heavy construction in its countries of origin (Anonymous 1989).

Similar to the growth performances in its countries of origin, the species shows fairly fast growth rate in Sabah. The mean total height and mean diameter at breast height (DBH) of 9-year-old trees grown in a trial plot of Luasong Forestry Centre (LFC), Tawau, are 23.2 m and 26.1 cm, respectively. Inclusion of the species for future forest plantation will further increase the possible choices of tree species for different uses. However, in selecting tree species for large plantation programmes, information on the rate of survival and growth alone is not sufficient. The suitability of the timber for certain product and end-uses is largely determined by its wood properties.

This paper highlights the results of a study on the physical and mechanical properties of planted *X. xylocarpa*. An understanding of the basic properties of the species is useful for better utilisation and the information on the properties variation within-tree is useful in allocating various parts of the tree to the appropriate manufacturing processes.

MATERIALS & METHODS

Field sampling

Nine-year-old *X. xylocarpa* trees were obtained from Luasong Forestry Centre, Tawau, Sabah, located at 117°23'E and 4°36'N. The location is approximately 132 m above sea level, and the mean annual rainfall is more than 2000 mm. The seedlings were line-planted at an initial spacing of 3 m x 3 m.

Five vertical trees of fairly straight and cylindrical bole with no sign of mechanical damage or attack by fungi and insects were selected from the plot of *X. xylocarpa*. The DBH of the trees were measured, and the trees were felled at approximately 15 cm above the ground. Various measurements were then collected for each felled tree. The descriptions on the sample trees are as shown in Table 1.

From each tree, cross-sectional discs of approximately 5 cm in thickness were taken at three height levels: bottom (30 cm above ground), middle (50% of clear bole height) and top (80% of clear bole height) (Figure 1). Each disc was marked with the tree number and height level. The discs were immediately wrapped with aluminium foil and kept in air-tight plastic bags to reduce the loss of moisture. All the wrapped discs were placed in a cold room (about 4°C) upon arrival at the Forest Research Centre (FRC), Sandakan until further processing. These discs were used as samples for the determination of wood physical properties. Bolts of approximately 2 m length were also taken at three height levels: bottom (B), middle (M) and top (T) of tree as shown in Figure 1. These bolts were used as samples for the evaluation of mechanical properties.

Table 1. Sample trees of *X. xylocarpa*.

Species	Tree no.	DBH (cm)	Clear bole (m)*	Total height (m)
X. xylocarpa	1	25.4	8.9	23.0
	2	27.0	9.8	23.5
	3	26.5	10.6	23.2
	4	24.6	7.9	21.9
	5	26.9	7.9	24.5
	Mean	26.1	9.0	23.2

* Height of bole from the ground up to the first branching

Preparation of test samples for physical properties

Radial strips of wood of about 3 cm width were cut from the discs. The strips were labelled with tree number (1 to 5), disc number (1 to 3) and strip number (1 to 4). Each strip was then cut into halves, and cubic samples of 2 cm x 2 cm x 2 cm dimensions were taken immediately from two positions (inner: 20% radius from pith; outer: 80% radius from pith) from the first part. These samples were used for the determination of green moisture content, basic density and shrinkage in accordance with ISO-3130 standard (Anonymous 1975a). Another part of the strip was immediately oven-dried at 102 ± 3°C and used for the determination of oven-dry density.

The green moisture content was determined using samples of 2 cm x 2 cm x 2 cm. All samples were dried in an oven (102 ± 3°C) until constant weight, i.e., less 0.1% change in weight six hours after the last measurement. The samples were cooled over dry silica gel in dessicator and weighed. The moisture content was calculated with the following formula:

$$MC = [W_i - W_o] / W_o \times 100\%$$

where

MC = moisture content (%)
W_i = original weight measurement (g)
W_o = final weight measurement (g)

The samples used for the determination of green MC were also used for the determination of the basic density of the wood. The oven-dry density was determined using samples of 2 cm x 2 cm x 2 cm prepared from the oven-dried wood strips. All samples were put in an oven at 102 ± 3°C until constant weight was achieved. The samples were then cooled over dry silica gel in dessicator, and the weight and dimensions were measured. The density was calculated as follows:

$$\rho = W_o / V_o$$

where

ρ = density (g/cm^3)
W_o = oven-dry weight (g)
V_o = volume (cm^3)

The shrinkages of wood from green to air-dry equilibrium moisture content (EMC) condition, and from green to oven-dry were calculated for radial and tangential directions based on dimensions measurement obtained in the wood MC and density determination. It is known that the shrinkage of wood in axial or longitudinal direction is normally small, thus only the shrinkage from green to oven-dry was calculated. The formula for shrinkage calculation is as follows:

$$S = [D_i - D_o] / D_i \times 100\%$$

where

S = shrinkage (%)
D_i = original dimensions
D_o = final dimensions

Preparation of test samples for mechanical properties

Four boards with nominal thickness of 3 cm were sawn from each bolt obtained from the trees. The boards were cut parallel to the anatomical planes of wood. Then sticks of 3 cm x 3 cm were prepared from two positions (inner: 20% of radial distance from pith; outer: 80% of radial distance from pith). The sticks were labelled according to tree number (1 to 5), bolt number (1 to 3), board number (1 to 4) and the position in tree (inner or outer). The radial and tangential surfaces of the sticks were marked with r and t, respectively. All wood sticks were then stacked to air dry in the testing room at 20 ± 2°C and 65 ± 3% RH (relative humidity). Once the sticks reached the EMC, the samples for mechanical properties test were then prepared in accordance with the ISO-3129 standard (Anonymous 1975b). The specifications of the wood samples are shown in Table 2.

Table 2. Wood samples for mechanical properties evaluation.

Property	Sample size (cm)	Number of samples
Bending (MOR; MOE)	2 x 2 x 32	120
Compression (Parallel to grain)	2 x 2 x 6	120
Shear (Radial; Tangential)	2 x 2 x 2	240
Hardness (Radial; Tangential)	2 x 2 x 6	240

MOR = modulus of rupture
MOE = modulus of elasticity

Evaluation of mechanical properties

Testing of mechanical properties namely, static bending, hardness, compression and shear parallel to grain were conducted in accordance with ISO-3133 (Anonymous 1975c), ISO-3350 (Anonymous 1975d), ISO-3787 (Anonymous 1976a) and ISO-3347 (Anonymous 1976b) standard, respectively. The tests were performed by using a Zwick 1474 testing machine attached to a computer, in a testing room with standard condition of 20 ± 2°C and 65 ± 3% RH.

Analysis of data

Data on wood properties obtained from each tree were pooled to compute the overall minimum, maximum, mean and standard deviation of wood properties.

Analysis of variance (ANOVA) was used to examine the variability of wood properties within tree. Each wood property variable was evaluated independently to determine if variations among sampling height levels and radial positions were significant.

RESULTS & DISCUSSION

Physical properties of *X. xylocarpa*

The physical properties of 9-year-old *X. xylocarpa* planted in Sabah are presented in Table 3. The green MC ranged from 40.1 to 65.8% and the average was 49.8%. The average MC in this study is comparable to the reported green MC (48.6%) of *X. xylocarpa* in India (Alex 1936).

The mean wood basic and oven-dry densities obtained were 0.72 g/cm^3 and 0.78 g/cm^3, respectively, while the wood density at EMC (12% MC) was 0.76 g/cm^3. These values are lower than those reported elsewhere. Keating & Bolza (1982) reported the density of *X. xylocarpa* to range between 0.81-1.01 g/cm^3 at 13% MC in Burma. Ramesh & Juneja (1971) found it to be 0.85 g/cm^3 at 12% MC in India.

Table 3. Physical properties of 9-year-old *X. xylocarpa*.

Property	Minimum	Maximum	Mean	SD
Green MC (%)	40.1	65.8	49.8	3.0
Basic density (g/cm^3)	0.65	0.78	0.72	0.12
Oven-dry density (g/cm^3)	0.70	0.81	0.78	0.16
Shrinkage (green to air-dry):				
Radial (%)	1.11	1.25	1.17	0.19
Tangential (%)	2.05	2.60	2.37	0.82
Shrinkage (green to oven-dry):				
Radial (%)	2.44	3.62	3.35	0.26
Tangential (%)	3.93	5.80	5.76	0.29
Axial (%)	0.33	0.44	0.39	0.11

SD = standard deviation
Total number of specimens = 120

In general, the wood density of 9-year-old *X. xylocarpa* planted in Sabah was higher than the density ranges of other fast growing plantation species such as *A. mangium*, *G. arborea*, *P. falcataria* (Table 4). It was comparable with the density of *Tectona grandis* and even to some local popular hardwood timber such as *E. zwageri* (Belian), *I. palembanica* (Merbau), *Shorea laevis* (Selangan Batu Kumus) and *Vatica cuspidata* (Resak).

Table 4. Wood density of plantation and some popular hardwoods species.

Species	Density (g/cm^3)	Age (year)
*Paraserianthes falcataria**	0.23 – 0.28	12
*Gmelina arborea**	0.36 – 0.49	11
*Eucalyptus deglupta**	0.36 – 0.49	20
*Acacia mangium**	0.38 – 0.54	9
*Tectona grandis***	0.61 – 0.75	10
*Eusideroxylon zwageri****	0.83 – 1.19	na
*Intsia palembanica****	0.52 – 1.04	na
*Shorea laevis****	0.96 – 1.16	na
*Vatica cuspidata****	0.65 – 1.15	na

* Anonymous (1993)
** Trockenbrodt (1999)
*** Keating & Bolza (1982)
na = not available

The averages of wood shrinkage from green to air-dry condition were 1.17% and 2.37% for the radial and tangential directions, respectively. The wood shrinkage from green to oven-dry was high with 3.35% and 5.76% for the radial and tangential directions, respectively. The tangential shrinkage was thus about twice as high as that of the radial. The ratio of tangential to radial shrinkage from green to air-dry was small (1.72%), indicating a low risk of deformation in wood during drying. The ratios of tangential to radial shinkage considered to be high are those over 2.2% (Rijsdijk & Laming 1994). Alex (1936), Howard (1951), and Anonymous (1979) also reported the rate of shrinkage of *X. xylocarpa* to be low, but the timber requires careful and slow seasoning to prevent checking and splitting.

Similar to other wood species, the axial or longitudinal shrinkage of *X. xylocarpa* was very small, with a mean shrinkage (green to oven-dry) of only 0.39%. The difference between the longitudinal and horizontal (radial and tangential) shrinkage is due to the alignment of wood cells (Anonymous 1992). As water is removed from the cell walls, the cells move closer together. Movement in the horizontal direction is greater than in the longitudinal direction.

Variations in physical properties of *X. xylocarpa*

The analysis of variance of the physical properties of 9-year-old *X. xylocarpa* is summarised in Table 5. The radial position had no significant effect on the radial and tangential shrinkage (green to oven-dry) but significantly affected the other properties. Height level showed insignificant effect on the physical properties except for basic density and tangential shrinkage (green to air-dry). The interactions of radial position and height level were more apparent on MC and basic density.

Table 5. Summary of ANOVA on the physical properties of *X. xylocarpa*.

			Shr (Green - AD)		Shr (Green - OD)		
Source of Variation	MC	BD	R	T	R	T	A
Radial Position (P)	*	*	*	*	ns	ns	*
Height level (H)	ns	*	ns	*	ns	ns	ns
Tree (T)	*	*	ns	ns	ns	ns	ns
P x H	*	*	*	ns	ns	ns	ns
P x T	ns	ns	ns	ns	ns	ns	ns
H x T	ns	ns	ns	ns	ns	ns	ns
P x H x T	*	*	*	*	*	ns	ns

Shr = shrinkage
AD = air-dry
OD = oven-dry
MC = moisture content
BD = basic density

* significant (P < 0.05)
ns = not significant (P > 0.05)
R = radial
T = tangential
A = axial

Significant differences in green MC were found among the radial positions within a stem. It is evident that MC in the inner part was significantly ($P < 0.05$) higher than that at the outer part of the stem. However, the observed green MC was not significantly different ($P > 0.05$) among the sampling heights within a stem. The variation of green MC was thus more significant radially rather than vertically.

A significant decrease of wood density with tree height was observed. The basic and oven-dry densities at the bottom were 0.80 g/cm^3 and 0.82 g/cm^3, compared to 0.75 g/cm^3 and 0.76 g/cm^3 respectively, at the top level. The decreasing trend of density from bottom to the top has also been reported in sycamore wood (Land *et al.* 1983) and in *Azadirachta excelsa* (Lathsamy 1998). However, the increase or decrease of density values with tree height is not always the case in hardwoods. Mohd Hamami & Ismail (1992) found that the specific gravity of *Anthocephalus chinensis* increases with height. According to Zobel & Buijtenen (1989), wood density is normally high at the bottom due to the higher proportion of heartwood formation at the stump, and higher proportion of juvenile wood near the top. Larson (1969) attributed an increase in specific gravity at points high in the stem to the inclusion of greater proportion of high density knots in the wood of the upper portion and/or the presence of a larger amount of tension wood.

A lower value of wood basic density at the inner part (0.61 g/cm^3) compared to outer part (0.71 g/cm^3) of the stem was observed. The difference in densities between the two radial positions was significant. This trend is expected, as the increase of density from the pith to the bark is associated to the transition of juvenile wood to mature wood. This also indicates that cell walls are thinner near the pith and they become thicker at the outer part. The increase in density of wood from the pith to the bark has also been reported in *A. excelsa* (Lathsamy 1998), *G. arborea* (Tang & Ong 1982) and *Octomeles sumatrana* (Trockenbrodt & Tze 1997).

The mean radial shrinkage of wood from green to air-dry increased significantly ($P < 0.05$) from the centre to the periphery of the stem (Table 5). Similarly, the radial shrinkage of wood from green to oven-dry also increased, but insignificantly ($P > 0.05$) from the centre to the periphery of the stem. The radial shrinkage from green to air-dry and from green to oven-dry were not significant among the height levels.

It is evident that the mean tangential shrinkage of wood from green to air-dry increased significantly ($P < 0.05$) from the inner part to the outer part of the stem, and was significantly different ($P < 0.05$) among height levels. It increased from the bottom (2.05%) to the middle (2.60%), and then slightly decreased at the top (2.49%). However, the tangential shrinkage from green to oven-dry was not significant ($P > 0.05$) among height levels.

The mean axial shrinkage from green to oven-dry was not significantly different at different height levels. In radial position, the mean shrinkage increased significantly from 0.35% at the inner part to 0.43% at the outer part of the stem.

