Diurnal Resting Site Selection and Daytime Feeding Behaviour of Wild Malayan Flying Lemur Galeopterus variegatus in Western Java, Indonesia

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Source: Mammal Study, 40(1) : 35-45

Published By: Mammal Society of Japan

URL: https://doi.org/10.3106/041.040.0107

Mammal Study 40: 35–45 (2015)

Short communication

Diurnal resting site selection and daytime feeding behaviour of wild Malayan flying lemur *Galeopterus variegatus* in Western Java, Indonesia

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The Malayan flying lemur (*Galeopterus variegatus*) belongs to the Order Dermoptera, and is mainly distributed in the southern parts of Thailand, Indochina, Malay Peninsula, Sumatra, Java, Borneo, and the islands nearby (Lim 2007). It inhabits both lowland and mountainous areas, and is found in a large variety of habitats, including primary and secondary forests, coconut groves, and rubber plantations (Lim 2007; Baba 2008). Recent data on mitochondrial DNA of the flying lemurs have shown that this species is closely related to primates, likely related to our distant relatives (Schmitz et al. 2002; Lim 2007).

Feeding, ranging, social, and reproductive behaviour data are fundamental information on animal ecology. However, to the best of our knowledge, information on habitat utilisation by flying lemurs and its determinants remains limited, and basically, we only know that flying lemurs are arboreal and nocturnal animals (Byrnes et al. 2011), that during the daytime they can be found in tree holes or hollows (Yasuma 1994), hanging from branches, or holding onto tree trunks, and that they are active at dusk (Lim 2007). Recent studies have reported about their home range size, nocturnal activity, and habitat preference (Baba 2008; Lim et al. 2013). With regard to feeding behaviour, information about Malayan flying lemur is fragmental (Agoramoorthy et al. 2006; Lim 2007; Baba 2008; Dzulhelmi and Abdullah 2009), compared to its sister Philippine species (Wischusen and Richmond 1998).

In this study, we investigated diurnal resting site selection by the wild Malayan flying lemurs inhabiting West Java, Indonesia, at the plant-species and landscape level. We focused on forest structure, such as the extent of concealed areas and canopy cover, as these often influence resting site selection in other mammal species (Heymann 1995; Di Bitetti et al. 2000; Tsuji 2011). Lim et al. (2013) reported that flying lemurs in Singapore preferred forested areas with higher coverage; therefore, we aimed to confirm this finding in our study site. Besides we record several food items eaten in daytime. The relative importance of the daytime feeding seems lower than nocturnal one, but providing fundamental information on diet of the rarely studied-mammalian species would be meaningful.

Methods

Study site

The Pangandaran Nature Reserve (PNR, hereafter) is located at 108°40'E and 7°43'S on the southern coast of West Java, Indonesia, on a small peninsula approximately 3-km long and 2-km wide (Sumardja and Kartawinata 1977). The elevation of this peninsula ranges 0–150 m a.s.l., and its average height is approximately 100 m. The average annual rainfall from 1990 to 2010 was 2,940 mm, although it presents some inter-annual variation (Rosleine and Suzuki 2012). Air temperature and humidity from 1984 to 1985 were 22.5–35.0°C and 88.5–96.5%, respectively (Kool 1993). The nature reserve is located at the top of a peninsula, bordering with the rest of the island through an isthmus approximately 200-m wide, linking the peninsula to the mainland. The reserve is divided into two zones: a public use zone (nature recreation park) of 38 ha, and the actual nature reserve, which consists of 370 ha and includes the remaining area. Our study area was confined within the northern section of the nature recreation park, where forest rangers frequently observe flying lemurs (Prayitno, pers. obs.), but exact number of animals inhabiting the area was unknown. The study area included a small section of swamp forest within the nature reserve, and a beach forest in the northern part. The total study area was 27.7 ha. Topography inside the study area was relatively flat, and a paved forest path (5-m wide), is set inside the recreation park for visitors' convenience.

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Vegetation survey

Between 2011 and 2014, we conducted a vegetation survey within the study site in order to gather information regarding the forest structure. We divided the study area into 20 × 20 m-sized quadrats ($n = 693$), and recorded the GPS location of each tall tree (> 5 m) using a handheld GPS receiver (GPS MapCSx, Garmin Co., Kansas, USA). The quadrat size was chosen for being appropriate to evaluate the relationship between forest structure and diurnal resting site selection by the flying lemurs, since they are solitary animals, and their home range sizes in Western Java are between 1.3 and 1.8 ha (Baba 2008). For each tall tree, we recorded species, tree height (*TH*) and the height of the lowest branch (*TB*) within 0.1 m, using a handheld laser rangefinder (TruPulse200, Laser Technology Inc., Colorado). On the other hand we roughly measured the maximum crown diameter (*CD*) and categorised the values into seven classes by eye: (1) 0–4.9 m, (2) 5.0–9.9 m, (3) 10.0–14.9 m, (4) 15.0–19.9 m, (5) 20.0–24.9 m, (6) 25.0–29.9 m, and (7) ≥ 30.0 m. Subsequently, we estimated the crown volume (*CV*, m^3) of given tall tree by the following formula:

$$CV = (TH - TB) \times \left(CD/2\right)^2 \times \pi$$

For our convenience we assumed that representative values of *CD* (m) for each class to be (1) 2.5, (2) 5, (3) 10, (4) 15, (5) 20, (6) 25, and (7) 30, respectively. In order to quantify the total *CV* within a given quadrat, we summed up the *CV* value for each tall tree within the quadrat.

Diurnal resting site/trees

We conducted four intermittent field surveys between 2011 and 2013 (153 days in total). We recorded the location of flying lemurs in the forest observed during our fieldworks (from 6h00 to 18h00 in usual). Whenever we observed a flying lemur resting or feeding, we recorded (1) the GPS location of the animal, (2) number of animals (except for cubs still closely associated with their mothers) found within 10 m, (3) plant species, and (4) height of the tall trees occupied by the flying lemurs. If we found the flying lemurs more than one time at same tall tree in same day we recorded only once to avoid double-counting. If we observed daytime feeding by the flying lemurs, we recorded the plant species and parts eaten. Our methodology adhered to Indonesian/Japanese legal requirements.

