

Preliminary Survey on Population and Daily Activity Pattern of Long-Tailed Macaque (*Macaca fascicularis*) in Tanjung Datu National Park, Sarawak

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ABSTRACT

Long-tailed macaques (*Macaca fascicularis*) are an endangered species that are facing increasing threats due to habitat fragmentation and limited foraging grounds. Thus, their extensive range of behaviours requires attention from research and management perspectives for their conservation. Studying the behaviour of the *M. fascicularis* population in Tanjung Datu National Park (TDNP), Sarawak, one of the smallest protected areas that is rich in biodiversity, is crucial for ensuring their conservation success. The purpose of this study was to examine the demographic and behavioural ecology of the long-tailed macaques in TDNP, as there is currently insufficient information available on the *M. fascicularis* population in the protected area. A population estimation study was conducted using a census walk from February 23rd to March 1st, 2024. The behaviour of *M. fascicularis* was observed using the scan sampling method during this period. The study was conducted within an area of around 11,222 m², with a total of 181 individuals recorded from two groups. Group A (175 individuals) was recorded near the HQ area, while Group B (6 individuals) was recorded in Telok Upas. No solitary individuals were observed during the study, and due to the direct count method, no variance estimate was calculated. Present results indicated that long-tailed macaques spent most of their time moving (53.79%), followed by resting (14.48%), feeding (13.44%), other activity category (7.93%), vocalisation (5.52%) and grooming (4.83%). Data from the population census and behaviour of the long-tailed macaques can help the park's management in prioritising habitat protection areas and monitoring the population trends for effective long-term conservation of the species within TDNP.

Key words: Behavioural ecology, Borneo, long-tailed macaque, population census, primate

INTRODUCTION

Long-tailed macaques (*Macaca fascicularis*) are members of the family Cercopithecidae and are notable for their extensive geographic distribution, which spans a diverse range of habitats across Asia (Roos *et al.*, 2014). Their range includes Bangladesh, Brunei, Cambodia, India, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor Leste, and Vietnam (Mohd-Azlan *et al.*, 2017). Within the genus *Macaca*, which comprises over 20 species, *M. fascicularis* stands out as the most common species in Malaysia. This wide distribution has led to substantial variation among populations in terms of behaviour, social structure, habitat use, morphology, and genetic diversity (Hamada *et al.*, 2008; Md-Zain *et al.*, 2010; Mohd-Isa *et al.*, 2023).

Despite their adaptability and broad distribution, long-tailed macaques face significant conservation challenges and are classified as Endangered by the IUCN Red List of Threatened Species (Hansen *et al.*, 2022). The species' considerable behavioural and cultural diversity reflects its ecological and behavioural resilience, yet this resilience does not fully protect them from environmental pressures and habitat loss. While the broad distribution suggests a level of adaptability, the specifics of how these traits vary across different environments and how long-tailed macaques adapt to diverse conditions remain poorly understood (McFarland *et al.*, 2013; Hansen *et al.*, 2022). This gap in knowledge is the main reason for conducting this study on long-tailed macaques at TDNP, with the aim of gaining a better understanding of how they respond to different habitat conditions and environmental pressures. Observing social behaviours such as grooming, playing, fighting, and maternal care in TDNP provides important insights into macaques' interaction with their environment, ensuring group cohesion and social stability, which are crucial for effective management and conservation within protected areas (Kappeler & van Schaik, 2002; Entezami *et al.*, 2024).

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Long-tailed macaques have demonstrated high ecological flexibility, enabling them to adapt to a variety of environments. During seasons with fruit unavailability, they may shift their diet to other food sources such as insects, stems, young and mature leaves, flowers, seeds, grass, mushrooms, invertebrates, bird eggs, clay, and bark (Wheatley, 1980; Yeager, 1996; Son, 2003). In areas near human settlements such as urban parks or tourist sites, long-tailed macaques frequently rely on anthropogenic food sources, including food waste and direct provisioning, which can affect their behaviour and increase human-wildlife conflict (Hambali *et al.*, 2012; Ruslin *et al.*, 2014). In logged forests, they have been observed to change their foraging habits and wander further to find more resources (Osman *et al.*, 2022). There is a critical knowledge gap concerning their population dynamics and daily activity patterns within specific protected areas. Long-tailed macaques live in multi-male, multi-female groups, exhibiting a matrilineal social structure in which females remain in their natal groups while males disperse (Md-Zain *et al.*, 2010; Mohd-Isa *et al.*, 2023). In wild habitats, group sizes typically range from 5 to 40 individuals, while in human-influenced areas with food provisioning, groups may exceed 100 individuals (Gumert & Fuentes, 2011; Riley *et al.*, 2015). Their home range sizes also vary by habitat type, such as from vast natural forest settings to very small urban forest edges (Yeager, 1996; Riley *et al.*, 2015). This gap limits our knowledge of their behavioural patterns that is important in understanding habitat use and population monitoring. These social and spatial dynamics provide important context for interpreting group size and structure in TDNP. Therefore, this study aimed to establish baseline data on the population abundance, distribution, and behaviour of long-tailed macaques. This information will help evaluate population trends, habitat use, and behavioural changes in response to a shifting environment. Additionally, the baseline data will be valuable for monitoring the effectiveness of current and future management strategies for long-tailed macaques at TDNP.

