ACTA
VETERINARIA
INDONESIANA

Vol. 14, No. 1: 72-81, March 2026
DOI : 10.29244/yvq9ma51
P-ISSN 2337-3202, E-ISSN 2337-4373

Research Article

OPEN ACCESS

Zoo-Based Study: Daily Activities of Müller's Gibbon (*Hylobates muelleri*) and Javan Langur (*Trachypithecus auratus*) in Yogyakarta, Indonesia

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Article history:
Received: 25 November 2025
Revised : 3 February 2026
Accepted: 20 February 2026

Keywords:
daily activities
captive primates
Hylobates muelleri
Trachypithecus auratus
Gembira Loka Zoo

ABSTRACT

Background: Understanding the daily activities of primates in captivity is essential to evaluate behavioral patterns and support proper zoo management. Differences in species, age, sex, time of day, and management conditions may influence activity budgets and welfare outcomes.

Aims: This study aimed to analyze the daily activities of Müller's Gibbon (*Hylobates muelleri*) and Javan langur (*Trachypithecus auratus*) living in a zoo and to compare intraspecies and interspecies variations, including age and sex classes.

Methods: Behavioral observations were conducted using the scan sampling method at 1-minute intervals. Statistical analyses included t-tests and nonparametric tests to assess differences within species and between species. Comparisons were also made based on age-sex classes, time of day (morning and afternoon), and day type (weekdays and weekends).

Results: Comparisons between the two species indicated significant differences in resting, feeding, moving, and social activities. Müller's Gibbon showed the highest duration in moving activities. Within Müller's Gibbon, differences were observed in resting, moving, feeding, and social activities among age-sex classes. In Javan langurs, significant differences were found in all activities. Morning and afternoon comparisons predominantly revealed significant differences. Within-species comparisons between weekdays and weekends showed significant differences in resting behavior in Javan langurs. Furthermore, interspecies comparisons reveal significant differences in feeding, moving, and social behavior.

Conclusion: This study identified variances in daily activities within and between species. These findings provide important information for management adjustments to better align captive behaviors with natural patterns and support animal welfare in zoo environments.

INTRODUCTION

The significant contribution of zoos to the conservation of endangered species has been widely acknowledged (Fa et al., 2014). The concept of animal captivity is primarily aimed at safeguarding species from extinction. This practice seeks to establish new populations while implementing husbandry techniques that preserve natural behaviors in their native habitats (Britt, 1998). Significant elements of captive management include feeding, social grouping, and housing management, all of which consider the behavior and welfare of the animals involved. Animal welfare pertains to the natural conditions that define an animal, which elucidate the quality of life of the individual animal (Bracke et al., 1999; Michael et al., 2011). The physical environment, health, nutrition,

naturalistic behavior, reproduction, and mental state of animals are essential for fulfilling the conservation mission.

Animal behavior signifies the adaptation to various internal and external conditions. It is defined as an animal's active and consistent response to stimuli (Blackshaw & Wash, 1986). However, the evaluation of behavior aids in identifying how these factors impact primates, such as heightened stress or modified activity due to the presence of visitors, restricted spaces, and being managed (Hosey, 2005; Roth & Cords, 2020; De la Barrera Cardozo et al., 2021; Hosey et al., 2023). Alternatively, conducting behavior studies in zoological institutions can really make a meaningful contribution to both fundamental and applied research, encompassing areas such as physiology and health, thereby enhancing the welfare of both captive and wild animals (McEwen et al., 2022; Edes, 2023). Comparing captive and wild behaviors reveals captivity's effects and guides zoo improvements (Robbins & Sheridan, 2021).

In the present study, we have observed Müller's Gibbon and Javan Langur, which are classified under the families Hylobatidae and Cercopithecidae, respectively. The Müller's Gibbon (*Hylobates muelleri* Martin 1841) is globally classified as an Endangered species by the IUCN. It faces threats primarily from habitat loss attributed to the expansion of agricultural plantations, clear-felling for timber, and, to a lesser degree, selective logging (Marshall et al., 2020). Conversely, the Javan langur (*Trachypithecus auratus* E. Geoffroy Saint-Hilaire, 1812) was classified as vulnerable due to a persistent decline in the population of this langur, which is a result of capture for the illegal pet trade, hunting for sustenance, as well as continuous habitat loss (Nijman, 2021).