Wood density influences the shrinkage of wood. Wood with high density has proportionately more cell wall and less lumen, and tends to shrink or swell more (Walker 1993). The decrease of shrinkage from bottom to the top of the tree, and the increase from the inner to outer part of the stem, reflect the common relationship between shrinkage and density of the wood.

Mechanical properties of *X. xylocarpa*

The ranges, means and standard deviations of the test results are tabulated in Table 6. In general, the strength properties of young *X. xylocarpa* are almost comparable to other mature popular hardwood species as shown in Table 7. The average values for modulus of rupture (MOR) and compression were 134.8 N/mm^2 and 68.3 N/mm^2, respectively. These values are lower than that of *E. zwageri* and *S. laevis*, but are higher than *I. palembanica* and *V. cuspidata*. The mean modulus of elasticity (MOE) of young *X. xylocarpa* at 12861 N/mm^2 is low in comparison to the other species.

Table 6. Mechanical properties of 9-year-old *X. xylocarpa*.

Property	Minimum	Maximum	Mean	SD
MOR (N/mm^2)	68.6	186.8	134.8	23.4
MOE (N/mm^2)	1603	19207	12861	2923
Compression (N/mm^2)	27.8	81.7	68.3	7.7
Hardness (kN):				
Radial	4.17	11.98	7.86	1.56
Tangential	3.31	11.26	7.40	1.40
Shear (N/mm^2):				
Radial	10.10	27.43	18.95	2.85
Tangential	8.83	30.60	23.38	3.52

MOR = modulus of rupture
MOE = modulus of elasticity
SD = standard deviation

Number of specimens = 120

Table 7. Mechanical properties of some heavy hardwood species.

Species	MOR (N/mm^2)	MOE (N/mm^2)	Comp. (N/mm^2)	Shear (N/mm^2)
Eusideroxylon zwageri	178	18080	94	20.0
Intsia palembanica	116	15400	58	12.6
Shorea laevis	142	20100	76	15.0
Vatica cuspidata	105	18100	61	12.5

MOR = modulus of rupture
MOE = modulus of elasticity
Comp. = compression parallel to grain

Source: Keating & Bolza (1982)

The radial and tangential shear strength of *X. xylocarpa* were 18.95 N/mm^2 and 23.38 N/mm^2, respectively, higher than the mean shear values of *I. palembanica* (12.5 N/mm^2), *S. laevis* (15 N/mm^2) and *V. cuspidata* (12.5 N/mm^2), despite its young age.

Variations in mechanical properties of *X. xylocarpa*

The analysis of variance on mechanical properties of *X. xylocarpa* is summarized in Table 8. The mean values of compression, shear and hardness decreased significantly from the base to the top of the tree, whereas the mean values for MOR and MOE decreased insignificantly. This is similar to the trend of variation of wood density of the species. Wood density is known to be closely related to the mechanical properties of wood (Panshin & de Zeeuw 1980) and many have reported significant linear relationship between mechanical properties and wood density (Pearson & Gilmore 1971; Gammon & Schniewind 1980; Zhang 1992). The results of the present study also showed similar trend with species such as *A. excelsa* (Lathsamy 1998), *Michelia formosan* and *Cyclobalanopsis longinex* (Tang 1995).

Table 8. Analysis of variance of mechanical properties of *X. xylocarpa*.

Source of Variation	Statistical significance						
	MOR	MOE	Comp.	Hardness		Shear	
				R	T	R	T
Radial position (P)	*	*	*	*	*	*	*
Height level (H)	ns	ns	*	*	*	*	*
Tree (T)	*	*	*	*	*	*	*
P x H	*	*	*	*	*	*	*
P x T	*	*	*	*	*	*	*
H x T	ns	ns	*	*	*	*	*
P x H x T	*	*	*	*	*	*	*

MOR = modulus of rupture
MOE = modulus of elasticity
Comp. = compression
R = radial
T= tangential

* significant ($P < 0.05$)
ns = not significant ($P > 0.05$)

All the mechanical properties varied significantly in the radial position (Table 8). Overall, the values of the mechanical properties at the outer part were higher than that at the inner part of the stem. There are several causes for this radial variation pattern, such as the relationship of strength to the age of the cambium (Zobel & Buijtenen 1989). Larson (1969) reported that juvenile wood is formed in the early stage of the life of trees, and comprises growth rings that are formed close to the pith. The formation of juvenile wood near to the pith is always associated with wood of low density (Zobel & Buijtenen 1989) and wood density is closely related to mechanical properties (Panshin & de Zeeuw 1980). Hillis (1989) found that the decrease of fibril angle during the change from juvenile wood to mature wood will increase the strength.

CONCLUSION

The wood of *X. xylocarpa* is very heavy and dimensionally stable as indicated by a low to moderate rate of shrinkage. In addition, the ratio in tangential to radial shrinkage is moderate, indicating a low risk of wood deformation during drying.

Within-tree, the wood density decreased from the bottom to the top, and increased from the inner to outer part of the stem. In contrast, the MC increased with height, and decreased in radial position from the inner to outer part of the stem. The trend of shrinkage was found to be similar to that of density. Shrinkage was higher at the outer part than the inner part of the stem, and it decreased from the bottom to the top of stem.

Generally, within-tree variations of physical properties were more pronounced in radial positions than the height levels. Most properties evaluated consistently showed significant differences at different radial positions, which could be attributed to age and transition from juvenile to mature wood.

Significant within-tree variations were observed in most mechanical properties. Generally, the mechanical properties of species decreased with height, and increased from the inner part to outer part of the stem, similar to the trend of density variation.

Overall, the wood properties of planted *X. xylocarpa* were comparable to a number of local hardwood species such as Merbau, Selangan Batu and Resak, indicating its suitability for heavy construction uses. However, samples used in the study came from only one site. More samples from different sites and different growth rates will have to be studied to draw general conclusions of the wood properties of the species planted in Sabah. In addition, further research to fully investigate the wood quality indicators will be critical for promoting the species for various uses such as wood durability, seasoning characteristics and machining properties.

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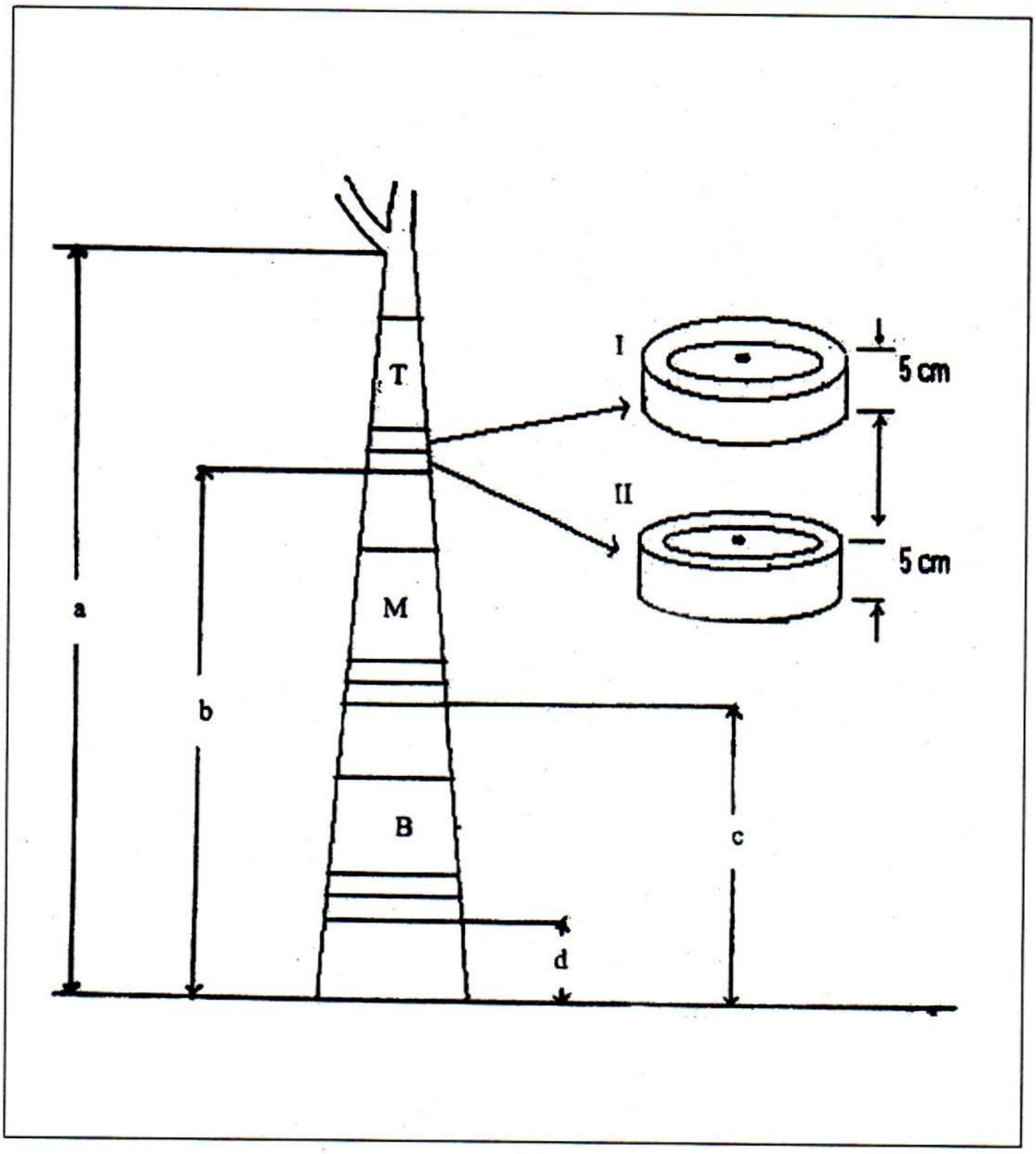

Figure 1. Sampling points within a selected tree.

a = total clear bole height
b = 80% of clear bole height
c = 50% of clear bole height
d = 30 cm above ground
I = disc for anatomical property evaluation
II = disc for physical property evaluation
Bolts of 2 m length for mechanical test:
B = bottom
M = middle
T = top

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Vertical distribution of fruit-feeding butterflies in Sabah, Borneo

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Abstract. Investigation of vertical distribution of fruit-feeding butterflies in the complex tropical rainforest of Sabah is important for understanding butterfly diversity in the tropics and for determining responses of butterflies to forest disturbance. We used fruit-baited traps to investigate the vertical distribution of fruit-feeding butterflies in primary rainforest and to determine if ground-based surveys can reliably survey nymphalid butterflies, or whether there are significant numbers of these species restricted to the canopy. The results show that whilst ground-based transect techniques can survey Satyrinae and Morphinae butterflies fairly reliably, they are likely to miss the canopy component of the fauna. Movements of recaptured butterflies between traps at different heights were minimal, indicating that species are confined to certain heights.

Keywords: fruit-feeding butterflies, tropical rainforest, vertical stratification

INTRODUCTION

Insects are an important group for studying the patterns of biological diversity in tropical rainforests (DeVries *et al.* 1997). This is because more than half of all described species are insects (Holloway *et al.* 1992), and because diversity is highest in tropical regions. Many insect species are dependent on closed-canopy forests but the destruction of tropical rainforests is occurring at a rapid rate (Collins 1990). Therefore, studies of diversity patterns are urgently needed in order to understand tropical communities and their conservation value (Holloway *et al.* 1992; DeVries *et al.* 1997; Spitzer *et al.* 1997). Studies of insects are particularly important given that they play a major role in many ecosystem processes such as pollination, decomposition, nutrient cycling, seed predation, parasitism, and herbivory (Janzen 1987; Bond 1994).

Light is important in determining the distribution of many forest insects, and many insects including butterflies are vertically stratified from the ground to the canopy (Davis & Sutton 1998). Some studies have suggested that there is a distinctive canopy fauna and that ground-based surveys miss a substantial component of forest biodiversity (Hughes *et al.* 1998; Davis & Sutton 1998). Several studies investigating vertical stratification in butterflies have demonstrated a distinctive canopy fauna compared with understorey, probably due to the differences in the light environment in the canopy compared with the understorey (DeVries *et al.* 1997; DeVries *et al.* 1999; Beck & Schulze 2000; Hill *et al.* 2001). However, studies on butterflies in the canopy are still lacking, particularly in South East Asian rainforest (Schulze *et al.* 2001).

In this study we used fruit-baited traps to sample butterflies in the canopy. This is a method that allows easy access to the canopy (Barker & Sutton 1997). Fruit-baited traps sample species of butterfly that feed as adults on rotting fruit; these species generally belong to the family Nymphalidae. Approximately 75% of nymphalid species recorded in Sabah feed on fruit. As far as we are aware, this was the first study to investigate vertical stratification of butterflies over one full year in lowland dipterocarp rainforest in South East Asia. The results of this study will provide baseline data on fruit-feeding butterflies in undisturbed tropical rainforest of Sabah.

The aims of this study were as follows:

i) To investigate the vertical distribution of fruit-feeding butterflies in primary rainforest;

ii) To investigate the longevity of fruit-feeding butterflies;

iii) To investigate if ground-based surveys can reliably survey butterflies, or whether there are significant numbers of these fruit-feeding nymphalid species restricted to the canopy.

MATERIALS & METHODS

Study site

The study site was located within the unlogged lowland primary forest adjacent to the Danum Valley Field Centre (DVFC), Sabah (for details of study site see Marsh & Greer 1992). Six traps were fixed at three levels (40 m - high level, 2 traps; 20 m - medium level, 2 traps; 2 m - low level, 2 traps) on tree platforms around an emergent *Shorea johorensis* tree. The low and medium level traps were under dense canopy cover, whereas the high-level traps were within the canopy and received higher levels of sunlight (estimated at 70-85% canopy openness). Sunlight penetration at ground level was minimal (< 10%).

Sampling of butterflies

Butterfly traps (Figure 1) were operated every month for 14 days each month, from March 1999 until February 2000 (12 months). Traps were baited with two fresh bananas on the first day of trapping and were re-baited every second day with a small piece of fresh banana. This ensured that all traps contained a mixture of fresh and well-rotten bait. Traps were emptied each day between 1600 and 1800 hours.