MATERIALS AND METHODS

Study site

Tanjung Datu National Park (TDNP) is one of Sarawak's smallest national parks (Figure 1), with a total area of 1,379 hectares and characterised by a mix of beach forest, mixed dipterocarp forest (MDF), and patches of secondary forest regenerating from historical disturbance (Mohd-Azlan *et al.*, 2018). The TDNP is situated near the Malaysian-Indonesian border; Sarawak and Kalimantan make up half of the peninsula. According to Hazebroek and Abang (2000), although TDNP is relatively pristine, selective logging activities were reported in some nearby areas before its official gazettement. The structure of the coastal forest zone is influenced by natural disturbances such as salt spray from the beach and seasonal storms. Anthropogenic disturbance within TDNP is minimal due to its remote location and restricted access, although the proximity to Telok Melano village on the Indonesian border creates some edge effects from nearby agriculture and settlements. The population survey and daily activity pattern of long-tailed macaques were conducted primarily around the TDNP headquarters and Teluk Upas, where sightings of the macaques were notably more frequent.

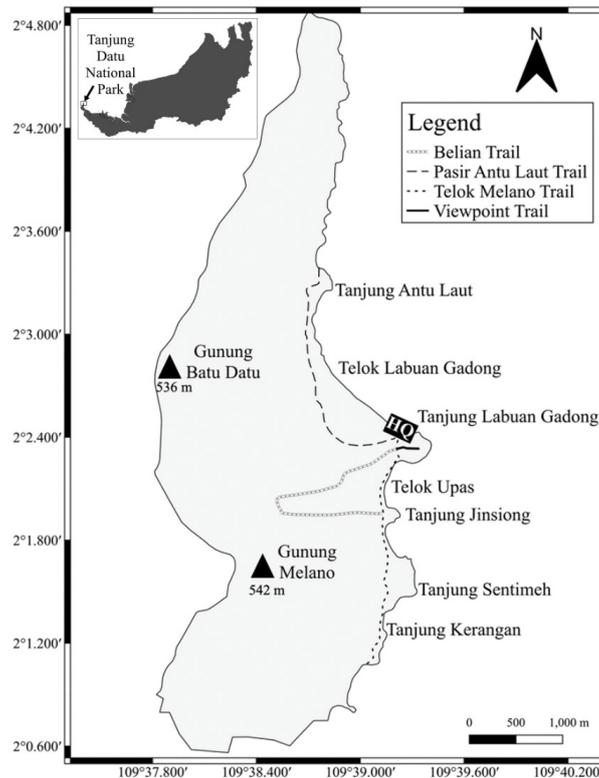


Fig. 1. Tanjung Datu National Park is located at the tip of Borneo, bordering Kalimantan, Indonesia.

Population survey

The census walk technique was utilised for the initial population survey observations (Abd Rahman *et al.*, 2019; Zamri & Md-Zain, 2022). This method involved recording all visible and relevant data encountered during the survey. Each observed macaque group was documented according to its estimated size, age composition (adult male, adult female, subadult, juvenile, infant), and distinguishing features, including group structure and location. Individuals were not counted independently across sessions unless they were viewed in different situations or groupings. The population size was determined by combining the number of group encounters and their respective sizes, followed by averaging across daily sessions while eliminating possible resightings. This method follows established primate census practices in similar habitats where visual identification and temporal-spatial separation are used to minimise duplicate counts (Md-Zain *et al.*, 2010; Dzulhelmi *et al.*, 2019; Bernathirdin *et al.*, 2023). Macaques were then classified according to sex and age characteristics based on the criteria established by Fittinghoff (1978) and Mohammad and Wong (2019) (see Table 1).