In contrast, the two animal studies were physiologically different. Müller's gibbons have a simple digestive tract suited for fruit-eating (frugivore) (McConkey et al., 2002). Javan langurs possess a multi-chambered stomach specialized for leaf digestion, along with comparatively small incisors (Fleagle, 2013), and they have shorter limbs that are adapted for less acrobatic movement than those of Müller's gibbons. The behavioral differences observed in the daily activities of the study animals may be compared with those of wild animals to evaluate their similarities. In the future, this research may provide recommendations for management adjustments that align the behaviors of each animal in captivity with their wild counterparts, thereby enhancing animal welfare in captive environments. This study compared the daily activities of both animals, categorized by morning and afternoon, during weekdays and weekends.

MATERIALS AND METHODS

Study Cite

The study is located at Gembira Loka Zoo in Yogyakarta City, Indonesia. It covers 22 hectares (54 acres) and is a significant ex-situ conservation site in Central Java. Notably, it has a collection of native Indonesian fauna. The primate enclosures are situated within a study site shaded by several large, overhanging trees surrounding the area.

Animals and Data Collection

The study involved eight individuals comprising two primate species: the Javan langur (*Trachypithecus auratus*) and (*Hylobates muelleri*). The Javan langur group consisted of six individuals, including two adult males, two adult females, one juvenile male, and one juvenile female. In contrast, Müller's gibbon group comprised only two adult individuals, one male and one female, separated in each cage.

This study used observational, non-invasive methods; therefore, formal ethical approval from an Institutional Animal Care and Use Committee was not required under local regulations. No direct physical contact occurred between the researchers and the animals, nor were there any experimental manipulations of the animals' diet, social structure, or captivity environment. All data collection was performed at a visitor's viewing distance (5m) to minimize stress, in accordance with strict habituation protocols. Permission to conduct the study was granted by the management of Gembira Loka Zoo, and all procedures complied with the institution's internal animal welfare guidelines. Habituation protocols were implemented to familiarize (Samuni et al., 2014) and memorize (Turk-Browne et al., 2008; Hanson & Riley 2018) the animals with the observer's presence and vice versa. We maintained a consistent position near the cage, wearing the same attire. The enclosure provides a resting area for each individual, food and drink containers, and enrichment features such as logs, rope, and tires.

We identify each animal based on physical features like body and facial coloration. Daily activities observations were conducted using scan sampling, with recording and instantaneous techniques (Martin & Bateson, 1986). We recorded the activity of each individual in 1-minute time intervals, considering the high mobility of the study animals. The activities categorization was based on an ethogram in Table 2,

which was classified into: (1) resting, (2) feeding, (3) social, (4) moving, and (5) foraging. Additionally, there were two recording sessions (morning and afternoon), at 8 am-12 pm and 1 pm -4 pm, respectively. In total, 7 hours a day. The research used a watch, writing tools, and a camera to document animal activities. The study was conducted over 70 days, including 10 days of habituation and 60 days (n=60) of observation, amounting to 480 hours from March 28 to June 6, 2022.

Data Analysis

Recorded data were prepared in Microsoft Excel (Microsoft, USA). Focused on quantifying the frequency and duration of the animal's activities, provides insight into the daily activity patterns within the captive enclosure. Therefore, the percentage duration of activities was calculated as follows:

$$\%\ activities = \left(\frac{duration\ of\ activities\ X}{total\ observation\ time} \right) . 100 \ldots\ldots \quad (1)$$

The *X* represents each activity (Eq. 1). Statistical differences between age groups and sexes include intraspecies and interspecies was compared by t-tests (and nonparametric tests). Results were considered statistically significant using the *p*-value, denoted as follows: $p > 0.05$ was considered not significant (ns), $p \leq 0.05$ (*), $p \leq 0.01$ (**), $p \leq 0.001$ (***), and $p \leq 0.0001$ (****). These annotations were used to indicate the degree of statistical significance in pairwise comparisons across groups' activity durations, as generated and processed by GraphPad Prism 10 (GraphPad, USA).

RESULTS AND DISCUSSION

Comparison of the Daily Activities Patterns

Resting was the predominant activity for both species, followed by moving and feeding (Fig. 1A). However, statistical analysis revealed significant inter-species differences in time allocation for resting, feeding, moving, and social activities ($p < 0.05$), with foraging being the only exception. Müller's gibbons exhibited significantly higher movement rates compared to Javan langurs, consistent with their energetic locomotor style, whereas Javan langurs allocated a greater portion of their budget to feeding.

