Population dynamics and ranging behaviors of provisioned silvered langur (*Trachypithecus cristatus*) in Peninsular Malaysia

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Abstract

Tourists are attracted to the Bukit Melawati Kuala Selangor (BMKS) of Peninsular Malaysia, a small hill park, both for its status as a historical site and the free-ranging silvered langurs (*Trachypithecus cristatus*) that come for provisioning. We assessed the population trends and group sizes of *T. cristatus* over 10 years in the BMKS and examined their ranging patterns. Comparisons of observed populations between 2005 (190 individuals) and 2017 (193 individuals) revealed the stable demography and group sizes of the six *T. cristatus* groups in the BMKS. Based on a total of 185 location points of the six groups in 2017, their mean ranging area was 3.6 ha with a range of 0.86 to 6.93 ha with extensive spatial overlap. We also found a significant positive correlation between the six groups' ranges and group sizes in 2017. Additionally, qualitative ecological comparisons with a previous study on *T. cristatus* in 1965 (before provisioning) suggest that the artificial food supply in the study area could modify the socioecology of the *T. cristatus*. The modifications might alter their range size and territoriality in the BMKS. Overall, we found that provisioning had negative effects on the ecology of *T. cristatus* in the BMKS. Therefore, modifying management policies, such as banning feeding and implementing educational programs, may contribute to their proper conservation.

Keywords: Colobinae; lutong; group size; population size, home range; Bukit Melawati Kuala Selangor

Introduction

The monitoring of animal populations is essential for developing effective management plans for long-term conservation (Wich and Marshall 2016). Primates are long-lived mammals with slow life cycles, so they generally respond slowly to dramatic environmental changes and human interference (Chapman et al. 2006). Therefore, long-term population monitoring data is indispensable for understanding their population dynamics (Chapman et al. 2007; Matsuda et al. 2020). Knowledge of a species' ranging behavior could also contribute to better understanding its behavioral ecology and habitat requirements, leading to effective conservation strategy designs (Nathan et al. 2008). Among various environmental factors, food distribution and abundance are significant influences on population characteristics and ranging in many primate species (e.g., Ampeng and Md-Zain 2012; Clutton-Brock 1975; Green et al. 2020; Hanya et al. 2020; Matsuda et al. 2009; Olupot et al. 1994; Raemaekers 1980; Zhou et al. 2007).

Both direct (e.g., being fed by tourists) and indirect (e.g., garbage eating) human or tourist provisioning affect primate demography and ranging behaviors (Altmann and Muruthi 1988; Asquith 1989; Kurita et al. 2008; Md-Zain et al. 2010; Ruslin et al. 2019; Sha and Hanya 2013). Initially, when primates are provisioned, the daily travel distance, and their total ranging area, generally decrease (Altmann and Muruthi 1988; José-Domínguez et al. 2015; Sengupta et al. 2015) since the high nutrient foods provided by humans are available to individuals/groups in specific areas. However, access to such energy-rich artificial foods generally leads to an increase in primate birth percentages, inducing larger group sizes and reducing individual foraging efficiency (Janson 1988). Larger groups living in those

provisioning areas would normally travel greater distances and have a larger home range area.

As a result of provisioning, animals are often over-habituated (Russon and Wallis 2014b). Therefore, provisioning can trigger human-animal conflict, which is of great concern to conservationists and wildlife managers. For example, several conflicts involve situations such as monkeys attacking and injuring tourists, possibly infecting tourists and vice versa, and damage to natural habitat (e.g., Brennan et al. 1985; Fuentes et al. 2007; Kurita 2014; Md-Zain et al. 2011; Palacios et al. 2011; Sha et al. 2009). Consequently, ecotourism that includes free-ranging primates, especially concerning provisioning, should be implemented with caution.

We assessed changes in the population abundance and group size of silvered langurs (*Trachypithecus cristatus*) during 2005–2017. We examined their ranging patterns in the Bukit Melawati Kuala Selangor (BMKS), a small hill park located in Peninsular Malaysia. *T. cristatus*, classed as vulnerable by the IUCN and widely distributed in Southeast Asia (Meijaard and Nijman 2015), are foregut-fermenting colobines. Ecological knowledge of *T. cristatus* is limited. According to a preliminary study (Hock and Sasekumar 1979), they are predominantly folivorous, with leaves comprising over 90% of their diet. Tourists are attracted to the BMKS due to its status as a historical site, beautiful offshore scenery, and the presence of free-ranging habituated *T. cristatus* as a result of tourist provisioning (e.g., feeding the animals bread or cookies) (Mohd-Daut 2020). Before provisioning, the *T. cristatus* ranging area was strictly territorial, and the ranges of adjacent groups overlapped by only a few trees in the BMKS (Bernstein 1968). The normal home range is approximately 20 ha, with 350 m of the mean daily path length . Although it is unclear when tourist