Table 1. Sex-age characteristics of long-tailed macaques (Fittinghoff, 1978; Mohammad & Wong, 2019)

Sex	Age	Morphology
Adult male (AM)	More than 5 years old	Their limbs are longer than those of AF, their tails are thicker and longer than those of other age classes, they are taller, their penis is more noticeable, and their scrotum is bigger and pink in colour.
Sub-Adult Male (SA)	4 ½ - 5 ½ years old	The scrotum is smaller than AM, but the penis is still visible despite being thinner and less muscular.
Adult Female (AF)	4 or more years	The nipples are longer, the body hair is faded and grey, and the facial hair is always present.
Sub-Adult Female (SF)	4-5 years	smaller and thinner than F, with shorter facial hair and shorter nipples.
Juvenile	1-4 years	Thinner, harder to identify gender
Infant	0-12 months	Clinging to or being carried by its mother's body.

Population census surveys were conducted within the same observation area surrounding the TDNP headquarters and along the Telok Upas trail. The approximate area covered during the survey period was estimated using the polygon measurement tool in Google MyMaps. The boundary was drawn based on the outermost points of repeated daily observations, including foraging trees, resting areas, and movement locations. The length of each survey area was measured along areas surrounding the park headquarters and Telok Upas trail, while the width was estimated based on the long-tailed macaque movements during observations.

The study took place in the morning (0700 hr to 1000 hr), in the afternoon (1200 hr to 1400 hr), and in the evening (1600 hr to 1900 hr), following the same trail path and viewpoints. Repeated censuses and tally counters were needed for the counting procedure to guarantee the accuracy of the data gathered from the census walk (Taufet-Rosdi & Md-Zain 2023). Each sighting was recorded, including group size, age-sex composition, and location along the trail to minimise the possibility of double-counting. Between the observation days, data were reviewed to identify consistently observed groups based on group sizes and structure. Additionally, final estimates of group number and total population size were derived from the total number of groups observed over the sampling day period.

Behavioural sampling

Data on the daily activity of long-tailed macaques were collected using scanning sampling (Ruslin *et al.*, 2019). During each scan, the actions of all observable individuals were simultaneously recorded, and behaviours were classified (Table 2). Individuals were identified by age-sex class: adult male, adult female, juvenile, or infant.

Two focal groups were chosen for behavioural observations due to their recurrent sightings during the population survey. These groups were frequently seen near the TDNP headquarters and along the Telok Upas trail. Daily searches were conducted to locate the groups based on prior movement patterns and resting or feeding locations. The groups displayed minimal avoidance behaviour and tolerated the presence of the observer at a distance of 10–20 meters, suggesting moderate habituation due to occasional exposure to park staff and visitors.

The category of observed behaviour of long-tailed macaque included locomotion, resting, foraging and others (Table 2).

Table 2. Categories of behaviour of long-tailed macaques (Md-Zain *et al.*, 2010; Mohammad & Wong, 2019)

Activity categories	Description
Locomotion	Moving or changing position from the previous one. Walking, running, climbing, swinging, jumping
Resting	Inactive, defecating, urinating, and grooming
Foraging	Chewing, holding food, drinking water
Others	Playing, agonistic, copulation

Behavioural data were collected using the scan sampling method, whereby each macaque was observed at fixed intervals, and all behaviours across a range of categories were recorded. Specifically, each individual's activity was observed at ten-minute intervals, and the individuals were not monitored continuously. Each scan lasted approximately 2 to 5 minutes, depending on visibility, and this method is followed by a five-minute pause for documentation and note-taking (Md-Zain *et al.*, 2010). Observations were scheduled in the morning (0700 to 1000 hr), afternoon (1200 to 1400 hr), and evening (1600 to 1900 hr). Binoculars facilitated detailed observation during these scanning sessions. Additionally, photo analyses were utilised to verify

age structure and group counts, ensuring accurate results (Abd Rahman *et al.*, 2019). Group compositions, individual traits (size, facial features & infant carriage), and behaviours were all recorded in these photos. This data is crucial for estimating population abundance, including individual and group counts. Additionally, this information is important for describing the demographic characteristics of long-tailed macaques in TDNP and assessing their viability.

Data analysis

Population count of long-tailed macaques in TDNP

The group structure of *M. fascicularis* at TDNP was documented in a table along with the number of groups, total number of individuals, sex, adult, sub-adult, juvenile, and infant, as the population was counted during the census walk. Therefore, the total number of individuals could be determined.