Age-Sex Class Variations

Significant behavioral variations were observed across age-sex classes in Müller's gibbons. Adult females allocated significantly more time to resting ($p = 0.01$) and moving ($p = 0.02$) compared to males. Conversely, adult males dedicated a greater percentage of time to feeding ($p = 0.006$) and social activities ($p < 0.0001$). Foraging behavior did not differ significantly between the sexes.

Table 1. Daily activity ethogram of Javan langur and Müller's gibbon

Activity	Description
Resting (Res)	Sitting, reclining, and sleeping on the logs or flat surface, with eyes closed or open
Feeding (Fed)	Taking food, carrying, putting food into the mouth, chewing, drinking from a bowl, and rejecting food
Social (Soc)	Interact with each other, including: Auto-grooming and allo-grooming: licking, nibbling, or picking through the fur. Agonistics: fighting, chasing, biting, and clawing. Tense, bared teeth, threatening faces. Playing: Non-aggressive, play faces or relaxed open mouth, exaggerated movements, play invitations, mimicry, not aimed to injure. Vocalization: the individual produces sounds with their mouth, like calls. These may serve as greeting calls, disturbing calls, and communication between individuals (calling).
Moving (Mov)	Moving quadrupedally, leaping over a log or on the ground (Javan langur) Bipedal walking, brachiating, or climbing (Müller's gibbon)
Foraging (For)	Searching, sorting, locating, and collecting food

Age-sex class comparisons in Javan langurs revealed distinct developmental patterns (Fig. 1B). Juveniles spent significantly less time resting than adults but allocated a greater proportion of their time to moving and feeding. Specifically, juveniles were the most active demographic, showing higher engagement in social play and movement, while foraging rates remained low across all groups (0.5%–1.22%). Social activity in adult females and foraging across classes showed no statistically significant variance.

Resting Behavior and Physiological Implications

While both species exhibited high resting budgets (>50%), aligning with previous studies on Müller's gibbon (Suryabroto & Yulianto, 2019; Saputra & Rayadin, 2020) and Javan langur (Fitriyani & Purba, 2023), the postural behaviors differed markedly, reflecting distinct physiological needs. Müller's Gibbons consistently utilized elevated positions, predominantly adopting a sitting posture or sleeping. This high resting budget supports energy conservation and thermoregulation (Pontzer et al., 2010; Campbell et al., 2018).

Javan Langurs showed a marked increase in movement during morning hours, particularly among juveniles. Unlike the gibbons, langurs rarely exhibited quadrupedal walking. In captivity, langurs tend to be less active than their wild counterparts due to spatial limitations and the absence of foraging pressures for food availability. To mitigate obesity risks associated with the lower activity levels of Javan langurs, particularly in adults, feeding enrichment such as placing browse at opposite ends of the enclosure should be spatially distributed to encourage active foraging and movement.

Locomotion and Environmental Constraints

Müller's Gibbons exhibited four primary behaviors: brachiating, climbing, jumping (ricocheting), and bipedal walking. Brachiation was the most frequent mode, facilitated by a larger cerebellum relative to other apes, which aids balance and coordination (Butler & Suddendorf, 2014; Barlett, 2007). Although movement was limited by the captive environment, activity budgets (~28.95%) remained comparable to wild populations (~23–48%) (Inoue et al., 2016). Management strategies must address species-specific locomotor needs to ensure physical health. For Müller's gibbons, enclosures require vertical complexity, including ropes and flexible poles, to facilitate natural brachiation and prevent muscle atrophy.

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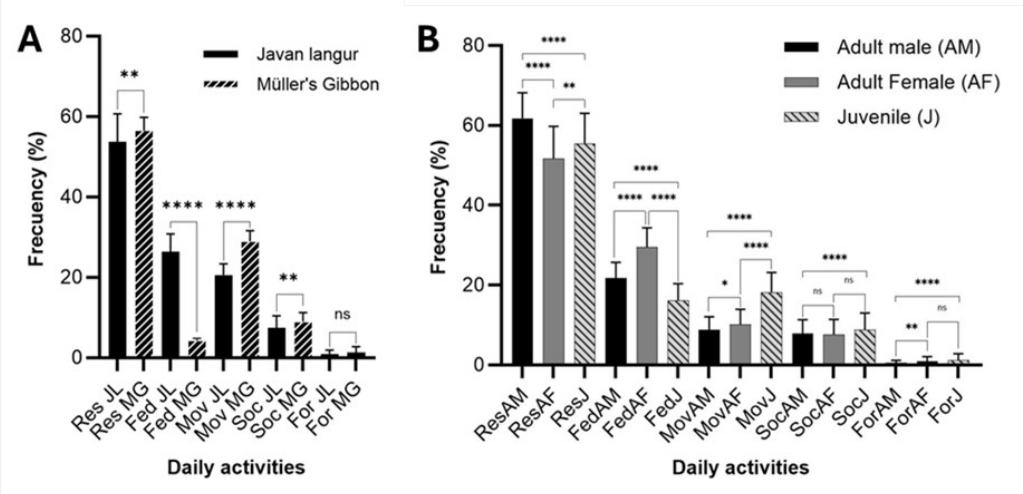

