



Seminar Biologi Kebangsaan 2025

<https://semarakilmu.my/index.php/spnes/index>
ISSN: 3083 - 8193



Population Census and Ranging Pattern of The Long-Tailed Macaques (*Macaca fascicularis*) at Human-Altered Environment

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ABSTRACT

The Universiti Kebangsaan Malaysia (UKM), Bangi campus is located within the natural habitat of the long-tailed macaque (*Macaca fascicularis*). Its proximity to surrounding forested areas has resulted in a high degree of habituation among the macaques toward human presence. However, data on their population size and ranging patterns remain limited. This study aimed to determine the population size and ranging areas of habituated long-tailed macaques within the UKM main campus. Systematic field surveys were conducted from October 2021 to October 2022, involving group identification, population census, and GPS-based location mapping. Ranging areas were calculated using the Minimum Convex Polygon (MCP) and 95% Kernel Density Estimation (KDE) methods. Core areas and disturbance zones were further delineated for each identified group. A total of 10 macaque groups comprising 581 individuals were recorded across the campus. Based on 965 GPS location points, the groups' areas ranged from 7.99 ha to 39.54 ha (mean \pm SD: 19.30 \pm 8.85 to 23.52 \pm 12.45 ha). Twelve overlapping zones were detected, seven identified as core areas shared among multiple groups. These findings provide updated insights into the population dynamics and spatial ecology of long-tailed macaques at UKM. The information obtained serves as a critical reference for developing effective management and mitigation strategies to reduce human-macaque conflicts within the campus environment.

Keywords: ranging area; core area; group composition; overlap; territories

1. Introduction

Animals exhibit specific activity areas ranging from small-scale to extensive territories spanning thousands of square kilometers [1]. They use specific areas called home ranges to carry out their daily activities at different times. Rather than occupying their home ranges homogeneously, animals often concentrate their activities and behaviors within specific core areas [2]. Understanding the home range occupied by primate populations is vital for predicting their response to environmental changes [3] and determining species-specific ecological requirements. This, in turn, helps with efficient species management and conservation efforts [4]. Primates often establish home ranges in resource-rich areas, including locations with concentrated and predictable food sources like exotic plants, cultivars, and human food waste, which can attract them to reside nearby [5-7]. Given the extensive alteration of their native habitats for human development and activities, it is unsurprising that primates now inhabit regions close to or within human community areas [8]. The ability of

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primate species to adapt to fragmented habitats created by the human-built environment becomes crucial for their survival. The long-tailed macaque (*Macaca fascicularis*) has been habituated within the main campus of Universiti Kebangsaan Malaysia, Bangi. Originating from the nearby Bangi Forest Reserve, these macaques have established their home range within the UKM area due to the availability of food resources, primarily from the student residential college [9] (Md-Zain et al., 2010). Consequently, disturbances and conflicts between humans and macaques have arisen among campus residents, leading to issues such as zoonotic disease outbreaks, mental distress, and community fear [10-11]. To effectively address these challenges, this study seeks to comprehensively investigate the population size and ranging area of long-tailed macaque groups within UKM. Understanding these aspects is essential for constructing sustainable management practices for the species and mitigating human-macaque conflict.

2. Methodology

2.1 Study Site

Universiti Kebangsaan Malaysia (UKM) main campus, situated in Bangi, Selangor, Peninsular Malaysia. UKM is located adjacent to Bangi Forest Reserve, believed to be the original habitat of long-tailed macaques. The campus features fragmented forest areas amidst human activity centers, encompassing ten residential colleges, eight faculties, administrative buildings, research institutes, sports facilities, a mosque, a health center, and a staff housing area called Bukit Puteri (PBP).

2.2 Data Collection

Between October 2021 and September 2022, systematic population counts of long-tailed macaques were conducted. They were considered the group occupying the UKM area, as i) they have established a habitat with at least one sleeping site within that area, and ii) they were observed to extensively use the area for their daily activities. Group identification primarily relied on the recognition of alpha males, with detailed photographs of their facial and body structures used for accurate identification. The age-sex classification was done using established techniques based on a few characteristics, such as body size and facial fur length, as described in previous studies [12]. Confirmation of belonging to the same group was based on collective movement, spatial separation from other groups, and the maintenance of spatial relationships over an extended period. Population estimates were derived from repeated group-size counts conducted during locomotion activity, particularly when macaque traversed linear features such as roads and poles. Each group was counted at least five times throughout the study to ensure accurate enumeration of its members. A handheld Global Positioning System (GPS) was used to determine the locations of the groups. We tracked the macaque groups on foot, following them from their sleeping site to their ranging area and back. Over the course of 201 days, tracking and observation occurred on an average of 5 days per week, starting from their sleeping site at 0700, following them within their ranging area, until they returned to their sleeping site by 1930. A total of 965 location points were collected with 96.5 ± 34.56 points per group.

2.3 Statistical Analysis

From the population census, we calculated two metrics: (i) the socioeconomic sex ratio (SSR), defined as the ratio of adult males to adult females within each group, and (ii) the infant ratio, defined as the ratio of infants to adult females within each group. Both 100% Minimum Convex Polygon (MCP) analysis and 95% Kernel Density Estimation (KDE) were used to calculate the ranging area size and overlapping area for each macaque group. The core area, representing the habitat preference of the macaque group inside the home range, was calculated using 50% KDE.