The population densities were calculated using the following Equation 1:

$$D = \sum n / m^2$$

Where,

D = density

$\sum n$ = the sum of the total individuals observed and

m^2 = the length (meter) multiplied by the width (meter)

Behaviour of long-tailed macaques in TDNP

The long-tailed macaque's behavioural results were presented as frequency percentages (%) (Boonkusol *et al.*, 2018; Zamri & Md-Zain, 2022). The following Equation 2 was used to determine the proportion of behaviours shown by long-tailed macaques:

$$P = k/K \times 100\%$$

Where,

P = Percentage of particular behaviour

k = Total frequency of the particular behaviour

K = Total frequency of all behaviours

The Chi-square test, a non-parametric statistical method, was employed to analyse the behavioural data. This test was particularly useful for evaluating the significance of activity categories that differed from a normal distribution (Hambali *et al.* 2012). In this study, the Chi-square test was used to assess whether the frequency of different behavioural activities varied significantly across the three daily observation periods. This analysis could address the specific research question of whether long-tailed macaque behavioural patterns changed according to time of day under natural forest settings.

To compare the daily activity pattern of long-tailed macaques, cluster analysis was performed across various study sites. The purpose of this comparison was to determine whether the daily behavioural patterns seen in TDNP were similar to those found in provisioned or disturbed environments. Cluster analysis was used to visualise behavioural similarities based on selected sites for comparison, including Padang Teratak Wildlife Sanctuary (PTWS) (Mohammad & Wong, 2019), Kuala Selangor Nature Park (KSNP) (Hambali *et al.*, 2012), and Universiti Kebangsaan Malaysia (UKM) (Md-Zain *et al.*, 2010). A phenogram was created to assess the degree of similarity among these locations.

RESULTS

Population survey

Based on the data obtained, a total of 181 long-tailed macaques from two different groups were successfully observed during the study. Group A, which was observed around the TDNP headquarters areas, occupied an estimated area of approximately 7,568.64 m². Group B, observed along the Telok Upas trail, ranged within an estimated area of 3,652.83 m² (Figure 2). The majority of individuals of long-tailed macaques were found at the HQ, as many as 175, while only 6 individuals were sighted at Telok Upas. The age structure of macaques observed at HQ and Telok Upas was adult males ($n=57$), adult females ($n=35$), sub-adult ($n=38$), juveniles ($n=49$) and infants ($n=2$) (Table 3). The population density for group A and group B was 2.31×10^{-2} ind/m² and 1.64×10^{-4} ind/m², respectively (Table 4).

Table 3. Age-gender categories of long-tailed macaque in TDNP

Macaque Group	AM	AF	SA	J	I
Group A	54	35	37	47	2
Group B	3	0	1	2	0
Total	57	35	38	49	2

Note: AM = Adult male, AF = Adult Female, SA=Sub-adult, J=Juvenile, I=Infant.

Table 4. Population size in each group of long-tailed macaques

Macaque Group	Area (m ²)	Total Individuals	Relative abundance (ind/m ²)
Group A	7,568.64	175	2.31 × 10 ⁻²
Group B	3,652.83	6	1.64 × 10 ⁻³
Total population	11222	181	24.74 × 10 ⁻³

Behaviour of long-tailed macaques

The study was conducted for a total of nine days, from February 23, 2024, to March 1, 2024. The total of direct observation time with the macaques encountered was 14 hr 15 min out of 72 hr of sampling effort. Throughout observation, Group A at the park HQ encountered more often than Group B at Telok Upas. Both groups were found in the tree canopy and seldom on the ground. Group A was mostly seen brachiating and foraging on the *Calophyllum inophyllum* L. tree (penaga laut), feeding on the fruits and leaves.



Fig. 2. Long-tailed macaque feeding on fruits.

Table 2 classified the six types of behaviours that *M. fascicularis* exhibited during the study. The majority of the macaques' time was found to be spent moving (53.79%), resting (14.48%), and foraging (13.44%) in this study. Meanwhile, playing and being in mother's care (7.93%) rose to the fourth greatest activity seen, vocalisation (5.52%) and grooming (4.83%) to the lowest action. Consequently, Figure 3 displayed the proportion of the long-tailed macaque's behavioural activity.

