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Foraging Ecology of the Sunda Colugo (*Galeopterus variegatus*) in Bako National Park, Sarawak, Malaysia

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A study on the foraging activities of the Sunda Colugo (*Galeopterus variegatus*) by direct observation was conducted from 16th August 2008 to 22nd July 2009 in Bako National Park, Sarawak. Sunda colugos were observed foraging on 12 species comprising 10 families of trees, over 34 occasions and at 24 locations in the Telok Assam study area. The most preferred species in the diet of the Sunda colugos, comprising a total of 50.46 % of all forage trees identified, was *Buchanania arborescens* (Family: Anacardiaceae). This paper provides valuable documentation on important food plant species utilised by Sunda colugos and describes the first observation of this species feeding on ants (*Paratrechina longicornis*). The results may assist the management and maintenance of the habitat that provide food sources for the Sunda colugos, which are attractive species with high eco-touristic value in Bako National Park.

Keywords: Colugo, *Galeopterus variegatus*, Bako National Park, foraging ecology, *Paratrechina longicornis*

INTRODUCTION

Information on dietary preferences is valuable to understand the importance of food plant utilisation and dietary breadth in the niche of a species. According to Sharpe and Goldingay (1998), understanding feeding requirements is important because dietary requirements and preferences influence animals' ecological requirements and habitat utilization. Hence, such knowledge enables predictions to be made about the life history of a species. The Sunda Colugo (*Galeopterus variegatus*) is a nocturnal arboreal mammal from the Order Dermoptera. There are two known Colugo species, *Galeopterus variegatus* and *Cynocephalus volans* (Stafford and Szalay 2000, Stafford 2005, Francis 2008). The former occurs from Northern Laos (Ruggeri and Etterson, 1998), through the Sunda region, peninsular Thailand, southern Indochina to Burma (Payne *et al.*, 1985). The latter also known as the Philippine Colugo (*C. volans*) occurs in parts of southern Philippines (Stafford 2005, Francis 2008).

To conserve a specific species that is prone to environmental changes (e.g. habitat alteration), specific studies of its ecological requirements are necessary (Goldingay and Kavanagh 1995). According to Ketol et al. (2006), lack of awareness among local villagers and ineffective enforcement may have contributed to drastic population declines and local extinction of Sunda colugo. Maryanto et al. (2008) stated that the Sunda Colugo is listed as Lower Risk by the IUCN, while Francis (2008) suggested that the Sunda Colugo is near threatened due to habitat loss and hunting. In Sarawak, Sunda colugos are hunted for food, flesh (Mohd-Azlan and Muhammad-Faisal 2006) and their fur (Dzulhelmi and Abdullah 2009). In Malaysia, *G.variegatus* is protected by a number of existing laws such as the Wildlife Protection Act 1972

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(enforced in Peninsular Malaysia), Wildlife Protection Ordinance 1998 (Sarawak state law) and Wildlife Conservation Enactment 1997 (Sabah state law).

The Sunda Colugo feeds on fruits (Yasuma and Andau 2000), leaves, leaf shoots, flower buds and sap, but data on their dietary preferences is scarce (Francis 2008). In addition, alternative diets for the Sunda Colugo in captivity includes banana, papaya, local orange, mango, greenery (e.g. lettuce) and leaves of wild passion fruits (*Passiflora foetida*) (Family: Passifloraceae) and these can be fed to the Sunda Colugo for about 15 weeks in captivity (Lim 1967). Dzulhelmi and Abdullah (2009) noted that nocturnal arboreal mammals occurring sympatrically with *G. variegatus* within their study area in Borneo included common palm civet (*Paradoxurus hermaphroditus)* and an unidentified flying squirrel species. These species most probably utilise similar plants species used by the Sunda colugo.

