BIODIVERSITAS
Volume 20, Number 2, February 2019
Pages: 430-435

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d200218

Short Communication:
A report on ranging behavior of Malayan flying lemurs, *Galeopterus variegatus*, in West Indonesia: Relationships with habitat characteristics

YAMATO TSUJI[1,♥], BAMBANG PRAYITNO[2], TAKAFUMI TATEWAKI[3], KANTHI ARUM WIDAYATI[4], BAMBANG SURYOBROTO[4]

[1]Primate Research Institute, Kyoto University. 41-2 Kanrin, Inuyama, Aichi Prefecture, 484-8506 Japan. Tel.: +81-568630539, Fax; +81-568630539, ♥email: ytsuji1002@gmail.com
[2]Natural Resources Conservation Center. Jl Kidang Pananjung, Pangandaran 46396, West Java, Indonesia
[3]University of Human Environments. 6-2 Kamisanbonmatsu Motojukucho, Okazaki, Aichi Prefecture, 444-3505 Japan
[4] Department of Biology, Faculty of Mathematics and Natural Sciences, Institut Pertanian Bogor. Jl. Raya Dramaga, Bogor 16680, West Java, Indonesia

Manuscript received: 25 December 2018. Revision accepted: 23 January 2019.

Abstract. *Tsuji Y, Prayitno B, Tatewaki T, Widayati KA, Suryobroto B. 2019. Short Communication: A report on ranging behavior of Malayan flying lemurs,* Galeopterus variegatus*, in West Indonesia: Relationships with habitat characteristics. Biodiversitas 20: 430-435.* We attached GPS telemeters to wild Malayan flying lemurs, or colugos (*Galeopterus variegatus*) (n = 3, one adult male, one adult female, one juvenile male) in Pangandaran Nature Reserve, West Java, Indonesia in August 2018, to preliminary evaluate their home range size and characteristics, paying special attention to relationships with forest structure. Home range sizes, generated from location points collected from 4 to 11 days, ranging from 1.2 to 5.4 ha (based on minimum convex polygon method) or from 1.3 to 4.2 ha (95% Kernel), which is much larger than home ranges of colugos inhabiting palm plantations. The home range sizes of adult colugos were larger than that of juvenile. The home ranges of an adult female and a juvenile overlapped. The generalized linear model demonstrated that the locations where the colugos stayed frequently possessed a small number of trees and/or had a single taller tree, and these effects were stronger than other factors. The home range preferences of colugos seem to be related to gliding effectiveness and/or predator avoidance. The mean gliding distances were 33 m, but sometimes reached > 250 m, and there were no significant differences among animals. Night time gliding frequency showed no clear difference between time periods. We confirmed the effectiveness of GPS telemetry for tracking colugo movements.

Keywords: Forest structure, gliding, home range, kernel, maximum convex polygon

INTRODUCTION

Malayan flying lemurs, or the Sunda colugo (*Galeopterus variegatus*), belong to the Order Dermoptera, are mainly distributed in South East Asia (Lim 2007). This species 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). Their home range size (Baba 2011), nocturnal activity (Byrnes et al. 2011, 2012), and habitat preference (Lim et al. 2013; Tsuji et al. 2015) have only been studied in recent years.

Colugos feed on young leaves and fruits (Agoramoorthy et al. 2006; Dzulhelmi and Abdullah 2009; Tsuji et al. 2015). Like as other folivorous/frugivorous animals such as primates and ungulates (Pearson et al. 1995; Albert et al. 2013), the colugo's home range use should be related to environmental characteristics, especially the density and distribution of the trees that provide their diets. However, there have been no systematic studies relating colugo ranging patterns with habitat characteristics. In this study, we apply GPS technology to evaluate (i) home range size, (ii) home range utilization and its relationship with habitat characteristics, and (iii) gliding characteristics (glide distance and distribution of gliding among time periods).

