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Group structure and arboreal activity of Javan surili in Gunung Gede Pangrango National Park, Indonesia

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Abstract. *Dharma AP, Mardiastuti A, Iskandar E, Rianti P. 2026. Group structure and arboreal activity of Javan surili in Gunung Gede Pangrango National Park, Indonesia. Biodiversitas 27 (4): d270436. https://doi.org/10.13057/biodiv/d270436.* The Javan surili is an endemic arboreal primate of Java whose population dynamics and behavioral ecology are strongly influenced by habitat quality and anthropogenic disturbance. This study aimed to analyze group structure, population density, and arboreal activity patterns of Javan surili in two contrasting sites, Tegallega and Sarongge Resorts, within Gunung Gede Pangrango National Park, Indonesia. Field data were collected over a 13-month period (March 2023-June 2024) using line transect surveys and scan sampling methods. A total of 10 groups comprising 40 individuals were recorded, with 25 individuals in Tegallega (6 groups) and 15 individuals in Sarongge (4 groups). Group structure showed a typical unimale polygynous system, with female-biased sex ratios of 1:1.25 in Tegallega and 1:1.13 in Sarongge, indicating stable reproductive potential. Population density was higher in Sarongge (5.99 ind/km², 2.14 groups/km², estimated 66 individuals) compared to Tegallega (3.03 ind/km², 1.33 groups/km², estimated 53 individuals), suggesting more concentrated space use and better habitat conditions. Behavioral observations revealed that feeding was the dominant activity (52.00% in Tegallega, 42.86% in Sarongge), followed by resting (21.33%, 27.14%), locomotion (14.67%, 15.71%), and social interactions (12.00%, 14.29%). All activities occurred exclusively in arboreal strata, with a strong preference for the mid-canopy layer (stratum C), which supported the highest number of plant species used for feeding and other activities. Key tree species such as *Castanopsis argentea*, *Liquidambar excelsa*, and *Schima wallichii* played essential roles in sustaining daily activities. These findings highlight the importance of habitat structure, particularly canopy connectivity and key food resources, in shaping Javan surili population and behavior. Differences between sites emphasize the influence of anthropogenic pressure and habitat heterogeneity, underscoring the need for targeted conservation strategies to maintain viable populations.

Keywords: Activity patterns, habitat quality, human disturbance, population density, *Presbytis comata*

INTRODUCTION

The Javan surili (*Presbytis comata*) is an endemic colobine primate restricted to the island of Java, Indonesia, inhabiting both lowland and montane forest ecosystems (Nijman et al. 2022). Its current distribution is largely confined to protected areas, including Gunung Gede Pangrango National Park (GGPNP), Gunung Halimun Salak National Park (GHSNP), and Gunung Ciremai National Park (GCNP), although remnant populations persist in fragmented landscapes outside conservation areas (Supartono 2016; Kusumanegara et al. 2017; Supartono et al. 2020; Hidayat 2021; Septiani et al. 2024). Despite legal protection and recent reassessment of its conservation status to Vulnerable, the species continues to experience population pressure driven by habitat loss, forest fragmentation, and increasing anthropogenic disturbances (Estrada et al. 2017, 2018; Nijman et al. 2022). These pressures remain important conservation concerns because they can reduce habitat quality, isolate local populations, and limit the long-term persistence of the species in both protected and unprotected landscapes.

As a highly arboreal and predominantly folivorous primate, the Javan surili is ecologically dependent on forest canopy continuity and vertical structural complexity. These habitat attributes are critical for ensuring access to food resources, facilitating locomotion, and reducing predation risk (Roos et al. 2014; Supartono et al. 2020). However, forest degradation, including selective logging and agricultural expansion, alters canopy connectivity and resource distribution, thereby constraining movement patterns and influencing habitat suitability. In fragmented landscapes, edge habitats may provide abundant young leaves but simultaneously increase exposure to predators and human disturbances, creating ecological trade-offs that shape behavioral adaptations (Arroyo-Rodríguez et al. 2017; Kusumanegara et al. 2017). Such conditions may also influence how individuals use space, select feeding sites, and adjust daily movements in response to variation in habitat structure and disturbance intensity.

Behaviorally, Javan surili exhibit complex activity patterns that reflect energy allocation strategies associated with feeding, resting, moving, and social interactions. As arboreal quadrupeds, their locomotion and daily activity budgets are closely linked to canopy structure and resource availability (Borgeaud et al. 2021; Thiel et al. 2021). Time allocation in primates is widely recognized as a key ecological indicator, revealing how individuals optimize energy expenditure under varying environmental conditions (Decemson et al. 2018). Both intrinsic factors (e.g., age, sex, and physiological condition) and extrinsic factors (e.g., food availability, weather, topography, and anthropogenic disturbance) significantly influence these behavioral patterns (Sha et al. 2022; Ramsay et al. 2023; Avenzora et al. 2024). Understanding these activity patterns is therefore essential for interpreting the species' behavioral flexibility under different environmental contexts.

In addition to activity patterns, group structure represents a fundamental aspect of primate socioecology, influencing reproductive strategies, predator avoidance, and resource competition. Variations in group size and composition are often shaped by habitat quality and disturbance levels, particularly in fragmented forests where ecological constraints may limit group cohesion and spatial distribution. Furthermore, the vertical use of forest strata plays a critical role in shaping both social organization and activity allocation, as different canopy layers offer varying levels of resource availability and safety (Santosa et al. 2020).

Various previous studies have examined the population conditions and habitat use of the Javan surili, detailed investigations integrating group structure and fine-scale arboreal activity across different habitat conditions remain limited. In particular, comparative studies at the resort level within protected areas are still scarce, despite potential variation in ecological pressures and habitat characteristics. This represents a critical knowledge gap in understanding how local environmental heterogeneity influences behavioral ecology in this species. Therefore, this study focuses on two distinct sites, Tegallega Resort and Sarongge Resort within GGPNP, which differ in terms of environmental conditions and anthropogenic influences. By examining variations in group structure and arboreal activity patterns between these sites, this research aims to provide new insights into the adaptive responses of Javan surili to habitat heterogeneity. The findings are expected to contribute to a more nuanced understanding of primate behavioral ecology and to inform conservation strategies for sustaining viable populations in increasingly disturbed forest ecosystems.