Previous field observations conducted by Lim (2004) on the plants consumed by Sunda Colugos were done at six different sites in Singapore. Agoramoorthy et al. (2006) found that the Sunda Colugo consumes leaves with less potassium and nitrogen but with higher tannin ($P > 0.05$) based on mineral and phytochemical contents determination of the Sunda Colugo in the Singapore Zoo and Night Safari compound. Detailed observations of the dietary preferences of *C. volans* were made by Wischusen and Richmond (1998) in Davao City, Mindanao, Philippines. Although such data is scarce, they are crucial as they can influence management decisions in the conservation effort for this taxon. This can include conserving the tree species foraged by *G. variegates* as they serve a dual function as habitat and food source (Lim 2004, 2007).

In Sarawak, Ketol et al. (2006) observed a mother colugo carrying its young feeding on rambai fruit (*Bacauria motleyana*) (Family: Phyllanthaceae) at Kampung Malaban Lumut. Additionally, the tagged Sunda Colugo specimens (09/26 and 09/29) in the Sarawak museum noted these individuals feeds on durian flower in the fruit orchard. However, up to date, there are no detailed studies on the dietary preferences of *G. variegatus* in Sarawak. Since *G. variegatus* occurs in Bako National Park, knowledge on their habitat is vital for the management and conservation of this species in the park. Furthermore, G. *variegatus* is one of the main attractions for eco-tourists visiting Bako National Park. Thus, this study was conducted to understand the dietary preference of *G. variegatus* in Bako National Park and identify of important plants species utilized by this rare and elusive creature.

MATERIALS AND METHODS

Study area

This study was conducted around the headquarters at Telok Assam, Bako National Park ($110^{o}26$'E, $1^{o}41$'N) in Sarawak, Malaysia. The vegetation types within this 2727 ha park area include beach forest, forest along cliffs, mixed dipterocarp forest, riverine forest, *kerangas* forest and mangrove forest (Hazebroek and Abang Kashim 2000, 2006). The diversity of habitats is one of the unique features of the park among protected areas in Sarawak. The north-west area of the park is bounded by the South China Sea at 244 m above sea level and the annual rainfall is about 4300 mm (averaged over 17 years) with a temperature range of 20 -32^{o}C at Telok Assam (Hazebroek and Abang Kashim 2000, 2006).

After preliminary reconnaissance surveys and interviews with the park personnel and Sarawak park guides, it was found that the Sunda Colugos can be easily detected around the Telok Assam Area. Thus, a four hectares main study area was demarcated at Telok Assam which includes the headquarters of Bako National Park. The main study area was easily accessible, with

less visually obstructing vegetation and hence suitable for direct observation and tracking of *G. variegatus* while they were foraging in the trees (Figure 1). Because of non-availability of specialised tools (e.g. radio telemetry or remote tracking device and good night vision binoculars), lack of trained support assistants, as well as limited trail access due to very thick undergrowth dominated by thorny vegetation, such as *Salaca* sp., *Calamus* spp. and *Onconsperma tigillarium*, direct observation and continuous tracking of this nocturnal species beyond the main study area was not possible.

Methods

Visual search of *G. variegatus* at diurnal roosting sites were conducted within main study area from 0800 to 1800 hours between 16th August 2008 and 22nd July 2009, for a period of 10 days in each month. The Sunda Colugo was followed to its foraging trees during its active period (Dzulhelmi and Abdullah 2009) from 1800 hours until it glided out of sight or out of the main study area. Visual observation during the foraging activity of *G. variegatus* was aided by using a flashlight (Dolphin Eveready 1209 with 4.8 volt /0.75 amp bulb).

Foraging ecology is defined as the dietary items selected by the Sunda Colugo for consumption. Thus for the purpose of this study, any preferential items that entered the mouth of G. *variegatus* were considered to be its food sources. The tree species foraged were identified, tagged and recorded (Figure 1). In addition, the dietary preferences of the Sunda Colugo were compared with the available information from Lim (2004) and Agoramoorthy et al. (2006). For the selected trees foraged, a total of eight vegetation plots (20 m x 20 m) were established (four plots on the left and four plots on the right consequently) along a 400 m transect in the middle of the main study area. Plants of $\geq$ 3 meters in height and $\geq$ 5 cm of diameter at breast height (DBH) were enumerated to assess their density. Tree species occurring in the main study area are listed in Appendix 1.