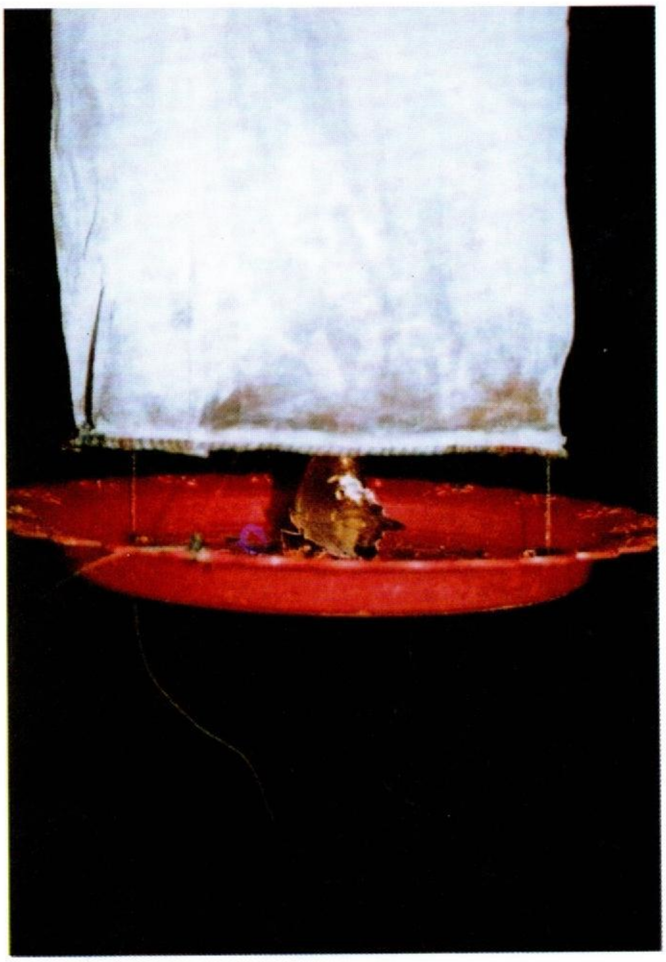


Figure 1. A butterfly trap, showing *Neorina lowii* feeding on fruit-bait.

All butterflies were individually marked on the underside of the forewing with felt-tipped pen according to trap location. For large butterflies (e.g. *Kallima limborgii, Bassarona dunya, Neorina lowii*) each individual was marked with a unique number; smaller butterflies were given a location-specific mark. All marked butterflies were then released back into the population unharmed. *Euthalia* spp. and *Tanaecia* spp. can only be identified reliably from male genitalia (Otsuka 1988) and were not identified to species in this study and so were excluded from the analyses. All other fruit feeding butterflies that were captured (and recaptured) were identified following Otsuka (1988).

Analysis of data

Species diversity of fruit-feeding butterflies was calculated using the Shannon-Wiener index, and Margalef's and Simpson's indices following recommendations by Magurran (1988). The Shannon index incorporates measures of species richness and evenness into a single measure, Simpson's index measures species evenness, and Margalef's index measures species richness. Longevity of fruit-feeding butterflies was investigated for the three most abundant species which had been individually marked, and these were *Bassarona dunya*, *Kallima limborgii*, and *Neorina lowii*.

RESULTS

Species assemblages of fruit-feeding butterflies

A total of 542 individuals from 40 species was recorded during the one year trapping period (total of 1008 trap days). Only 8% of all individuals captured were unidentified and so excluding these from the analyses is unlikely to have affected the results.

In this study 17 species were recorded only at low level, whereas 3 species were recorded only at medium level and another 4 species only at high level (107, 3 and 12 individuals, respectively). Thirty-one species were more common at low traps whereas 23 species were more common in medium and high traps. Table 1 shows the number of species trapped at different heights, and their relative abundance.

Diversity of fruit-feeding butterflies

Diversity values of Shannon-Wiener index, Simpson's and Margalef's indices at each level are shown in Table 2. Pairwise comparisons using randomization tests based on 10,000 random samples (Solow 1993), showed that there were no significant differences in species diversity between any of the levels ($P > 0.05$ in all cases).

Movement of fruit-feeding butterflies between traps at different heights

From 542 individuals captured in traps during the study, there were 615 recaptures (Table 1). Few individuals were recaptured moving between traps at different heights, but the greatest number was of individuals moving between low traps and medium traps (Table 3).

Adult longevity of fruit-feeding butterflies

Three commonly caught species of fruit-feeding butterflies were used to investigate adult longevity. These species were *Bassarona dunya* (total number of individuals caught = 77), *Neorina lowii* (total caught = 69), and *Kallima limborgii* (total caught = 33). Figure 2 shows adult longevity of each species in terms of the number of days over which species were recaptured. *Kallima limborgii* recorded the greatest longevity (maximum of 164 days between captures) whereas *Bassarona dunya* and *Neorina lowii* recorded a maximum of 60 and 24 days, respectively.

DISCUSSION

Collection of data

Investigation of the vertical stratification of butterflies is important for studying butterfly diversity in tropical rainforest (Wolda 1983; DeVries 1988). However, access to the canopy is a major problem and alternate methods to butterfly walk-and-count transects (Pollard & Yates 1993) need to be used. In this study, the problem of gaining access to the canopy was partially overcome by using trapping methods. However, fruit traps only trap the guild of butterflies that are attracted to rotting fruit and so only a part of the butterfly fauna can be studied. Also there is no information concerning the distances over which species are attracted to traps, or if different species are attracted differently to traps making it difficult to determine the sampling area of traps. The advantage of using traps is that it reduces the problems of identification in the field because all individuals are captured and more easily identified. Thus fruit-baited traps are currently the best technique to sample butterflies in the canopy.

Vertical distribution of fruit feeding butterflies

Some studies have suggested that ground-based surveys will miss a large component of diversity that is confined to the canopy (DeVries *et al.* 1997). Out of 14 species recorded from walk-and-count transects (Tangah 2000), 13 were caught in low level traps. However 6 species of Satyrinae and Morphinae were caught in traps but not recorded on transects, and 4 of these were caught above ground level. These data indicate that whilst ground-based transect techniques can survey Satyrinae and Morphinae butterflies fairly reliably, they are likely to miss a component of the fauna that does not occur at ground level. Species caught in low level traps but not seen on transects may have been crepuscular (active only at dawn) (Corbet & Pendlebury 1992), and these species will also be under-recorded using walk-and-count transects.

Other studies of fruit-feeding butterflies have shown higher diversity at ground level, compared with the canopy (Hughes *et al.* 1998). This may be because rotting fruit generally fall to the ground. In this study, 17 of 40 of species (43%) were recorded only in the low level traps. However, 9 species (23%) were recorded only in intermediate or in high level traps (e.g. *Elymnias dara*, *Polyura athamas* and *Charaxes solon*; Table 1) indicating that some fruit may normally rot *in situ* or may often get trapped in the upper branches.

Table 1. Number of individuals of butterflies (Nymphalidae) captured and recaptured (shown in brackets) in fruit-baited traps at three different heights (2 m - low; 20 m - medium; 40 m - high) in primary forest.

	Low	Medium	High	Total
Satyrinae				
Neorina lowii Doubl.	68(126)	1(1)	0	69(127)
Coelites epiminthia West.	0	1	0	1
Elymnias dara Dist.	0	0	3	3
Ragadia makuta Fruh.	62	0	0	62
Melanitis leda Linn.	22(5)	20(5)	13(1)	55(11)
Mycalesis anapita Fruh.	3	1	0	4
Mycalesis dohertyii Fruh.	2	0	0	2
Mycalesis horsfieldi Fruh.	0	1	1	2
Mycalesis kina Stau.	4(2)	0	0	4(2)
Mycalesis maianeas A. & U.	5	0	0	5
Mycalesis orseis Fruh.	14(5)	0	0	14(5)
Mycalesis patiana Eli.	6(4)	1	0	7(4)
Morphinae				
Amathusia phiddipus Linn.	1(1)	4(1)	2	7(2)
Amathusia masina Fruh.	0	0	1	1
Amathuxidia amythaon Butl.	0	1	0	1
Zeuxidia aurelius Fruh.	1(1)	0	0	1(1)
Xanthotaenia busiris Stich.	1	0	0	1
Discophora necho C. & R. Fel.	3	0	0	3
Faunis canens Fruh.	1	0	0	1
Faunis stomphax West.	2(1)	0	0	2(1)
Nymphalinae				
Cirrochroa tyche Fruh.	1	0	0	1
Cupha erymanthis Dru.	1	0	0	1
Bassarona dunya Fruh.	73(331)	4(1)	0	77(332)
Bassarona teuta Dist.	7(6)	12(11)	3(1)	22(18)
Amnosia decora Fruh.	3(1)	0	0	3(1)
Kallima limborgii Moo.	30(50)	3	0	33(50)
Parthenos sylvia Stau.	0	1	0	1
Dophla evelina Fruh.	30(18)	26(16)	2(1)	58(35)
Dichoraggia nesimachus Fruh.	2	5(1)	0(1)	7(2)
Lexias canescens Butl.	2	0	0	2
Paduca fasciata C. & R. Fel.	1	0	0	1
Terinos clarissa Fruh.	2	0	0	2
Stibochiona schoenbergi Hon.	2	0	0	2
Rhinopalpa polynice Fruh.	1	2	0	3
Charaxinae				
Prothoe franckii Fruh.	38(22)	14(2)	1	53(24)
Polyura athamas Roth. & J.	0	0	3	3
Charaxes bernardus Butl.	0	1	7	8
Charaxes solon Butl.	0	0	5	5
Charaxes durnfordi Roth.	5	4	0	9
Agatasa calydonia Fruh.	2	4	0	6
Number of individuals captured	395	106	41	542
Number of recaptures	(573)	(38)	(4)	(615)

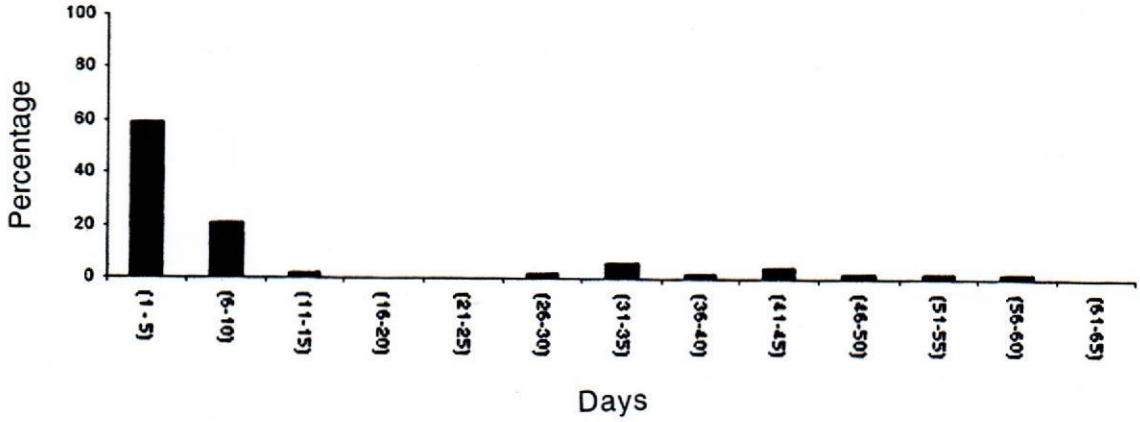
Table 2. Species diversity of fruit-feeding butterflies at three different heights.

	Low (2 m)	Medium (20 m)	High (40 m)
Number of species	28	19	11
Number of individuals	395	106	41
Shannon-Wiener index, H'	2.51	2.34	2.06
95% confidence interval	0.22	0.38	0.14
Simpson's index	8.87	7.81	6.83
95% confidence interval	1.92	3.75	5.37
Margalef's index	5.02	3.87	2.69
95% confidence interval	1.00	1.07	0.81

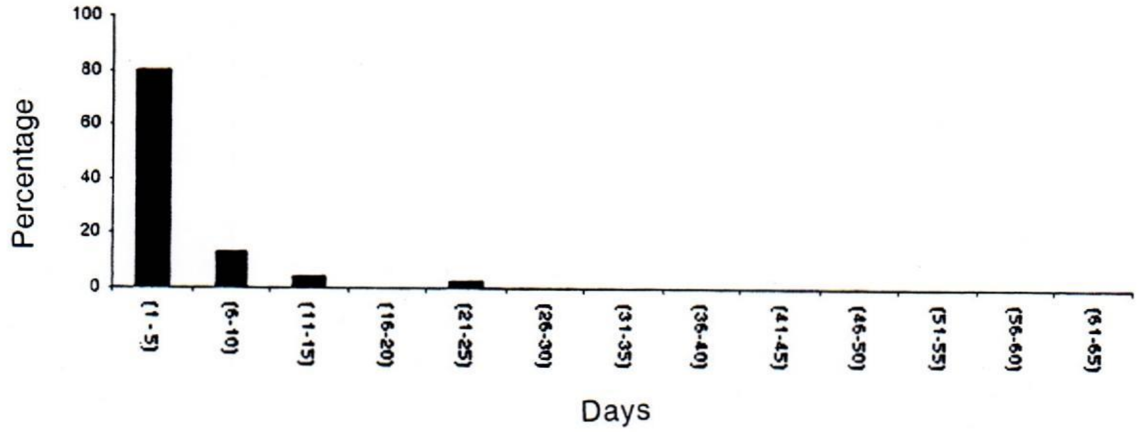
Table 3. Recapture rates among low, medium, and high level traps.

	Low	Medium	High
Medium	40 (6.5%)	0	0
High	2 (0.3%)	5 (0.8%)	0

a) *Bassarona dunya*



b) *Neorina lowii*



c) *Kallima limborgii*

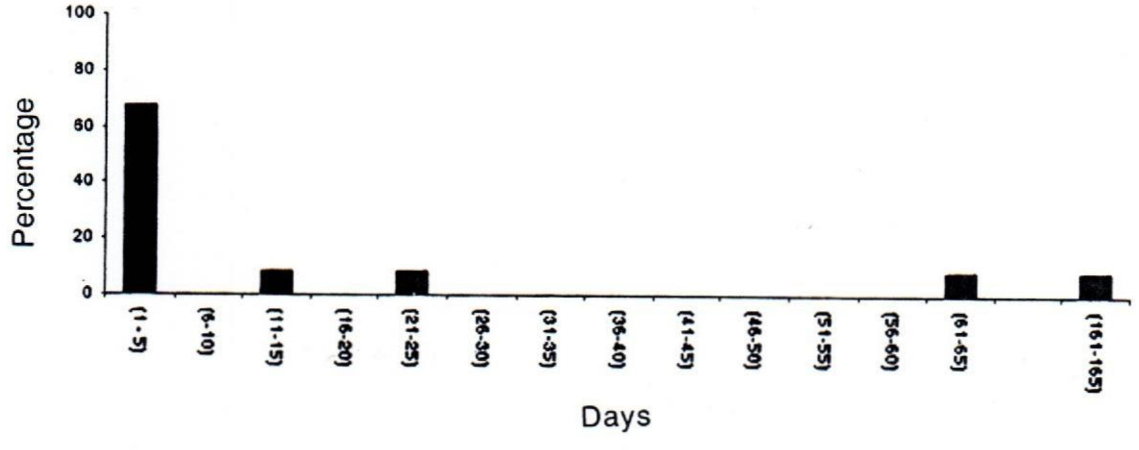


Figure 2. Longevity of fruit-feeding butterflies based on percentage of marked individuals recaptured over different time periods.