Figure 1. Daily activities of the Javan langur (JL) and Müller's gibbon (MG). (A) Percentage of daily activities (n=60). (B) comparisons of daily activities by age-sex classes in Javan langur. Asterisks show significant differences between means. ns = not significantly different.

should be spatially distributed to encourage active foraging and movement.

Feeding Strategies and Dietary Adaptations

Feeding behaviors in both species highlighted clear anatomical adaptations and social hierarchies regarding food access. Gibbons preferred high-energy items like bananas and corn over foliage. This preference correlates with their dental morphology, sharp, spatulate incisors and low-cusped molars, ideal for processing soft, fleshy fruits rather than fibrous leaves (McConkey et al., 2003). Leaves were consumed mainly as dietary bulk when preferred foods were scarce. Feeding was often followed by

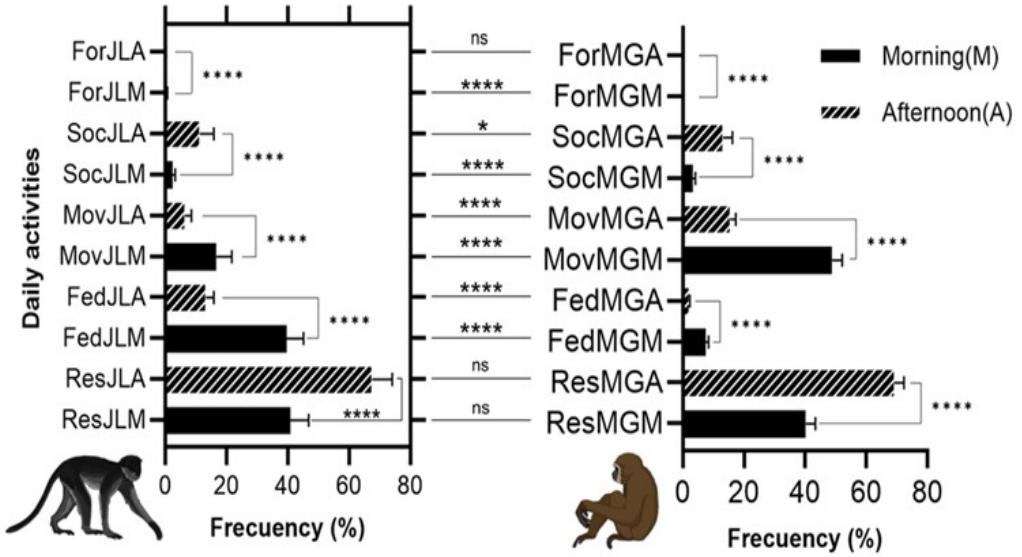

Figure 2. Comparisons of daily activities within and between species in the morning (8-12 am) and afternoon (1 pm-4 pm). Asterisks indicate significant differences between means. ns = not significantly different.