MATERIALS AND METHODS

Study site

We studied colugo ranging behavior at the Pangandaran Nature Reserve (PNR), West Java, Indonesia, which is located on the southern coast of West Java, Indonesia (7°43′S, 108°40′E) (Sumardja and Kartawinata 1977). The PNR is divided into two sections; namely, the northern 38-ha forest park opened for citizen, and the southern 370-ha, strictly-managed nature reserve (Figure 1). Though the forest park is primarily covered by secondary forest, there are several abandoned *Tectona grandis* and *Swietenia macrophylla* plantations (Mitani et al. 2009; Tsuji et al. 2015).

Colugo capturing

We captured three colugos (one adult male, one adult female, and one juvenile male, age-classes were assessed by body size) using a net at the forest park in August 2017 (Table 1).

Table 1. Captured animal and GPS telemetry data.

Variables	Animal ID		
	RS	**BB**	**NN**
Sex	Male	Male	Female
Age class	Juvenile	Adult	Adult
Capture date	2017.8.23	2017.8.23	2017.8.23
Head length (cm)	9.0	9.5	9.0
Body length (cm)	20.0	30.0	23.0
Tail length (cm)	16.0	17.0	16.5
Body weight (g)	368	861	535
Location of capture	S07 42’ 20.4” E 108 39’ 21.6”	S07 42’ 18.6” E 108 39’ 35.3”	S07 42’ 20.5” E 108 39’ 20.5”
Data collection period	2017.8.24-8.27	2017.8.24-9.1	2017.8.24-9.3
# Location points	86	196	272