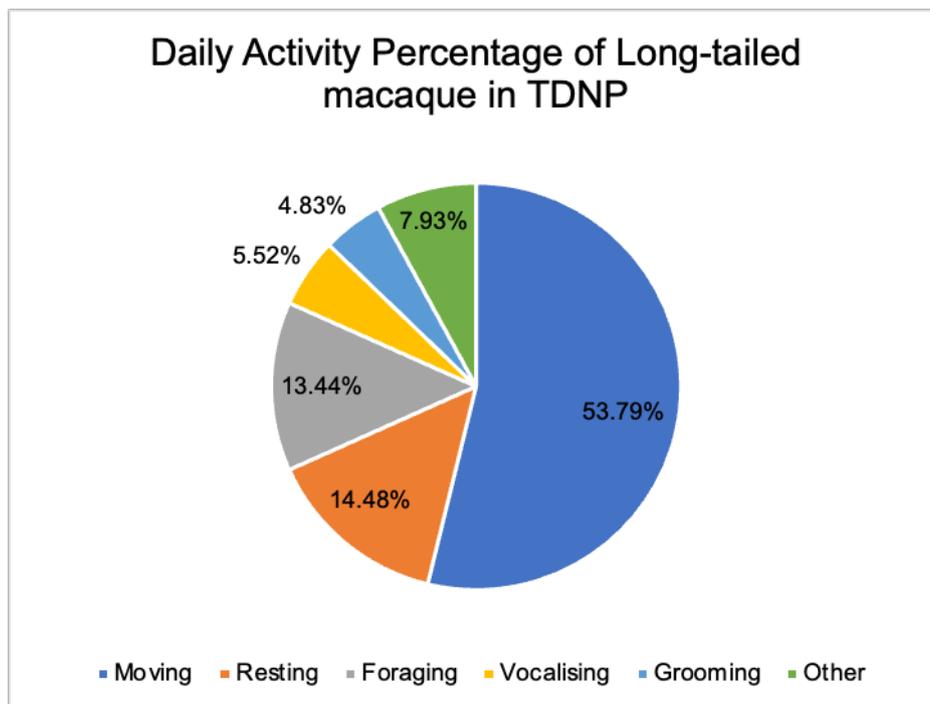


Fig. 3. Percentages of behaviour of long-tailed macaque observed in TDNP.

its time moving (53.52%), followed by resting (14.79%), foraging (9.86%), and vocalising (10.68%). There were also observations of other social habits, such as grooming (4.93%) and other activities, which were playing (7.93%). Only two behaviours were successfully seen in Group B; moving (66.67%) was the most often observed activity, and playing (33.33%) came in second.

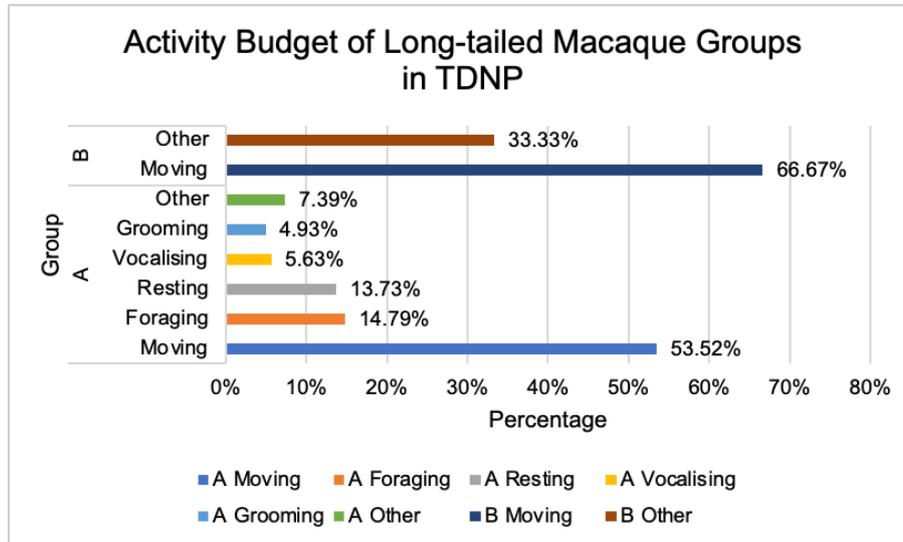


Fig. 4. Graph of the percentage activity budget of *M. fascicularis* groups observed in TDNP.

Comparison with previous studies in Malaysia

Table 5 compares the results of this study with those of other studies carried out in UKM, KSNP, and PTWS. The findings indicated that, across all research sites, movement was the activity most frequently seen. From the cluster analysis (Figure 5), KNSP and UKM had the closest similarities. TDNP and PTWS exhibit lower levels of similarity when compared to UKM and KSNP.