Adult longevity of fruit-feeding butterflies

In this study, *Kallima limborgii* recorded the greatest longevity with a maximum of 164 days (approximately 5½ months). *Bassarona dunya* recorded the second highest longevity with a maximum of 60 days (8½ weeks), and *Neorina lowii* recorded a slightly lower longevity at 24 days (3½ weeks). The results shown here may be used as preliminary information on longevity of fruit-feeding butterflies in Sabah.

Other studies on longevity of fruit-feeding nymphalids in highland dipterocarp forest of Sabah (Beck & Schulze 2000) showed that some butterflies may live up to six weeks, in broad agreement with our results. These results contrast with data from neotropical rainforests where pollen-feeding *Heliconius* butterflies (Heliconiinae) have been recorded to live up to 6 months longevity (Dunlap-Pianka *et al.* 1977). In temperate regions, adult longevity of some butterflies may be similarly long but only in species where adults are inactive during the winter (Pollard & Yates 1993). For temperate species where adults do not enter diapause, adult longevity is generally only 1–2 weeks (Thomas & Hanski 1997; Thomas *et al.* 1998).

Movement of butterflies

In this study, movements of recaptured butterflies between traps at different heights were minimal. This indicates that species are confined only to certain heights. This vertical stratification may be maintained by adult resources or other factors such as distribution of larval host plants (Beccaloni 1997) or predation (Schulze *et al.* 2001). Results from this study show that fruit-traps are a good method for sampling in the canopy. However, there are few long-term studies, such as this, that have sampled in the canopy and more research is needed to investigate how habitat disturbance (e.g. commercial selective logging) affects vertical stratification (Davis & Sutton 1998).

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Vertical stratification of beetles (Coleoptera) using flight intercept traps in a lowland rainforest of Sabah, Malaysia

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Abstract. This study investigated the beetle assemblages, using flight intercept traps set up at different levels (ground, 6 m and 12 m) of an aluminium-alloy tower in a lowland dipterocarp forest in Sabah. A total of 215 morphospecies from 48 families were recorded from 12 samplings between March and September, 2000. Staphylinidae and Scarabaeidae (mainly dung beetles) were the most prominent families, sampled mainly at the ground level. Species richness and abundance of beetles were significantly lower in both 6-m and 12-m levels compared to the ground level. Sampling with mist-blowing from previous study was compared, and the study has shown that the sampling technique is vital in determining prominent beetle groups to be sampled. The high number of beetle singletons sampled in lowland rainforest suggested that beetles generally resemble non-interactive communities, which can be regarded as non-equilibrium communities.

Keywords: beetles, canopy, Coleoptera, flight intercept traps, vertical stratification

INTRODUCTION

Beetles are often used as a group to characterize terrestrial habitats or communities, especially in the tropical ecosystem (Erwin 1982; Hammond 1990; Stork 1991). This is because they are highly diverse, representing almost 25% of all living organisms globally (Hammond 1995). Due to their high diversity, it is interesting to investigate the assemblages of beetles at different levels of a habitat. Different beetle groups may occupy different levels of a habitat, from the ground to the top level of the canopy. Various studies have been conducted to examine stratification of insects (e.g. Sutton & Hudson 1980; Sutton 1983; Davis *et al.* 1997; Bruhl *et al.* 1998; Chung *et al.* 2001), using different sampling techniques. Methods to gain access to the canopy were highlighted by Lowman *et al.* (1993) and Moffett (1993) while sampling in the canopy was discussed in depth by Basset *et al.* (1997).

The purpose of this study is to investigate the species richness, abundance and composition of the beetle assemblages at different levels of the forest using flight intercept trap on an aluminium-alloy tower. Chung *et al.* (2001) did a similar study by mist-blowing at different levels of the canopy. The results from this study can be used to compare the efficacy of mist-blowing and flight-intercept-trapping on an aluminium-alloy tower.

MATERIALS & METHODS

Study site

This study was conducted at the Sepilok Arboretum in Sandakan, Sabah. It is a lowland rainforest of an area of 106.7 hectares and is 15-45 m above sea level. It was gazetted as an arboretum in 1971 and is located adjacent to the Kabili-Sepilok Forest Reserve. Lee & Berhaman (1992) gave a detailed account of the Sepilok Arboretum. The horizontal and vertical profiles of the sampling site are shown in Figure 1 while Table 1 lists the tree species at the site. Half of the trees at the sampling site are dipterocarps. The trees are of moderate size with diameters at breast height of less than 50 cm and heights below 25 m, indicating that the site is a regenerating dipterocarp forest.

Table 1. Details of tree species at the sampling site.

Code	Species	Family	DBH* (cm)	Height (m)
1	*Anisoptera costata*	Dipterocarpaceae	19	16
2	*Anisoptera costata*	Dipterocarpaceae	35	22
3	*Anisoptera costata*	Dipterocarpaceae	26	21
4	*Garcinia mangostana*	Guttiferae	30	12
5	*Parashorea tomentella*	Dipterocarpaceae	29	22
6	*Endospermum diadenum*	Euphorbiaceae	30	18
7	*Mallotus wrayi*	Euphorbiaceae	6	5
8	*Canarium denticulatum*	Burseraceae	29	16
9	*Shorea xanthophylla*	Dipterocarpaceae	31	17
10	*Dehaasia incrassata*	Lauraceae	12	8
11	*Chisocheton beccariana*	Meliaceae	14	9
12	*Shorea xanthophylla*	Dipterocarpaceae	12	16
13	*Dacrydes* sp.	Burseraceae	29	20
14	*Sterculia affine*	Sterculiaceae	27	23
15	*Shorea waltonii*	Dipterocarpaceae	47	25
16	*Shorea xanthophylla*	Dipterocarpaceae	46	24

* Diameter at breast height

Sampling procedure

Sampling was carried out between March and September, 2000 at a fixed location of the arboretum. A 12-m aluminium-alloy tower was set up and a flight intercept trap was placed at the ground level, 6-m and 12-m intervals. Details of the tower were discussed by Chung *et al.* (2001). A total of 16 samplings were taken throughout the project. However, only 12 samplings were used in the analyses because some samples were blown off by strong wind. In each sampling, the flight intercept trap was set up for three nights starting on Friday and specimens were collected on Monday (for description of flight intercept trap, see Chung *et al.* (2000)). In this study, only specimens from three trays of each flight intercept trap were taken and analysed. This was to reduce the workload of mounting the specimens. Moreover, the trays in a trap were not samples on their own but were pseudo-replicated.

Specimens were identified to morphospecies and were grouped according to families. Various taxonomy keys and literature (e.g. White 1983; Booth *et al.* 1990) were used in identification. The specimens are deposited in the Insect Museum, Entomology Section, Forest Research Centre (FRC) in Sepilok.

RESULTS & DISCUSSION

A total of 215 morphospecies from 394 individuals were sampled in this study. Forty eight families were recorded (Appendix 1). Staphylinidae was the most speciose family, followed by Scarabaeidae, Scolytidae, Curculionidae and Hydrophilidae. Scarabaeidae was the most abundant family. In the study by Chung *et al.* (2001), also at the Sepilok Arboretum but using mist-blowing, Chrysomelidae was the most prominent family sampled, followed by Curculionidae, Coccinellidae, Mordellidae and Phalacridae.

Scarabaeidae and Staphylinidae were prominently sampled at the ground level while at the 6-m and 12-m levels, various families such as Curculionidae, Staphylinidae, Corylophidae and Hydrophilidae were speciose and abundant. Curculionidae were consistently dominant in species and abundance at both levels. The ground level showed the highest number of species and individuals sampled throughout the study while there were no significant differences between the 6-m and 12-m levels (Figure 2). The large numbers of beetles at the ground level were largely due to the presence of dung beetles (Scarabaeidae) and rove beetles (Staphylinidae). A vast majority of the animal dung is on the ground and thus it is not surprising that many of the dung beetles are found at the ground level. Rainforest dung beetles are also known to utilize fungi and decaying plant material, mostly abundant on the ground (Davis 1993). Many of the staphylinids feed on smaller arthropods which are usually abundant on the ground too. More than 90% of the species and individuals of these two families were recorded from the ground level (Chi-Square, $P < 0.05$). Other families which were significantly more speciose and abundant at the ground level are shown in Appendix 1.

In the study by Chung *et al.* (2001), there was no significant reduction of species and individuals from the bottom to top level in the arboretum as assessed by mist-blowing. The prominent families sampled in all the three levels were the herbivorous Chrysomelidae and Curculionidae. There were also no significant differences on the proportions of respective families between levels except for the abundance proportion of Chrysomelidae which was greater at the bottom level. Scarabaeidae were not sampled through mist-blowing. This suggests that trapping methods are vital in determining what group of beetles to be sampled. Fewer beetles sampled by flight intercept trap at the 6-m and 12-m levels did not portray that there were fewer arboreal beetles (since mist-blowing did not show reduction of beetle numbers from bottom to top), but it may suggest that flight intercept trap is more suitable in sampling understorey and ground beetles.

The results show very few overlap species (Table 2). Thus, there was a large number of exclusive species in one level as sampled by flight intercept trap. This is because approximately 70% of the species sampled were singletons. Figure 3 shows the distribution of the singletons at each level of the habitat from this study. Although Floren & Linsenmair (1998) collected approximately 9,000 beetle specimens, the number of singletons was still high representing about 60% of the 409 species, and 96% of the species comprised less than 10 individuals. Thus, it is not the small sample size in this study that contributed to the high number of singletons. Moran & Southwood (1982) suggested that singletons should be regarded as tourists because one cannot assess whether they belong to the tree-associated fauna or to the non-resident fauna that is dispersing between habitats. Floren & Linsenmair (1998), however, disagreed as it is unlikely for nearly all the beetles to be caught by chance. Chung *et al.* (2001) and other studies in the tropics (see Floren & Linsenmair 1998) also shared similar findings of large number of singletons, which suggest that generally beetles of primary lowland rainforests resemble non-interactive communities, which can be regarded as non-equilibrium communities (Floren & Linsenmair 1998).

Table 2. Overlap species between habitat levels.

Overlap levels	Overlap species	Total species in overlap levels	Percentage of overlap species
Ground – 6 m	8	197	4.1
6 m – 12 m	7	54	13.0
Ground – 6 m – 12 m	3	215	1.4

The abundant beetle species, mostly dung beetles were sampled only at the ground level (Table 3). Dung beetles show a continuum of behaviour, from intense interspecific competition, with weak competitors being excluded from the local community and a few individuals dominating, to strong intraspecific associations leading to aggregation and within-patch mixed species assemblages, where the type of interaction largely depends on the size of the resource relative to those species inhabiting it (Davis 1993). Their high frequency in sampling, especially *Onthophagus semiaureus* (Sca1) and *Onthophagus* sp. (Sca3) not only suggests that they were abundant on the forest floor and understorey level but their occurrence was well-distributed throughout the few months of sampling and that they recolonized the sampling area very quickly. The genus *Onthophagus* belongs to the Onthophagini tribe, which is one of the most important and widespread tribes in Africa and Eurasia, with over 2000 described species (Davis, 1993). In Sabah, more than 59 species of *Onthophagus* were recorded by Davis (2000). Species within this genus are generally small tunnelers (Doube 1983), with sizes ranging from 4-15 mm (Davis 1993). Although they are mostly ground dwellers, Davis *et al.* (1997) have revealed that a few arboreal *Onthophagus* spp. were found from a few metres above the forest floor up to the high forest canopy, feeding on primate dung caught on canopy vegetation.

Table 3. Prominent species sampled throughout the 12 samplings at the Sepilok Arboretum.

No.	Species	Family	Total abundance	Frequency in sampling	Level(s) recorded
1	*Onthophagus semiaureus*	Scarabaeidae	26	11	0m
2	*Onthophagus* sp. (Sca3)	Scarabaeidae	15	8	0m
3	*Sisyphus thoracicus*	Scarabaeidae (Sca21)	13	4	0m
4	Species Hyd2	Hydrophilidae	11	7	0m, 6m, 12m
5	Species Sta4	Staphylinidae	9	6	0m
6	*Onthophagus semicupreus*	Scarabaeidae (Sca2)	8	5	0m
7	Species Mor5	Mordellidae	6	4	0m
8	Species Lei1	Leiodidae	5	4	0m
9	Species Sta6	Staphylinidae	5	3	0m, 6m, 12m
10	Species Bip1	Biphyllidae	5	3	0m, 12m

The diversity of beetles (Table 4) did not show a decreasing trend although all the samplings were conducted at the same location. The sampling intervals varied from five days to three weeks. This suggests that a five-day period is sufficient for the beetle assemblage to recover from flight-intercept-trapping (with only three collecting trays at each trap). There was no significant relationship detected between the beetle numbers, diversity and rainfall during the sampling days. Rainfall in each sampling is shown in Table 4.

CONCLUSION

This study has shown that the sampling technique is vital in determining prominent beetle families to be sampled. Therefore, in assessing a beetle assemblage and also other insect assemblages of a study area, one would have to interpret the results based on the method used and not make assumptions on the assemblages on an area as a whole. Magurran (1988) has also pointed out that the effectiveness of the sampling technique is an important factor in determining the diversity of communities. As assessed with flight intercept trap, many dung beetles were confined to the ground level only and these beetles were not sampled through mist-blowing. Unlike other insects, e.g. ants, beetle species in a lowland rainforest often occur in low abundance, resembling non-equilibrium communities, with the exception of some dung beetle species as indicated in this study.

Table 4. Sampling dates, species richness, abundance, diversity indices and rainfall data of the 12 samplings at the Sepilok Arboretum.