provisioning started, the langurs in the site appear to be over-habituated as early as the 2000s. For example, they have been observed approaching visitors to beg for food, staring at and touching tourists, and stealing food from tourists; however, the langurs do not initiate aggressive contact. Only one study (Hambali et al. 2016) reported the non-territorial ranging behavior of one *T. cristatus* group in the site (home range: 1.0 ha; daily path length: 10–200 m), though the information on the ranging patterns in other adjacent groups was not available. Additionally, we have almost no empirical information about their ecology and behaviors in relation to the effects of provisioning in the BMKS based on long-term monitoring.

In the present study, to gain a complete picture of the demography and ranging patterns of *T. cristatus* in the BMKS, we sought to (1) evaluate population changes between 2005 and 2017 and (2) estimate the range size of all groups at the site. The effects of provisioning on their demography and ranging behavior are discussed by qualitatively comparing records from a previous study, conducted before tourist provisioning (Bernstein 1968).

Materials and Methods

We observed groups of silvered langurs (*Trachypithecus cristatus*) from March to April 2005 and from October to December 2017 in a part of the BMKS (3°20′ 26.36 N, 101°14′42.46 E), located approximately 62 km from Kuala Lumpur, Malaysia (Hambali et al. 2016). The study area covers ca. 22.5 ha, surrounded by the Kuala Selangor Nature Park, a mangrove forest along the coastline that includes a residential area. Historical structures and monkey habitats in this open area attract visitors and make the BMKS a renowned tourism area in Selangor.

Although fragmented, the study area still harbors important plant resources, including both natural and ornamental plants. The mean minimum and maximum temperatures were approximately 26.5◦C and 29.8◦C, respectively, and total precipitation at the site was 1505.5 mm (Metereology Department of Malaysia).

We observed that groups with one male, multiple females, and immature males were well-habituated to humans due to the tourist site's popularity. Although all *T. cristatus* langurs of the study site groups were not individually identifiable, some group members with distinctive features, such as scars and limb defects, were recognizable. Thus, at least, identification for all groups was possible. We estimated each individual's relative age using age/sex categories while referring to Aggimarangsee (2002) and Hamada and Yamamoto (2010)**.**

At 0800 h each day, observers arrived at the study site and followed the groups until they selected evening sleeping trees and started sleeping, usually at 1900 h. We completed 520 and 1023 hr observations in 2005 and 2017, respectively. Once-daily, we checked the numbers, age class, and sex of group members. During the observations, we spontaneously recorded the groups' locations using Global Positioning System. We recorded 185 location points of the six *T. cristatus* groups. Then, we transferred data coordinates in decimal degrees and projected them into meters (WGS 1984 UTM zone 48N) using the projection tool in ArcMap version 10.5. Biotas 2.0 Alpha was used to calculate and investigate the ranging area. The most common method, namely Minimum Convex Polygon (MCP) 100%, was used to analyze each group's home range in the population. Google Earth was used to map and estimate the land area used in the study site.

We compared the group size of six one-male-multi-female groups between 2005 and 2017, using a Wilcoxon rank-sum test. We examined the correlation between home range size and the six groups' sizes in 2017, using linear regression analysis. The correlation between the total area size of forest patches within each group's ranging areas and their group size was also tested using linear regression analysis. We used the Bonferroni correction to correct for multiple comparisons of those linear regression analyses (P = 0.05/N: N is the number of comparisons made, i.e., 0.025). The significance level was set to $\alpha = 0.05$. We report means with standard deviation for all results. All statistical analyses were performed in the R statistical computing environment (R-Core-Development-Team 2019).

Results

Population comparison between 2005 and 2017

In 2005, we counted 190 *Trachypithecus cristatus*s in six groups with one male and multiple females at the study site. The group size was almost the same in 2017 (193), though we found an additional all-male group (Table 1). The mean size of groups with one male and multiple females was 31.7 ± 16.5 and 31.5 ± 12.4 individuals in 2005 and 2017, respectively, and the size was not significantly different between the years (W = 17; *p*-value: 0.916). We found that, out of the six one-male-multi-female groups, two groups had more members (i.e., A and F), and two groups maintained their group size (i.e., B and E). In contrast, the other two groups had fewer members (i.e., C and D). Groups A and F experienced an increase of 10 and 2 members, respectively. On the other hand, Group C experienced a decrease of 3 members in

the total group size of 24 individuals. Meanwhile, Group D, which consisted of 46 individuals, decreased by 10 members.