Table 5. Percentage of daily activity budget of long-tailed macaque compared with other studies in Malaysia

No.	Behaviour category	TDNP	UKM ^a	KSNP ^b	PTWS ^c
1.	Locomotion	53.79	23.96	20.27	28.40
2.	Foraging/Feeding	13.44	18.71	18.78	25.20
3.	Resting	14.48	17.04	17.05	19.10
4.	Grooming	4.83	8.84	10.84	12.30
5.	Vocalization	5.52	13.25	10.36	0.50
6.	Other (Playing)	7.93	13.25	10.50	3.60

^aMd-Zain *et al.*, 2010; ^bHambali *et al.*, 2012; ^cMohammad & Wong, 2019

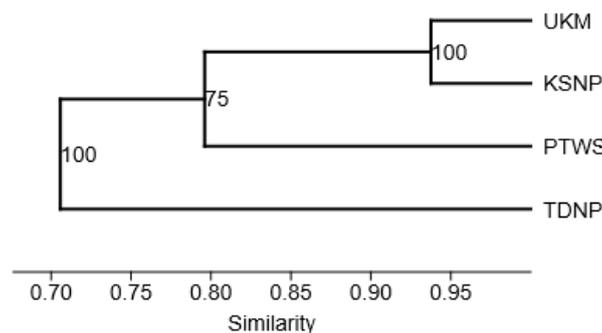


Fig. 5. Phenogram of the comparison between other study areas in Malaysia.

DISCUSSION

Based on the results obtained, an obvious gap in the difference in the number of individuals observed can be discovered. A total of 175 individuals of *M. fascicularis* were observed at the TDNP's headquarters area, and a significant difference of only 6 individuals was observed in the Telok Upas trail. The varying group sizes in the areas may be due to the finding that certain macaque groups were dispersed over habitats with lesser food availability, while others are found near food sources around the park HQ (Md-Zain *et al.*, 2010). From the results, Group A had the most individuals sighted compared to macaques from Group

B. This was possibly due to the difference in the abundance of food in both areas. For instance, the park HQ was nearer to the beach. The macaque's group there would have easier access to hunting for seafood such as crabs. Meanwhile, Telok Upas consisted of dense vegetation, and the macaques were seen hanging and swinging to avoid predators and humans. It was very hard to sight them as they were hiding in the high treetops.

The population structure was divided into different categories, ranging from adult males, adult females, juveniles, and infants. Genital organ identification was used to differentiate between adult monkeys. For example, an adult male was identified by its fully developed testes and penis, while an adult female was identified by the presence of its vulva and nipples (Riley *et al.*, 2015; Zamri & Md-Zain, 2022). Undeveloped genital organs were used to identify juveniles, and the babies were recognised by their distinctive, rather dark hair and usually found clinging to the mother's body (Bernathirdin *et al.*, 2023).

This study found that *M. fascicularis* spent the majority of its time moving. Several studies by other researchers had supported this finding as locomotion was the most observed activity among all (Md-Zain *et al.*, 2010; Hambali *et al.*, 2012; Mohammad & Wong, 2019). *Macaca fascicularis* are diurnal primates that are mainly active throughout the day (Bernathirdin *et al.*, 2023). Md-Zain *et al.* (2010) and Hambali *et al.* (2012) also mentioned that they moved by brachiation on tree branches and jumping from one tree to another out of their habitat range to forage for food. In the evening, they would eventually go back to their nesting area to rest for the day (Ayu *et al.*, 2020). This study was supported by the claim made by Rajeshkumar (2014) and Otani *et al.* (2020) that the availability and distribution of food influenced macaques' movement. However, as they were not acclimated to humans, they would flee or climb the closest tree to remain safe from predators. It was noted throughout this study that macaques would be very skittish while researchers were near them, which may have had an indirect impact on the frequency of their movement (Reinegger *et al.*, 2023). Moreover, more individuals were spending their time on locomotion in Group A compared to Group B. This may be due to the difference in size of area, as the park HQ was bigger compared to the walkway along Telok Upas. A bigger area allowed them to travel better to forage for food before going back to their resting nests. As TDNP is situated on the Datu Peninsula in the southwest corner of Borneo, the groups of long-tailed macaques and other wildlife were not exposed to any human settlements, enabling them to move freely in a protected, natural environment.