Statistical analyses

To test for tree species preference, we compared the frequency of tree use as diurnal resting site and the relative percentage of tall trees of the given species present in the area, using a chi-square test of independence. To test for tree height class preference as diurnal resting sites, we compared the frequency of utilisation (we did not consider number of individuals) for each tree height class with the frequency of the tree class within the study area, using a two-sample Kolmogorov-Smirnov test. For the latter analysis, we classified *TH* values into seven classes: (1) 5.0–9.9 m, (2) 10.0–14.9 m, (3) 15.0–19.9 m, (4) 20.0–24.9 m, (5) 25.0–29.9 m, (6) 30.0–34.9 m, and (7) 35.0–39.9 m. We compared mean tree heights among three preference classes (preferred, neutrally used, and avoided) using a Kruskal-Wallis test. In order to confirm Lim et al. (2013)'s finding, suggesting that flying lemurs predominantly select areas with a dense canopy cover, the effects of the *TH* (m) and the *CV* (m^3) on the frequency of quadrat utilisation were tested using generalised linear models (GLM). Specifically, we conducted two-level analyses: initially, we tested the relationship between plant characteristics and quadrat utilisation, assuming that the error structure of our data is binomially distributed (i.e., fitted to a logistic regression). In addition, we tested the relationship between plant characteristics and frequency of utilisation for each quadrat that was used by the flying lemurs at least once. In this case, we assumed that the error structure of our data followed a Poisson distribution (i.e., fitted to a Poisson regression). For the GLM analyses, we used *TH* and *CV* as explanatory variables. The level of significance (α) was set at 0.05 for each, and all data analyses were performed using the statistical software R 2.15 (R Development Core Team 2012).

Results

Vegetation in the study site

In total, 132 different woody plant species, belonging to 39 families, were recorded within 27.7 ha of the study area (Appendix 1). The total number of tall trees (> 5 m in height) within the study site was 9,624. The trees were mainly from the following 10 species: *Syzygium antisepticum* (Myrtaceae, n = 1,305), *Dysoxylum caulostachyum* (Meliaceae, n = 1,130), *Tectona grandis* (Verbenaceae, n = 674), *Pterospermum javanicum* (Sterculiaceae, n = 668), *Swietenia macrophylla* (Meliaceae, n = 504), *Buchanania arborescens* (Anacardiaceae,

Table 1. Tree species used as diurnal resting sites by Malayan flying lemurs and their preference in Pangandaran Nature Reserve, Western Java, Indonesia

No.	Family	Species	Diurnal resting sites		Density		Statistics		
			#	%	#	%[a]	χ^2	*P*	Preference
1	ANACARDIACEAE	*Mangifera* sp.	8	4.35	36	0.37	52.7	< 0.001***	(+)
2		*Buchanania arborescens*	3	1.63	428	4.45	2.6	0.108	
3	ANNONACEAE	*Cananga odorata*	1	0.54	29	0.30	0.0	1.000	
4	COMBRETACEAE	*Terminalia catappa*	4	2.17	22	0.23	18.5	< 0.001	(+)
5	ELAEOCARPACEAE	*Elaeocarpus glaber*	3	1.63	2	0.02	61.9	< 0.001***	(+)
6	FLACOURTIACEAE	*Casearia grewiaeiolia*	1	0.54	140	1.45	0.5	0.481	
7		*Hydnocarpus heterophylla*	1	0.54	355	3.69	4.0	0.044*	(–)
8	HERNANDIACEAE	*Hernandia peltata*	9	4.89	78	0.81	28.1	< 0.001***	(+)
9	LECYTHIDACEAE	*Barringfonia spicata*	15	8.15	35	0.36	185.0	< 0.001***	(+)
10	LEGUMINOSAE	*Cynometra ramiflora*	15	8.15	31	0.32	203.3	< 0.001***	(+)
11	LYTHRACEAE	*Lagerstroemia speciosa*	2	1.09	70	0.73	0.0	0.899	
12		*Lagerstroemia flosregineae*	4	2.17	49	0.51	6.3	0.012*	(+)
13	MELIACEAE	*Dysoxylum alliaceum*	5	2.72	129	1.34	1.5	0.214	
14		*Dysoxylum caulostachyum*	5	2.72	1,130	11.74	11.5	< 0.001***	(–)
15		*Swietenia macrophylla*	12	6.52	504	5.24	0.3	0.573	
16	MORACEAE	*Ficus benjamina*	3	1.63	5	0.05	36.9	< 0.001***	(+)
17		*Ficus sumatrana*	3	1.63	27	0.28	6.7	0.010*	(+)
18		*Ficus subcordata*	1	0.54	3	0.03	2.4	0.119	
19		*Ficus annulata*	1	0.54	8	0.08	0.7	0.418	
20		*Ficus variegata*	4	2.17	3	0.03	86.2	< 0.001***	(+)
21		*Ficus pubinervis*	10	5.43	8	0.08	240.5	< 0.001***	(+)
22		*Ficus microcarpa*	1	0.54	3	0.03	2.4	0.119	
23		*Ficus* sp.	1	0.54	–	–	–	–	
24	MYRTACEAE	*Syzygium antisepticum*	1	0.54	1,305	13.56	21.7	< 0.001***	(–)
25		*Eugenia polyantha*	6	3.26	242	2.51	0.1	0.701	
26	RUBIACEAE	*Nauclea orientalis*	2	1.09	17	0.18	3.7	0.055	
27	SAPINDACEAE	*Erioglossum rubiginosum*	5	2.72	160	1.66	0.6	0.429	
28	STERCULIACEAE	*Pterospermum javanicum*	25	13.59	668	6.94	9.1	0.003**	(+)
29		*Pterospermum divirsifolium*	4	2.17	89	0.92	1.8	0.186	
30		*Sterculia coccinea*	9	4.89	117	1.22	15.5	< 0.001***	(+)
31		*Pterocymbium javanicum*	1	0.54	1	0.01	5.8	0.016*	(+)
32	VERBENACEAE	*Tectona grandis*	6	3.26	674	7.00	3.0	0.084	
33		*Vitex pubescens*	3	1.63	333	3.46	1.2	0.267	
	Others	–	10	5.43	–	–	–	–	
	Total		184	100.00					

[a] Percentage of tree density was obtained by dividing number of tall trees by total tall trees (n = 9,624).
***: $P < 0.001$, **: $P < 0.01$, *: $P < 0.05$.
(+): preferred, (–): avoided.

n = 428), *Polyalthia lateriflora* (Annonaceae, n = 356), *Hydnocarpus heterophylla* (Flacourtiaceae, n = 355), *Croton argyratus* (Euphorbiaceae, n = 339), and *Vitex pubescens* (Verbenaceae, n = 333). Among them, *T. grandis* and *S. macrophylla* were artificially planted species (Rosleine and Suzuki 2012). These 10 major species represented more than 63% of all recorded tall trees within the study site, and the top 30 species represented over the 80% of the trees. Mean (± *SD*) *TH* and the *CV* were 12.4 ± 5.8 m (range: 5.0–36.9) and 273 ± 690 m^3 (range: 0–15,975), respectively. See Appendix 1 for further details.

