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Still Frugivorous: Temporal Feeding Behavior and Food Composition of Müller's Gibbon (*Hylobates muelleri*) in a Zoo Environment

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Abstract: *Understanding feeding behavior in captive primates is important for improving ex-situ conservation and animal welfare management. This study analyzed the feeding duration and food composition of captive Müller's gibbons (Hylobates muelleri) at Gembira Loka Zoo, Yogyakarta, Indonesia. Observations were conducted for 60 days using scan sampling at 1-minute intervals on one adult male and one adult female. Feeding duration for each food category was quantified and analyzed descriptively, while differences between individuals were evaluated using the Mann–Whitney test. Fruits constituted the largest proportion of the diet for both individuals. Adult males spent 60% of feeding duration consuming fruits, 15% tubers, and 17% leaves, whereas adult females spent 79% consuming fruits, 14% tubers, and 7% leaves. Statistical analysis indicated no significant difference in feeding duration between individuals. The findings demonstrate that captive feeding practices generally reflect the frugivorous tendencies of Müller's gibbons observed in natural habitats. This study contributes preliminary information for improving dietary management, ex-situ conservation strategies, and contextual biology learning related to animal behavior and conservation.*

Keywords: *Feeding behavior; Captive primate; Hylobates muelleri; Gembira Loka Zoo.*

1. INTRODUCTION

Zoos play an important role in protecting endangered species by maintaining healthy populations and studying their needs (Melfi et al., 2020). Three key aspects of animal care in zoos are feeding practices, social group arrangements, and habitat design, all of which help maintain animal health and welfare (Anderson, 2014). Understanding what animals eat, when they eat, and how much time they spend feeding provides important information for creating better management plans that meet both their nutritional needs and behavioral requirements.

The Müller's gibbon (*Hylobates muelleri* Martin 1841) is listed as Endangered by the IUCN because its populations are declining. The main threats include habitat loss from farming expansion, logging, and forest destruction (Marshall et al., 2020). Like other gibbon species, Müller's gibbons eat mainly fruits and show different feeding behaviors between males and females. They also play an important role in forests by spreading seeds (Clink et al., 2017; Pang et al., 2022). To conserve this species effectively, we need information from both wild and captive populations. Zoo environments should provide food that matches their natural diet and allows them to behave naturally, which supports their health and breeding success (Ning et al., 2019; Naher et al., 2021). Detailed records of feeding patterns in zoos therefore help improve conservation programs.

Although many studies have examined gibbon feeding behavior in wild habitats, less is known about how captive Müller's gibbons feed, especially in Indonesian zoos. Previous research

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has mainly described what gibbon species eat in general (Kim et al., 2010; Ning et al., 2019) or studied wild populations (Clink et al., 2017). However, few studies have measured how much time individual gibbons spend eating different foods or compared feeding patterns between males and females in captive settings. No previous study has systematically measured feeding time for male and female Müller's gibbons in zoos. This information is important for improving zoo feeding practices and ensuring that captive gibbons can maintain natural feeding behaviors.

This study fills these gaps by measuring feeding duration and food types for captive Müller's gibbons in a zoo environment. We used systematic observations over 60 days to: (1) record what foods were provided and how often, (2) measure how much time males and females spent eating different food types (fruits, tubers, and leaves), and (3) compare these feeding patterns with what has been reported for wild populations. These results are important for developing better feeding plans for captive gibbons and supporting conservation efforts.

2. MATERIAL AND METHOD

Study Cite

The research was conducted at Gembira Loka Zoo (GLZ), located in Yogyakarta City, Indonesia. It serves as a crucial ex-situ conservation area in Central Java, featuring a diverse range of native Indonesian wildlife. The site is distinguished by numerous large trees that encircle the animals in captivity, as illustrated in Figure 1. The enclosure offers a designated resting area for each individual, along with containers for food and drink and enrichment elements such as logs and ropes.