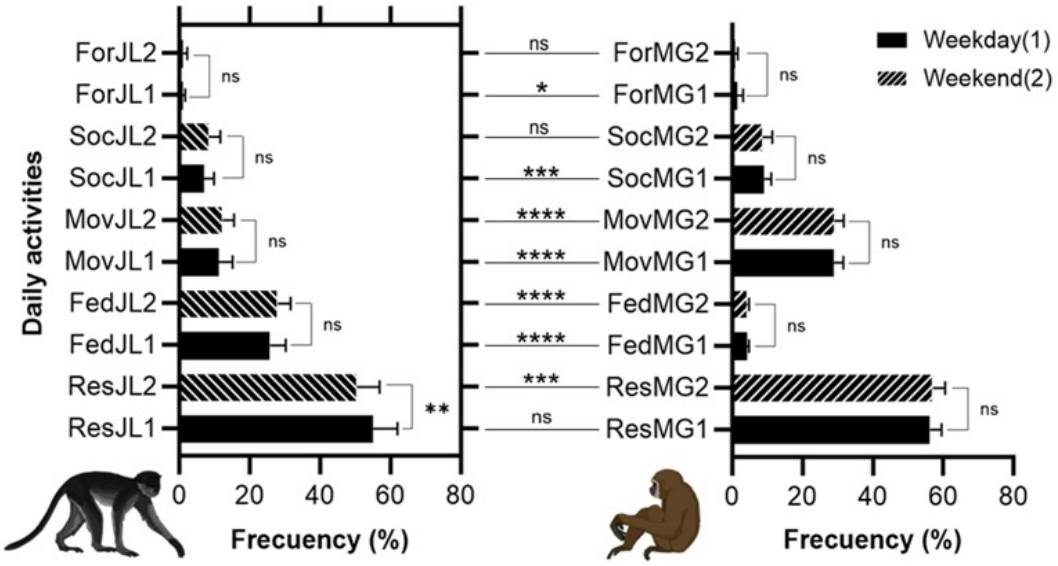

Figure 3. Comparisons of daily activities within and between species on weekdays (Monday to Friday) and weekends (Saturday and Sunday). JL = Javan langur, MG = Müller's gibbon, asterisks indicate significant differences between means, ns = not significantly different.

climbing to the upper cage strata to consume food, a behavior likely driven by competition or safety.

In contrast, Javan langurs are adapted to a folivorous diet. While the zoo diet was predominantly fruit/vegetable-based (92%), leaves were a favored food source, with adult females consuming up to 43.27% of them (Purba et al., 2024). Their multi-chambered, tripartite stomach supports foregut fermentation, allowing efficient digestion of fibrous material via gut microbes (Bauchop & Martucci, 1968; Chivers, 1994; Matsuda et al., 2019). The provision of sugary foods in captivity must be monitored, as avoiding high-sugar items in the wild helps prevent systemic acidosis (Bauchop & Martucci, 1968; Sutherland-Smith et al., 1998). Management should aim to increase the browse (leaf) proportion of the diet to match wild behaviors (where leaves constitute ~50%) and reduce readily available sugars.

Foraging accounted for <2% of activity but revealed important natural behaviors. Javan langurs utilized enrichment (soil and logs) to engage in geophagy (soil consumption). This behavior is critical for mineral supplementation, pH regulation, and detoxification of plant secondary compounds, such as tannins and alkaloids (Matsuda et al., 2020; Behie et al., 2022). A critical finding is the extremely low foraging time (<2%) compared to wild primates. The rapid consumption of nutrient-dense food leads to extended periods of inactivity. To improve welfare, food presentation should be altered to increase handling time.

Social Interactions and Vocalization

Social dynamics differed significantly between the species, driven by their distinct social structures. The Javan Langurs' social activity was defined largely by grooming, particularly adult females grooming infants, which reinforces group cohesion (Napier & Napier, 1985). The high grooming rates in females indicate that social housing is non-negotiable for the psychological health of this species. Agonistic behaviors (chasing, biting, threat displays) were observed exclusively among adult males, often triggered by food competition. Juveniles engaged in

Figure 4. Captive Müller's gibbon and Javan langur in Gembira Loka Zoo. (a) resting Müller gibbon, (a) Hanging Müller gibbon, (c) resting, (d) feeding, (e) grooming, (f) locomotion of Javan langur.