No.	Sampling dates	Species richness	Abundance	Shannon Index	Variance Shannon Index	Rainfall (mm)
1	31/3 –3/4/2000	30	42	3.134	0.030	10.6
2	14/4 – 17/4/2000	27	33	3.229	0.017	24.2
3	21/4 –24/4/2000	33	37	3.433	0.016	28.7
4	12/5 – 15/5/2000	22	31	2.934	0.023	20.0
5	26/5 – 29/5/2000	22	25	3.032	0.023	2.5
6	2/6 –5/6/2000	29	34	3.307	0.016	16.5
7	16/6 – 19/6/2000	38	53	3.506	0.012	25.5
8	23/6 – 26/6/2000	28	36	3.208	0.019	19.8
9	21/7 – 24/7/2000	19	25	2.844	0.023	9.9
10	4/8 – 7/8/2000	18	18	2.890	0.026	18.3
11	18/8 – 21/8/2000	34	37	3.499	0.014	0.0
12	1/9 – 4/9/2000	19	22	2.839	0.032	57.2

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(a)

(b)

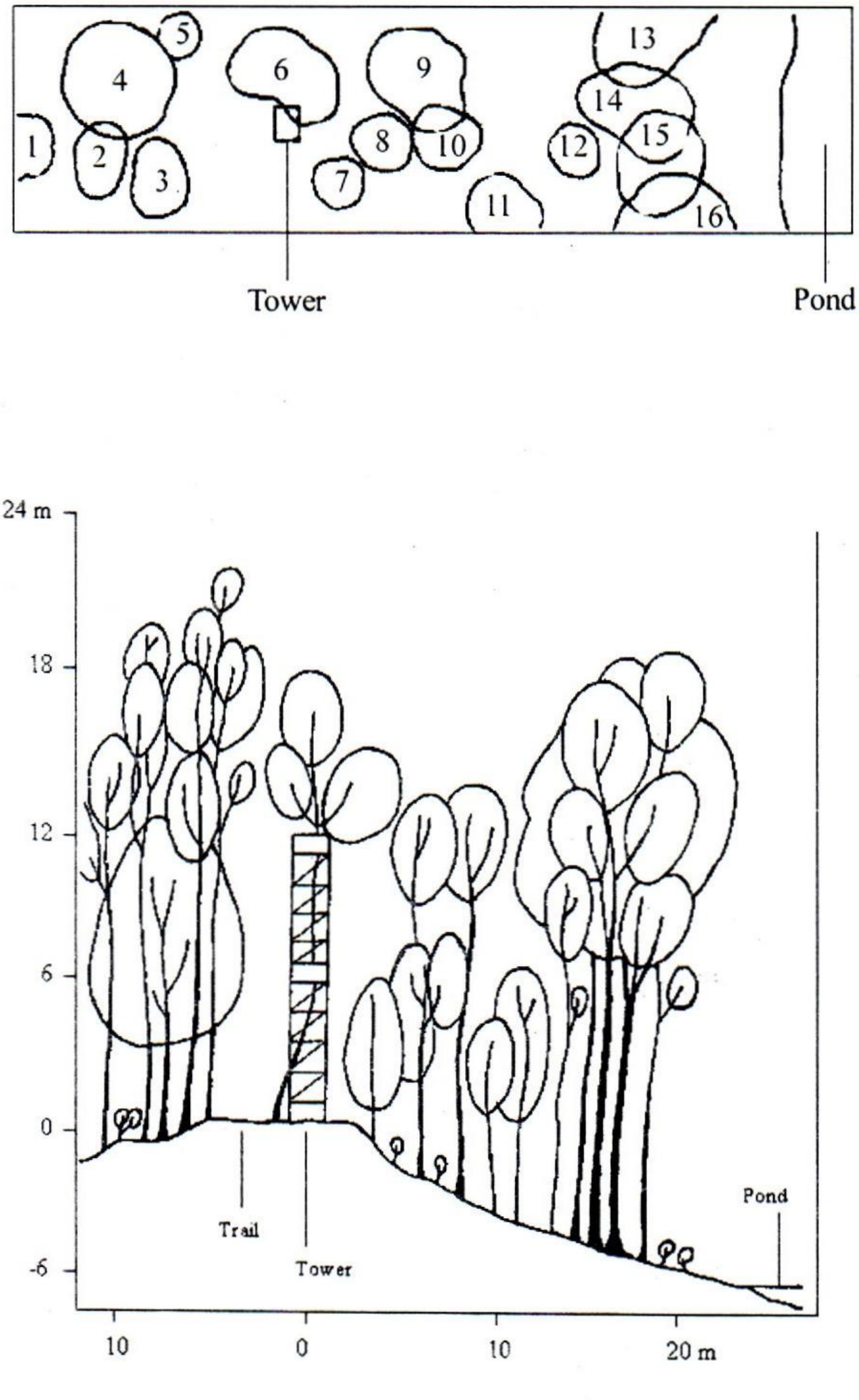
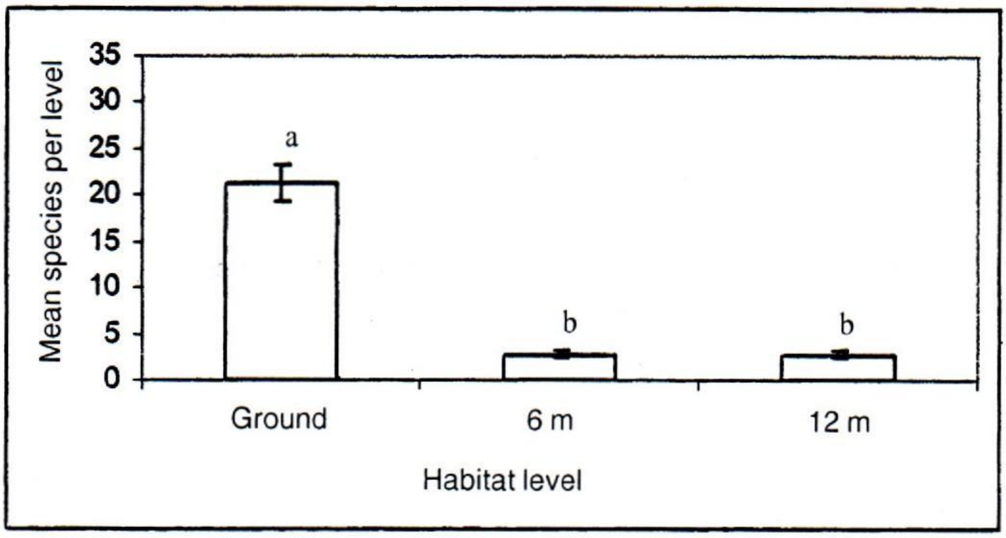


Figure 1. Horizontal (a) and vertical (b) profiles of the stratified vertical sampling with flight intercept traps set at different levels of the 12-m aluminium-alloy tower at the Sepilok Arboretum (See Table 1 for tree species and other details).



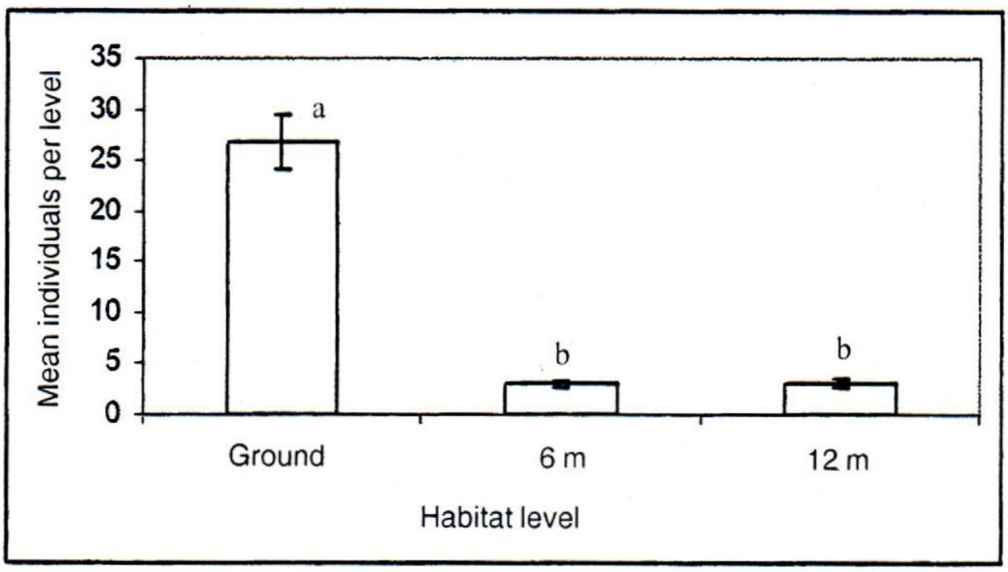


Figure 2. Mean beetle species and individuals per level (with standard error) collected at different habitat levels using flight intercept traps at the Sepilok Arboretum. Means followed by the same letter are not significantly different (Tukey's HSD, $P < 0.05$).

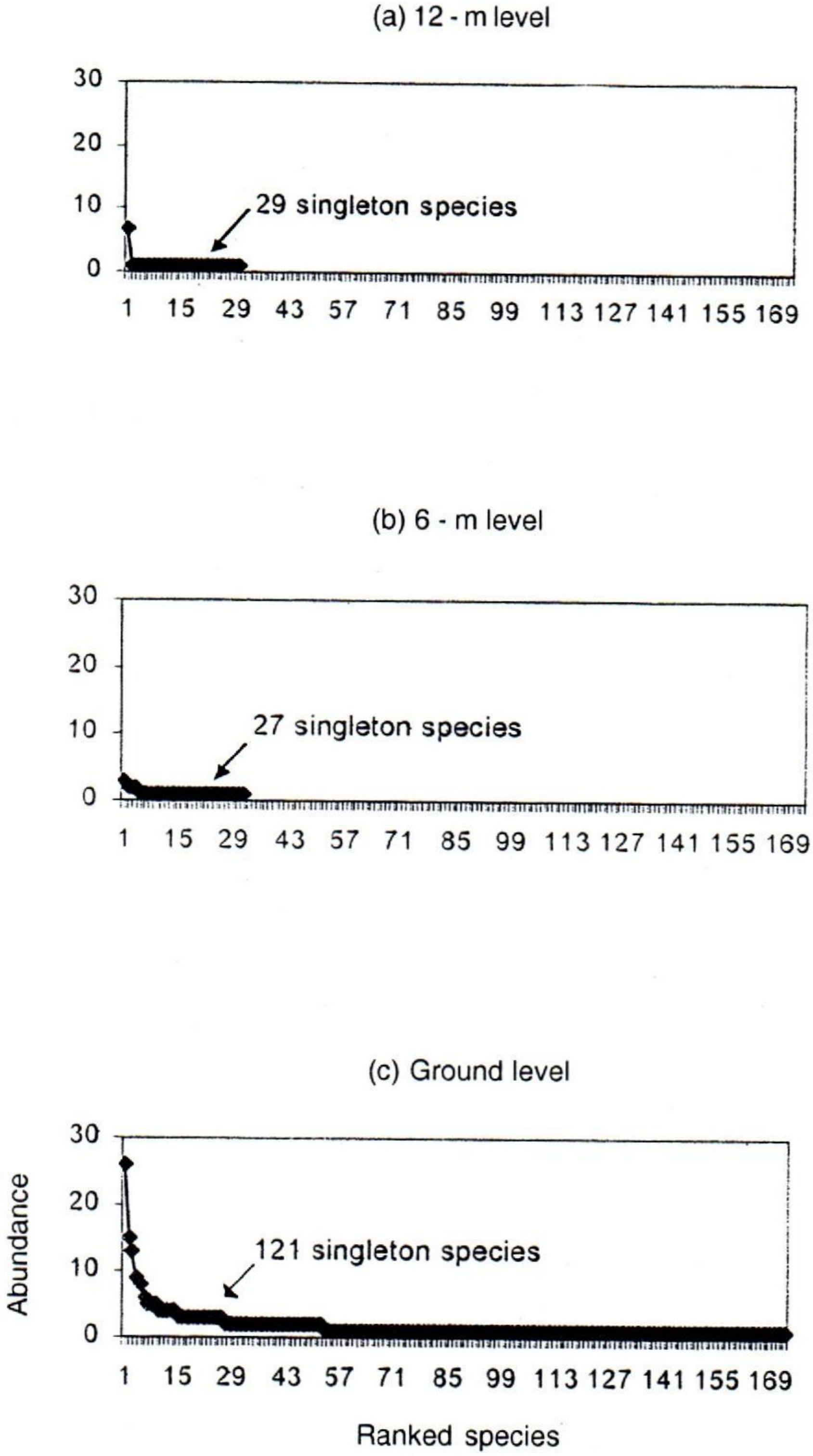


Figure 3. Species abundance distribution of beetles at different levels at the Sepilok Arboretum.

Appendix 1. Species and individuals of beetle families collected using flight intercept traps at various levels at the Sepilok Arboretum.

Family	Species Ground	Species 6 m	Species 12 m	Species Chi-Square	Individuals Ground	Individuals 6 m	Individuals 12 m	Individuals Chi-Square
Carabidae	1	0	0		1	0	0	
Hydrophilidae	15	2	1	*	18	3	7	*
Histeridae	3	0	0		3	0	0	
Scydmaenidae	2	0	0		5	0	0	
Leiodidae	3	0	0		7	0	0	*
Staphylinidae	27	3	1	*	44	3	1	*
Pselaphidae	6	1	0		7	1	0	*
Scaphidiidae	5	0	0		5	0	0	
Acanthoceridae	2	0	0		3	0	0	
Scarabaeidae	21	1	0	*	86	1	0	*
Hybosoridae?	1	0	0		2	0	0	
Chelonariidae	0	1	1		0	1	1	
Eucnemidae	1	0	1		3	0	1	
Elateridae	3	1	2		5	1	2	
Throscidae	3	0	0		7	0	0	*
Lycidae	1	0	0		1	0	0	
Lampyridae	1	0	0		1	0	0	
Dermestidae	2	0	0		5	0	0	
Anobiidae	0	1	1		0	1	1	
Ptinidae	1	1	0		1	1	0	
Lophocateridae	1	0	0		3	0	0	
Cleridae	1	0	1		1	0	1	
Melyridae	2	1	0		3	1	0	
Nitidulidae	1	0	0		1	0	0	
Phalacridae	2	1	0		3	2	0	
Sphindidae	0	1	1		0	1	1	
Laemophloeidae	0	0	1		0	0	1	
Biphyllidae	2	1	1		5	1	1	
Erotylidae	2	1	0		2	1	0	
Cerylonidae	0	1	0		0	1	0	
Corylophidae	3	3	3		3	5	3	
Endomychidae	4	0	0		10	0	0	*
Coccinellidae	1	1	1		1	1	1	
Discolomidae	2	0	0		3	0	0	
Colydiidae?	2	0	0		2	0	0	
Mycetophagidae	1	0	0		1	0	0	
Mordellidae	7	0	2	*	13	0	2	*
Anthicidae	1	0	0		3	0	0	
Pedilidae	2	0	0		6	0	0	*

Family	Species Ground	Species 6 m	Species 12 m	Chi-Square	Individuals Ground	Individuals 6 m	Individuals 12 m	Chi-Square
Aderidae	2	0	0		2	0	0	
Othniidae	0	0	1		0	0	1	
Tenebrionidae	1	0	1		1	0	1	
Alleculidae	1	0	0		1	0	0	
Chrysomelidae	1	2	1		1	3	1	
Anthribidae	7	1	1	*	7	1	1	*
Curculionidae	9	4	6		9	4	6	
Scolytidae	18	1	0	*	34	1	0	*
Platypodidae	0	1	0		0	1	0	
Unidentified	3	1	3		3	1	3	
Total	174	31	30		322	36	36	

* Significant difference ($P < 0.05$) on the number between levels.