Diurnal resting site description and preference

During the study period, we observed flying lemurs holding onto trees on 184 occasions. In most cases (n = 147), we found single individuals or a pair of a mother and a cub, but sometimes more than one adult individual

were observed together ($n = 33$ for two adults, $n = 2$ for three adults, and $n = 2$ for four adults); we could not identify the sex of animals. From all the woody plant species analysed, 33 different species, belonging to 16 families (representing 25% of all plant species recorded in the study site), were used as diurnal resting trees by the flying lemurs (Table 1). Species such as *Pterospermum javanicum* (Sterculiaceae, 25 times), *Barringtonia spicata* (Lythraceae, 15 times), *Cynometra ramiflora* (Leguminosae, 15 times), *Swietenia macrophylla* (Meliaceae, 12 times), and *Ficus pubinervis* (Moraceae, 10 times) were the ones most used by the flying lemurs, and these top five species represented approximately the half of all the trees used for resting sites (Table 1). Among these 33 tree species, 14 were significantly preferred by flying lemurs for their density (chi-square test of independence, $P < 0.05$), while three tree species (*Hydnocarpus heterophylla*, *Dysoxylum caulostachyum*, and *Syzygium antisepticum*) were significantly avoided by the flying lemurs for their density ($P < 0.05$) (Table 1). Except for *Pterospermum javanicum*, the top 10 tree species mentioned above were not preferred by flying lemurs. Mean tree heights did not significantly differ among preferred, neutrally used, and avoided tree species (Kruskal-Wallis test, $\chi^2 = 4.9$, $df = 2$, $P = 0.083$). On the contrary, tree height used by flying lemurs ranged between 5–40 m and peaked at 10–25 m, which was significantly greater than that within the study site (two-sample Kolmogorov–Smirnov test, $\chi^2 = 122.9$, $P < 0.001$) (Fig. 1). In summary, flying lemurs had a tendency to prefer taller trees as their diurnal resting sites.

GLM analyses showed that quadrats with trees with a higher mean *TH* had a tendency to be selected as diurnal resting sites (GLM: $z = 3.38$, $P < 0.001$); however, total *CV* of the quadrat did not affect site selectivity ($z = –1.22$, $P = 0.222$). On the other hand, quadrats with higher mean *TH* and lower total *CV* showed a significant tendency to be repeatedly used (GLM, *TH*: $z = 2.50$, $P = 0.012$; *CV*: $z = –3.31$, $P < 0.001$) (Fig. 2).

Daytime diet of the flying lemurs

During the study period we observed flying lemurs performed daytime feeding on 11 separate occasions. They fed on eight different woody species and one liana species (*Agelaea macrophylla*, Connaraceae), representing 10 different items. The list of items previously reported as eaten by flying lemurs is shown in Table 2. Five out of nine plant species were new records as Malayan flying lemurs' diets. In our study area, flying lemur mainly feed on young leaves, following the observations reported in previous studies from other study sites (Table 2). In addition, flying lemurs consumed water from *Cynometra ramiflora* (Leguminosae) leaves once (Table 2).

Discussion

Malayan flying lemurs used 33 different tree species as their diurnal resting sites. The diversity of species used as diurnal resting sites in this study was much greater than that reported for palm plantations in Pandeglang, where flying lemurs used mainly coconut palm and betel palm trees within the plantations (Baba 2008). Tree utilisation did not depend on tree density. The lemurs significantly preferred 14 out of 33 tree species, while three tree species were significantly avoided. Except for *Pterospermum javanicum* (Sterculiaceae), none of top 10 tree species presenting the highest density were preferably chosen, and for three of them (*Hydnocarpus heterophylla*, *Dysoxylum caulostachyum*, and *Syzygium antisepticum*) this tendency was significant (i.e., avoided). Furthermore, the planted species *Tectona grandis* was never used by the flying lemurs, despite it presented the higher density. There was no significant difference in mean tree height among the three preference classes (preferred, neutrally used, and avoided), and it was not clear whether there was any type of tree preference at the species level. On the other hand, at the landscape level, we found that quadrats with higher mean tree height had a tendency to be selected as diurnal resting sites with higher probability, and quadrats with higher *TH* and/or lower *CV* were repeatedly used as resting sites. Thus, it is likely that flying lemurs preferred isolated taller trees regardless of the species. These results suggest that the species preference detected (Table 2) was a reflection of forest structure and not of the characteristics of the tree species. Possibly, the reason behind this pattern of tree selection is associated with gliding efficiency, as the flying lemurs are mainly active after sunset, and start to glide from their diurnal resting sites to feeding trees (Lim 2007). Flying lemurs have been recorded to glide up to 136 m in a single gliding event, with a corresponding drop in vertical height of 10–12 m (Walker 1983). To achieve such long distance glides, the trees being at a distance might be advantageous. Predator avoidance is likely to be an additional reason swaying the preference toward isolated tall trees; in fact, Philippine monkey-eating eagles (*Pithecophaga jefferyi*) are known to prey primarily on Philippine flying lemurs, representing 54–90% of the eagles' total diet (Lim 2007). Although no previous studies have

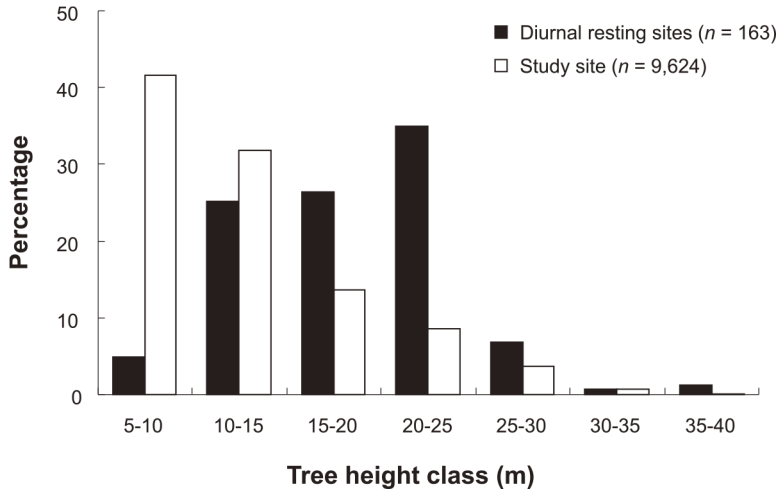

Fig. 1. Comparison of tree height distribution (5-m interval) between the trees used as diurnal resting sites (filled bars) and those species that grow within the study site (27.7 ha, open bars). For the former, we omitted 21 out of 184 cases due to lack of information regarding tree height.