MATERIALS AND METHODS

Study area

This study was conducted at Tegallega Resort and Sarongge Resort, Gunung Gede Pangrango National Park, West Java, Indonesia (Figure 1), from March 2023 to June 2024. According to the Decision Letter of the GGPNP Directorate General No. SK 120/IV-T.11/BT.5/2016, the defined resort areas span 1,747.87 ha or 17.4787 km^2 in Tegallega and 1,108.71 ha or 11.0871 km^2 in Sarongge.

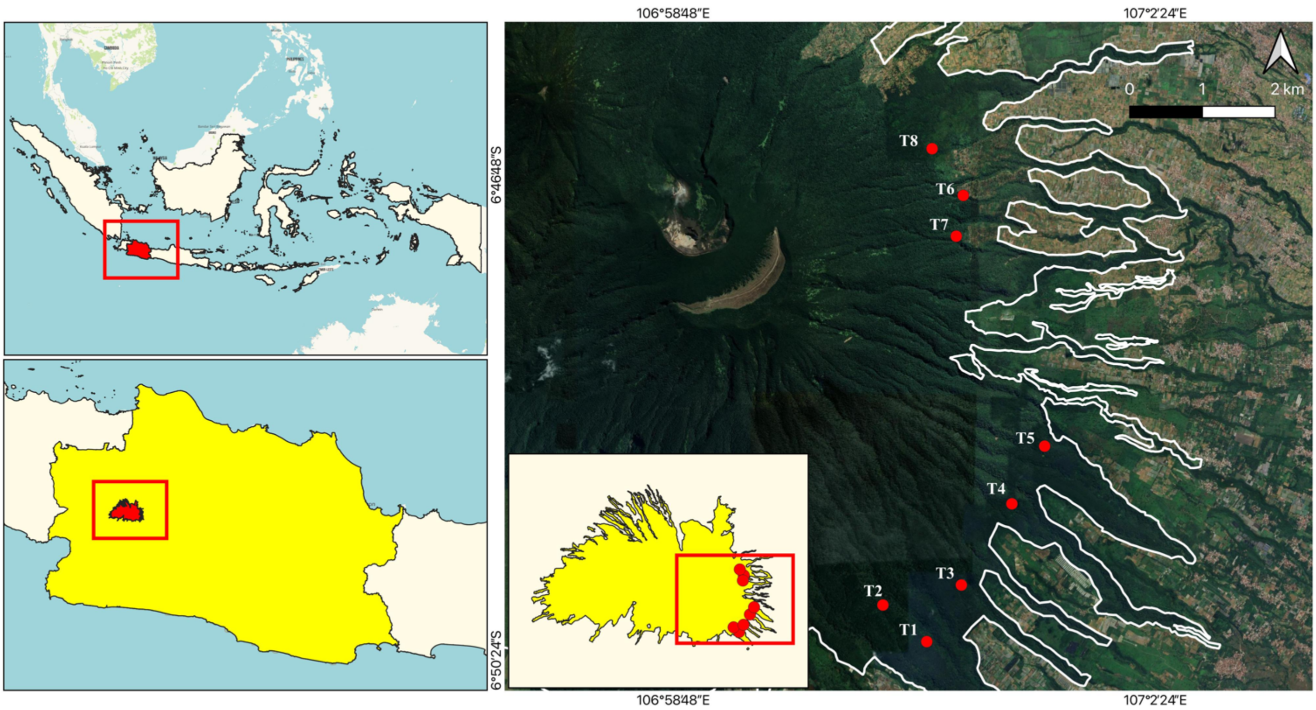

Figure 1. Map of research area of Tegallega (T1-T5) and Sarongge (T6-T8) Resorts in Gunung Gede Pangrango National Park, West Java, Indonesia

Table 1. Javan surili observation transect area in Tegallega and Sarongge Resorts, Gunung Gede Pangrango National Park, West Java, Indonesia

Resort		Coordinat points		Transect length (km)	Transect area (km^2)	Number of repetitions (times)
Tegallega						
T1	Legok Go'ong, Gekbrong Village	06º50'15.67"S	107º00'41.65"E	2.6	0.26	38
T2	Blok Kuta, Gekbrong Village	06º49'59.37"S	107º00'21.98"E	3.0	0.30	46
T3	Kebonpeuteuy Village	06º49'50.47"S	107º00'57.15"E	2.5	0.25	22
T4	Tegallega Village	06º49'14.33"S	107º01'19.79"E	2.6	0.26	11
T5	Bunikasih Village	06º48'48.66"S	107º01'34.46"E	3.0	0.30	14
Total				13.7	1.37	131
Sarongge						
T6	Galudra Village	06º46'57.06"S	107º00'57.99"E	2.6	0.26	28
T7	Sukamulya Village	06º47'15.22"S	107º00'54.87"E	2.5	0.25	26
T8	Sarongge Village	06º46'36.27"S	107º00'44.03"E	2.5	0.25	19
Total				7.6	0.76	73

Note: T1-T8: Transect 1-8

Data collection

A total of five transects (T1-T5) were established in Tegallega Resort, and three transects (T6-T8) at Sarongge Resort, with a total of 131 survey repetitions in Tegallega and 73 in Sarongge. The total survey area was determined by establishing a transect length of 2.5 to 3.0 km with an observation width of 50 m to the left and right. This design resulted in a representative observation area of 1.37 km^2 in Tegallega and 0.76 km^2 in Sarongge Resort (Figure 1, Table 1). Each survey was conducted once per day with an observation duration of approximately 6-8 hours (06:00-18:00 WIB). Surveys were distributed across different days and months to minimize temporal bias.