Animals and Data Collection

The study involved two individuals of Müller's gibbon: one adult male and one adult female. The habituation process was undertaken before conducting observations. This habituation phase was implemented for ten days at the commencement of the study to enable the observed subject to acclimate to the presence of the observer, and reciprocally. The habituation involved maintaining a stationary position near the enclosure. Employing the same inconspicuous attire throughout the habituation made it easier for the animals to recognize and remember the observer.

The study was conducted over 70 days, including 10 days of habituation followed by 60 days of observation (n=60), totaling 480 observation hours from March 28 to June 6, 2022. Each individual's activity was monitored using scan sampling at one-minute intervals from a distance greater than 5 meters (Purba et al., 2024). Observations were carried out in two daily sessions, from 08:00 to 12:00 and from 13:00 to 16:00, resulting in seven observation hours per day. A watch was used to keep time, while writing tools and a camera were used to record and document animal activities. Additionally, this study adhered strictly to non-invasive, observational protocols involving no direct physical contact or experimental manipulation. Consequently, institutional ethical approval was waived in accordance with local regulations.

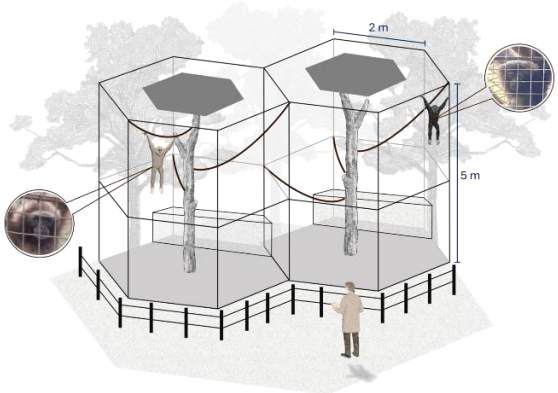


Figure 1. Illustration of a captive Müller's gibbon and observer position in Gembira Loka Zoo. Left: adult male, right: adult female.

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Data Analysis

The recorded data were organized in Microsoft Excel (Microsoft, USA). The focus was on quantifying the frequency and duration of the animal's feeding activities, which provides insights into the activity patterns within the captive enclosure. Feeding activities of the animals are defined by the length of each feed, expressed as a percentage. Consequently, the feeding duration percentage for each feed is calculated as follows:

$$(\%) = \frac{duration\ of\ feed\ A}{total\ observation\ time} x\ 100$$

The *A* represents each feeding duration of the feed. Given the small sample size (n=2, one male and one female) and the non-normal distribution expected from behavioral data, a nonparametric Mann-Whitney U test was employed to compare feeding durations between sexes. The significance level was set at $p < 0.05$. GraphPad Prism 10 (GraphPad, USA) was used to perform all statistical analyses. Due to the limited sample size, results are presented primarily as descriptive observations with statistical tests used as supplementary indicators of potential patterns that warrant further investigation with larger sample sizes.

3. RESULTS AND DISCUSSION

Food Composition

The nutrition department at GLZ establishes the food composition for Müller's gibbon with the approval of the veterinarian responsible for the animals. This is done after observing individual food preferences and the animals' natural diets. Every morning at 8:00 a.m., the keeper distributes food to each cage after cleaning them, and the animals receive it between 8:30 and 9:30 a.m.

The food composition of Müller's gibbon provided by Gembira Loka Zoo consists of fruits (67%), leaves (20%), and tubers (13%). The type of food was then classified based on frequency over 60 days, as shown in Table 1, which lists 15 items. Feeding frequency was categorized as: (1) always, meaning food was provided every day for 60 days (100%), including banana, corn, carrot, tomato, cucumber, and banyan; (2) often, indicating food was given between 75-95% of the days, such as snake fruit, green beans, celery, and bok choy; and (3) rarely, meaning food was provided less than 75% of the days, including guava, sweet potato, apple, orange, and pear.