Ranging area in 2017

Based on 185 location points of six one-male-multi-female groups, their mean ranging size was 3.6 ± 2.08 ha with a range of 0.86 to 6.93 ha (Table 2 and Fig. 1). Within their ranging areas, the most dominant habitat type was the vegetated area (54.8 ± 7.34 ha), followed by the grass/open area (32.7 ± 5.35) and the building/construction area (12.6 ± 3.99), though the percentage of each habitat type was different across the six groups (Table 3).

There was range area overlap among the six one-male-multi-female groups; the mean overlapped area based on all dyadic combinations for six groups was 1.28 ± 1.08 ha (21.9% ± 16.2%) with a range of 0.12–4.39 ha (1.44%–62.7%) (Table 4). The core area where all six groups utilized was 0.33 ha (Fig. 1).

The six groups' per capita ranging size differed across the groups with a range of 0.07 to 0.15 ha (Table 2). There was a significant positive correlation between their ranging area and group sizes (Fig. 2; R^2: 0.81; corrected *p*-value: 0.030). There was also a significant positive correlation between the vegetated area within each group's range and group sizes (Fig. 2; R^2: 0.82; corrected *p*-value: 0.025).

Discussion

The population size of the *Trachypithecus cristatus* in the BMKS study area was slightly larger in 2017 (193 individuals) with the addition of an all-male group than in 2005 (190

individuals). However, their numbers were stable over the decade. Group sizes in 2017 (27.6) were smaller than in 2005 (31.7), but it was not a significant difference. Although provisioning impacts primate demography in general (Rothman and Bryer 2019), we could not detect significant changes in population or group sizes in the study site. This result suggests that a constant supply of high nutrient artificial foods provided by tourists in the 2000s (Md-Zain et al. 2009) may have had a minimal effect on the demography of the *T. cristatus*. The "real" population density in our study site is not available since the study groups sometimes moved out of the study area (22.5 ha). However, the density of *T. cristatus* using the area in 2017 was unusually higher (ca. 858/km^2) than those of *Trachypithecus* spp. in other study sites (Newton and Dunbar 1994): mean value = 101/km^2; range = 2.1–345/km^2, indicating the effects of provisioning on their high population density in our study area.

Although the demography was stable even under the provisioning condition over the decade, it is reasonable to expect the *T. cristatus* population size to increase due to the effects of artificial foods provided by tourists in the 2000s but not in the 1960s in the BMKS (Bernstein 1968). In 1965, however, the six *T. cristatus* groups, including at least 160 individuals with a mean group size of 33.5 individuals/group (the mean of only four accurately counted groups), have been reported (Bernstein 1968). This finding suggests that the demography was stable even over five decades in the BMKS. Nonetheless, since we only conducted the population survey in a part of the BMKS that tourists can access, additional groups might inhabit the forested area. A population survey of the *T. cristatus* in the entire BMKS area would conclude if tourist provisioning has not influenced the demography over the last five decades.

The artificial food supply in the study area may modify the socioecology of *T. cristatus*, altering their range size and territoriality in the BMKS. The study group ranging areas in 2017 (mean of the six groups = 3.6 ha) were much smaller than the 1965 ranging areas (20 ha: Bernstein 1968; Yeager and Kool 2000). As the study groups sometimes moved out of the area and briefly inhabited the forested area (NMD personal observations), the real sizes of the study group home ranges might be underestimated. However, we observed that the *T. cristatus* groups mostly spent their time in the BMKS study area and even slept there at night, which would minimize errors in estimating their home range values. It may not be necessary for *T. cristatus* to forage larger areas to satisfy their nutrient requirements as they could easily obtain energy-rich artificial foods in the study area. Such behavioral changes reportedly led to decreases in ranging areas or daily path lengths in other provisioned primate species, e.g., pig-tailed macaques (José-Domínguez et al. 2015), rhesus macaque (Sengupta et al. 2015), and baboons (Altmann and Muruthi 1988). Thus, because no artificial or feeding maintenance occurred in 1965 (Bernstein 1968), the observed change of the *T. cristatus* range sizes in our study area may be influenced by recent tourist provisioning.