Slight inconsistencies in the data collected were due to several factors notably the uncontrolled movement of the studied species. Owing to these shortcomings the data obtained were analysed as percentage (%) of total observed foraging activities. The densities of the tree species preferred by the Sunda colugos are given in Appendix 2 and were calculated using the formula:

$$D = T_{sp} \times 10,000 m^2 / (8 \text{ plots} \times 20 \text{ m} \times 20 \text{ m})$$

where, D = Density of individual tree species per hectare, and

T_{sp} = Total number of tree species counted.

RESULTS

The total time spent foraging was 9.5 % (547 mins out of 5757 mins) of total observation time over 120 nights between 1800 hours and 0600 hours. From a total of 34 foraging occasions observed, on one occasion we observed *G. variegatus* feeding on an ant species (*Paratrechina longicornis*) while on five occasions the Sunda Colugos were feeding on sap from tree bark (2.7 %). We also found that on four occasions the Sunda Colugos were drinking water (5.9 %) and 28 observations eating leaves (85.2 %). *B. arborescens* (50.5 %) was the most preferred food plant while *O. trigillarium* (0.2 %) was the least preferred of the species selected by the Sunda

colugos. On the other hand, *Paratrechina longicornis* (6.2 %) was the only insect recorded consumed by the Sunda colugo. The summary results on the foraging activities are shown in Appendix 2.

The comparative data obtained by visual field observation on the plant species foraged by the Sunda Colugo in Singapore and present study are given in Table 1. Both authors, Lim (2004) and Agoramoorthy et al. (2006) had similar results regarding four species of plants consumed by the Sunda colugos. However, Lim (2004) did not indicate the location of the tree species consumed within Bukit Timah Nature Reserve by the Sunda colugos while Agoramoorthy et al. (2006) only observed the plant species consumed by Sunda colugos in the Singapore Zoo and Night Safari compound. However, the present study listed 12 species consumed by the Sunda colugo in Bako National Park, Sarawak.

Figure 1 shows the location of the selected tree species and the ant species (hosting on *V. pubescens*) (Family: Verbenaceae) utilised by the Sunda Colugo at the main study area. The symbols for each dietary item can be referred in Appendix 2. A total of 24 locations were been identified as the foraging trees of the Sunda Colugo in the study area. The percentage (%) of feeding time on the 12 species (10 families) of trees and the ant species during this study are given in Figure 2.