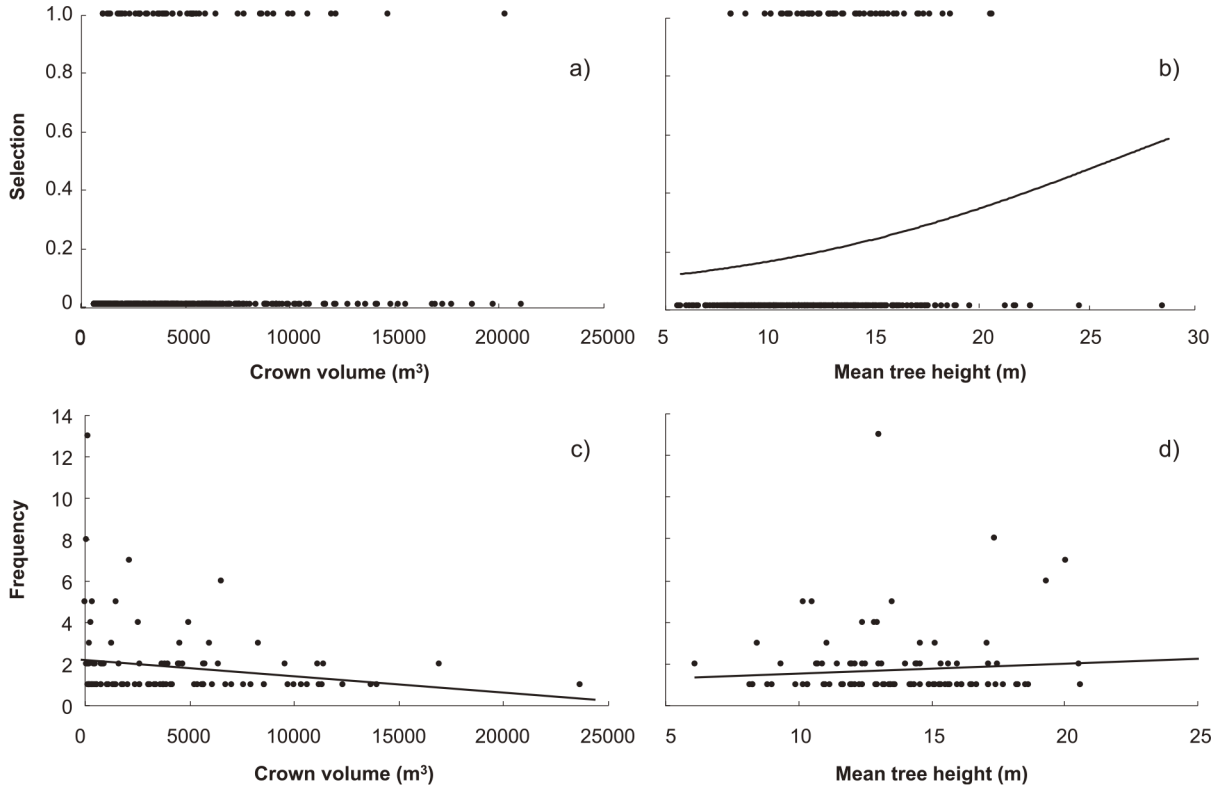

Fig. 2. Effects of crown volume (m^3) (a, c) and mean tree height (m) (b, d) on the proportion of resting sites among quadrats within our study site (27.1 ha) (a, b) and number of repeated use (c, d). Lines show significant relationships.

comprehensively investigated predation on Malayan flying lemurs, there have been several reported cases of predation by raptors, pythons, wildcats, and long-tailed macaques (Harahap and Sakaguchi 2003; Lim 2007). Potential predators, such as monitor lizards, civets, feral dogs, and long-tailed macaques occur within the PNR (Brotoisworo 1991). On one occasion, we actually observed a flying lemur rapidly climbing a tree and escaping into the canopy after a group of macaques closed up on the flying lemur while holding on the tree trunk (Tsuji, pers. obs.). Using isolated tall trees would be advantageous to decrease predation risk. This preference for taller trees has also been reported in plantation of Pandeglang (Baba 2008), where middle-sized carnivores, such as leopard cats and civets, occur (Nakamoto et al. 2006).

The number of daytime food items consumed by flying

Table 2. List of diets of wild Malayan flying lemurs obtained from five study sites

No.	Family	Species	Study site				
			Bukit Timah, Singapore	Singapore Zoo, Singapore	Bako, Malaysia	Pandeglang, Indonesia	Pangandaran, Indonesia[a]
1	ANACARDIACEAE	*Buchanania arborescens*			ML, W		YL
2		*Campnosperma auriculata*	YL	ML			
3		*Campnospermum* sp.			SP		
4	AQUIFOLIACEAE	*Ilex cymosa*			ML, SP		
5	PALMAE (ARECACEAE)	*Oncosperma tigillarium*			SP		
6	BOMBACACEAE	*Ceiba pentandra*				L, FB, YF	
7		*Durio zibethinus*				L, B	
8	CLUSIACEAE	*Calophyllum soulattri*			ML, W		
9	CONNARACEAE	*Agelaea macrophylla*					YL
10	EUPHORBIACEAE	*Macaranga pruinosa*			L		
11	LAURACEAE	*Persea americana*				L, FB, Fl	
12	LEGUMINOSAE	*Cynometra ramiflora*					YL, W
13		*Parkia speciosa*				B, L	
14		*Petophorum pterocarpus*	YL	YL			
15		*Pithecellobium lobatum*				L	
16		*Saraca cauliflora*		YL			
17		*Saraca thaipingensis*	YL				
18	LORANTHACEAE	*Scurrula* sp.				L	
19	MELIACEAE	*Melia azedarach*				L	
20	MORACEAE	*Artocarpus kemando*	ML				
21		*Artocarpus heterophyllus*				L	
22		*Ficus microcarpa*			L		FR
23		*Ficus pubinervis*					YL
24		*Ficus variegata*					YF
25		*Ficus* sp.				L	YL
26	MYRTACEAE	*Eugenia polyantha*					YL
27		*Rhodamnia cinera*	YL	ML			
28		*Syzygium acuatinervium*			L, SP		
29		*Syzygium grande*	YL	ML, YL			
30		*Syzygium lineatum*	YL				
31		*Syzygium pachyphyllum*		ML, FR			
32		*Syzygium palembanicum*		ML			
33		*Syzygium* sp.			L		
34	ORCHIDACEAE	*Arachnis* sp.			RT		
35	SAPINDACEAE	*Nephelium lappaceum*				L	
36	STERCULIACEAE	*Sterculia coccinea*					YL
37	RHIZOPHORACEAE	*Gynotroches axillaris*			L		
38	VERBENACEAE	*Vitex pubescens*			L, SP		
39	FORMICIDAE	*Paratrechina longicornis*			ANT		
	Reference		Lim (2007)	Agoramoorthy et al. (2006)	Dzulhelmi and Abdullah (2009)	Baba (2008)	This study

ANT: ants, B: buds, FL: flowers, FR: fruits, L: leaves (including both mature and young), ML: mature leaves, YF: young fruits, YL: young leaves, SP: sap, W: water.