Sampling efforts were highly intensive to maximize the probability of detection and minimize bias resulting from low encounter rates with the Javan surili, a species sensitive to human presence. The difference in the frequency of observations between the two resorts is due to weather conditions and limited funding from the researchers. Initial information regarding the potential location of Javan surili groups was crucial and was gathered from GGPNP officers and farmers residing near the forest. This groundwork ensured that the selected transects accurately covered known potential habitats. The field team comprised three people: the principal researcher and two members of the local community forestry police partners (LCFPs). Observations were strictly conducted during the Javan surili diurnal activity period, from 06:00 to 18:00 WIB (Santosa et al. 2020; Supartono et al. 2020). To avoid observational bias, field work was suspended during heavy rain or thick fog.

Group structure and sex ratio of Javan surili

Javan surili group structure and sex ratio were determined by identifying the number of individuals in each group and classifying them into adult males, adult females, and immature individuals (subadults, juveniles, and infants). Sex and age-class identification was conducted based on observable morphological characteristics, body size, distinctive behavioral traits, and the relative position of individuals within the group that could be visually detected in the field. Sex ratio analysis was restricted to comparisons between adult males and adult females due to the difficulty of reliably determining the sex of immature and juvenile individuals (Santosa et al. 2020).

Population density of Javan surili

The population density of Javan surili was estimated based on the number of individuals observed along the survey transects while accounting for the total area surveyed. Density estimates were expressed as individuals per square kilometer (individuals/km^2) and were used to provide a quantitative description of the Javan surili population status in each study resort. These density values were subsequently compared between study sites to evaluate spatial variation in population conditions within GGPNP.

Activity of Javan surili

Behavioral data were collected using scan sampling method during direct encounters with Javan surili groups. Observations were conducted from 08:00 to 18:00 WIB. When a group was detected, the activity of all visible individuals was recorded simultaneously at 5-minute intervals (Bateson and Martin 2021). If the encounter duration was less than 5 minutes, a single instantaneous scan was recorded at the time of first detection. Each individual observed within a scan was treated as one behavioral record. Activities were classified into feeding, locomotion, resting, and social interaction. The total time spent by the surili on activities during the observation was 176 minutes (2.93 hours) in Tegallega Resort and 144 minutes (2.40 hours) in Sarongge Resort.

Simultaneously with activity observations, the tree strata used by Javan surili during their activities were documented. Tree strata were classified into five vertical layers: (i) stratum A (>30 m), representing the uppermost layer consisting of the tallest trees emerging above the main canopy; (ii) stratum B (20-30 m), representing the main forest canopy composed of large trees that visually dominate the forest structure; (iii) stratum C (4-20 m), consisting of medium-sized trees and regenerating shoots of large trees forming the supporting canopy layer; (iv) stratum D (1-4 m), consisting primarily of shrubs and small tree saplings; and (v) stratum E (0-1 m), representing ground vegetation and herbaceous plants (Kusmana et al. 2022). If more than one type of behavior or a shift in canopy strata occurred during a single encounter, all behavioral changes and vertical movements were recorded as long as the individual or group remained within the observable range. Vegetation height was measured using a laser distance meter to ensure accurate estimation of canopy height. During field observations, the identification of local plant names utilized by Javan surili during their activities was assisted by members of the forest ranger community partners (FRCP). For scientific identification, plant specimens including leaves, fruits, and flowers were collected and sent to the Laboratory of Biology Generation for taxonomic verification.

Data analysis

Group structure and sex ratio of Javan surili

Data on group structure were collected by recording the number of individuals, sex, and age categories within each observed group. Javan surili group structure was categorized based on age classes, including adult males, adult females, subadults, juveniles, and infants. Sex ratio was calculated as the proportion of adult males to adult females within each transect and was presented in the form of a ratio.

Population density of Javan surili

The analysis of Javan surili population density in Tegallega Resort and Sarongge Resort was conducted based on field survey data collected along predetermined observation transects. The number of individuals and groups observed was used to calculate estimates of individual density and group density for each resort, thereby providing an overview of differences in Javan surili population conditions between the two study sites. The resulting density values provide an initial quantitative basis for evaluating the population status of Javan surili within the two resorts of GGPNP. The formula used to estimate population density is presented as follows: population density (individuals/km^2) = number of individuals encountered per transect (N)/number of survey repetitions x survey area (km^2). Subsequently, the average population density was calculated by dividing the total population density by the number of observation transects. The population size estimate for each resort was then calculated using the following formula: population estimated (P) = average population density (individuals) x occupied area (km^2).

Activity of Javan surili

Daily activity patterns were analyzed by calculating the proportion of each behavioral category based on scan sampling data (Bateson and Martin 2021). The percentage of each activity was calculated using the following formula:

$$P_i = \frac{n_i}{N} \times 100\%$$

Where, P_i is the percentage of activity i, n_i is the number of observations of activity i, and N is the total number of behavioral observations across all individuals and scan intervals.

For encounters lasting more than one scan interval, repeated scans were included in the analysis. The resulting values represent the proportion of observed activities during encounter periods rather than a complete daily activity budget.

RESULTS AND DISCUSSION

Group structure and sex ratio of Javan surili

The population survey for the Javan surili identified a total of 10 groups comprising 40 individuals across the two observation sites (Table 4). Tegallega Resort recorded a higher number, with 6 groups and a total of 25 individuals identified. Meanwhile, Sarongge Resort had four groups consisting of 15 individuals. Group structure analysis revealed that the population is dominated by adult females, a characteristic typical of *Presbytis* species. The mean sex ratio between adult males and adult females at Tegallega Resort was 1:1.25 (6 adult males to 9 adult females). A similar ratio was found at Sarongge Resort, at 1:1.13 (4 adult males to 5 adult females). This tendency for a higher ratio of adult females is highly favorable for the population's long-term viability, as it indicates stable and active reproductive potential in both areas.