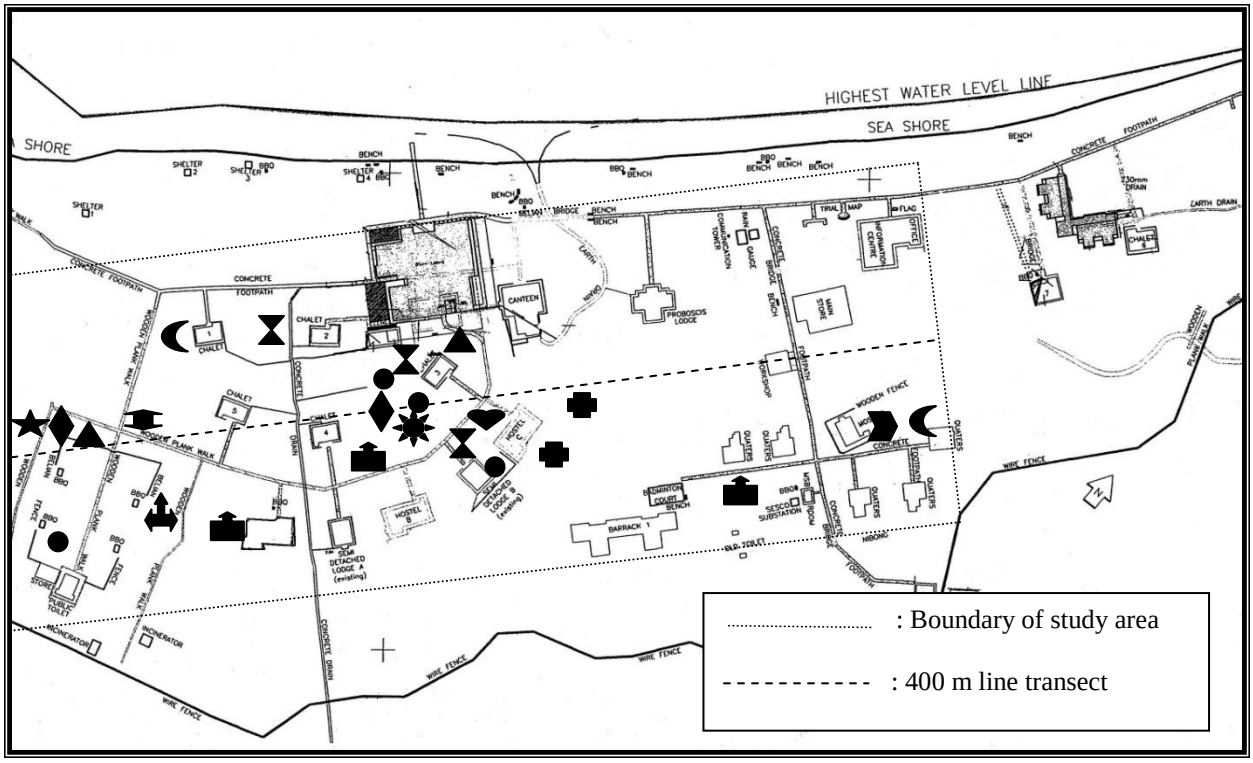

Figure 1: Map of main study area at Telok Assam, Bako National Park and locations of food plants utilised by Sunda colugo. Details of the symbols can be referred in Appendix 2. Drawn to scale.

Table 1. Field observation on the tree species foraged by the Sunda Colugo by Lim (2004) and Agoramoorthy *et al.* (2006) in Singapore and the present study (2008-2009) in Sarawak.

No.	Family	Species	Lim (2004)	Agoramoorthy *et al*. (2006)	Present study (2008-2009)
1.	Anacardiaceae	*Buchanania arborescens*			√
2.		*Campnosperma auriculata*	√	√	
3.		*Campnospermum* sp.			√
4.	Aquifoliaceae	*Ilex cymosa*			√
5.	Arecaceae	*Oncosperma tigillarium*			√
6.	Clusiaceae	*Calophyllum soulattri*			√
7.	Euphorbiaceae	*Macaranga pruinosa*			√
8.	Leguminosae	*Peltophorum pterocarpus*	√	√	
9.		*Saraca cauliflora*		√	
10.		*Saraca thaipingensis*	√		
11.	Myrtaceae	*Rhodamnia cinera*	√	√	
12.		*Syzygium grande*	√	√	
13.		*Syzygium lineatum*	√		
14.		*Syzygium pachyphyllum*		√	
15.		*Syzygium palembanicum*		√	
16.		*Syzygium acuatinervium*			√
17.		*Syzygium* sp.			√
18.	Moraceae	*Artocarpus kemando*	√		
19.		*Ficus microcarpa*			√
20.	Orchidaceae	*Arachnis* sp.			√
21.	Rhizophoraceae	*Gynotroches axillaris*			√
22.	Verbenaceae	*Vitex pubescens*			√