[a] Data collected in Pangandaran is daytime feeding.

lemurs in this study was 10 (nine species). Predominantly, the lemurs consumed young leaves, following the observations reported in previous dietary studies (Lim 1997; Agoramoorthy et al. 2006; Baba 2008; Dzulhelmi and Abdullah 2009). Five out of nine species (*Agelaea macrophylla*, *Cynometra ramiflora*, *Ficus pubinervis*, *F. variegate*, and *Nephelium lappaceum*) were newly recorded as part of the flying lemurs' diet. Flying lemurs

have been observed to feed in several plant, such as *Vitex pubescens* (in Bako, Malaysia; Dzulhelmi and Abdullah 2009), and *Syzygium* sp. (in Bako and Singapore; Agoramoorthy et al. 2006; Dzulhelmi and Abdullah 2009); however, flying lemurs did not feed on these species within the study area at least in daytime, even though they are present in the PNR. Although there is a possibility that we just did not directly observe this feeding behaviour, these results suggest certain level of behavioural plasticity in food selection in response to the food availability.

In this study we did not conduct any observations regarding nocturnal activity. Flying lemurs' ranging and feeding habits at night are therefore unclear. In future studies, observations of nocturnal behaviours, using night vision cameras and GPS collars, including home range utilisation and dietary sources, should be conducted for further understanding of their ecology.

Acknowledgments: We would like to thank R. Tsuji for her assistance during the vegetation survey. We would like to thank the forest rangers of the PNR, especially Mr. Y. Hendrayana and O. Norwana, for access to their facilities. We particularly thank T. Oshida and two anonymous reviewers for their constructive comments. We would like to thank to Drs. A. Takahashi and N. Imai for their advice on the statistics. We also thank the staff of the Department of Biology of Bogor Agricultural University for their constructive comments on an earlier version of this manuscript. This study was funded by a grant from the AS-HOPE of the Japan Society of Promotion of Science to Y. Tsuji (2010–2011), Grant-in-Aid from the Department of Academy and Technology of Japan (No. 23780160 and 24405018), and Grant for John Mung Program from Kyoto University to Y. Tsuji (2013).

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Received 24 July 2014. Accepted 8 January 2015.
Editor was Tatsuo Oshida.

Appendix 1.

List of woody plants recorded by quadrate survey at Pangandaran Nature Reserve, Western Java, Indonesia

No.	Family	Species	Local name	*n*	%	Tree height (m)		Crown volume (m^3)	
						Mean ± *SD*	Range	Mean ± *SD*	Range
1	ANACARDIACEAE	*Dracontomelon mangiferum* Bl.	Dahu	53	0.55	12.2 ± 3.8	5.1–21.7	63.1 ± 147.7	0.5–918.9
2		*Spondias pinnata* (L. F.)	Kedongdong hutan	4	0.04	20.1 ± 4.6	16.0–27.9	728.0 ± 384.8	202.2–1,272.3
3		*Mangifera foetida* Lour.	Limus	1	0.01	8.7	–	86.4	–
4		*Mangifera* sp.	Mangga pari	36	0.37	13.3 ± 6.3	5.3–28.7	474.2 ± 688.6	3.9–2,921.7
5		*Buchanania arborescens* (Bl.) Bl.	Pohpohan	428	4.45	10.8 ± 3.5	5.0–28.6	91.2 ± 164.1	0.0–1,688.6
6		*Gluta renghas* L.	Rehunghas	1	0.01	30.1	–	72.2	–
7	ANNONACEAE	*Stelechocarpus burahol* Hook. F. et Thomson	Burahol	17	0.18	11.6 ± 3.5	7.3–21.0	51.9 ± 64.1	24.5–306.3
8		*Cananga odorata* Hook. F. et THOMS.	Kananga	29	0.30	22.2 ± 7.1	6.1–32.5	782.0 ± 833.6	11.8–3,298.7
9		*Polyalthia lateriflora* King	Sauheun	356	3.70	9.9 ± 3.2	5.0–21.2	66.3 ± 110.6	0.0–1,209.5
10	APOCYNACEAE	*Cerbera manghas* L.	Bintaro	1	0.01	9.6	–	34.4	–
11	AQUIFOLIACEDAE	*Ilex pleiobrachiata* Loes.	Kibonteng	4	0.04	18.9 ± 3.2	15.0–23.7	477.9 ± 645.3	24.5–1,590.4
12	BIGNONIACEAE	*Dolichandrone spathacea* (L.f.) Seem.	Kijaran	20	0.21	11.3 ± 2.9	5.9–15.7	495.4 ± 480.4	21.1–1,853.5
13		*Oroxylum indicum* (L.) Benth. ex Kurz	Pongporang	11	0.11	11.6 ± 4.2	7.1–20.3	110.0 ± 196.0	4.9–628.3
14	BOMBACACEAE	*Bombax ceiba* L.	Randu alas	1	0.01	26.7	–	4,074.3	–
15	COMBRETACEAE	*Terminalia bellirica* (Gaerth.) Roxb.	Jaha	1	0.01	36.0	–	6,440.3	–
16		*Terminalia catappa* L.	Ketapang	22	0.23	11.4 ± 2.9	5.6–17.6	710.7 ± 584.7	25.5–2,102.9
17	CRYPTERONIACEAE	*Crypteronia paniculata* Bl.	Kibanen	1	0.01	20.5	–	306.3	–
18	DILLENIACEAE	*Dillenia* sp.	Junti	2	0.02	5.9 ± 0.8	5.1–6.7	20.6 ± 3.9	16.7–24.5
19		*Dillenia excelsa* (Jack) Girg	Kisegel	114	1.18	8.7 ± 2.8	5.0–20.7	115.1 ± 162.6	6.4–1,013.2
20	EBENACEAE	*Diospyros truncata* Zoll. et Moritzi	Kicalung (Balung injuk)	11	0.11	12.5 ± 4.1	5.3–18.7	4.4 ± 40.6	5.4–153.2
21	ELAEOCARPACEAE	*Elaeocarpus glaber* Bl. Bijdr.	Katulampa	2	0.02	14.1 ± 1.4	12.7–15.5	458.5 ± 350.5	108.0–809.0
22	EUPHORBIACEAE	*Alchornea rugosa* (Lour.) Muell. Arg.	Burutu	16	0.17	8.1 ± 2.6	5.4–14.3	25.6 ± 12.2	4.4–58.9
23		*Antidesma bunius* (L.) Spreng.	Huni	13	0.14	11.4 ± 5.5	5.4–24.7	177.1 ± 292.2	8.8–1,107.4
24		*Aporosa sphaeridophora* Merr.	Kiendog	1	0.01	7.1	–	21.1	–
25		*Croton argyratus* Bl.	Parengpeng	339	3.52	9.4 ± 3.1	5.0–21.0	61.4 ± 100.4	2.0–973.9
26		*Glochidion molle* Bl.	Kihuut	1	0.01	6.8	–	7.9	–
27		*Mallotus ricinoides* (Pers.) Mull.Arg.	Kibajing	42	0.44	8.6 ± 1.6	5.2–11.4	49.3 ± 45.0	0.0–149.2
28		*Suregada glomerulata* (Blume) Baill.	Kibeunteur	8	0.08	6.2 ± 1.2	5.0–8.9	18.0 ± 6.4	4.9–25.5
29	FLACOURTIACEAE	*Casearia grewiaefolia* Vent.	Kiminyak	140	1.45	11.0 ± 4.1	5.0–22.7	58.1 ± 148.2	0.0–1,421.6
30		*Hydnocarpus heterophylla* (Bl.) Shloot.	Buntut lutung	355	3.69	10.4 ± 3.8	5.0–33.2	59.2 ± 269.4	0.0–4,859.7
31		*Flacourtia rukam* Zoll. & Mor. or *Scolopia spinosa* (Roxb.) Warb.	Rukem	96	1.00	8.5 ± 2.6	5.0–16.7	46.8 ± 54.2	0.0–369.1