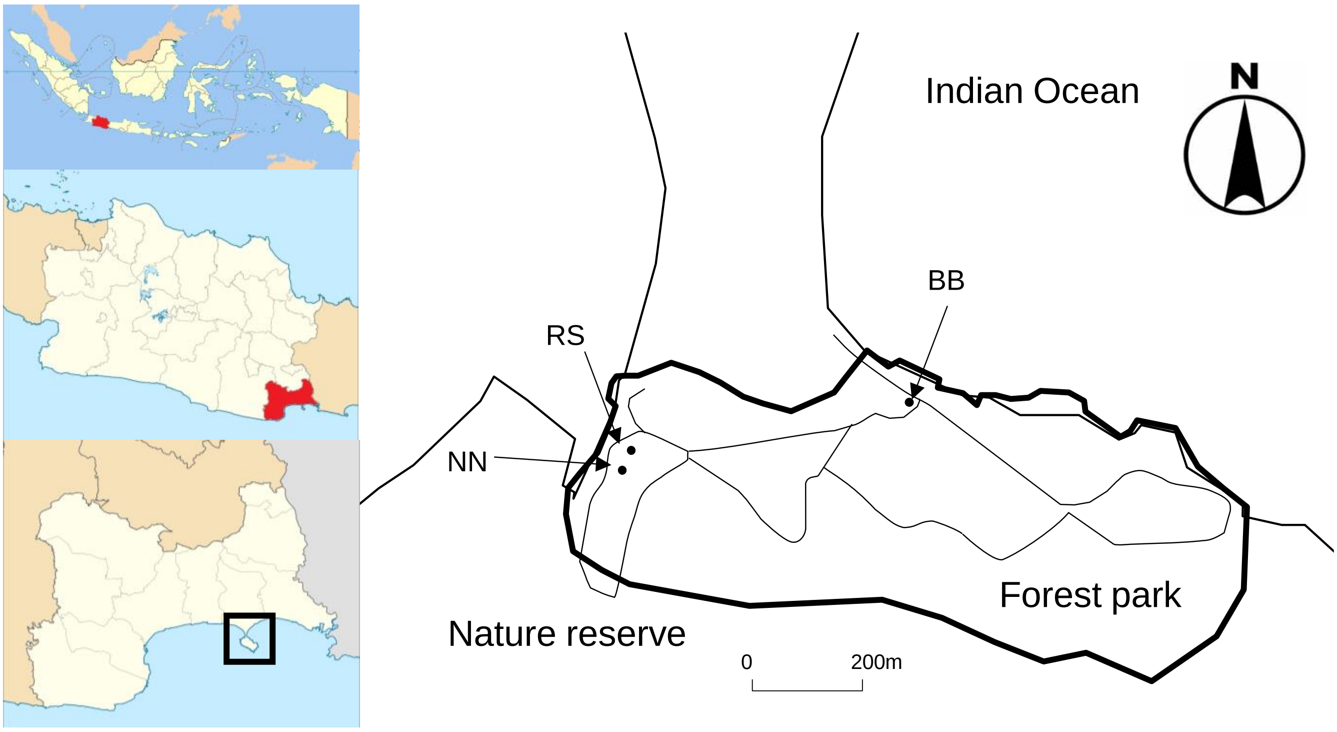

Figure 1. Location of the Pangandaran Nature Reserve in Pangandaran District, West Java Province, Indonesia (*left*) and the study area (*right*). The area surrounded by the thick line represents the forest park, located to the north of the nature reserve, and the narrow line represents trails. The sites at which we captured the animals are also shown as solid circles in the *right* figure

We fitted 5g-GPS telemeters (PinPoint120, SIRTRACK, Havelock North, New Zealand) to the animals with epoxy resin and cyanoacrylate adhesive. After release, we observed the animals until they climbed and then rested or groomed on the tree. Considering their nocturnal nature (Lim 2007; Byrnes et al. 2011), we recorded their location every 30 minutes during the night (18:00-06:00 of the next day), but only four times during the day (07:00 10:00. 13:00, and 16:00), in which they seemed less active (Lim 2007). Animal capturing and handling procedures followed guidelines approved by the Mammal Society of Japan (http://www.mammalogy.jp/guideline.html), and our study was approved by the ethical committee of Bogor Agricultural University (No. 49-2017 IPB).

Colugo ranging

Location data were downloaded in the field every day. Although the battery of the telemeter attached to the juvenile (RS) was drained three days after release, we were able to collect more than seven days of data from the other two animals. To remove large location errors, we used only three-dimensional fixes with PDOP (position dilution of precision) values < 6 (Nishikawa et al. 2014). Based on the obtained location points, we evaluated four characteristics of colugo home ranges. First, home range size was generated by two methods; the minimum convex polygon (MCP) and the kernel methods (95% as the home range, and 50% as the core area) (Worton 1989). The home range size was calculated using the R package “adehabitatHR” and QGIS ver. 2.8.18 (R Development Team 2016; QGIS Development Team, 2017). Next, we calculated single gliding distances during the night (18:00-6:00) by connecting any continuous data points. We then examined the temporal rhythm of gliding by comparing the frequency of long-distance gliding (> 50 m), which was a shifting away from a foraging tree, among four time periods (18:00-21:00, 21:00-24:00, 0:00-3:00, and 3:00-6:00). For this analysis, we employed the chi-square tests. Finally, we estimated the total travel distance of a single day (between 18:00 on the first day and 18:00 on second day) by connecting consecutively recorded location points. Travel distances were standardized to within a 24-h period. We compared the gliding distances between individuals by the Kruskal-Wallis tests. The statistical standards (α) in these analyses were set to be 0.05.

To identify the environmental determinants of colugo range patterns, we studied the relationships between the characteristics of each area and number of location points there; we divided the home range into 20 m × 20 m quadrats and treated the quadrants as a unit. We conducted a generalized linear model (GLM, response variable: number of location points for each quadrant; explanatory variables: number of tall (> 5 m in height) trees, mean height of tall trees, height of the tallest tree, number of tall trees producing colugo foods, total crown volume and crown volume of the largest tree (data source: Tsuji et al. 2015) within the quadrat) to select the best-fit models based on Akaike's information criterion (AIC) (Akaike 1973). We treated any models with differences in AIC (ΔAIC) of less than 2 to be identical. We assumed that the error structure of the response variables followed a Poisson distribution.