Additionally, the six *T. cristatus* group ranging areas were more concentrated to our study area where human food was accessible and abundant in 2017 than those in 1965 (Bernstein 1968). Thus, the population density in 2017 would be more biased to such a specific tourist area of the BMKS. This bias may explain why the six *T. cristatus* groups in 1965 ranged larger areas and were more territorial, with less spatial overlap, among the groups (Bernstein 1968) compared to those in 2017. In the 1960s, the population might have been near or above carrying capacity, and groups would be territorial at high densities in the BMKS. However, when people started provisioning, the population might have dipped below

carrying capacity, and the groups would be non-territorial. This explanation also fits the hypothesized theoretical relationship among home range overlap, individual density, and carrying capacity, according to Yeager and Kool's (2000) description of primate territorial behaviors.

Although the ranging behaviors of the study groups would be influenced by the provisioning (i.e., decreased ranging area), there was a significant positive correlation between ranging areas and group sizes of the six *T. cristatus* groups. Theoretically, increases in group size should reduce individual foraging efficiency (Janson 1988), i.e., larger groups generally travel greater distances with a larger home range area (e.g., Makwana 1978; Takasaki 1981). We also found a significant positive correlation between vegetated areas within the ranging area of each group and group size, suggesting that provisioned foods may not be sufficient to meet their nutrient requirements. Thus, the larger *T. cristatus* groups would still need to forage natural foods within the larger vegetated areas in their ranging area. In non-human primates, the increase of day range, possibly with increasing group size, has been used as an index to evaluate the degree of food competition within groups. This hypothesis on weak/absent food competition is supported by the fact that a flat relationship exists between group size and day range across various colobines (Yeager and Kool 2000). Therefore, a significant positive correlation between the group size and ranging area of the six *T. cristatus* groups in this study indicates their high intraspecific competition for food. However, it may be difficult to conclude if the highly competitive foods in this study site are artificial or natural. We suggest that future studies on *T. cristatus* examine their food habits and nutrients as these will be key to understanding the demography in the BMKS and their socioecology in relation to intraspecific competition in folivorous primates.

Overall, we found the negative effects of provisioning on the ecology of the *T. cristatus* in the BMKS, suggesting that the study groups need effective management. Although ecotourism does not always negatively impact primate conservation, it has often failed to deliver conservation benefits for free-ranging primates, especially provisioning (Russon and Wallis 2014a). Therefore, we recommend that local authorities take appropriate actions to make visitors aware that they should stop feeding animals through educational methods explaining the negative impacts of provisioning on the ecology of *T. cristatus* in the BMKS.

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Table 1 Composition of groups of *Trachypithecus cristatus*, with several one-male-multifemale groups (OMG) and an all-male group (AMG) in 2005 and 2017.

			Age and sex categories						
Group ID	Group type	Year	Adult male	Adult female	Subadult male	Subadult female	Juvenile	Infant	Total
A	OMG	2005	1	12	0	1	3	2	19
		2017	1	14	1	4	7	2	29
B	OMG	2005	1	22	3	2	2	3	33
		2017	1	21	2	2	4	3	33
C	OMG	2005	1	13	4	3	3	3	27
		2017	1	18	1	1	1	2	24
D	OMG	2005	1	8	7	11	24	5	56
		2017	1	32	0	7	2	4	46
E	OMG	2005	1	28	1	1	7	6	44
		2017	1	33	2	4	1	3	44
F	OMG	2005	1	7	0	3	0	0	11
		2017	1	5	1	2	2	2	13
G	AMG	2005	-	-	-	-	-	-	-
		2017	4	0	0	0	0	0	4

Table 2 Range area and per capita ranging area of the study *T. cristatus* groups

Group ID	Total group members	Ranging area (ha)	Per capita ranging area (ha)
A	29	2.15	0.07
B	33	3.93	0.11
C	24	3.26	0.14
D	46	6.93	0.15
E	44	4.45	0.10
F	13	0.86	0.07
G	4	Unknown	--

Table 3 Percentage of the land used for each *T. cristatus* group.

Group	A	B	C	D	E	F
Vegetation and canopy	47.04	61.10	47.42	61.54	61.55	49.87
Grass and open space	37.72	29.10	41.01	28.95	28.51	30.64
Building/construction areas	15.24	9.89	11.56	9.51	9.94	19.49

Table 4 The area size (upper) and percent (bottom) of spatial overlap between the six one-male-multifemale groups.