Appendix 1. continued

No.	Family	Species	Local name	*n*	%	Tree height (m)		Crown volume (m^3)	
						Mean ± *SD*	Range	Mean ± *SD*	Range
32	GUTTIFERAE (CLUSIACEAE)	*Garcinia dioica* Bl.	Ceuri	18	0.19	11.3 ± 2.2	7.4–14.2	44.7 ± 65.2	2.0–306.3
33		*Garcinia celebica* L.	Manggis hutan	4	0.04	7.3 ± 1.9	5.4–9.6	20.2 ± 9.0	12.3–35.3
34		*Calophyllum inophyllum* L.	Nyamplung	21	0.22	9.6 ± 3.4	5.5–18.7	444.6 ± 512.1	17.7–1,767.1
35	HERNANDIACEAE	*Hernandia peltata* Meisn.	Borogondolo	78	0.81	13.7 ± 4.2	5.0–24.6	473.3 ± 568.5	11.8–2,668.4
36	LAURACEAE	*Neolitsea cassia* (L.) Kosterm.	Huru	31	0.32	10.2 ± 4.0	5.3–24.1	75.1 ± 77.6	4.9–314.2
37		*Neolitsea* sp.	Huru batu	15	0.16	8.5 ± 2.7	5.6–15.0	39.1 ± 37.0	3.4–115.8
38		*Actinodaphne* sp.	Huru payung	6	0.06	9.3 ± 2.2	6.1–13.0	74.0 ± 50.6	17.7–149.2
39	LECYTHIDACEAE	*Barringtonia asiatica* (L.) Kurz	Butun	1	0.01	6.7	–	70.7	–
40		*Barringfonia spicata* Bl.	Putat	35	0.36	17.2 ± 5.9	6.2–28.2	677.5 ± 843.3	2.0–2,921.7
41		*Barringtonia racemosa* (L.) Spreng.	Sanggom	1	0.01	8.0	–	123.7	–
42		*Chydenanthus exelsus* (Bl.) Miers.	Balundeng	14	0.15	9.8 ± 4.7	5.1–19.6	515.5 ± 871.4	11.8–2,880.4
43	LEGUMINOSAE	*Afzelia javanica* (Miq.) J. Leonard	Kijulang	3	0.03	23.9 ± 0.8	22.7–24.5	390.7 ± 269.0	172.8–769.7
44		*Albizia lebbeck* (L.) Benth.	Kitoke	9	0.09	17.4 ± 4.3	9.3–22.9	241.0 ± 274.4	3.9–769.7
45		*Tamarindus indica* L.	Asem	3	0.03	11.6 ± 3.6	8.6–16.7	166.9 ± 49.4	121.7–235.6
46		*Cynometra ramiflora* L.	Kateng-kateng	31	0.32	9.6 ± 2.9	5.6–20.8	229.8 ± 319.9	16.2–1,500.1
47		*Desmodium umbellatum* (L.) Benth.	Kibalanak	12	0.12	6.6 ± 0.9	5.3–8.8	79.1 ± 31.4	17.7–117.8
48		*Pongamia pinnata* (L.) Pierre	Kipahang	3	0.03	9.9 ± 1.7	8.1–12.2	392.7 ± 189.8	125.7–549.8
49		*Trachylobium verrucosum* Hayne	Kisapi	4	0.04	18.2 ± 5.0	14.1–26.6	295.6 ± 373.2	32.4–934.6
50		*Dalbergia latifolia* Roxb.	Sonokeling	23	0.24	16.6 ± 5.2	7.1–25.7	390.6 ± 502.9	8.8–2,173.6
51		*Cassia javanica* L.	Tanggoli	2	0.02	12.2 ± 2.6	9.6–14.8	254.3 ± 240.5	13.7–494.8
52	LYTHRACEAE	*Lagerstroemia speciosa* (L.) Pers.	Benger	70	0.73	14.1 ± 5.8	5.1–25.7	279.9 ± 505.7	2.0–2,562.4
53		*Lagerstroemia flosregineae* Retz.	Bungur	49	0.51	12.6 ± 4.3	5.9–21.2	271.1 ± 516.0	2.0–2,474.0
54	MALVACEAE	Abelmoschus moschatus Medik.	Kakapasan	106	1.10	7.7 ± 1.9	5.0–13.6	31.9 ± 34.8	2.0–233.7
55		*Hibiscus similis* Bl.	Waru	133	1.38	7.7 ± 1.5	5.0–12.1	195.5 ± 227.3	8.8–1,643.4
56		*Hibiscus tiliaceus* L.	Waru laut	10	0.10	7.1 ± 1.2	5.2–9.2	201.3 ± 150.3	68.7–432.0
57		*Schoutenia ovata* Korth.	Walikukun	6	0.06	10.7 ± 2.3	6.7–13.0	79.8 ± 67.2	3.4–166.9
58	MELIACEAE	*Dysoxylum alliaceum* Bl.	Kadoya	129	1.34	10.3 ± 4.0	5.0–21.2	124.5 ± 359.9	2.0–2,721.4
59		*Dysoxylum densiflorum* (Bl.) Miq.	Karaminan	1	0.01	27.5	–	3,180.9	–
60		*Dysoxylum caulostachyum* Miquet	Kokosan monyet	1,130	11.74	12.0 ± 3.8	5.0–30.9	113.1 ± 281.5	2.5–5,937.6
61		*Swietenia macrophylla* King	Mahoni	504	5.24	18.0 ± 5.1	5.0–31.5	807.0 ± 1,166.1	4.9–8,001.2
62		*Aglaia barbatula* K. & V.	Siloar	1	0.01	15.7	–	47.6	–
63	MIMOSAE	*Acacia auriculiformis* A.Cunn. ex Benth.	Acasia	16	0.17	9.3 ± 3.9	5.0–16.8	209.0 ± 224.7	13.7–777.5