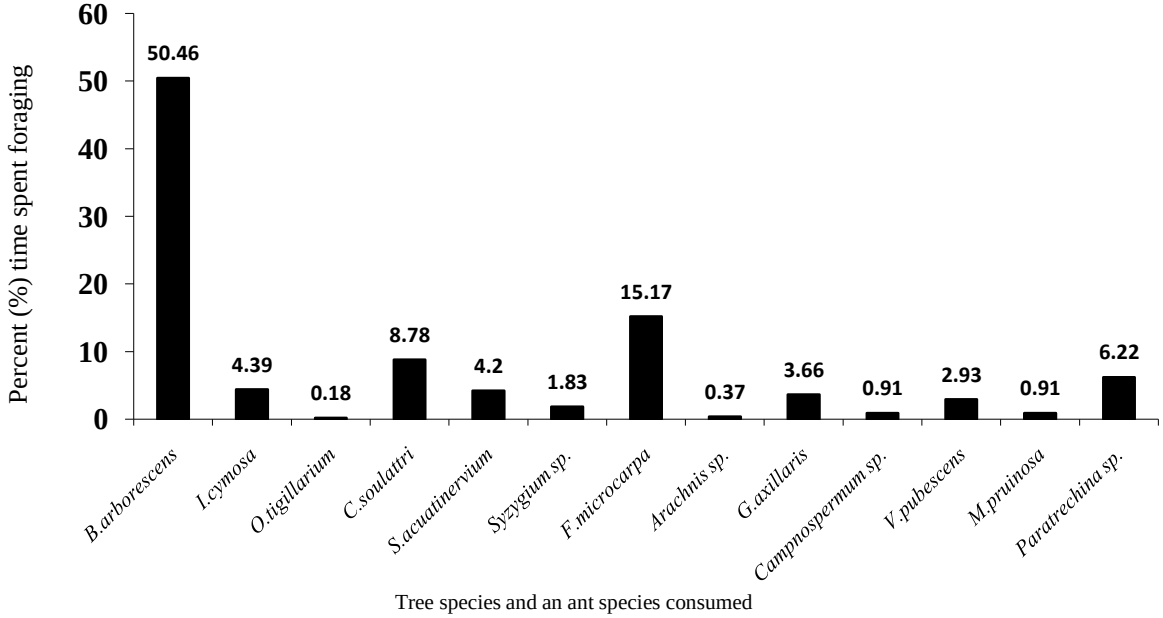

Figure. 2: Percent (%) times the Sunda Colugo foraged on various plants and an ant species in Bako National Park, Sarawak.

DISCUSSION

Research constraints

Data acquisition of the nocturnal Sunda colugos by direct observation aided with flashlight was very difficult and challenging. First, the presence of the observer and flashlight might influence or disturb the normal foraging pattern of the free ranging Sunda colugos. Secondly, maintaining continuous visual contact was very difficult due to obstructions from the dense foliage and thick thorny undergrowth that hampered observer's movement at night. Thirdly, the behaviour and movement patterns of the study animal were unpredictable. The colugo often moved out of sight from the main study area. In addition, the habitat alteration by human activities at Telok Assam, Bako National Park has heavily affected the food sources available for this species at the main study area.

The amount of time spent feeding of different items will differ as the Sunda colugos were affected by these factors throughout their active period. For example, sometimes, the Sunda colugos were observed foraging continuous in the study area for the entire active period. However, there were certain occasions when the Sunda colugos were found in the main study area, but then suddenly glided out of sight after a certain period of time. The weather conditions (e.g. raining) also affected our ability to maintain continuous visual observation of the foraging activities of the Sunda colugos.

Diet preferences of the Sunda Colugo

The present study indicates that the Sunda colugos have high preference for *B. arborescens* (50.46 %), although this was also the most common species in the study area with a density of 84.38 ha^{-1}. According to Lim (2004), the Sunda colugos prefer foraging in species of the family Myrtaceae (*Syzygium* spp.). This finding was also supported by Agoramoorthy et al. (2006) who observed that 50 % of feeding observations of Sunda colugos were in *Syzygium* spp. in Singapore Zoo and Night Safari compound. The difference in dietary preference between Bako and Singapore are likely due to different habitat structure as well as the availability of different food sources. Apparently, only three *Syzygium* spp. with a total density of 12.51 ha^{-1} were available within the main study area at Bako. Farhan-Ihsan (2007) reported that Silvered leaf langur (*Presbytis cristata*) feed on both *B. arborescens* and *Syzygium* spp. in Bako National Park. This suggests that *B. arborescens* and *Syzygium* spp. are an important diet component for these mammals, and indicating both species share the food resources in the same habitat. Therefore, food resource partitioning may be achieved and competition avoided by the nocturnal (e.g. *G.variegatus*) and diurnal (*P. cristata*) habits of these species. There were no observations of the Sunda colugos feeding on fruits in this study although it has been mentioned by Yasuma and Andau (2000) and Ketol et al. (2006).