Population density of Javan surili

The results of population density, group density, and population estimates indicate that density values in Sarongge Resort are higher, despite having smaller transect coverage and fewer survey repetitions. This finding suggests that transect area and survey repetitions primarily influence sampling coverage and detection probability, whereas density values and population estimates more accurately reflect the intensity of space use and the spatial distribution of Javan surili within the area, rather than merely the magnitude of sampling effort.

The higher population estimate in Sarongge Resort is primarily influenced by the higher population and group densities per unit area. This indicates that Sarongge supports more intensive space use by Javan surili, resulting in a greater accumulation of individuals within a relatively smaller area. In contrast, Tegallega Resort appears to exhibit a more dispersed distribution of individuals across a broader area, reflecting differences in habitat structure or spatial resource availability between the two study sites.

Table 4. Group structure of Javan surili in Tegallega and Sarongge Resorts, Gunung Gede Pangrango National Park, West Java, Indonesia

Resort	Groups	Adult male	Adult female	Subadult	Juvenile	Infant	Total individuals	Sex ratio
Tegallega	6	6	9	4	5	1	25	1:1.25
Sarongge	4	4	5	2	3	1	15	1:1.13

Table 5. Population density and group density of Javan surili in Tegallega and Sarongge Resorts

Resort	Population density (ind/km²)	Group density (groups/km²)	Population estimate (ind)
Tegallega	3.03	1.33	53
Sarongge	5.99	2.14	66

Activity of Javan surili

During observations, Javan surili were recorded engaging in feeding, locomotion, resting, and social activities, all occurring exclusively in an arboreal context. Feeding activity was the most dominant behavior, accounting for approximately 52.00% of total observations, followed by resting (21.33%), locomotion (14.67%), and social interactions (12.00%). Javan surili in Tegallega Resort predominantly utilize stratum C (mid-canopy) for all activities, particularly feeding (10 plant species), locomotion (9 species), resting (7 species), and social interactions (3 species). In contrast, stratum B and A are used less frequently and involve a smaller number of plant species (Table 6).

In Sarongge Resort, the dominant proportion of time was spent on feeding (42.86%), followed by resting (27.14%), locomotion (15.71%), and social (14.29%). Javan surili in Sarongge Resort predominantly utilize stratum C (mid-canopy) for all activities, particularly feeding (7 plant species), resting (7 species), locomotion (5 species), and social interactions (4 species). Meanwhile, stratum B is used with lower intensity and involves a smaller number of plant species (Table 7). The plant species most frequently used by Javan surili in both Tegallega and Sarongge Resorts are *Castanopsis argentea*, *Liquidambar excelsa*, and *Schima wallichii*, as they play an important role in supporting all major activities. This indicates that these species are key habitat components that provide food resources, canopy structure, and sites for resting and social interactions.

Discussion

Group structure and sex ratio of Javan surili

Group structure and sex ratio of Javan surili are fundamental components of primate socioecology, directly influencing reproductive strategies, predator avoidance mechanisms, and resource-use efficiency. In this study, Javan surili observed in Tegallega and Sarongge Resorts formed relatively small groups, ranging from 2-6 individuals per group. This observed group size is consistent with the general pattern of the genus *Presbytis*, which is characterized by a one-male polygynous (unimale) social system, consisting of one adult male, multiple adult females, and their offspring (Nijman and Nekaris 2012; Nijman 2017).

Birth intervals in several species within the genus *Presbytis* typically range between 1-2 years. For example, *Presbytis entellus* exhibits an average birth interval of approximately 15-16 months (Harley 1985), while *Presbytis thomasi* shows a longer interval of around 26.8 months (Wich et al. 2007). These reproductive parameters are strongly influenced by infant survival and food availability. Birth intervals tend to be longer when previous offspring survive compared to cases of infant mortality. Detailed observations indicate that females whose infants survive to approximately 9 months of age have a median birth interval of 15.4 months, whereas females experiencing pregnancy failure or neonatal loss show shorter median intervals of 9.6 and 10.7 months, respectively. This suggests that the presence of a nursing infant delays subsequent conception by approximately 5-6 months. Conversely, the loss of offspring after 5-6 months of age does not significantly accelerate reproductive recovery or shorten the birth interval (Harley 1985).

Javan surili do not exhibit strict reproductive seasonality, allowing mating to occur throughout the year (Abimanyu 2024). Observations from both study sites indicate that females typically give birth to a single offspring per reproductive event, suggesting that population recruitment is ongoing and functionally stable. This pattern implicitly indicates that the habitat provides sufficient nutritional resources to support successful reproduction and offspring development. The sex ratio (male:female) in both Tegallega and Sarongge was slightly female-biased, reflecting a relatively stable reproductive potential within the population. Female-biased sex ratios are a common characteristic of harem-based or one-male polygynous systems (Nijman and Nekaris 2012; Nijman 2017; Manansang and Sinaga 2024; Septiani et al. 2024). In this system, a single male monopolizes access to multiple females, a strategy that maximizes reproductive output while minimizing intraspecific male competition. Female-biased group composition is also commonly observed in other *Presbytis* species, as it enhances reproductive assurance. Even if a dominant male is lost due to predation or dispersal, the presence of multiple females ensures the continuity of the lineage. Furthermore, a polygynous system reduces the need for a large number of adult males, thereby lowering the risk of male-male aggression and competition over resources. The relatively balanced yet female-biased sex ratio observed in both study sites indicates that the social structure of Javan surili remains intact and resilient, despite variations in anthropogenic disturbance. This pattern reflects an evolutionary mechanism that allows Javan surili to optimize individual reproductive success while maintaining group stability under varying environmental pressures (Majolo et al. 2008).