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NOTES

A note on the vegetation of Malawali Island, Sabah

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Abstract. A brief survey on the flora in Pulau Malawali was carried out. There are four vegetation/ forest types in Pulau Malawali, namely ultramafic forest (consists of two sub-forest types, Sempilau (*Gymnostoma nobile*) forest and mixed forest), mangrove forest, rocky beach forest and secondary forest (consists of grassland-Simpoh association and old growth). A list of plants collected at Pulau Malawali is given. Of particular conservation importance are the unique and rare stands of pole-sized Sempilau trees on the island.

Keywords: flora, forest types, *Gymnostoma nobile*, Malawali, sub-forest types

INTRODUCTION

Pulau Malawali is an ultramafic island in the Balabac Straits off the northern coast of Sabah, located about 100 km northeast of Kudat town and only accessible by boat (Figure 1). The island has a total area of about 3,925 hectares, covered with dense Sempilau (*Gymnostoma nobile*) forest except for the southeastern part which is grassland, and is surrounded by numerous coral reefs. The terrain is undulating and gradually sloping up towards the centre of the island. The highest point is the Malawali peak (139 m). The soils on the island are classified under two main associations, namely Bidu-bidu and Weston. The Weston association occurs mainly within the tidal area of the mangrove forest. The soil of the Bidu-bidu association is mainly of reddish brown coarse texture, derived from ultrabasic rock (Plate 8) which is the oldest in Sabah identified as the metamorphic rock. The island is very dry with only two seasonal rivers, Sungai Maralas and Sungai Simpangan. There is also a stream flowing from Malawali hill but it seems to dry fast due to the removal of vegetation cover.

MATERIALS & METHODS

The survey of flora was carried out by the authors and other participants on August 8-11, 2002. All of the vegetation types were surveyed except for burnt and secondary forest types.

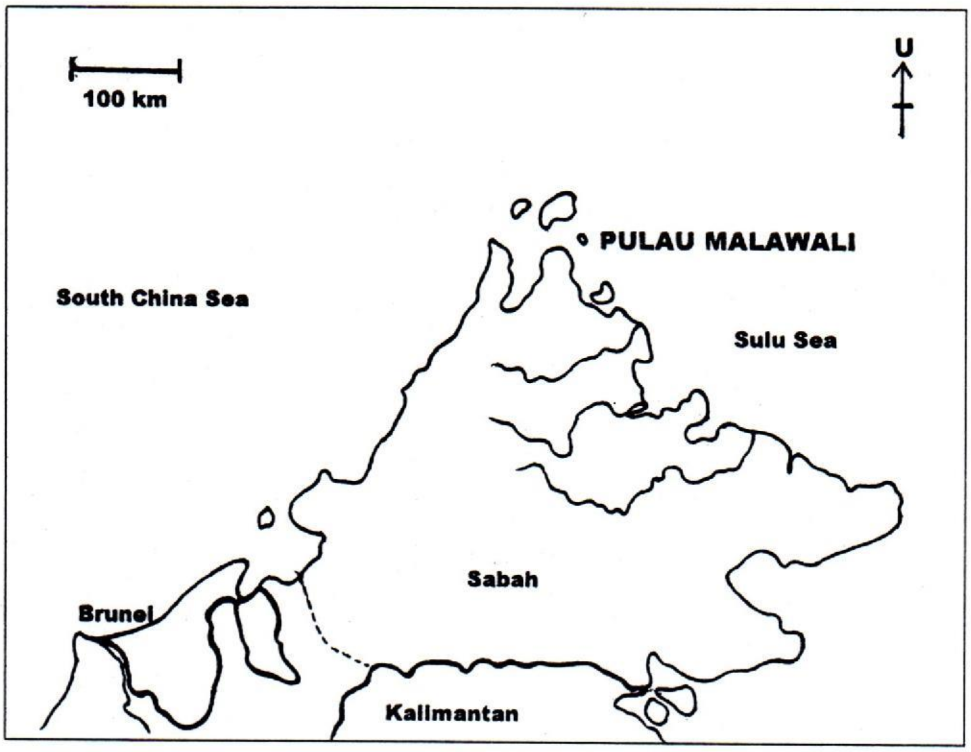

Figure 1. Location of Pulau Malawali.

Plant collections were made along the trails during the survey using the Sandakan Herbarium (SAN) series. Voucher specimens were also collected for plants without flower or fruit. They were later identified at the Sandakan Herbarium, Systematic Botany Section of the Forest Research Centre (FRC). References include Kern (1976), Vermeulen (1991), Soepadmo & Wong (1995), Soepadmo *et al.* (1996), Wood (1997), Soepadmo & Saw (2000), Soepadmo *et al.* (2002). Herbarium search, including locating specimens collected during the previous botanical surveys, such as that carried out by the staff of Sabah Forestry Departmnt in 1979, was also performed for comparison. There might be earlier collections by Brackenridge in 1849 (Van Steenis 1950), but the specimens could not be located.

RESULTS & DISCUSSION

Flora

Pulau Malawali is made up largely of ultramafic forest, which is dominated by Sempilau (*Gymnostoma nobile*). The rest are patches of mangrove forest, few patches of coastal beach forest and secondary forest (grassland with Simpoh (*Dillenia luzonensis*) and old growth) (Figure 2).

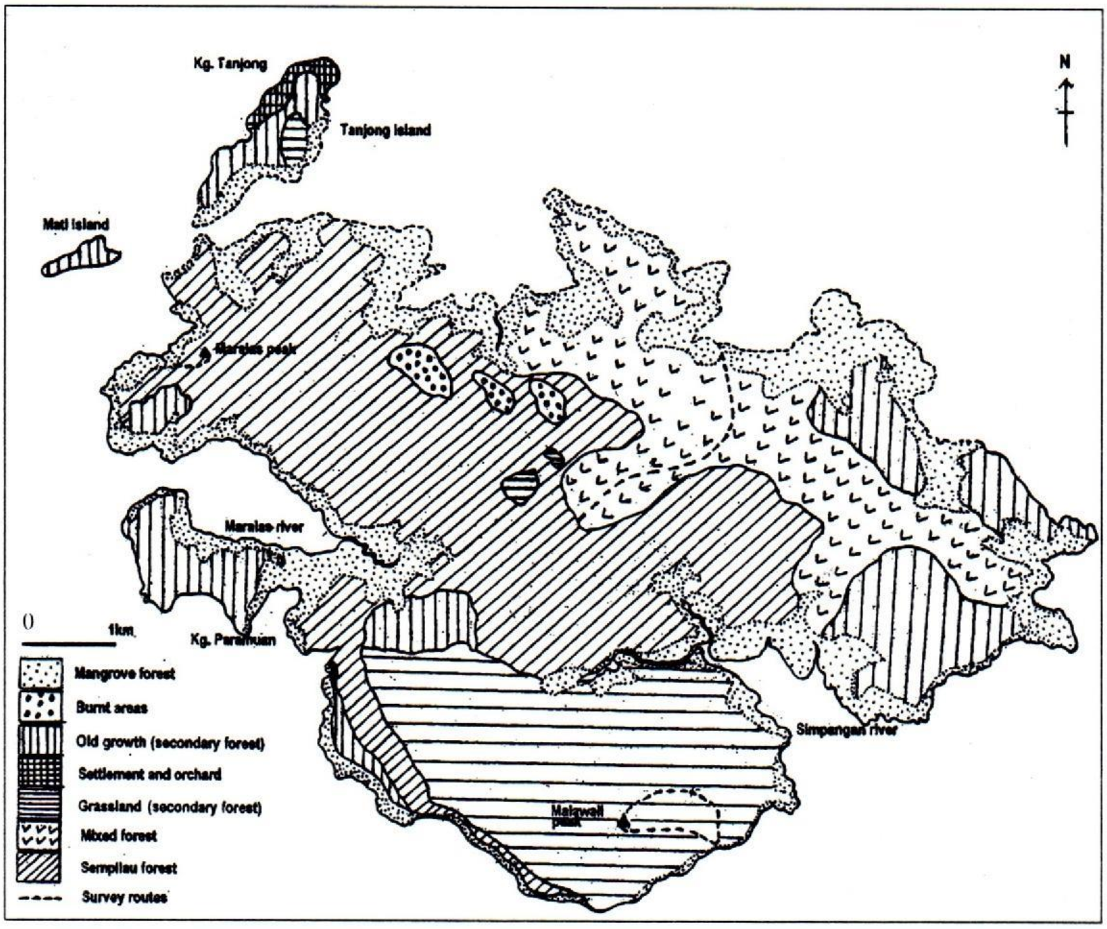

Figure 2. Vegetation map of Pulau Malawali.

In terms of species diversity, the island is considered relatively poor compared with the dipterocarp forest. For example, in Sempilau forest, Sempilau trees are predominant with scattered occurrence of Pulai Tipu (*Alstonia macrophylla*). The occurrence of almost pure stands of Sempilau forest on Pulau Malawali shows that species diversity is low compared with other ultramafic areas in Sabah, like Mt. Silam (Proctor *et al.* 1988), Ranau (Fox & Tan 1971), and Meliau Range (Sugau 2004). *Borneodendron aenigmaticum*, a species endemic to ultramafic forest (Airy Shaw 1975), was not found or recorded from the island.

Ultramafic forest

Two plant communities may be distinguished on the ultramafic soils, namely the Sempilau forest and the mixed forest.

i. Sempilau forest

This plant community develops on ultramafic soil invading from the mangrove forest to the hilly area in the centre of the island. The forest is generally low with an even canopy, about 10 to 15 m tall. This forest is dominated by the Sempilau tree (*G. nobile*) with sporadic occurrence of Pulai Tipu (*A. macrophylla*). Such pure stands of pole-sized Sempilau trees are unique and rare in Sabah. The Tongkat Ali, *Eurycoma longifolia*, is found scattered under the canopy. Patches of pandan, *Pandanus motleyanus* (Plate 4) and a thorny shrub, *Fagerlindia emanuelssoniana*

(*Rubiaceae*), are noted to form impenetrable thickets in the understorey. The forest floor is covered with fallen twigs of Sempilau. Ground herbs and shrubs are lacking.

ii. Mixed forest

The canopy of the forest is about 10 - 20 m tall, without any single dominating species. Among the most common tree species found are *Alstonia macrophylla, Carallia brachiata, Dacryodes* spp., *Drypetes* sp., *Knema* sp., *Palaquium rostratum*, *Podocarpus polystachyus, Syzygium* sp., *Tristaniopsis* sp. and *Vatica maritima*. Treelet species are *Archidendron* sp., *Croton* sp., *Dillenia luzonensis, Kopsia* sp., *Licania splendens*, *Rinorea bengalensis*, *Rothmannia merrillii*, *Psychotria* sp. and *Tarenniodea wallichii*. A few palm species such as *Arenga undulatifolia*, *Licuala sabahana*, *L. spinosa* were also encountered, and the rattans are represented by *Calamus malawaliensis* (Plate 10), *C. laevigatus* and *C. subinermis*. The large solitary palm, *Corypha utan* (Plate 9), was also found to be very common in the northeastern part of the island. Among the climbers are two members of Menispermaceae, as well as *Spatholobus* sp. and *Dinochloa darvelana*. Fern diversity was poor, represented only by *Pyrrosia* sp. and *Drymoglossum* sp. Three species of orchid are found near the mangrove forest, *Apostasia wallichii, Cleisostoma* sp. and *Vanda lamellata* (Plate 14). Only one species of the ginger family was recorded, *Alpinia aquatica* (Plate 11). Patches of dense community of pandan, *Pandanus motleyanus*, are also common. The thorny scrambling scrub, *Fagerlindia emanuelssoniana* is also common near the mangrove strip.

Mangrove forest

The island is almost covered all around with a narrow strip of mangrove forest. Only the southwestern part (Kampung Paramuan), southern and eastern parts are devoid of mangrove forest (Figure 2). Among the mangrove species found are *Carallia brachiata, Ceriops tagal* and *Rhizophora* spp. (all Rhizophoraceae), *Lumnitzera littorea* (Combretaceae), *Sonneratia alba* (Sonneratiaceae) and *Avicennia marina* (Verbenaceae).

Rocky beach forest

This forest type is very narrow and occurs only in small patches at certain part on the rocky coastal area. Among the species found are *Heritiera littoralis, Cycas rumphii* (Plate 12), *Rothmannia merrillii, Pongamia pinnata* and *Pandanus odoratissimus.*

Secondary forest

Secondary forest develops on about 30% of the total area of the island. Fire was the main factor of disturbance to the primary forest on Pulau Malawali. Newly burnt areas were also observed in the northern part of the island covering about 5% of the total area. The secondary forest can be divided into two phasic communities based on the stages of development and plant association. They are grassland-Simpoh and old growth of the secondary forest.

i. Grassland-Simpoh

Almost 20% of the island, mostly of the southern part of the island, is covered with sedges such as *Schizachyrium* sp., *Schoenus* sp., *Scleria levis* and *Tricostularia undulata* with Simpoh, *D. luzonensis* (Plate 6). Other species found here are *Glochidion littorale, Gymnostoma nobile, Rothmania merrillii, Nepenthes gracilis, Melastoma malabathricum* and *Imperata cylindrica.*

ii. Old growth

The old growth of the secondary forest is mostly dominated by woody and shrubby species from the Sempilau and mixed forest. It seems that this vegetation will replace the grassland over time. This community covers about 10% of the total area of the island.