Group ID	A	B	C	D	E	F
A		1.31 ha	1.73 ha	0.93 ha	0.41 ha	0.43 ha
B	27.6%		1.24 ha	1.90 ha	0.12 ha	0.21 ha
C	46.8%	20.8%		2.32 ha	1.83 ha	0.80 ha
D	11.5%	21.2%	25.6%		4.39 ha	0.86 ha
E	6.61%	1.44%	31.1%	62.7%		0.69 ha
F	16.5%	4.64%	24.2%	12.4%	15.0%	

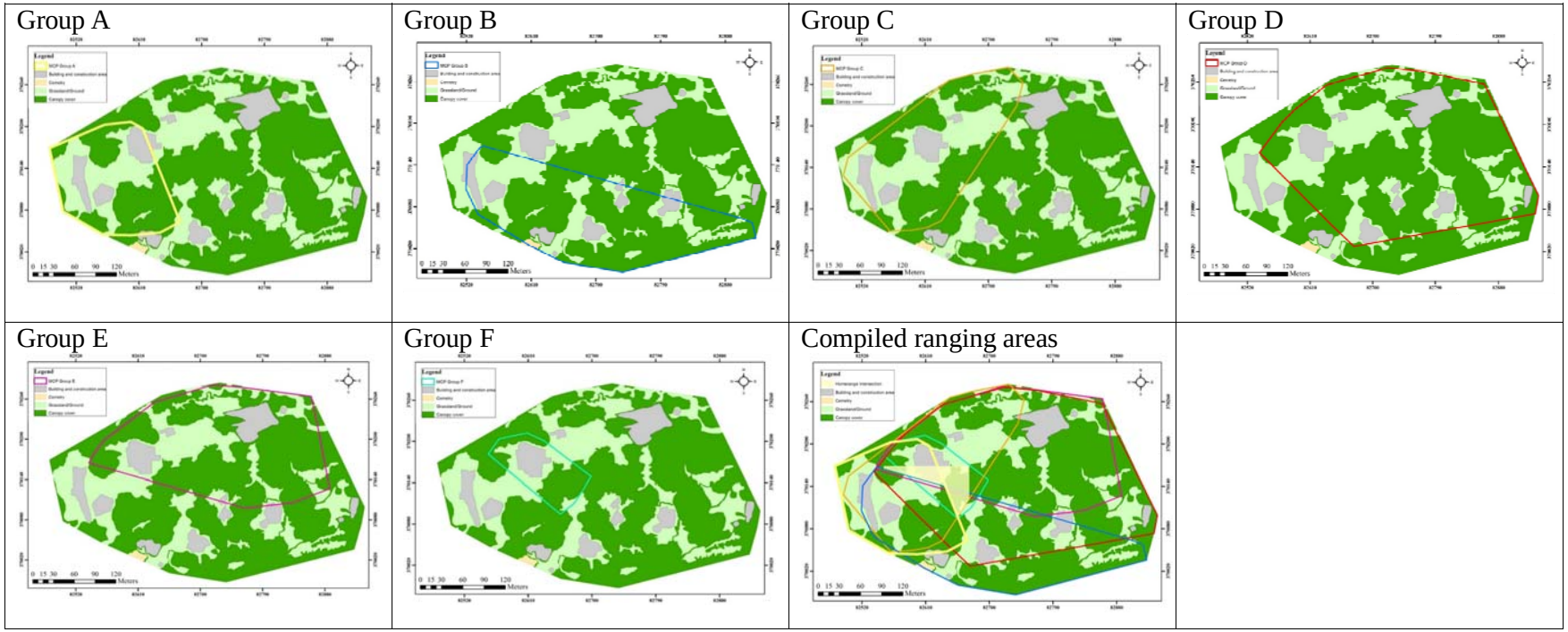


Figure 1. Ranging area of each *T. cristatus* group (Group A–E) with compiled ranging areas of all six groups at the study site.