Appendix 1. continued

No.	Family	Species	Local name	*n*	%	Tree height (m)		Crown volume (m^3)	
						Mean ± *SD*	Range	Mean ± *SD*	Range
64	MORACEAE	*Artocarpus elasticus* Reinw. ex Bl.	Benda	4	0.04	17.6 ± 3.3	13.3–21.0	151.2 ± 50.4	86.4–204.2
65		*Ficus annulata* Bl.	Kiara koneng	8	0.08	17.7 ± 2.7	12.8–21.3	1,063.2 ± 840.6	49.1–2,670.4
66		*Ficus benjamina* L.	Beringin	5	0.05	12.5 ± 3.4	6.3–16.0	344.8 ± 288.6	5.9–830.6
67		*Ficus elastica* Roxb.	Kendal	1	0.01	11.5	–	432.0	–
68		*Ficus hispida* L.	Bisoro	2	0.02	12.0 ± 1.8	10.2–13.7	141.4 ± 39.3	102.1–180.6
69		*Ficus microcarpa* L.F.	Pereng	3	0.03	13.3 ± 1.4	12.1–15.2	867.9 ± 960.9	172.8–2,226.6
70		*Ficus pubinervis* Bl.	Kopeng	8	0.08	12.6 ± 4.2	7.8–18.7	231.6 ± 332.1	22.6–1,083.8
71		*Ficus septica* Burm.	Kiciat	147	1.53	9.8 ± 2.9	5.2–18.7	54.5 ± 110.4	2.9–1,113.3
72		*Ficus sumatrana* Miq.	Kiara beas	27	0.28	17.0 ± 7.4	5.8–36.7	2,083.3 ± 3,074.4	58.9–14,137.2
73		*Ficus subcordata* Bl.	Kiara kebo	3	0.03	17.6 ± 7.3	7.7–25.2	457.5 ± 341.0	29.5–863.9
74		*Ficus variegata* Bl.	Kondang	3	0.03	18.8 ± 6.0	12.2–26.8	1,062.3 ± 755.9	329.9–2,102.9
75		*Ficus* sp.	Kiara sp.	17	0.18	19.1 ± 7.7	7.1–35.0	1,930.1 ± 3737.9	11.8–15,975.0
76	MYRISTICACEAE	*Horsfielldia glabra* (Reinw. Ex Bl.) Warb.	Kalapacung	39	0.41	15.3 ± 3.5	6.5–22.7	232.0 ± 226.8	11.8–824.7
77		*Myristica guatterifolia* DC.	Kimokla	26	0.27	10.4 ± 4.0	5.0–18.3	70.3 ± 56.2	4.9–225.8
78	MYRTACEAE	*Decaspermum fruiticosum* J.R. Forst. & G. Fost.	Ipis kulit	55	0.57	11.4 ± 4.2	5.4–26.4	197.1 ± 322.9	3.4–1,714.1
79		Eugenia polyantha Wight.	Salam	242	2.51	14.4 ± 5.3	5.1–31.3	156.8 ± 492.9	0.5–4,523.9
80		*Rhodamnia cinerea* Jack	Kibesi	67	0.70	9.1 ± 2.8	5.6–19.7	46.6 ± 75.2	0.0–565.5
81		*Syzygium antisepticum* (Bl.) Merr.& L.M.Perry	Kipancar	1,305	13.56	9.3 ± 2.7	5.0–24.8	79.7 ± 125.4	0.5–1,311.6
82		*Syzigium aqueum* Alston	Jambu air	2	0.02	7.6 ± 0.4	7.2–8.0	51.8 ± 24.8	27.0–76.6
83		*Syzygium racemosum* (Bl.) DC.	Kopo	22	0.23	9.5 ± 2.4	5.5–13.8	56.2 ± 120.7	10.3–596.9
84		*Syzigium* sp.	Jambu alas	13	0.14	7.9 ± 2.1	5.0–11.6	80.9 ± 65.3	1.5–194.4
85	PALMAE (ARECACEAE)	Arenga obtusifolia Mant	Langkap	85	0.88	10.5 ± 3.3	5.4–24.0	101.5 ± 153.8	10.8–895.4
86		*Cocos nucifera* L.	Kelapa	32	0.33	12.1 ± 3.9	6.7–22.1	78.9 ± 99.8	11.8–589.0
87		Corypha gebanga Bl.	Gebang	2	0.02	11.8 ± 4.4	7.4–16.2	283.7 ± 171.8	111.9–455.5
88		?	Palm	1	0.01	13.9	–	80.5	–
89	PANDANACEAE	*Pandanus furcatus* Roxb.	Cangkuang (Pandan hutan)	23	0.24	6.9 ± 1.5	5.1–10.9	35.2 ± 26.5	2.0–82.5
90		*Pandanus bidur* Jungh. ex Miq.	Pandan gede	3	0.03	14.0 ± 4.9	7.7–19.7	91.3 ± 54.1	24.5–157.1
91	PHYLLANTHACEAE	*Baccaurea racemosa* (Reinw. ex Bl.) Müll.Arg.	Menteng	30	0.31	9.0 ± 2.1	5.1–12.8	59.6 ± 43.5	6.4–151.2
92	RUBIACEAE	*Ixora paludosa* Kurz	Soka	5	0.05	9.3 ± 6.0	5.2–21.1	146.2 ± 252.9	9.8–651.9
93		*Nauclea obtusa* Bl.	Dempol	2	0.02	8.1 ± 1.7	6.4–9.7	98.2 ± 58.9	39.3–157.1
94		*Nauclea orientalis* (L.) L.	Kelepu	17	0.18	18.5 ± 5.8	9.9–34.3	752.8 ± 786.1	76.6–2,580.0
95		*Nauclea pallida* Bl. Ex Miq.	Tengek caah	98	1.02	6.8 ± 1.6	5.0–12.7	46.9 ± 53.6	2.5–424.1
96		*Nauclea* sp.	Kitaleus	2	0.02	16.1 ± 8.2	7.9–24.3	499.2 ± 490.4	8.8–989.6
97		*Neonauclea excelsa* (Bl.) Merr.	Cangcaratan	30	0.31	13.4 ± 4.7	5.3–24.6	239.0 ± 297.2	2.0–1,237.0
98		*Hypobathrum frutescen* Bl.	Kihapit	87	0.90	7.2 ± 1.9	5.0–13.7	26.6 ± 24.4	1.0–127.6
99		*Plectronia glabra* Benth. & Hook.f. ex Kurz.	Kokopian (Kikopi)	17	0.18	12.8 ± 3.4	7.9–20.8	52.3 ± 47.4	8.3–149.2
100		*Psychotria viridiflora* Reinw. Ex Bl.	Kikores	4	0.04	8.3 ± 3.0	5.8–13.2	59.6 ± 47.5	7.9–123.7