Table 6. Use of tree strata based on surili activity at Tegallega Resort, Gunung Gede Pangrango National Park, West Java, Indonesia

Activity	Stratum	Percentage (%)	Number of plant species	Plant species used
Feeding	C	84.62	10	*Saurauia cauliflora* (kileho), *Maesopsis eminii* (kayu Afrika), *Castanopsis argentea* (saninten), *Calliandra houstoniana* (kaliandra), *Homalanthus giganteus* (jajawai, manggong), *Schima wallichii* (puspa), *Liquidambar excelsa* (rasamala), *Claoxylon longifolium* (huru sampeu), *Ficus ribes* (walen)
	B	15.38	4	*Castanopsis argentea*, *Liquidambar excelsa*, *Trema orientale* (kuray), *Maesopsis eminii*
Resting	C	62.50	7	*Schima wallichii*, *Castanopsis argentea*, *Liquidambar excelsa*, *Picrasma javanica* (ki besi), *Magnolia sumatrana* (manglid), *Oreocnide sylvatica* (nangsih), *Ficus ribes*
	B	18.75	3	*Castanopsis argentea*, *Homalanthus giganteus*, *Trema orientale*
	A	18.75	3	*Schima wallichii*, *Liquidambar excelsa*, *Castanopsis argentea*
Locomotion	C	90.91	9	*Castanopsis argentea*, *Liquidambar excelsa*, *Pinus merkusii* (pinus), *Schima wallichii*, *Trema orientale*, *Homalanthus giganteus*, *Astronia spectabilis* (huru kacang), *Melia azedarach* (ki haji), *Oreocnide sylvatica*
	B	9.09	1	*Astronia spectabilis*
Social	C	77.78	3	*Castanopsis argentea*, *Liquidambar excelsa*, *Magnolia sumatrana*
	B	11.11	1	*Castanopsis argentea*
	A	11.11	1	*Schima wallichii*

Table 7. Use of tree strata based on surili activity at Sarongge Resort, Gunung Gede Pangrango National Park, West Java, Indonesia

Activity	Stratum	Percentage (%)	Number of plant species	Plant species used
Feeding	C	60.00	7	*Castanopsis argentea*, *Liquidambar excelsa*, *Schima wallichii*, *Litsea castanea* (huru cangkring), *Astronia spectabilis*, *Heptapleurum rugosum* (ramogiling), *Maesopsis eminii*
	B	40.00	4	*Castanopsis argentea*, *Astronia spectabilis*, *Schima wallichii*, *Liquidambar excelsa*
Resting	C	52.63	7	*Schima wallichii*, *Liquidambar excelsa*, *Homalanthus giganteus*, *Maesopsis eminii*, *Litsea castanea*, *Castanopsis argentea*, *Cupressus* sp. (cemara)
	B	47.37	3	*Castanopsis argentea*, *Schima wallichii*, *Liquidambar excelsa*
Locomotion	C	72.73	5	*Castanopsis argentea*, *Schima wallichii*, *Homalanthus giganteus*, *Heptapleurum rugosum*, *Maesopsis eminii*
	B	27.27	2	*Liquidambar excelsa*, *Astronia spectabilis*
Social	C	90.00	4	*Castanopsis argentea*, *Liquidambar excelsa*, *Homalanthus giganteus*, *Schima wallichii*
	B	10.00	1	*Castanopsis argentea*

Comparisons with other Javan surili populations provide further insights into the flexibility of their social structure. Variation in group size is likely associated with local habitat quality. Lower montane forests with higher tree diversity and greater food availability may ecologically support the formation of larger groups. This variability highlights that Javan surili are not constrained to a fixed group size; instead, group size may decrease in habitats with limited resources or high human disturbance, and increase in environments with abundant food resources and higher habitat quality. The relatively small group size of Javan surili is also intrinsically linked to their folivorous diet. Leaf-eating primates typically require extensive home ranges and incur higher energetic costs for digestion. Maintaining large group sizes under such conditions may be energetically inefficient, particularly in montane forest environments where food resources are often seasonally limited and spatially heterogeneous. In contrast, genera such as *Macaca* are able to form larger multi-male, multi-female groups due to their dietary flexibility and opportunistic omnivory (Supriatna 2019).

The relatively small group size observed in Javan surili reflects a series of important adaptive trade-offs that are critical for survival. These trade-offs involve balancing intragroup competition with predation risk. On one hand, smaller group sizes reduce competition for food resources, which is particularly important for folivorous species that depend on food sources that are abundant in volume but low in nutritional quality. Reduced competition minimizes energetic costs and internal conflict, thereby enhancing feeding efficiency at the individual level. On the other hand, small group sizes increase vulnerability to predation due to the limited number of individuals. This results in reduced effectiveness of collective vigilance and a lower capacity to produce effective alarm calls. In the TNGGP landscape, potential predators include the Javan leopard (*Panthera pardus melas*) (Ario et al. 2018, 2022) and several raptor species, such as Javan hawk-eagles *Nisaetus bartelsi* and changeable hawk-eagle *Nisaetus cirrhatus* (Dharma et al. 2022). Although no predation events were directly observed during this study, the presence of these predators likely contributes to maintaining group cohesion and heightened vigilance behavior.

Small group-living colobines often rely on camouflage and rapid escape strategies rather than coordinated defense. This mechanism may explain the frequent fleeing responses observed in Tegallega, where Javan surili rapidly retreated upon encountering humans, likely perceiving them as predator-like threats. Predation cases in other colobine species, such as snub-nosed monkeys, have been reported to involve predators including leopard *Panthera pardus*, grey wolf *Canis lupus*, and large raptors such as golden eagle *Aquila chrysaetos* and northern goshawk *Accipiter* (Kirkpatrick and Grueter 2010). When responding to potential predators, Javan surili tend to exhibit low vocalization and rapid escape through mid-canopy strata, whereas *Presbytis melalophos* often produces loud vocalizations and escapes quickly through the upper canopy (Nijman and Nekaris 2012). These differences indicate species-specific anti-predator strategies, in which escape behavior and vocal responses are adapted to habitat structure and predator pressure.