CONSERVATION PERSPECTIVE

Malawali is the only ultramafic island in Sabah with relatively intact natural vegetation. Other ultramafic island, such as Sakar, are already devoid of their natural forest. Sempilau forest is the main attractive feature in Pulau Malawali. Although almost 40% of the island is covered with grasses and shrubs, elements of the ultramafic flora are still significant and should be given full attention in conservation aspect. Of major concern are species of special interest such as *Calamus malawaliensis,* which is endemic to the island, *Dillenia luzonensis, Alstonia macrophylla, Vatica maritima* and *Dinochloa darvelana,* which are mostly restricted to ultramafic forest.

Grassland dominates the open areas in the southern part of the island. The Sempilau forest was destroyed by fires in the past said to be started by the seafarers. Seafarers keep on setting fire to the bushes near the water bodies (small streams) on the island to ease their way to get fresh water from the coastal streams.

Undisturbed forests play a major role and serve as a water catchment for Maralas and Simpangan rivers. Local people rely on these rivers for fresh water supply as it was said that they would not dry up even during droughts. These rivers are flowing from the undisturbed forest upstream. This indicates that forest cover plays an important role in protecting water catchments on Malawali, and therefore ensuring a constant supply of water throughout the year. At present, there are two villages/settlements in Pulau Malawali, namely Kampung Tanjong (population of about 200 people) in Pulau Tanjong and Kampung Paramuan (four families) near Maralas estuary. The inhabitants of Kampong Tanjong, however, can get water from the wells but not during the drought as the water becomes salty. Thus they have to travel about one or two kilometres by boat to Simpangan river to get fresh water for domestic use.

RECOMMENDATION

It is recommended that the island to be protected for the benefit of the present and future generations. Any future development of this ultramafic island should take into consideration the preservation of the flora and fauna of Pulau Malawali.

ACKNOWLEDGEMENTS

We thank Mr. Mokran Ingkat (District Forest Officer, Kudat), for logistic and boat arrangements. The boatmen were Kayapis and Entoh, RH Taha and Azman A. We also thank the field force police at Malawali island, led by Sgt. Ahmad Japar (72464) and L/Kpl Ribu (110759), for providing security. We are grateful to the local people of Malawali for providing information. Staff of the Systematic Botany Section helped to identify the plant specimens. Mr Ubaldus Majawal prepared the map drawings. We thank the participants of the expedition for their team spirit and field assistance.

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Appendix 1. Some photos of the flora and vegetation of Pulau Malawali (by J.B. Sugau).

Plate 1. The almost pure stand of pole-sized Sempilau trees (*Gymnostoma nobile*) on Pulau Malawali (Photo: J. Tangah).

Plate 2. Sempilau forest develops behind the mangroves.

Plate 3. Seedlings of Sempilau (*Gymnostoma nobile*) and Pulai Tipu (*Alstonia macrophylla*) are common in gaps of the Sempilau forest.

Plate 4. The pandan (*Pandanus motleyanus*) community is sometimes growing in thickets under the canopy and very hard to penetrate.

Plate 5. Grassland in the southern part of the island. This covers mostly the Malawali hill and its surroundings.

Plate 6. Grassland, scenery taken on top of Malawali hill.

Plate 7. Mixed forest develops behind the mangroves. This forest type is found mostly in the northeastern part of the island.

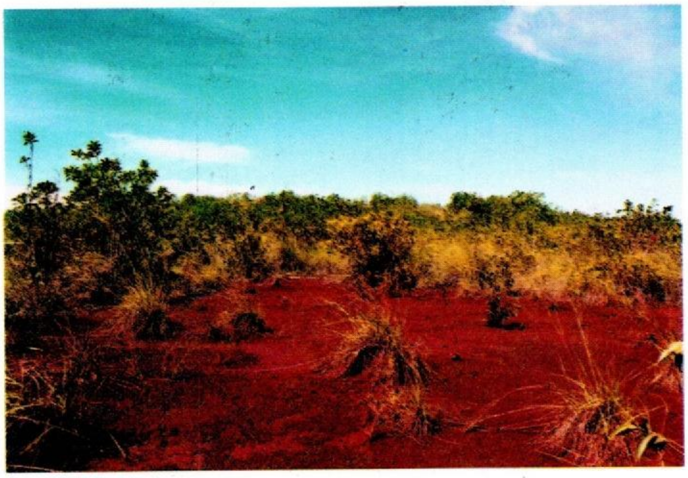

Plate 8. Reddish brown coarse texture is the feature of soil in Pulau Malawali. The soil is ultramafic derived from ultrabasic rock.

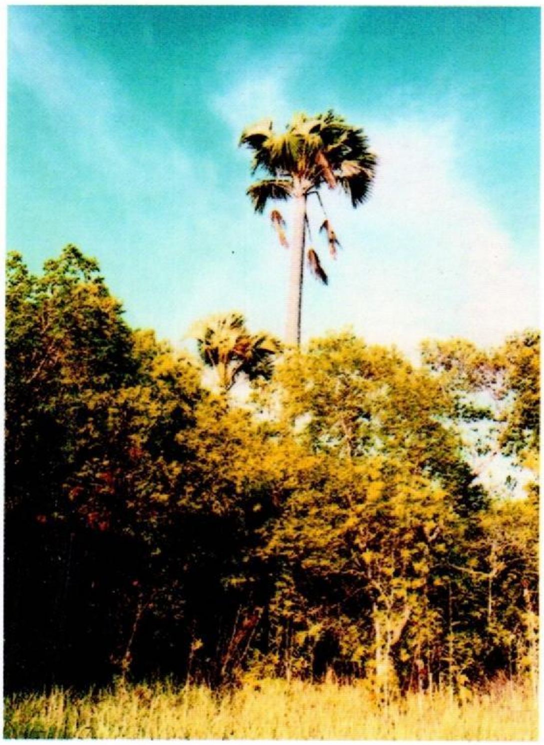

Plate 9. *Corypha utan,* a large solitary palm common in Pulau Malawali as well as in the Bengkoka Peninsula of mainland Sabah.

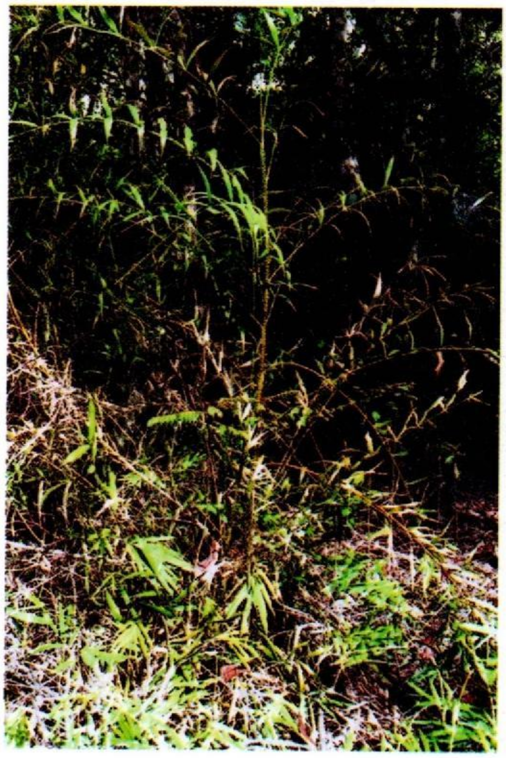

Plate 10. *Calamus malawaliensis,* a rattan endemic to Pulau Malawali.

Plate 11. *Alpinia aquatica,* the only ginger found during the survey in Pulau Malawali.

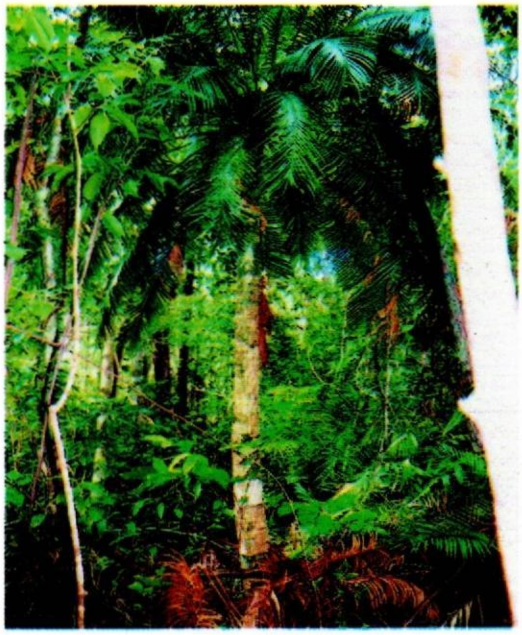

Plate 12. *Cycas rumphii.* This cycad is found behind the mangroves in mixed forest and also in the stony coastal beach forest.

Plate 13. *Nepenthes gracilis* is the common pitcher plant growing among sedges and shrubs in the grassland.

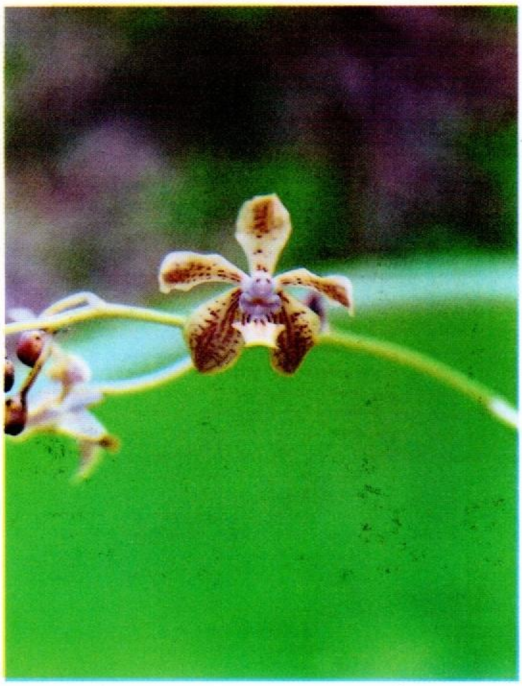

Plate 14. *Vanda lamellata,* one of the orchid species found in Pulau Malawali.

Appendix 2. Plant species collected during the survey.

Species	Family	Notes
Actephila gitingensis	Euphorbiaceae	Borneo, Philippines
Adenia heterophylla	Passifloraceae	Widespread
Aegiceras corniculatum	Myrsinaceae	
Alpinia aquatica	Zingiberaceae	
Alstonia macrophylla	Apocynaceae	
Antidesma coriaceum	Euphorbiaceae	Widespread, Common in kerangas
Antirhea inaequalis	Rubiaceae	
Apostasia wallichii	Orchidaceae	
Ardisia elliptica	Myrsinaceae	Widespread, Common
Ardisia serrata	Myrsinaceae	Widespread, Common
Avicennia marina	Verbenaceae	Widespread
Brackenridgea palustris	Ochnaceae	Widespread, Common in Sabah
Buchanania arborescens	Anacardiaceae	
Buxus rolfei	Buxaceae	
Calamus malawaliensis	Palmae	Endemic to Malawali island
Carex perakensis	Cyperaceae	
Champereia manillana	Opiliaceae	
Cleistanthus baramicus	Euphorbiaceae	
Croton sp.	Euphorbiaceae	
Dillenia luzonensis	Dilleniaceae	Common in ultramafic forest around Sabah
Dinochloa darvelana	Gramineae	
Diospyros elliptifolia	Ebenaceae	
Diospyros maritima	Ebenaceae	Widespread. In Borneo, only on Sabah islands
Drypetes sp.	Euphorbiaceae	
Eranthemum sp.	Acanthaceae	
Euonymus cochichinensis	Celastraceae	Widespread. Uncommon in Borneo
Eurycoma longifolia	Simaroubaceae	
Exocarpos sp.	Santalaceae	
Fagerlindia emanuelssoniana	Rubiaceae	
Flagellaria indica	Flagellariaceae	
Guettarda speciosa	Rubiaceae	
Guioa pubescens	Sapindaceae	

Species	Family	Notes
Gymnostoma nobile	Casuarinaceae	Palawan, Borneo, Kerangas, ultramafic forest
Heritiera littoralis	Sterculiaceae	Widespread
Homalium panayanum	Flacourtiaceae	
Hypserpa nitida	Menispermaceae	
Ixora fucosa	Rubiaceae	
Ixora philippinensis	Rubiaceae	
Leuconotis sp.	Apocynaceae	
Licania splendens	Chrysobalanaceae	Widespread. Very common in Sabah
Licuala sabahana	Palmae	
Maclurodendron porteri	Rutaceae	
Maclurodendron sp.	Rutaceae	Widespread
Melastoma malabathricum	Melastomataceae	Widespread. Common
Morinda citrifolia	Rubiaceae	
Neolitsea cassia	Lauraceae	
Nepenthes gracilis	Nepenthaceae	Widespread
Ormosia bancana	Leguminosae	
Pandanus motleyanus	Pandanaceae	
Pavetta sp.	Rubiaceae	
Phyllanthus sp.	Euphorbiaceae	
Podocarpus polystachyus	Podocarpaceae	
Polyalthia cauliflora	Annonaceae	
Pongamia pinnata	Leguminosae	
Pouteria linggensis	Sapotaceae	Widespread. Common in Sabah
Pouteria obovata	Sapotaceae	
Protium connarifolium	Burseraceae	Borneo and the Philippines
Psychotria sp. 1	Rubiaceae	
Psychotria sp. 2	Rubiaceae	
Psydrax sp.	Rubiaceae	
Rhodamnia cinerea	Myrtaceae	Widespread. Common
Rinorea bengalensis	Violaceae	
Rothmannia merrillii	Rubiaceae	
Schizachyrium sp.	Gramineae	

Species	Family	Notes
Schoenus sp.	Cyperaceae	
Scleria levis	Cyperaceae	Widespread
Suregada sp.	Euphorbiaceae	
Syzygium sp. 1	Myrtaceae	
Syzygium sp. 2	Myrtaceae	
Tabernaemontana pandacaqui	Apocynaceae	
Tarenniodea wallichii	Rubiaceae	
Thespesia populnea	Malvaceae	Widespread. Sandy sea shores
Timonius flavescens	Rubiaceae	
Tricostularia undulata	Cyperaceae	Widespread
Tristaniopsis sp.	Myrtaceae	
Vanda lamellata	Orchidaceae	
Vatica maritima	Dipterocarpaceae	
Vernonia sp.	Compositae	
Vitex trifolia	Verbenaceae	Widespread

Sepilok Bulletin 1: 57-59 (2004)

Seed sterilization of *Dryobalanops lanceolata* Burck

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Abstract. Seeds of *Dryobalanops lanceolata* Burck pretreated with 70% alcohol and sterilized with 30% commercial Clorox for 5 minutes and cultured in half-strength of Murashige Skoog (MS) without seed coat showed less than 20% contamination. The method is therefore recommended to produce aseptic seedlings of *D. lanceolata*.