Feeding Duration

The feeding behaviour of Müller's Gibbon can be observed by calculating the feeding duration of each type of food given. Male had a slightly longer total feeding duration than female. Adult male consumed fruits 60% of the time, tubers 15%, and leaves 17%. In contrast, adult female ate fruits 79% of the time, tubers 14%, and leaves 7%. No statistically significant differences were detected, as indicated by the Mann-Whitney test ($p > 0.05$). Additionally, the percentage corresponding to each food item is shown in Figure 2.

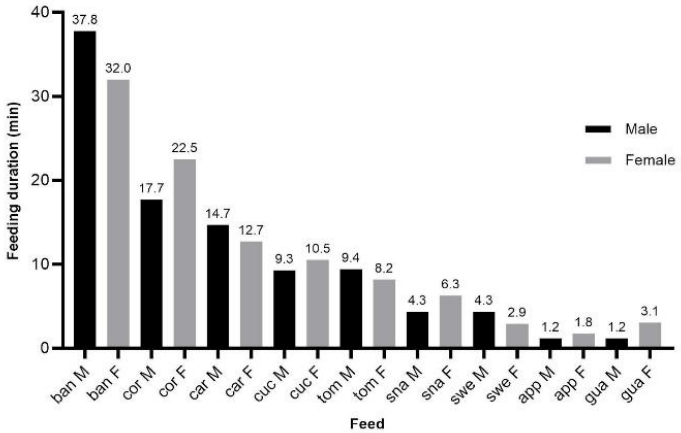


Figure 2. Feeding duration of captive Müller's gibbon in Gembira Loka Zoo. (ban) banana, (cor) corn, (car) carrot, (cuc) cucumber, (tom) tomato, (sna) snake fruit, (swe) sweet potato, (app) apple, (gua) guava.

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Although statistical differences were not detected, the observed variation in feeding duration between male and female individuals may reflect differences in energetic requirements, behavioral preference, or feeding strategy. Female gibbons showed a higher proportion of fruit consumption, which may indicate stronger preference toward high-energy food resources. In primates, fruit selection is commonly associated with caloric optimization because ripe fruits contain higher concentrations of carbohydrates and simple sugars compared to fibrous vegetation (Uwimbabazi et al., 2021; Fuh et al., 2022; Martins et al., 2022). Meanwhile, the relatively higher proportion of leaves consumed by males may indicate greater dietary flexibility under captive feeding conditions. Such variation suggests that even within managed environments, individual feeding strategies may still emerge in response to food availability and preference.

Discussion

Müller's gibbons are primarily frugivorous, with fruits comprising approximately 67% of their diet, alongside leaves and other sources. Consistent with other gibbon species, they preferentially consume ripe, energy-rich fruits, which directly supports their vital ecological role as seed dispersers (Kim et al., 2010; Ning et al., 2019; Mishra & Saudagar, 2024; Wijayanti et al., 2023). At Gembira Loka Zoo, the feeding pattern of Müller's gibbons reflects this natural tendency, with approximately 67% of the diet consisting of fruits, indicating that their preferences remain largely consistent with those observed in the wild (Kim et al., 2010).

The observed sex-specific differences in feeding duration, while not statistically significant, suggest potential behavioral variations that warrant consideration. The male's higher consumption of leaves (17% vs. 7%) may reflect different energy requirements or foraging strategies. In wild gibbon populations, sex-specific dietary differences have been linked to body size dimorphism and reproductive energy demands (Ni et al., 2015). Although Müller's gibbons exhibit minimal sexual dimorphism, the captive environment may amplify subtle behavioral differences by eliminating competitive foraging pressures present in wild populations.