In small Javan surili groups characterized by a one-male polygynous (unimale) mating system, where a single dominant male monopolizes access to females, reproductive output is concentrated in one individual. This condition results in a relatively low effective population size, which may lead to a reduction in genetic diversity within the group. The presence of infants and juveniles in both resorts confirms that population regeneration and reproduction are ongoing. However, the relatively small population size in Tegallega and Sarongge places these populations in a demographically vulnerable condition. The loss of even a few adult males could have significant consequences for social structure stability and overall population viability. Therefore, continuous monitoring of sex ratio (male:female) and natality rates is essential for effective conservation management in the study area.

From a population genetics perspective, small populations that persist over multiple generations are prone to loss of genetic variation (Ewens 2016). This process can ultimately reduce the species' adaptive capacity in response to unexpected environmental changes (Lande and Barrowclough 1987). Accordingly, maintaining an adequate effective population size and ensuring long-term genetic diversity are fundamental components of conservation strategies. In this context, maintaining habitat connectivity between Tegallega and Sarongge is critically important to facilitate individual movement and gene flow among subpopulations (Prasetyo et al. 2017). Without functional ecological corridors, Javan surili populations face a high risk of fragmentation and genetic decline, which could seriously threaten their long-term persistence.

Population density of Javan surili

Population density is a fundamental ecological indicator that plays a crucial role in evaluating primate population health, as it reflects the combined effects of habitat quality, food resource availability, predation risk, and anthropogenic pressure. The relationship between transect length, surveyed area, and sampling repetition influences estimates of population density, group density, and overall population size in both resorts by increasing sampling coverage and detection probability. Tegallega Resort had a greater total transect length compared to Sarongge Resort, resulting in broader survey coverage and more stable observational data. However, increased sampling effort does not necessarily produce higher density estimates, as density primarily reflects the intensity of space use by Javan surili, rather than the magnitude of sampling effort alone.

In contrast, Sarongge Resort exhibited higher population density and group density, despite having smaller transect coverage and fewer sampling repetitions. This suggests that Javan surili in Sarongge utilize space more concentratedly, resulting in a higher number of individuals and groups per unit area. In population estimation, the total area of the resort directly influences results because density values are multiplied by the extent of the habitat area. Consequently, although Tegallega has a larger total area, the estimated population in Sarongge remains higher due to its greater individual and group density. Overall, differences in density values and population estimates between the two resorts are more strongly determined by spatial distribution patterns and habitat use intensity, rather than differences in sampling design.

The higher population density of Javan surili in Sarongge strongly indicates that better habitat conditions and lower levels of anthropogenic disturbance influence both the spatial distribution and the carrying capacity of the habitat. These findings emphasize the importance of interpreting density data within an ecological and socio-environmental context, rather than as an absolute measure of population abundance. Such variability reflects fundamental differences in forest structure, food availability, and environmental pressure (Nijman and Setiawan 2020).

In contrast, the lower population density observed in Tegallega Resort is likely the result of a complex interaction between ecological factors and anthropogenic pressures. First, the close proximity of Tegallega to agricultural land increases the intensity of human disturbance, including hunting activities and noise from local communities. Direct observations of hunters and hunting dogs further confirm that such pressures may reinforce avoidance behavior in Javan surili. This behavioral response can reduce detectability and may ultimately limit the viable population size that the area can support.

Second, the biophysical conditions of Tegallega, characterized by relatively steep topography and fragmented canopy structure, further constrain habitat suitability. Such landscape features hinder arboreal movement, as Javan surili rely heavily on continuous canopy connectivity for both foraging and predator avoidance. Canopy fragmentation also reduces the availability and spatial distribution of key food trees, which are essential energy sources for Javan surili. Additionally, intensified edge effects resulting from fragmentation and repeated disturbance may further degrade overall habitat quality, particularly for arboreal primates (Atmoko et al. 2021). Javan surili are generally classified as edge-avoiding specialists, given their specific habitat requirements and folivorous diet, which typically limit their use of edge habitats (Mardiastuti 2018). However, they retain some degree of adaptive capacity, as evidenced by their ability to persist in areas near human settlements under certain conditions (Kusumanegara et al. 2017). Overall, the population density observed in both Tegallega and Sarongge suggests that the current habitat remains functionally viable. Nevertheless, ongoing anthropogenic pressure poses a significant risk of future demographic decline, highlighting the need for proactive conservation strategies to ensure long-term population persistence.

Activity of Javan surili

The observations indicate that feeding, locomotion, resting, and social activities of Javan surili in both resorts are conducted entirely in an arboreal context and are distributed across multiple vertical strata, particularly the mid- to upper-canopy layers (Strata B-C). This pattern is consistent with findings in other colobine primates, such as *P. thomasi*, which predominantly performs activities at heights of 8-15 m (Ruskhanidar 2021), and *P. chrysomelas chrysomelas*, which more frequently used stratum C (21-30 m) for feeding, resting, moving, and socializing (Nur-Aizatul et al. 2025). This vertical use pattern aligns with the ecological characteristics of Javan surili as arboreal folivorous primates, which rely heavily on forest vertical structure to facilitate movement, food access, and protection from predators and disturbance (Supriatna and Ramadhan 2016; Nijman 2017). High vegetation density, greater species diversity, and abundant food availability are positively associated with more intensive vertical space use compared to horizontal space use (Musyaffa and Santoso 2020). *M. eminii* is recognized as one of the primary food tree species for primates, including surili. However, this species is classified as an invasive plant, and its presence may pose a significant threat to native and endemic tree species, such as saninten *C. argentea* within TNGGP (Noer et al. 2025).

In their daily activities, Javan surili preferentially select trees with large trunks and complex branching structures, particularly those exhibiting *cook's architecture* (umbrella-shaped branching) and *Leeuwenberg's architecture* (upward-narrowing branching). Increased canopy connectivity between trees facilitates movement and enhances foraging efficiency. Movement between trees is also influenced by the need to avoid predators and to secure safe resting sites. The preferred canopy height for activity ranges between 10-24 m, typically occurring in areas with moderately steep to steep slopes, as reported in previous studies (Kusumanegara et al. 2017).