RESULTS AND DISCUSSION

The MCP home range sizes based on location points for RS (juvenile male, 86 points), BB (adult male, 196 points), and NN (adult female, 272 points) were 1.23, 3.86, and 5.41 ha, respectively (Figure 2, Table 1), and larger than ranges of colugos inhabiting the palm plantations of West Java (1.26 ha for adult females (n = 7) and 1.79 ha for adult males (n = 12), based on radio tracking for 1-3 weeks (Baba 2011)). Although our small sample size should be taken into account, this observation suggests that differences in habitat quality of the two sites, such as lower food availability in our study site (secondary forest) might force animals to inhabit larger home ranges. The effect of the habitat quality on the home range size has been reported for other animals (e.g., Takasaki 1981 for primates, Saïd et al. 2009 for ungulates). Other factors, such as environmental seasonality and (or) population density in the study area also likely affected the home range size. The home range sizes generated by the 95% Kernel (1.34, 4.23, and 3.62 ha for RS, BB, and NN, respectively) showed similar values to the MCP home ranges. The smaller home range of RS suggest that a juvenile might have not established its home range yet, or might still be relying on the presence of its mother, the security of known territory, or the small number of location points (collected over 3 days) of this animal.

The home ranges of RS and NN overlapped, and they often remained in close distance each other (Figure 2). This suggests that NN to be RS's mother. If this is true, adult individuals may still be solitary but keep in touch with their young until they are fully grown. Another possibility is that they are non-kin individuals: we have previously observed multiple (maximum: 4) animals staying in the same tree both in the daytime and at night (Tsuji et al. 2015, Tsuji, personal observation), but we refrain further discussion due to lack of enough data. Detailed study regarding colugo social systems, including kinship, is strongly required.

Gliding distances varied (grand mean: 32.6 m, range: 0-252 m), but the majority of distances were < 50 m (Figure 3a). The gliding distances did not differ among animals, though BB tended to glide a slightly longer distance (Kruskal-Wallis test: $\chi^2 = 5.67$, $df = 2$, $p = 0.059$). Mean (± SD) movement distance in a single day for RS, BB, and NN was 789 ± 270 (averaged for 4 day-data), 803 ± 429 (9 days), and 705 ± 278 (11 days), respectively, and showed no significant differences between animals (Kruskal-Wallis test, $\chi^2 = 03$, $df = 2$, $p = 0.873$). Poorer gliding ability of juvenile (Shapiro and Young 2012), reported from flying squirrels, was not found in this study, but in order to conclude this meaning, we need more samples. The number of feeding bouts appeared to be similar regardless of age- and sex-class, while the number of "hub" trees, from which colugos access distant feeding sites, might differ (i.e., adult > juvenile). Long-distance (> 50 m) gliding occurred regardless of time period for BB (Chi-square test, $\chi^2 = 2.0$, $df = 3$, $p = 0.571$), NN ($\chi^2 = 2.4$, $df = 3$, $p = 0.487$), and RS ($\chi^2 = 0.7$, $df = 3$, $p = 0.876$) (Figure 3b). Thus, feeding behavior of the individual colugos during the night was roughly similar regardless of age-sex differences.

Within the home ranges generated by the Kernel methods, one (RS and NN) or two (BB) core areas existed: the colugos used their home ranges unevenly. GLM analyses revealed that 1) total crown volume and 2) the height of the tallest tree was selected as determinants of the colugos' home range use (Table 2); the colugos frequently used quadrats with lower total crown volume and/or the quadrats with taller trees. Furthermore, for BB and NN, quadrats with a small number of trees and/or with many food trees were also used frequently. These observations suggest that the main determinants of colugo habitat use are the physical structure of the forest. For efficient foraging, colugos need to access wider range by longer gliding (Byrnes et al 2012). It has been reported that for the colugos need 10-12 m height for gliding 136 m (Walker 1983). This suggests that using taller tree is advantageous for longer gliding. Given the length of a single feeding bout of Philippine flying lemurs (*Cynocephalus volans*) (mean: 9.4 min, range: 3.0-13.8) and the percentage of time spent foraging (17%), the average number of foraging bouts (for different food species) per night was estimated to be 12 (Wischusen et al. 1998). If this general observation also applies to colugos, changing trees during the night and using an isolated taller tree as "a hub" would be an advantageous strategy to efficiently access many feeding sites that are separately distributed within the home range.