From this study, *M. fascicularis* spent more time resting than feeding. This contradicted the study conducted in KSNP, UKM and PTWS that found resting as the third highest activity seen (Md-Zain *et al.*, 2010; Hambali *et al.*, 2012; Mohammad & Wong, 2019; Koh & Rashid, 2020). Hambali *et al.* (2012) and Kurup and Kumar (1993) stated that macaques spend less time resting as their foraging activity increases; therefore, this difference in observation may be because of the time when the macaques were seen in TDNP. They were sighted more during the evening (1500 hr- 1630 hr) as it was frequently raining in the morning, preventing the macaques from getting out of their nests to forage for food. As macaques could only forage during the daytime, certain breaks were necessary for macaques to function at their best and digest food to survive for the night (Fitriyah *et al.*, 2021). Upon arriving at the location, newly arrived macaques would take a short break before proceeding to feed on available food (Dzulhelmi *et al.*, 2019). *Macaca fascicularis* often rested on the tree branches, sitting down as they napped. The macaques preferred to sleep in trees with bigger trunks that were not significantly higher than other surrounding trees, as it is alleged to improve sight over long distances and alertness to approaching predators (Brotcorne *et al.*, 2014). During the day, the macaques of Group A were seen to re-use a few favourite tree branches for resting, particularly the trunks that provided them with easy access to flee from potential predators (Brotcorne *et al.*, 2014).

Feeding was the third-highest observed activity in this study. In the morning, a large group of *M. fascicularis* would move around toward the *C. inophyllum* tree that was blooming with flowers, and an abundance of fruits could be seen hanging on the tree. Based on Orwa *et al.* (2009), the medium-sized tree *C. inophyllum* may grow to a height of 25 m, and occasionally it can reach 35 m. *Macaca fascicularis* was observed to occasionally move and jump to the highest peak of the tree to forage for food. *Macaca fascicularis* are frugivorous primates, and throughout this study, they were observed feeding most on the fruits, leaves, and even the blooming flowers on the top branches of the tree. This was supported by the previous studies led by Yeager (1996) and Wich *et al.* (2002), proving that ripe, fleshy fruits made up 66.7% of the food of macaques in Borneo in Kalimantan, whereas fruit constituted an even larger portion of the diets of macaques on Sumatra (82%). In TDNP, *M. fascicularis* spent most of its time feeding on the trees. Only a small group of long-tailed macaques was seen to be foraging for crabs at the sandy beach near the HQ area. This finding contradicted fully from the study conducted by Md-Zain *et al.* (2010) in UKM and Koh and Rashid (2020) in Universiti Malaya (UM) campus. The groups of *M. fascicularis* habituating in human settlements (eg: UKM, UM) were often seen foraging freely on the grounds, mostly without any sign of agitation from the contact with a large number of humans. They were acclimated to foraging for leftovers in garbage bins, and at times, they were provided with food by humans. This observation had been supported by Hambali *et al.* (2012), proving that in addition to their tiny size and arboreal specialisation, the distribution of food had a significant impact on their capacity to forage on trees. As TDNP is a protected area with very minimal disturbance by humans, the long-tailed macaques were able to freely forage in their natural habitat, without relying on anthropogenic food.

Vocalisation is the fourth highest behaviour that has been observed after feeding. Long-tailed macaques use vocalisations to communicate by making a great variety of sounds such as contact calls, barks, grunts, and screams (Lindburg, 1971). Additionally, it has been noted that macaques would vocalise when they noticed researchers getting close. This is probably to alert the other macaques to the presence of a predator. Brotcorne *et al.* (2014) had mentioned that another explanation for this behaviour might be that macaques vocalise as they reach their sleeping spot, which is consistent with behaviour connected to their sleep-related behaviour. *M. fascicularis*' vocalisation behaviour differed from that of the pig-tailed macaques, *Macaca nemestrina*. Despite their high vocalisation capacity, they frequently remain silent in scenarios when other primates, such as *M. fascicularis*, would be vocalising when fleeing. This significant difference between the two species was supported by Rowe *et al.* (1996), noting that their most common threat behaviour is a wide-open mouth with fixed gazing eyes while performing a silent bare-tooth display.

Next, grooming is the fifth-highest behaviour that has been observed during this study. In all age groups, self-grooming was frequently observed in *M. fascicularis*. It is described as repeatedly utilising the hands or legs to massage or scratch any portion of the body (Dzulhelmi *et al.*, 2019). Instead of utilising their front feet, both types of monkeys scratch their heads with their hind feet. Although adult male long-tailed macaques do not commonly auto-groom themselves in the wild, other individuals of lower

age groups routinely allogroom individuals of higher age classes due to a hierarchical factor (Brent and Veira, 2002; Md-Zain *et al.*, 2010; Dzulhelmi *et al.*, 2019). The female macaques would groom their mating partners to gain protection and food, while the adult mother of the long-tailed macaques frequently tended the infant it was carrying to strengthen the bonds between them (Md-Zain *et al.*, 2010; Hambali *et al.*, 2012). Interestingly, contradicting the behaviour of male *M. fascicularis*, a study by Dzulhelmi *et al.* (2019) found that a mature female southern pig-tailed macaque was observed being groomed by an adult male, and vice versa. This could be the initiation of the male in attracting the female.