The Sunda Colugo was also observed licking on the tree bark of selected tree species during this study. Lim (2007) stated that *G. variegatus* may be feeding on lichens for nutrients, or for salts and minerals present on the bark but, the actual function of licking tree bark is still not well understood. In addition, in this study the Sunda colugos were observed licking inside a tree hole occupied by the ant species (*Paratrechina longicornis*). The ants may provide a protein sources for *G. variegatus*. The tree hole of *V. pubescens*, which was licked by the Sunda colugo, was later checked and nothing unusual was noted other that that the ants were merely living inside. The time spent by Sunda colugos licking other tree species was only to a maximum of 5 mins, while the inside of the tree hole of *V. pubescens* occupied by the ants was licked for a total

of 34 mins. Thus, suggesting that this was not normal bark-licking behaviour and that the Sunda Colugo was probably feeding on the ants. Consumption of ants by this species may be very rare as up to date there is no formal report of such phenomenon. However, one of the tagged male Sunda Colugo specimens (09/28) from Sarawak museum noted that the individual feeds on ants. Thus, further studies on the diet and habitat utilisation of Sunda Colugos are needed to verify whether they are in fact an omnivorous mammal.

The Sunda Colugo consume plants with higher tannin levels, Tannins are known for protein binding properties, which may be important for the Sunda Colugos especially during pregnancy and for lactating females (Agoramoorthy et al. 2006). Unfortunately, the nutritional contents of the tree species selected by the Sunda colugos in this study are not known. Since the locations of the plant species consumed by the Sunda Colugo have been identified, a nutritional content study on these plant species can be conducted in the future.

Conclusions

The dietary selection of Sunda colugos have been documented at Telok Assam, Bako National Park. However, the studies on the diet of this species are still preliminary. Notably, there are no studies in various other vegetation types, such as dipterocarp forest, as well as other areas where the Sunda colugos exist. This study also documented the Sunda Colugo feeding on an ant species (*Paratrechina longicornis*). This is not consistent with previous understanding that Sunda colugos were herbivorous (Payne et al. 1985, Yasuma and Andau 2000) and folivorous (Agoramoorthy et al. 2006). Further study is needed to verify if *G. variegatus* is in fact an omnivorous species. Understanding the dietary preference of *G. variegatus* can help to conserve and protect the habitat requirement for this species. Bako National Park has been altered by human intervention for various infrastructure developments and thus documentation of the tree species used as the food sources by *G. variegatus* in Telok Assam, Bako National Park is crucially needed for management and *in-situ* conservation purposes. Furthermore, proper management for *in-situ* conservation of the Sunda colugos at Bako National Park can enhance the interest of the park to the public, as it may be one of the main attractions for tourists visiting the park.

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APPENDIX 1

List of tree species occurring in the main study area, Telok Assam, Bako National Park, Sarawak, Malaysia