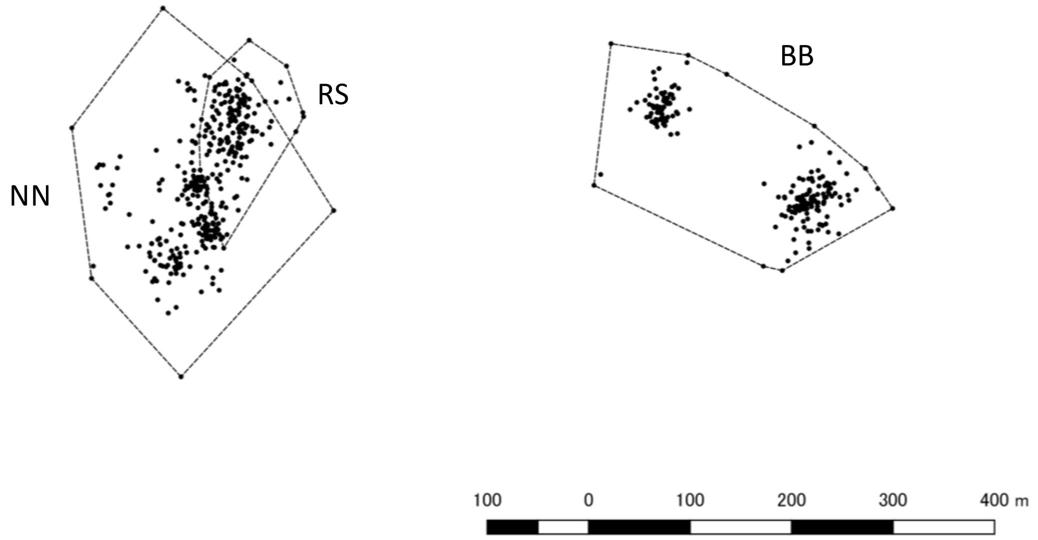

Figure 2. Home ranges (MCP) of three animals (RS: juvenile male, BB: adult male, and NN: adult female) obtained by GPS telemetry fixed at 30-min (18:00-7:00) or 3-hr (7:00-18:00) intervals. Solid circles represent fixed locations with lower PDOD (position dilution of precision) (< 6)