Other activities, especially playing was observed frequently in this study. Infants and juveniles frequently engage in socialising activities such as biting, mocking, chasing, wrestling, and vocalising as a way to create social relationships (Md-Zain *et al.*, 2010; Hambali *et al.*, 2012; Dzulhelmi *et al.*, 2019). Playing also involved swinging and hanging from trees. The juveniles would hold onto the tree limb with both of their hind legs, hanging upside-down, and play with each other with both hands. When they were playing too far, the monitoring mother would call them out to ensure their safety. One observing mother was also seen carrying an infant on its body, grooming, and breastfeeding it on a nearby tree branch.

Based on the results, certain limitations impacted the generalisation of this study. For instance, the macaques' groups were seen mostly in the high treetops. It was complicated for the researcher to properly observe them with only a pair of binoculars. As they were also fast at fleeing upon encountering humans, a strenuous effort was needed to successfully capture their pictures using a camera. The weather was an uncontrollable factor for this study, as the macaques were not encountered during rainy days, limiting the observation of their behaviours.

The uncommonly large group size recorded for Group A (175 individuals) reflected the cumulative number of distinct individuals consistently observed across all survey sessions. This group was encountered repeatedly near the TDNP headquarters, and its movement patterns suggested that it was a single social group rather than a collection of overlapped groups. Gumert and Fuentes (2011) had highlighted that provisioned populations are frequently linked to such large group sizes. However, due to the absence of individual identification methods, some degree of uncertainty may remain. Further long-term observation, detailed spatial tracking, and genetic sampling would be valuable to confirm accuracy and group stability over time (Gumert *et al.*, 2011).

Moreover, this study was conducted in a limited period of time, preventing the researchers from conducting an even more extensive observation on the behaviour of this species. Therefore, the sample size and duration were insufficient to support broad generalisations about long-term behavioural patterns or population dynamics. However, the data obtained offered a quick overview of daily activity patterns within the study period and provided a preliminary understanding of long-tailed macaque behaviour in a minimally disturbed forest setting. These limitations should be taken into consideration during results interpretation and may serve as a framework for more extensive studies in the future.

Additionally, to further improve the outcome of this study, a longer sampling period on different seasons (e.g., fruiting & non-fruiting seasons) can be conducted to better understand the dispersal of *M. fascicularis* at TDNP. The usage of the latest technology can be increased, such as deploying camera traps around the targeted areas, or using drones for a better sighting of the species.

The TDNP and PTWS exhibit lower levels of similarity compared to UKM and KSNP. This is because the macaques from both UKM and KSNP were already habituated to human presence. Ruslin *et al.* (2014) had highlighted the impact of food provisioning as the macaques were devoted to browsing for food waste and anthropogenic food from humans. Hambali *et al.* (2012) mentioned that macaques in their study area prefer human food to their natural food, as the macaques were frequently seen to be invading students' residential colleges and stealing their food. Although TDNP and PTWS did not have many similarities, the macaques in Borneo still rely mostly on natural food sources. Macaques at TDNP were less exposed to human settlements compared to those at PTWS, hence they travel further for food. As macaques in Borneo were not highly dependent on anthropogenic food, they had a significantly broader diet. The evaluation of their dietary preferences can be studied further to confirm this statement.

CONCLUSION

This study provides the first extensive evaluation of the long-tailed macaque (*M. fascicularis*) population and activity pattern in TDNP. A total of 181 long-tailed macaques were recorded, with 175 individuals in Group A and 6 individuals in Group B. The estimated population density for both groups, Group A and B were 2.31×10^{-2} ind/m² for Group A and 1.64×10^{-4} ind/m² for Group B, respectively. A total of 72 hr of sampling effort discovered that movement was significantly the most observed behaviour in this study of these two groups of long-tailed macaques, while grooming behaviour was the least seen. This study has provided information of long-tailed macaque population in TDNP, especially regarding its population densities and activity pattern which can be used as baseline data in further studies. The findings enhance understanding of macaque habitat use and social dynamics, supporting habitat protection efforts in TDNP.

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ETHICAL STATEMENT

Not applicable

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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