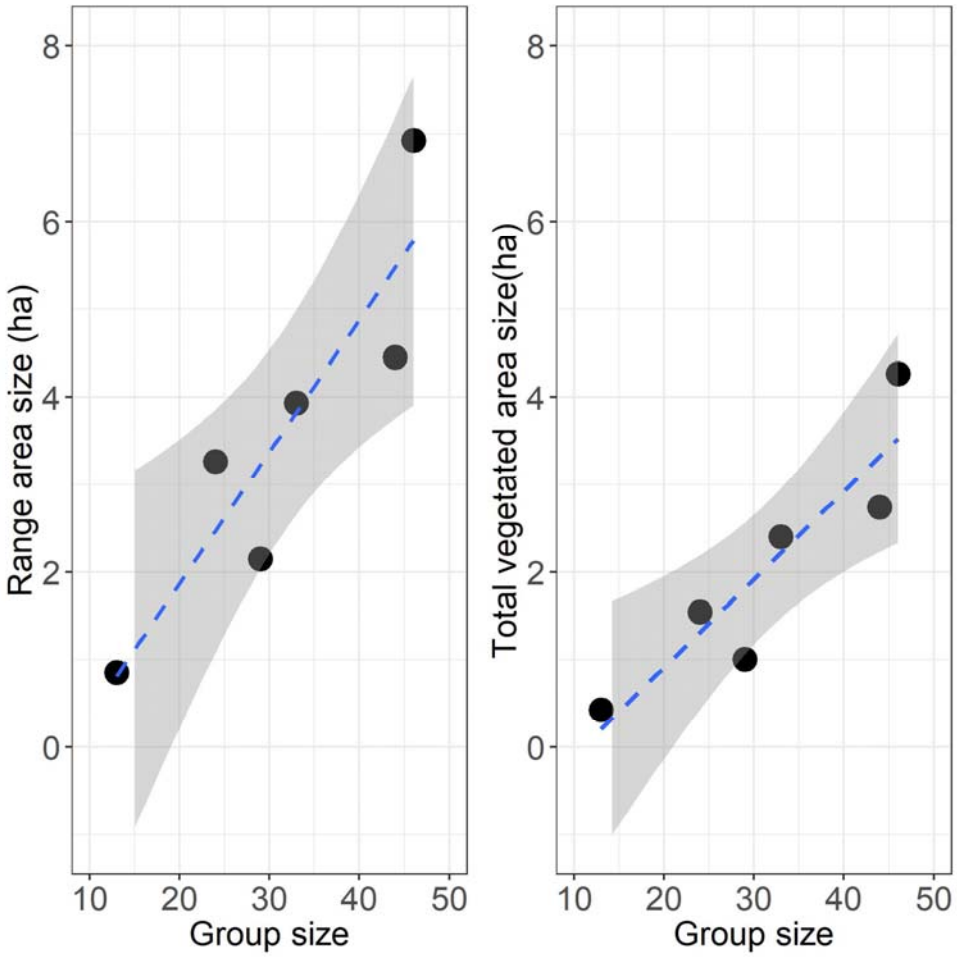
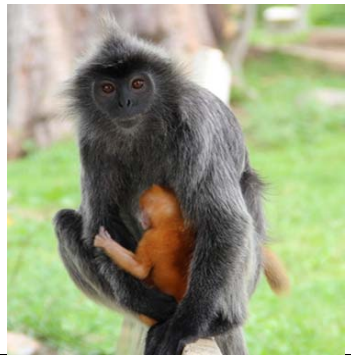
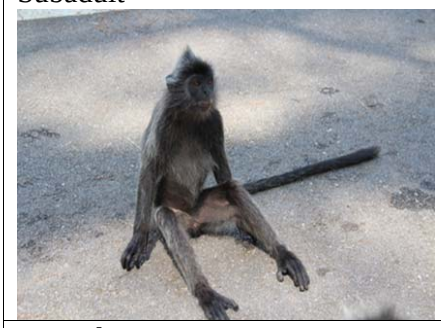


Figure 2. Relationships between the ranging area in each group (left) and the total vegetated area within each group's ranging area with group size (the number of group members in each group).

Appendix 1. Chart of age categories with associated morphological and physical characteristics according to Aggimarangsee (2002) and Hamada and Yamamoto (2010).

Age categories	**Morphology and physical characteristics**
Adult 	Large in body size and larger than the other age categories. The body growth stops as stature and reproductive organs reach maturity. In females, genital swelling is confined to the vulva and the surrounding perineum and is expected to occur most frequently during the female cycle. In males, the testes increase in size, and musculoskeletal development occurs.
Subadult 	Smaller than adults in body size but bigger than juveniles. Body size grows rapidly. Reproductive organs are immature, and the body size rapidly develops especially in the length of long bones (e.g., thigh, backbone, and femur).
Juvenile	Smaller body size than subadults and grow rapidly until more than three-quarters of the adult body size. At this stage, the pelage of the head and body changes to gray. Some juveniles occasionally breast-feed.
Infants	Newborns and individuals at weaning age are categorized as infants. The pelage of the head and body is orange in color and is starting to change to gray. The face skin is slightly pinkish and slowly changes to dark gray and black as the infant reaches the juvenile stage. Total coloration changes take about three months.