Javan surili exhibit an efficient locomotor mechanism characterized by arboreal quadrupedalism, involving running and leaping between branches or across trees. The maximum recorded leap distance reaches approximately 10-12 m (Napier and Napier 1967). This locomotor strategy is facilitated by the structural properties of the mid-canopy layer, which is dominated by robust and interconnected branches, providing a stable and continuous substrate for movement. In contrast, locomotion in the lower strata is less prominent due to the limited availability of adequate supporting branches. Locomotor behavior in arboreal primates, unlike that of most terrestrial vertebrates, is fundamentally shaped by two key ecological priorities: foraging efficiency and predator avoidance (Santosa et al. 2020). This pattern is consistent with other species within the genus *Presbytis*, such as *P. chrysomelas cruciger*, which similarly spend the majority of their daily activity cycle within the arboreal environment (Musyaffa and Santoso 2020).

Resting activity, predominantly concentrated in the mid- to upper-canopy strata, reflects an adaptive ecological strategy aimed at minimizing disturbance while maximizing security. Elevated canopy positions provide a significant visual advantage, enabling individuals to detect predators and human activity below without obstruction. This enhanced visibility is a crucial component of collective vigilance mechanisms within the group. Javan surili typically engage in resting periods during the morning and late afternoon, occurring before and after peak foraging activity. Resting behavior is also strongly influenced by climatic conditions. As ambient temperature increases, the frequency of resting behavior also rises, suggesting a functional role in thermoregulation to prevent overheating (Korsthens et al. 2010). Additionally, individuals tend to rest during heavy rainfall, likely as an energy-conservation strategy and to avoid exposure to wet conditions that may induce hypothermia (Sha et al. 2020).

This resting pattern further indicates a behavioral adaptation linked to the prolonged digestive processes required by a folivorous diet, while simultaneously reducing exposure to terrestrial risks. Folivorous primates inherently exhibit lower activity levels compared to frugivorous species, reflecting an energy-conservation strategy associated with the digestion of high-fiber, low-quality food resources (Sayers 2013; Ganzhorn et al. 2017; Lauer et al. 2025). From a physiological perspective, the digestive system of Javan surili, as a large-bodied primate, functions similarly to that of other monogastric mammals with simple stomachs, where digestive enzymes are secreted from the stomach into the intestines to break down complex food into simpler forms that can be absorbed in the lower digestive tract (Saha and Pathak 2021).

Microbial fermentation of ingested food occurs prior to the action of gastric digestive enzymes (Matsuda et al. 2019). This digestive strategy is characteristic of colobine primates and is closely associated with dietary preferences. For instance, *P. rubicunda* demonstrates selective feeding behavior by preferentially consuming young leaves, which contain higher levels of digestible protein and lower crude fat content compared to seeds (Hanya and Bernard 2015). Essential organic and inorganic nutrients required for physiological functioning include proteins, fats, carbohydrates, water, minerals, and vitamins. These nutrients are fundamental to maintaining vital biological processes, and their absence severely compromises physiological performance. Undigested food residues and partially digested microbial matter are eventually excreted through the rectum as feces (Saha and Pathak 2021). Therefore, consistent dietary intake is crucial for sustaining integrated physiological systems that support survival, growth, development, and reproduction.

Social behaviors such as nursing, play, and grooming were also observed in Javan surili. These activities generally occur during resting periods, indicating a temporal overlap between energy conservation and social interaction. Nursing behavior is typically observed within the mid-canopy stratum, where sufficient canopy density provides structural protection for both mother and infant from external disturbances. The selection of this microhabitat reflects a prioritization of security and comfort, ensuring optimal protection for offspring. Play behavior is primarily exhibited by juvenile individuals, involving dynamic movements such as leaping and physical interactions, including pulling on the limbs of adult individuals while positioned on tree branches. This behavior, which is generally restricted to immature individuals, plays a critical role in the development of motor skills and social competence, and does not directly correlate with overall group size (Lehmann et al. 2007).

Grooming behavior (both auto-grooming and allogrooming) was observed across all canopy strata, from lower to upper levels, and is performed by adult individuals as well as between group members. Beyond its role in body maintenance, grooming serves a crucial function in reinforcing social bonds and group cohesion. In small-bodied and small-group primates such as Javan surili, allogrooming is particularly important in maintaining cooperative dynamics and relational stability, especially under conditions of external disturbance (Lehmann et al. 2007).

The activity patterns of Javan surili clearly reflect an optimized ecological strategy aimed at balancing multiple functional demands, including efficient access to food resources, adequate protection from predators, and energy efficiency during arboreal movement (Thiel et al. 2021; Dharma et al. 2024). Studies on arboreal primates in Southeast Asia consistently demonstrate that the mid- and upper-canopy strata function as critical ecological zones. These strata support the availability of young leaves, fruits, and flowers, which constitute the primary dietary components, while simultaneously providing substantial and stable branches that facilitate safe locomotion and reduce the risk of falling (Nur-Aizatul et al. 2025). As arboreal forest-dwelling primates, Javan surili also play an essential functional ecological role as seed dispersers. Through their movement patterns and feeding activities, they directly influence the spatial dynamics of tree regeneration and the overall composition of forest vegetation. This ecological function underscores the importance of maintaining viable Javan surili populations, as their presence contributes significantly to sustaining ecological processes and the structural integrity of forest ecosystems (McLean et al. 2016; Supriatna 2019; Thiel et al. 2021).

Strategic conservation implications for the Javan surili

The conservation of the Javan surili on Java Island holds high relevance for other Colobinae primate species facing similar ecological pressures across Southeast Asia, such as the challenges confronting *Trachypithecus delacouri* in Vietnam or *Pygathrix nemaeus* in Laos. In those species, habitat fragmentation and anthropogenic disturbance are also identified as major threats limiting population survival (Estrada et al. 2018). Therefore, the successful implementation of strategies to mitigate anthropogenic threats, manage edge habitats, and strengthen community involvement in Java can be replicated and adapted to support broader regional conservation efforts.