Appendix 1. continued

No.	Family	Species	Local name	*n*	%	Tree height (m)		Crown volume (m^3)	
						Mean ± *SD*	Range	Mean ± *SD*	Range
101	RUTACEAE	*Acronychia laurifolia* (Bl.)	Kijeruk (Jujulukang)	18	0.19	9.4 ± 2.0	6.1–12.9	33.1 ± 37.8	7.4–135.5
102		*Clausena excavata* Burn. f.	Kibaceta	3	0.03	6.5 ± 0.9	5.5–7.6	29.5 ± 12.5	20.1–47.1
103	SAPINDACEAE	*Erioglossum rubiginosum* (Roxb.) Bl.	Kilalayu	160	1.66	9.7 ± 3.3	5.1–25.8	62.1 ± 139.6	2.5–1,449.1
104		*Erioglossum* sp.	Kilalayu batu	1	0.01	14.3	–	47.6	–
105		*Mischocarpus sundaicus* Bl.	Kihoe	26	0.27	7.3 ± 2.1	5.0–13.6	60.0 ± 57.5	1.0–233.7
106		*Nephelium lappaceum* L.	Rambutan	1	0.01	11.2	–	23.1	–
107		*Pometia pinnata* J.R.Forst. & G.Forst.	Leungsir	6	0.06	12.1 ± 5.7	6.0–19.4	482.0 ± 533.7	2.9–1,431.4
108		*Schleichera oleosa* (Lour.) Oken	Kosambi	112	1.16	11.9 ± 3.8	5.0–23.7	151.1 ± 271.9	3.4–1,453.0
109	SCROPHULARIACEAE	*Radermachera gigantea* (Bl.) Miq.	Padali	1	0.01	20.9	–	471.2	–
110	STERCULIACEA	*Heritiera littoralis* Dryand.	Dungun	2	0.02	10.4 ± 4.6	5.8–15.0	137.9 ± 123.2	14.7–261.1
111		*Kleinhovia hospita* L.	Tangkolo	36	0.37	14.1 ± 3.6	7.0–21.5	331.5 ± 1,007.1	19.1–6,220.4
112		*Pterocymbium javanicum* R. Br.	Tang kalak	1	0.01	21.1	–	392.7	–
113		*Pterospermum divirsifolium* Bl.	Cerlang	89	0.92	10.8 ± 3.6	5.0–21.4	93.2 ± 190.8	3.4–1,453.0
114		*Pterospermum javanicum* Jungh RBR	Caruy	668	6.94	17.3 ± 7.4	5.1–36.9	664.7 ± 1,248.0	0.0–9,817.5
115		*Sterculia coccinea* Roxb.	Hantap heulang	117	1.22	18.5 ± 6.8	5.9–33.3	636.9 ± 1,017.9	2.9–4,618.1
116		*Sterculia foetida* L.	Kondang laer	2	0.02	17.7 ± 8.5	9.2–26.1	996.5 ± 917.9	78.5–1,914.4
117		*Sterculia urceolata* Smith.	Jejebugan	48	0.50	7.2 ± 1.5	5.2–12.2	38.5 ± 38.5	2.0–182.6
118	THEACEAE	*Ternstroemia* sp.	Umpang	50	0.52	8.9 ± 2.0	5.5–13.7	37.5 ± 31.6	10.3–216.0
119	TILIACEAE	*Grewia paniculata* Roxb.	Derawak	41	0.43	8.7 ± 2.7	5.2–16.1	48.3 ± 50.5	2.0–243.5
120	ULMACEAE	*Celtis philippensis* Bl.	Kipepetek	48	0.50	11.8 ± 3.9	5.2–23.1	121.1 ± 195.4	2.5–918.9
121	URTICACEAE	*Villebrunea rubescens* Bl.	Nangsi	2	0.02	8.2 ± 0.9	7.3–9.1	73.1 ± 66.3	6.9–139.4
122	VERBENACEAE	*Premna integrifolia* L. Mant.	Singkil	1	0.01	8.3	–	518.4	–
123		*Tectona grandis* L.	Jati	674	7.00	21.0 ± 5.5	5.1–33.7	914.4 ± 956.3	5.4–5,654.9
124		*Vitex pubescens* Vahl.	Laban	333	3.46	14.4 ± 4.9	6.2–33.0	378.0 ± 510.5	0.0–3,552.0
125	VITACEAE	*Leea angulata* Korth. ex Miq.	Kibuaya	99	1.03	11.5 ± 3.7	5.4–24.7	140.3 ± 384.8	2.5–2,792.1
126	?	?	Katileng	3	0.03	13.1 ± 2.6	9.7–16.0	79.4 ± 62.1	29.5–166.9
127	?	?	Kihurang	9	0.09	8.4 ± 3.7	5.4–17.5	88.4 ± 89.4	2.9–310.2
128	?	?	Mata buta	1	0.01	12.1	–	51.1	–
129	?	?	Panggor	1	0.01	25.6	–	384.8	–
130	?	?	Sampang	2	0.02	18.8 ± 1.1	17.7–19.9	199.3 ± 2.9	196.3–202.2
131	?	?	Sembir	1	0.01	5.9	–	15.7	–
132	?	?	Andong	26	0.27	9.8 ± 2.5	6.7–16.1	68.1 ± 69.5	2.5–337.7
	Unknown			10	0.10	13.1 ± 7.5	6.1–27.4	443.3 ± 814.1	0.0–2,650.7
	Total			9,624	100.00	12.4 ± 5.8	5.0–36.9	273.5 ± 690.1	0.0–15,975.0