Family	Species	Local name	DBH (cm) Mean±SD	Height (m) Mean±SD	Density (ha^{-1})
Anacardiaceae	*Buchanania arborescens*	Otak udang	15.72±14.84	11.04±9.32	84.38
Anacardiaceae	*Campnospermum* sp.	Terentang	Not counted	Not counted	Not counted
Aquifoliaceae	*Ilex cymosa*	Kerdam air	29.18±10.08	23.76±7.69	53.13
Arecaceae	*Caryota mitis*	-	Not counted	8.00±0.00	9.38
Arecaceae	*Oncosperma tigillarium*	Nibong	Not counted	Not counted	112.5
Clusiaceae	*Calophyllum soulattri*	Bintangor	11.10±5.53	14.73±4.18	31.25
Clusiaceae	*Garcinia* sp.	Kandis asam	15.50±0.00	12.00±0.00	3.13
Clusiaceae	*Garcinia hombroniana*	Kandis laut	16.63±6.80	9.88±5.36	25.00
Euphorbiaceae	*Baccaurea* sp.	Tampoi	11.90±4.75	8.40±3.91	15.63
Euphorbiaceae	*Glochidion* sp.	Menyam	25.00±0.00	15.00±0.00	3.13
Euphorbiaceae	*Macaranga pruinosa*	Benuah	Not counted	Not counted	Not counted
Hypericaceae	*Cratoxylon arborescens*	Geronggang	48.3±15.10	27.8±8.04	15.63
Lecythidaceae	*Barringtonia asiatica*	Putat Laut	5.00±0.00	4.00±0.00	3.13
Melastomataceae	*Mamecylon* sp.	Nipis Kulit	5.00±0.00	4.00±0.00	3.13
Moraceae	*Ficus microcarpa*	Ara	Not counted	Not counted	Not counted
Myrtaceae	*Syzygium acuatinervium*	Ubah Padang	32.5±24.75	16.50±6.36	6.25
Myrtaceae	*Syzygium* sp.	Ubah laut	40.00±0.00	20.00±0.00	3.13
Myrtaceae	*Syzygium* sp.	Ubah Jambu	22.00±0.00	10.00±0.00	3.13
Myrsinaceae	*Ardisia elliptica*	Patah Dahan	12.83±1.04	9.33±1.15	9.38
Myristicaceae	*Gymnacranthera eugeniifolia*	Kumpang	42.00±0.00	32.00±0.00	3.13
Oxalidaceae	*Sarcotheca* sp.	Piang	15.00±0.00	10.00±0.00	3.13
Rhizophoraceae	*Gynotroches axillaris*	Sabar bubu	11.00±4.17	6.80±0.45	15.63
Rubiaceae	*Canthium* sp.	Tulang Ular	9.05±5.58	6.36±1.56	68.75
Verbenaceae	*Vitex pubescens*	Leban	22.88±7.12	14.00±5.16	81.25

APPENDIX 2

Plant species, ant species and other parts consumed by Sunda colugos (*G. variegatus*) at peat swamp forest of Bako National Park, Sarawak, Malaysia

ID symbol	Taxa			Parts consumed	Foraging strategies (mins)				Individuals			No. of times observed (n)	Tree Density per hectare (ha-1)
	Family	Species	Local name		Licking	Drinking	Eating	Total	GY	GN	ON		
Plants													
	Anacardiaceae	*Buchanania arborescens*	Otak udang	Leaves & water	0	30	246	276	D, E	-	D, E	10	84.38
	Anacardiaceae	*Campnospermum* sp.	Terentang	Sap	5	0	0	5	-	L	-	1	Not counted
	Aquifoliaceae	*Ilex cymosa*	Kerdam air	Sap & Leaves	2	0	22	24	E	L	-	2	53.13
	Arecaceae	*Oncosperma tigillarium*	Nibong	Sap	1	0	0	1	L	-	-	1	112.5
	Clusiaceae	*Calophyllum soulattri*	Bintangor	Leaves & water	0	2	46	48	E	D, E	-	5	31.25
	Euphorbiaceae	*Macaranga pruinosa*	Benuah	Leaves	0	0	5	5	-	-	E	1	Not counted
	Myrtaceae	*Syzygium acuatinervium*	Ubah Padang	Leaves & sap	3	0	20	23	L	E	-	2	6.25
	Myrtaceae	*Syzygium* sp.	Ubah Jambu	Leaves	0	0	10	10	-	E	-	2	3.13
	Moraceae	*Ficus microcarpa*	Ara	Leaves	0	0	83	83	E	E	-	4	Not counted
	Orchidaceae	*Arachnis* sp.	Orkid	Roots	0	0	2	2	-	E	-	1	Not counted
	Rhizophoraceae	*Gynotroches axillaris*	Sabar bubu	Leaves	0	0	20	20	E	E	E	3	15.63
	Verbenaceae	*Vitex pubescens*	Leban	Leaves & sap	4	0	12	16	-	L, E	-	1	81.25
Insects													
	Formicidae	*Paratrechina longicornis*	Semut	Organism	34	0	0	34	L	-	-	1	Not counted
Total (mins) / Total on number of times observed (n)					49	32	466	547	17	13	4	34	-
Total (%)					8.96	5.85	85.19	100	50.0	38.2	11.8	100	-

(GY: Grey & white colour, with young; GN: Grey & white colour, no young; ON: Orange & white colour, no young. (L: licking, D: drinking, E: eating)