The small population size of the Javan surili at both observation sites necessitates conservation efforts focused on preventing the loss of adult individuals, especially the single male who holds a central role in the unimale reproductive system. Key strategies include maintaining and restoring functional ecological corridors between Sarongge and Tegallega Resorts to ensure gene flow. Continuously monitoring the sex ratio and natality rate to track reproductive potential and the population's ability to survive and reproduce over a very long period (population viability). Anthropogenic pressure remains the primary ecological threat to the Javan surili population's survival in GGPNP. Although both Tegallega and Sarongge Resorts are protected areas, nearby human activities like agriculture, poaching, and tourism directly affect the Javan surili behavior, habitat use patterns, and long-term viability (Sha et al. 2022).

Poaching poses a major threat in Tegallega Resort, evidenced by hunters, air rifles, and hunting dogs. Although targeting other wildlife, these activities disturb Javan surili through noise and human presence, triggering frequent flight responses (Supartono 2016; Avenzora et al. 2024). This chronic disturbance reduces foraging efficiency, alters movement patterns, reinforces avoidance behavior, and creates a fear ecology that restricts home range and disrupts daily activities. Persistent anthropogenic pressure can fragment populations and reduce reproductive success, especially when repeated disturbance stresses pregnant or lactating females and lowers offspring survival. Therefore, stronger law enforcement and anti-poaching measures, including forest patrols and thermal drone monitoring, are essential.

Management strategies must be applied to edge zones (forest-agriculture boundaries and river edges) to reduce human-wildlife conflict, including with Javan surili. Minimizing disturbance in the edge zone will allow Javan surili to consistently utilize available food resources without being exposed to security risks. Thus, it is necessary to plant a buffer zone using thorny hedges (*Bougainvillea*), pucuk merah (*Syzygium oleina*) or lidah mertua (*Sansevieria* sp.) to impede direct contact, as well as planting teak trees with tough leaves. This strategy aims to gently steer Javan surili back toward the forest by ensuring their movement pathways are uncomfortable (due to thorns).

Tourism and recreational activities are a significant form of indirect anthropogenic disturbance. In other zones within GGPNP, such as Cibodas Resort, research has documented behavioral changes in Javan surili in response to ecotourism, including increased vigilance and avoidance of frequently used human trails (Avenzora et al. 2024). Although Tegallega and Sarongge Resorts currently have a lower frequency of visits, interest in nature tourism in this area shows an increasing trend. Without careful visitor management and strict enforcement of behavioral guidelines, a surge in visitors could potentially mimic the disturbance levels seen in Cibodas. Even non-consumptive forms of disturbance like photography, shouting, or exploring off-trail areas can substantially increase primate stress levels and cause displacement from primary habitat or foraging zones, negatively impacting individual foraging efficiency and energy allocation.

Primate conservation, especially for the Javan surili, is highly dependent on community engagement strategies. Integrating programs like the LCFPs into ecological surveys reflects the significant potential of participatory monitoring programs. This collaborative approach is designed to achieve dual benefits: i) ensures long-term data collection on population and habitat characteristics at a low operational cost, while building local technical capacity in biodiversity management; and ii) conflict mitigation and stewardship reinforcement: strengthens the community's sense of stewardship over the conservation area, directly impacting the reduction of poaching pressure and anthropogenic threats (Danielsen et al. 2014; McKay and Johnson 2017; Khair et al. 2021; Avenzora et al. 2024).

This approach is expected to effectively reduce human-wildlife conflict, especially when conservation programs are integrated with alternative economic initiatives, such as ecotourism or community empowerment in collaboration with universities. Such participatory and collaborative conservation approaches must be expanded and implemented throughout GGPNP to support long-term monitoring and ensure the sustainable conservation viability of the Javan surili population. Habitat and keystone resource protection must prioritize the key tree species (*L. excelsa*, *C. argentea*, and *S. wallichii*), which are proven vital for Javan surili feeding, resting, and social activities. The canopy quality and structural connectivity in the middle and upper stratum must be maintained. Canopy fragmentation (especially in Tegallega) must be minimized as it hinders arboreal movement and reduces the primate's foraging efficiency and self-defense capabilities. Furthermore, there is a need to plant these three keystone trees for regeneration, which can increase the number of food trees in the future. Tree planting activities should involve various stakeholders, including GGPNP management, local communities, conservation activists, students, and universities, thereby strengthening and encouraging all parties to protect the habitat and foster a collective sense of care to ensure the Javan surili remains conserved in its natural habitat.

In conclusion, a total of 10 groups comprising 40 individuals were recorded, with 25 individuals in Tegallega (6 groups) and 15 individuals in Sarongge (4 groups). Group structure showed a typical unimale polygynous system, with female-biased sex ratios of 1:1.25 in Tegallega and 1:1.13 in Sarongge, indicating stable reproductive potential. Population density was higher in Sarongge (5.99 ind/km², 2.14 groups/km², estimated 66 individuals) compared to Tegallega (3.03 ind/km², 1.33 groups/km², estimated 53 individuals), suggesting more concentrated space use and better habitat conditions. Behavioral observations revealed that feeding was the dominant activity (52.00% in Tegallega, 42.86% in Sarongge), followed by resting (21.33%, 27.14%), locomotion (14.67%, 15.71%), and social interactions (12.00%, 14.29%). All activities occurred exclusively in arboreal strata, with a strong preference for the mid-canopy layer (stratum C), which supported the highest number of plant species used for feeding and other activities. Key tree species such as *C. argentea*, *L. excelsa*, and *S. wallichii* played essential roles in sustaining daily activities. These findings highlight the importance of habitat structure, particularly canopy connectivity and key food resources, in shaping Javan surili population and behavior. Differences between sites emphasize the influence of anthropogenic pressure and habitat heterogeneity, underscoring the need for targeted conservation strategies to maintain viable populations.

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