3. Results & discussions

3.1 Population of *Macaca fascicularis*

A total of ten macaque groups were observed roaming and choosing sleeping sites within the UKM Bangi campus. The total macaque population residing within the UKM Bangi campus amounted to 581 individuals (Table 1). The size of these groups ranged from 33 to 100 individuals, with 58.1 ± 19.10 individuals per group. Comparing these findings with long-tailed macaque groups in university compounds across Malaysia, such as Universiti Malaysia Sabah (UMS) [12] and Universiti Malaya (UM) [13], our study at UKM reveals larger group sizes. However, the group sizes at UKM remain comparable to those observed in urban areas, where populations can sometimes exceed 100 individuals [14]. The sex ratio (SSR) at UKM ranges from 0.43 to 1.00, with only two groups (Bayu and Arjuna) falling within the wild troop ranges reported by Wheatley et al., [15], which show a female-biased dispersal pattern. The remaining groups exhibit high SSR values exceeding 0.70, indicating a male-dominated population. Regarding infant ratios, six groups at UKM exhibit ratios above 0.5, while the remaining four groups have lower ratios. This high infant ratio aligns with observations in highly provisioned long-tailed macaque populations in Bali and Gunung Meru, Indonesia [16]. The larger group sizes, higher sex ratios and infant ratios at UKM are likely influenced by the Macaques heavy reliance on human food sources.

Table 1

Group composition, sex and infant ratio of the *M. fascicularis* population in UKM

Group	Adult Male	Adult Female	Subadult	Juvenile	Infant	Total	Socionomic Sex Ratio (SSR)	Infant-to-Adult Ratio
Nik	21	26	19	18	16	100	0.81	0.62
Badang	11	15	14	20	8	68	0.73	0.53
Awang	9	10	24	17	7	67	0.9	0.70
Jebat	16	16	13	15	6	66	1.00	0.38
Jaka	10	15	13	13	8	59	0.67	0.53
Daik	10	16	13	13	6	58	0.63	0.38
Tuah	7	10	10	12	6	45	0.70	0.60
Lekiu	7	12	9	9	6	43	0.58	0.50
Bayu	6	14	8	9	5	42	0.43	0.36
Arjuna	5	8	7	10	3	33	0.63	0.38
Total	103	141	130	136	71	581	0.73	0.50

3.2 Ranging Area Size of *Macaca fascicularis*

The total area utilized by long-tailed macaque at UKM spans approximately 192.98 ha – 235.15 ha. It was found that seven out of ten groups of long-tailed macaques exhibit ranging area sizes (14.56 ha – 39.54 ha) comparable to those of long-tailed macaques in urban areas of Singapore (Klegarth et al., 2017). The remaining three groups fall within the range observed for provisioned long-tailed macaque groups in Indonesia [17] While the range area sizes of long-tailed macaques vary widely, those at UKM are relatively smaller compared to the sizes recorded for wild long-tailed macaque groups in Southeast Asia that inhabit mangrove, lowland, or secondary forests [18]. Like their counterparts in Singapore and Indonesia, these ranging areas are influenced by food sources, predominantly from residential trash bins or provisioning by community members [19,17]. This research underscores residential colleges as crucial sources of high-quality food for macaques at UKM, surpassing other campus buildings. The bins in these colleges offer a diverse array of food such as rice, leftover food, snacks, and water, which provide superior sustenance compared to bins in other buildings, primarily filled with non-food items like tissues, plastics, papers, and cans. Consequently, the majority of the macaques' ranging area at UKM is concentrated within these college areas, and leading to nuisance problems for college residents and management, as reported in past research [10,20]. The long-tailed macaques at UKM were found to strategically select sleeping sites within 120 to 150 meters from their nearest food source to optimize feeding efficiency and minimize travel distances, aligning with the food access hypothesis [21]. The macaques also exhibit keen awareness of prolonged human absence, such as during semester breaks suggesting a scarcity of food resources from garbage bins. Consequently, these macaques are less inclined to visit bins in the UKM area during semester breaks and instead expanding their ranging area to the Bangi Forest Reserve.

Table 2

Home range size and core area of all long-tailed macaque group in UKM

Group	Group Size	Ranging Area Size MCP (ha)	Ranging Area Size 95% KDE (ha)	Core Area 50% KDE (ha)
Nik	100	39.54*	26.41	8.06
Badang	68	7.48*	10.32	1.32
Awang	67	22.02	23.01	5.26
Jebat	66	14.56	11.69	1.66
Jaka	59	25.70	21.65	6.90
Daik	58	38.09	27.91	3.39
Tuah	45	34.49	28.81*	6.20
Lekiu	43	8.39	7.99	1.58
Bayu	42	33.19	27.54	3.85
Arjuna	33	11.70	7.65*	0.95

“*” indicates the largest and smallest ranging area size

4. Conclusions

Our findings demonstrate that abundant human-generated food resources and their accessibility in urban areas facilitate the thriving population of long-tailed macaques. Other factors such as geographical structure, predation, and behavioural viability, warrant further investigation to

comprehensively understand the ecological adaptability of long-tailed macaques in human-modified environments.

Acknowledgement

We thank the Department of Wildlife and National Parks Peninsular Malaysia for granting us the permit (JPHLandamp;TN(IP):100-34/1.24Jld16(14)) to conduct this study. We also appreciate the cooperation given by Prasarana UKM for providing current map of the UKM area and UKM's Geran Universiti Penyelidikan grant (GUP-2021-052) for funding this research.

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