Keywords: aseptic seedlings, *Dryobalanops lanceolata*, seed sterilization

INTRODUCTION

Dryobalanops lanceolata Burck is one of the tallest known dipterocarps and widely found in northern and eastern Borneo. It is commonly known as Kapur Paji in Sabah, Kapur Daram in Sarawak, Kapur Bukit in Brunei, and Kapur Tanduk in Kalimantan. Kapur is known locally as an excellent medium heavy, moderately durable constructional timber particularly resistant to fungal attack (Meijer & Wood 1964). It displays good growth performance in terms of mean height and diameter at breast height (DBH) compared to *Parashorea tomentella*, *Vatica acrocarpa* and some *Shorea* spp. in plantation species trials at Sibuga and Segaliud Lokan (SFD 1999). It has good potential to be included in forest plantation programmes.

Dipterocarp species have been propagated mostly through seeds and cuttings, but the seed production is infrequent and the plagiotropic growth of shoots from cutting is a problem in the production of stocks (Nakamura *et al.* 2000). To overcome these problems, embryo is used in tissue culture (Scott *et al.* 1989; Suharyati & Umboh 1989). Dipterocarp seeds have been used in tissue culture quite extensively by many researchers (Scott *et al.* 1989; Ishii *et al.* 1995; Sukartiningshi *et al.* 1995; Umboh & Yani 1995). However no proper method on the pretreatment and sterilization is described in their reports. The objective of this study was to find out the concentration of Clorox and duration which is suitable to sterilize the seeds of *D. lanceolata.*

MATERIALS AND METHODS

Explant source

Explant sources were collected from 49-year-old trees at Sibuga Plantation Species Trial, Sandakan. The height and diameter at breast height (DBH) of trees were about 25-35 m and 35-45 cm, respectively.

Sterilization of explants

Good freshly collected explants were dewinged or depericarped before being washed in a detergent solution (Glo). The explants were brushed and rinsed with running tap water for 20 minutes before pretreated and surface sterilized.

Explants were pretreated with 70% (v/v) absolute alcohol in distilled water for 1 minute before being treated with 30-55% solution (v/v) commercial Clorox plus 2-3 drops of Tween 20 for 10-30 minutes. This was followed by rinsing thrice with distilled water. Three replicates of 10 cultures were set up for each treatment and the explants were cultured in sterilized flasks containing 50 ml half-strength of Murashige Skoog basal medium (Murashige & Skoog 1962) supplemented with 3% sucrose and 0.27% gelrite. The medium was adjusted to pH 5.8 before autoclaving at 121°C for 20 minutes.

The cultures were incubated in a growth room at 25-26°C, for 16 hours under fluorescent light. Contamination rate was evaluated after two weeks.

RESULTS & DISCUSSION

Contamination was visually detected 5 days after sterilization. High percentage of contamination was observed in all treatments (Table 1). No contamination by bacteria was detected. The seed coat opened 3-4 days after sterilization whilst the radicle or cotyledon parts were still green and healthy. However, all were dead on the 10th day.

This study could not determine the exact methodology for sterilization of *D. lanceolata* seeds because seed supply was limited (fruiting season ended). However seeds sterilized with 30% commercial Clorox for 5 minutes and cultured without seed coat showed less than 20% contamination. Removal of seed coat helped reduce the percentage of contamination. Sterilization using up to 50% commercial Clorox for more than 20 minutes would break up the seed coat, hence expose the cotyledon and probably reduce the viability of seed.

Table 1. Contamination assessment of seed treated with commercial Clorox.

Time (min)	% Treatment			
	30	40	50	55
With seed coat				
10	4	4	4	4
20	4	4	4	4
30	4	4	4	4
Without seed coat				
5	2	FSE	FSE	FSE
10	FSE	FSE	FSE	FSE

Note: 0 = no contamination (no growth), 1 = satisfactory sterilization without killing the explant (with growth), 2 = less than 20% contamination, 3 = 20-50% contamination, 4 = more than 50% contamination, FSE = fruiting season ended.

To date, many researchers use seed for somatic embryogenesis especially for dipterocarp species (Scott *et al.* 1989; Suharyati & Umboh 1989; Umboh & Yani 1995). Suharyati & Umboh (1989) used 50% commercial Clorox for 30 minutes to sterilize immature fruits of *Shorea pinanga*. The percentage of commercial Clorox needs to be varied depending on the species and environment. The effect of treatment might be influenced by the presence of resin since fungus might still appear in the seed coat. The duration for pretreatment with alcohol needs to be extended because alcohol has the ability to partially remove resin, which would stop microorganisms from making contact with aqueous sterilants (Jainol 1997). It is suggested that seed must be sterilized with 30% commercial Clorox for 5 minutes and cultured without seed coat to get the aseptic seedling of *D. lanceolata*.

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Sepilok Bulletin 1: 61-63 (2004)

Suana concolor – Giant defoliator of *Acacia mangium*

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An *Acacia mangium* sapling, growing in the nursery of the Forest Research Centre (FRC) in Sepilok, was defoliated by a giant caterpillar during the rainy monsoon in December 2003. The big and fleshy caterpillar was about 16 cm in length, with tufts of hair on the sides of its seemingly powdery greyish brown body. Its presence caused much excitement in the nursery as it was definitely one of the biggest caterpillars around. However, it had to be handled with care as its tufts of hair could have urticating properties which might induce rashes on skin.

Three such caterpillars were found singly on the 3 m tall *Acacia mangium* sapling. The body of the caterpillar bore fine reticulated markings. Its meso- and metathorax had a blackish transverse band dorsally, with a prominent dark patch just behind the metathorax. The colouration of the caterpillar blended well with the tree trunk and branches, which offered protection against predators such as birds in times of non-feeding in the day. Feeding of the caterpillar occurred at night. Its mode of feeding was from the edge of the *Acacia mangium* leaf inwards, and each caterpillar could consume a large amount of foliage within a short span of time.

The giant caterpillars secreted copious silk for pupation a couple of days after they were collected. The whitish spindle-shaped cocoon was armed with short stiff needles, and could measure up to 17 cm in length. The quiescent pupal stage was rather long, as the adult moth emerged only after about a month later. The moth was identified as *Suana concolor* Walker (Lepidoptera: Lasiocampidae), a widespread species distributed from India through Borneo to Southern China (Holloway 1987). Wingspan of the female is about 13 cm, while the male is much smaller in size. The moth is smoky brown in colour, the female having a transverse pale band with a whitish discal spot on the forewing.

According to Browne (1968), the adult female could produce about 2000 eggs, which she places in clusters on the twigs of the host tree. Its caterpillar is polyphagous feeding on the foliage of dicotyledonous trees. Host trees include *Citrus* spp., *Albizia* spp., *Cassia fistula*, *Castanea sativa*, *Ceiba pentandra*, *Cinnamomum camphora*, *Eucalyptus* spp., *Shorea robusta*, *Syzygium cuminii* and *Tectona grandis*. Under natural circumstances, pupation occurs in cocoons in bark crevices or attached to branches. The species reportedly causes regular defoliation of *Shorea robusta* in India, but thus far it has not been recorded on the local *Shorea* spp.

A long list of insect pests of *Acacia mangium* was documented by Chey & Intachat (2000), and *Suana concolor* was recorded only as a leaf-eater of *Acacia farnesiana* (Ahmad & Ho 1980). This would appear to be the first record of the caterpillar feeding on the foliage of *Acacia mangium*, the most widely planted forest plantation tree in Sabah introduced from Australia in the 1960s.

Due to the high fecundity of its female moth, there is a danger that the species might establish itself as a major defoliator particularly in monoculture plantations. Vigilance should be kept and regular monitoring be done to prevent any such outbreaks.

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Figure 1. The giant hairy caterpillar of *Suana concolor* on *Acacia mangium*.
FRC nursery, Sepilok.

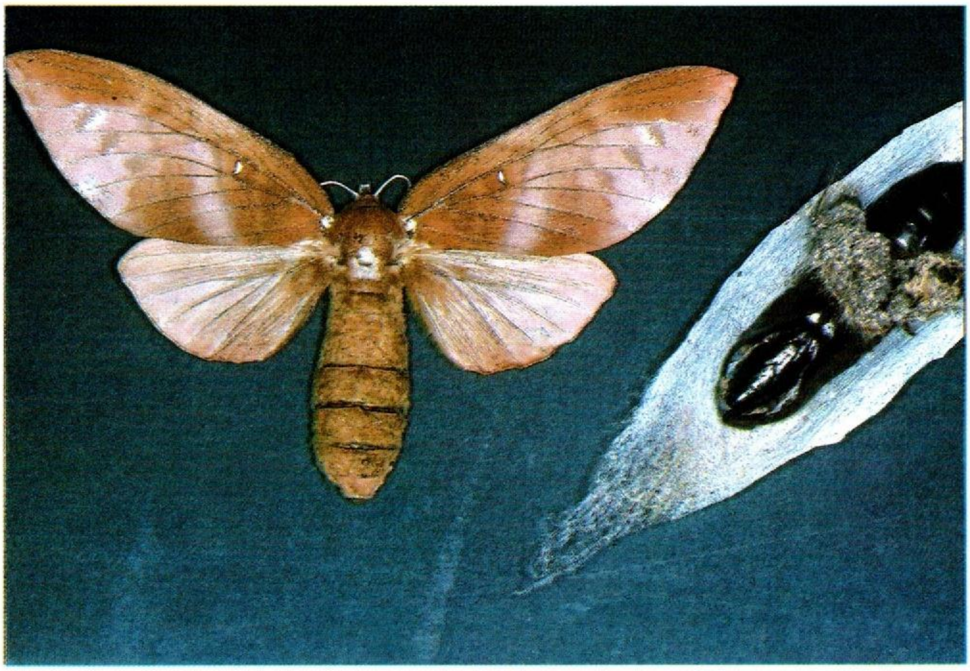

Figure 2. Female moth of *Suana concolor*.
Silken cocoon with dark brown pupal skin at the side.

Sepilok Bulletin 1: 65-66 (2004)

Fireflies of Sungai Klias and their display trees

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Fireflies have for ages fascinated people with their twinkling lights in the darkness of night. The world-famous writer W. Somerset Maugham (1949), in his trip going up river in Borneo back in 1922 describes them as such, "...The fireflies give the shrubs the look of a Christmas tree all lit up with tiny candles. They sparkle softly; the radiance of a soul at peace." It is indeed an exhilarating experience to watch the fireflies gregariously light up the riverside trees at night. Their synchronous flashing in the dark conjures up visions of a magical world of make believe, where winged fairies frolic in stardust, and all the fairy tales you know become real. Their display of lights is dazzling, and yet watching it is soothing to the mind.

In Malaysia, the best-known place for firefly watching is Kampung Kuantan in Kuala Selangor. The predominant species there is *Pteroptyx tener* Olivier (Coleoptera: Lampyridae) (Ballantyne & Menayah 2000; Wong 2001), and the general impression was that the mangrove tree *Sonneratia caseolaris* (L.) Engl. (Sonneratiaceae) is the much preferred if not the sole tree where the species roosts.

Here in Sabah, the river Sungai Klias near Beaufort is fast attracting visitors for its fireflies, apart from its proboscis monkeys. A trip was made in April 2004 to determine the identity of its firefly species, as well as the trees on which they roost.

A survey was done at nightfall on Sungai Klias near the Kota Klias jetty. For one thing, *Sonneratia caseolaris* is not common along its river banks, as its dominant tree is the Dungun, *Heritiera littoralis* Dry. ex W. Ait. (Sterculiaceae), a riverside emergent with coppery foliage.

Among the trees laden with sparkling fireflies in Sungai Klias, each with 100 individuals or more, five were found to be Dungun, one was a mangrove tree Bangkita, *Rhizophora apiculata* Bl. (Rhizophoraceae), and another was identified as *Excoecaria indica* (Willd.) Muell. Arg. (Euphorbiaceae), also known locally as Ligura which bears hard ball-shaped fruits that resemble marbles that kids like to play with. This confirmed *Excoecaria indica* as a preferred display tree, as Mahadimenakbar *et al.* (2003) also reported that most of the trees with fireflies in Danau Pitas, Lower Kinabatangan belong to that species, even though the fireflies there are fewer in numbers. Apart from the taller Dungun trees which stood at above 12 m, the other two trees were shorter in stature of about 6 m or less. Though not observed in this survey, *Ficus* (figs) and Pedada (*Sonneratia alba* Smith) trees are also said by the local people to be display trees for the fireflies of Sungai Klias.

The fireflies sampled alive by a sweep net were put into a jar for observation. They were similar to *Pteroptyx tener*, a small brown soft-bodied beetle with a pubescent darker elytra, and a bioluminescent organ on the ventral side and posterior end of the abdomen. The body length varies from 4 to 6 mm. Mating of the fireflies or something similar to it was observed, with the male on top bending its extended abdomen over that of the female. Flashing continued during mating and the combination of both male and female bioluminescent organs produced a stronger light. Period of mating was rather long, lasting more than half an hour. The fireflies continued flashing through the night until daybreak.

From this survey it is certain that *Pteroptyx tener* is not specific to what tree it roosts, its preference seems to be determined by tree suitability rather than specificity. On closer examination of the foliage of the firefly trees, some of the leaves bore scars, lesions and tunnels, which could have been caused by feeding of the adult fireflies.

The firefly larvae are known to be carnivorous feeding on snails, and Kirton & Boon (2003) reported that the larvae occur predominantly in the soil among sago and nipa palms. Along the Sungai Klias, nipa and sago palms are rather abundant which could function as a preferred habitat for the firefly life cycle. This illustrates the inter-dependency of the firefly with its surrounding river ecosystem. The biological requirements of its larvae, coupled with the fact that its adults roost not only on a particular species of tree, call for a holistic approach in its habitat conservation and management.

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CONTENTS

Front cover: Giant caterpillar of *Suana concolor*, a defoliator of *Acacia mangium*
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