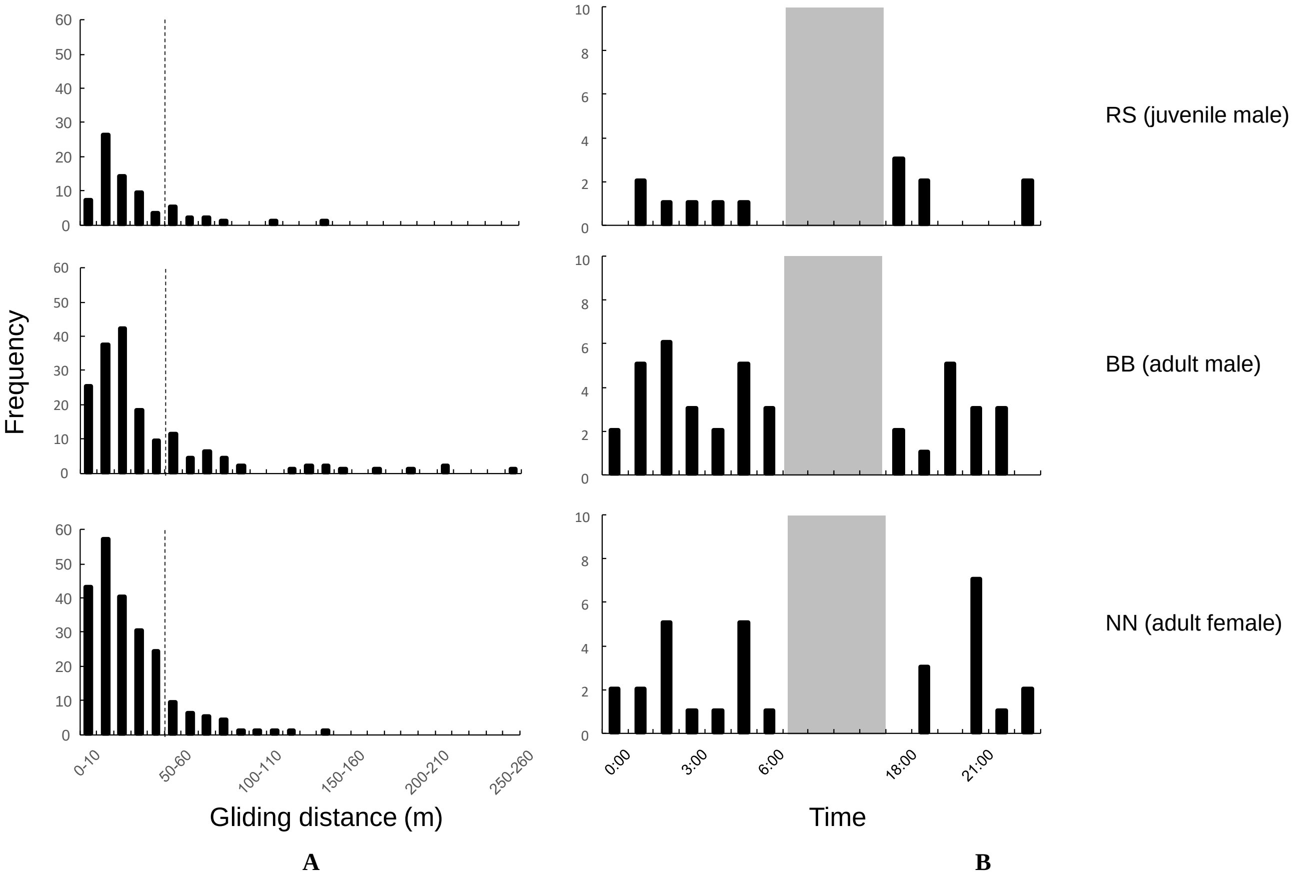

Figure 3. A. Distribution of single gliding distances (m), B. temporal rhythm of night-time long distance (>50 m) gliding for each animal (top: RS, middle: BB, and bottom: NN). We defined the distance to the right of the dotted lines to be long-distance gliding, which was considered a shift to a different foraging tree. The grey shaded areas represent daytime activity (6:00-18:00), when locations were recorded every 3-hr

Table 2. Summary of generalized linear models (GLM) to predict home range use of Malayan flying lemurs in Pangandaran Nature Reserve, West Java, Indonesia

Animal ID / Variables	Estimate ± SE	*z*	*p*
RS (juvenile male)			
Best model			
Intercept	1.00 ± 0.12	837	< 0.001
Total crown volume	-0.55 ± 0.16	-3.42	< 0.001
Height of the tallest tree	**0.65 ± 0.14**	4.72	< 0.001
AIC	132.1		
BB (adult male)			
Best model			
Intercept	1.44 ± 0.08	18.25	< 0.001
Tree number	**-0.61 ± 0.12**	-5.25	< 0.001
Total crown volume	0.36 ± 0.09	3.92	< 0.001
Food tree	0.17 ± 0.09	1.95	0.052
AIC	324.7		
Second best model			
Intercept	1.45 ± 0.08	18.40	< 0.001
Tree number	**-0.55 ± 0.11**	-4.86	< 0.001
Total crown volume	0.36 ± 0.99	4.00	< 0.001
AIC	326.3		
NN (adult female)			
Best model			
Intercept	1.35 ± 0.07	19.13	< 0.001
Tree number	-0.34 ± 0.12	-2.87	0.004
Total crown volume	-0.50 ± 0.15	-3.24	< 0.001
Largest crown volume	0.13 ± 0.12	1.10	0.27
Height of the tallest tree	**0.64 ± 0.13**	4.88	< 0.001
Food tree	0.27 ± 0.08	3.61	< 0.001
AIC	333.7		