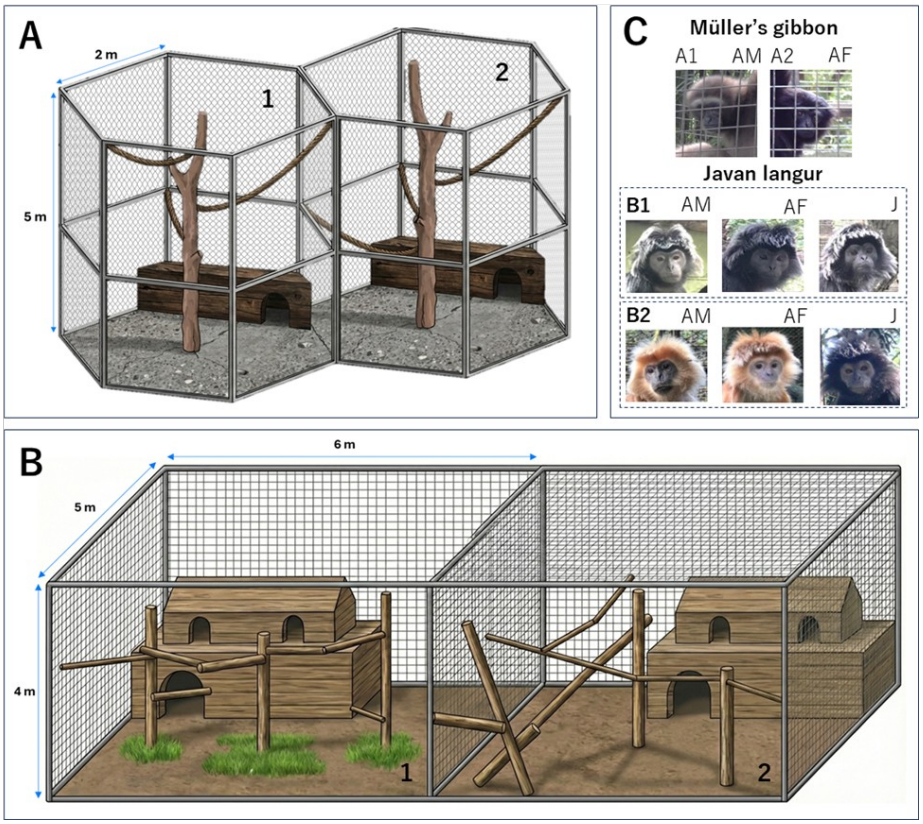

Figure 5. Illustrations of captivity for Müller's gibbons (A) and Javan langurs (B). Group composition and location of Müller's gibbons and Javan langurs at Gembira Loka Zoo (C). Adult male (AM), adult female (AF), Juvenile (J). Panels B and C are modified from Purba et al., 2024.

play (wrestling, chasing) to develop motor skills and predator evasion tactics (Spinka et al., 2001).

Social behavior in gibbons was dominated by vocalization rather than physical grooming. Males engaged in solo calls and duets with females, typically in the mornings. These loud, long bouts serve multiple functions: marking territory, strengthening pair bonds, and signaling conflict (Geissmann & Nijman, 2000; Geissmann & Orgeldinger, 2000; Geissman et al., 2005). Unlike the langurs, physical agonism was rare, with conflict managed through vocal signaling. The presence of regular morning calls and duets is a positive indicator of well-being and pair stability. A cessation of calling could indicate stress or illness and require further evaluation.

Study Limitation

Several limitations should be acknowledged to ensure a clear interpretation of these findings. First, the sample size was small and uneven, consisting of only two Müller's gibbons compared to six Javan langurs. Due to this imbalance, statistical comparisons between species should be viewed with caution; it is more important to focus on the biological meaning of the observed behaviors rather than on statistical significance alone. Additionally, this study did not account for seasonal changes or the potential influence of zoo visitors on daily activity levels. Consequently, these results should be interpreted as an assessment of specific captive management conditions rather than a direct reflection of wild population dynamics.

CONCLUSION

This study demonstrates that the daily activity budgets of Müller's gibbons and Javan langurs are shaped by distinct physiological and locomotor adaptations, necessitating species-specific captive management strategies. To optimize welfare, Müller's gibbons require vertical structural enrichment specifically ropes and flexible poles to facilitate natural

brachiation and prevent atrophy. Conversely, management of Javan langurs must prioritize dietary regulation and spatial distribution of feeding to mitigate obesity risks and social aggression. Future research should focus on quantifying the visitor effect on activity patterns, particularly for Javan langurs, and validating gibbon vocalization rates as a non-invasive indicator of psychological health. Ultimately, aligning zoo environments with these specific biological needs is essential for enhancing ex situ conservation standards.

ACKNOWLEDGEMENT

The authors thank the staff of Gembira Loka Zoo for their technical support of this research. AI image generation: Nano Banana Pro (Gemini 3 Pro Image, January 2026) was used to enhance the 3D visualization of PowerPoint-based enclosure illustrations shown in Figures 5A and 5B. The authors verified all illustrations for design accuracy.

AUTHORS CONTRIBUTION

J.F.A. and F.E.K.P. contributed equally to data collection, data analysis, and drafting of the manuscript. L.H.P.S.P. supervised the study and contributed to the study design and data interpretation. All authors contributed to the writing of the manuscript and approved the final version.

"The author declares that there is no conflict of interest with the parties involved in this research".

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