Note: Models with difference of AIC (ΔAIC) less than 2.0 were treated as identical. Note that coefficients were estimated after all explanatory variables had been standardized. Bold values represent main determinants

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 comprehensively investigated predation on colugos, 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). Using isolated tall trees would be an advantageous strategy to easily escape from arboreal predators. We are not sure which possibilities account most for the home rage use of colugos, but our previous finding that the daily resting sites of colugos were taller trees (Tsuji et al. 2015) supports this hypothesis.

In this study, we confirmed the effectiveness of GPS telemetry for tracking colugo movements and found that forest structure is an important determinant of colugo range patterns. To confirm these preliminary observations, we need to increase sample size (for this, we require low-cost GPS equipment with greater battery life) and to conduct data collection in different seasons.

ACKNOWLEDGEMENTS

We are grateful to the forest rangers of the PNR, especially Yana Hendrayana and Ona Norwana for access to their facilities and assistance during our fieldwork. We also thank the staff of the Department of Biology, Bogor Agricultural University for their technical help, and Mrs. Donell Hole and Jun-ya Hori for their kind support with GPS telemetry. This study was funded by Grants-in-Aid from the Department of Academy and Technology of Japan (Nos. 23780160 and 24405018), Bilateral Exchange JSPS/DG-RSTHE Joint Research Project, JSPS Core-to-Core Program (A. Advanced Research Networks), and a grant from the Wildlife Conservation Fund of Tokyo Zoological Association (FY 2015, 2016, and 2017).

REFERENCES

Agoramoorthy G, Sha CM, Hsu MJ. 2006. Population, diet and conservation of Malayan flying lemurs in altered and fragmented habitats in Singapore. Biodiv Cons 15: 2177-2185.

Akaike H. 1973. Information theory and an extension of the maximum likelihood principle. In: Petrov BN, Caski F. (eds.) Proceedings of the 2nd International Symposium on Information Theory. Akadimiai Kiado, Budapest, Hungary.

Albert A, Huynen MC, Savini T, Hambuckers A. 2013. Influence of food resources on the ranging pattern of northern pigtailed macaques (*Macaca leonina*). Intl J Primatol 34: 696-713.

Baba M. 2008. Ecology of the Malayan flying lemur. In: Katayama T (ed.). Colugo: Are They Flying Monkeys? Yasaka Shobo, Tokyo. [Japanese]

Baba M. 2011. Comparative ecology of flying giant squirrel and flying lemurs. Kyushu J Exp Anim 27: 33-36. [Japanese]

Brotoisworo E. 1991. The lutungs (*Presbytis cristata*) in Pananjung-Pangandaran Nature Reserve. Comp Primatol Monogr 3: 45-148.

Byrnes G, Libby T, Lim NTL, Spence AJ. 2012. Gliding saves time but not energy in Malayan colugos. J Exp Biol 214: 2690-2696.

Byrnes G, Lim NTL, Yeong C, Spence AJ. 2011. Sex differences in the locomotor ecology of a gliding mammal, the Malayan colugo (*Galeopterus variegatus*). J Mamm 92: 444-451.

Dzulhelmi MN, Abdullah MT. 2009. Foraging ecology of the Sunda colugo (*Galeopterus variegatus*) in Bako National Park, Sarawak, Malaysia. Malayan Nat J 61: 285-294.

Harahap SA, Sakaguchi N. 2003. Monitoring research on the Javan leopard *Panthera pardus melas* in a tropical forest, Gunung Halimun National Park, West Java. In: Sakaguchi N (ed.). Research on Endangered Species in Gunung-Halimun National Park. Research and Conservation of Biodiversity in Indonesia 11: 2-20.

Kleiber M. 1987. The Fire of Life: An Introduction to Animal Energetics. Krieger Pub., Huntington.

Kutner MH, Neter J, Nachtsheim CJ, Li W. 2004. Applied Linear Regression Models. McGraw-Hill/Irwin, New York, USA.

Lim NTL, Giam X, Byrnes G, Clements GR. 2013. Occurrence of the Sunda colugo (*Galeopterus variegatus*) in the tropical forest of Singapore: a Bayesian approach. Mamm Biol 78: 63-67.

Lim NTL. 2007. Colugo: The Flying Lemur of South-East Asia. Draco Publishing and Distribution Pte. Ltd., Singapore.

Mitani M, Watanabe K, Gurmaya KJ, Megantara EN, Purnama AR, Syarief YS. 2009. Plant species list from the Pananjung Pangandaran Nature Reserve, West Java, Indonesia, sampled in the El Niño-Southern Oscillation year of 1997. Hum Nat 20: 113-120.

Nishikawa M, Suzuki M, Sprague DS. 2014. Activity and social factors affect cohesion among individuals in female Japanese macaques: a simultaneous focal-follow study. Am J Primatol 76: 694-703.

Pearson SM, Turner MG, Wallace LL, Romme WH. 1995. Winter habitat use by large ungulates following fire in northern Yellowstone National Park. Ecol Appl 5: 744-755.

QGIS Development Team. 2017. QGIS Geographic Information System. Open Source Geospatial Foundation Project. Available from: http://qgis.osgeo.org.

R Development Core Team. 2016. R: A Language and Environment for Statistical Computing. Version 3.2.4. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/.

Saïd S, Gaillard JM, Widmer O, Débias F, Bourgoin G, Delorme D, Roux C. 2009. What shapes intra-specific variation in home range size? A case study of female roe deer. Oikos 118: 1299-1306.

Shapiro LJ, Young JW. 2012. Kinematics of quadrupedal locomotion in sugar gliders (*Petaurus breviceps*): effects of age and substrate size. J Exp Biol 215: 480-496.

Sumardja EA, Kartawinata K. 1977. Vegetation analysis of the habitat of banteng (*Bos javanicus*) at the Pananjung-Pangandaran Nature Reserve, West Java. Biotrop Bull 18: 1-49.

Takasaki H. 1981. Troop size, habitat quality, and home range area in Japanese macaques. Behav Ecol Sociobiol 9: 277-281.

Tsuji Y, Prayitno B, Nila S, Widayati KA, Suryobroto B. 2015. Diurnal resting site selection and daytime feeding behaviour of wild Malayan flying lemur *Galeopterus variegatus* in Western Java, Indonesia. Mamm Stud 40: 35-45.

Tsuji Y, Prayitno B, Widayati KA, Suryobroto B. 2018. Mass mortality of wild Malayan flying lemurs (*Galeopterus variegatus*) and its underlying causes. Mamm Stud 43: 61-65.

Tsuji Y, Prayitno B, Norwana O, Nishi E, Widayati KA, Mikami A, Suryobroto B. 2016. The notes on mammal carcasses collected in Pangandaran Nature Reserve, West Java, Indonesia. Hayati J Biosci 23: 35-38.

Walker EP. 1983. Mammals of the World. John Hopkins University Press, Baltimore.

Wischusen EW, Richmond ME. 1998. Foraging ecology of the Philippine flying lemur (*Cynocephalus volans*). J Mamm 79: 1288-1295.

Worton BJ. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164-168.