Critically, our findings contrast with some wild population studies where leaf consumption can reach 30-40% during fruit scarcity periods (Ni et al., 2013). The relatively low leaf consumption in our captive population (7-17%) likely reflects the consistent availability of preferred fruits in zoo settings, eliminating the need for fallback foods. This highlights a fundamental difference between captive and wild feeding ecology: while wild gibbons must adapt to seasonal resource fluctuations, captive populations receive predictable, human-mediated diets that may reduce natural dietary flexibility.

Categorizing feeding frequency as always, often, and rarely helps identify the preferred food items of Müller's gibbons. Fruits such as bananas were frequently consumed, indicating reliance on accessible and palatable resources. This pattern is consistent with wild gibbons, whose food choices are strongly influenced by food type and availability (Ni et al., 2015). Seasonal fluctuations in fruit production may also contribute to dietary variation, as observed in natural habitats (Ni et al., 2013). The categorization of feeding frequency reveals a preference hierarchy that aligns with palatability and energy content. However, this pattern also raises questions about optimal diet composition in captivity. While bananas constituted a large portion of consumed fruits, their nutritional profile differs significantly from wild tropical fruits. Previous research suggests that reliance on cultivated fruits may not fully replicate the nutritional complexity of wild diets, particularly regarding micronutrient and fiber content (Zhang & Zang, 2018).

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Table 1. Food composition and feeding frequency of Müller's Gibbon

Local Name (parts eaten)	Scientific Name	Feeding freq. (%)
Banana (a)	*Musa paradisiaca* L.	100
Corn (a)	*Zea mays*	100
Carrot (b)	*Daucus carota*	100
Tomato (a)	*Solanum lycopersicum*	100
Cucumber (a)	*Cucumis sativus*	100
Banyan (c)	*Ficus benjamina*	100
Snakefruit (a)	*Salacca zalacca*	95
Celery (c)	*Apium graveolens* L.	90
Green beans (1)	*Vigna unguiculata*	88,3
Bok choy (c)	*Brassica rapa*	75
Guava (a)	*Psidium guajava*	68.3
Sweet potato (b)	*Ipomoea batatas*	60
Apple (a)	*Malus domestica*	56.6
Orange (a)	*Citrus*, sp.	50
Pear (a)	*Pyrus*, sp.	16.67

Note: (a) fruits, (b) tubers, (c) leaves

The occasional rejection of vegetables (celery, bok choy) observed in our study may indicate either individual taste preferences or insufficient habituation to these food items. Vegetables such as celery and bok choy appeared to be less preferred, as these items were occasionally left uneaten in the cage overnight. This finding contrasts with studies showing successful integration of diverse vegetables in captive diets when introduced gradually during early development (Wijayanti et al., 2023). The reluctance to consume certain vegetables may also reflect differences in sensory perception or learned food preferences shaped by early feeding experiences. Taste differences are also known to influence primate feeding behaviour and preferences (Feng et al., 2024). Reviewing such items may help optimize diet composition by prioritizing nutritionally suitable foods that are more readily consumed, potentially reducing feed wastage.

The results also suggest behavioural flexibility when preferred foods are limited. In such situations, gibbons may consume alternative items such as guava or sweet potato, which are generally more fibrous and lower in energy. This adjustment reflects natural foraging strategies and highlights the importance of providing a varied diet that supports health and species-typical behaviour in managed care (Anderson, 2014; Fan et al., 2015).

Species within the genera Hylobates, Symphalangus, and Nomascus are primarily frugivorous, relying heavily on ripe fruits due to their high energy content (Tamrin et al., 2020). Similarly, *Hylobates moloch* shows a strong preference for fruits, with leaves consumed depending on seasonal availability (Kim et al., 2010; Kim et al., 2012). In tropical rainforest habitats where Hylobates species occur, diet composition can vary widely depending on local ecological conditions. For instance, *Hylobates agilis* shows a strong reliance on figs, indicating habitat-driven fruit preferences (Pang et al., 2022). Similarly, wild gibbons such as *Hylobates lar* and *Hylobates muelleri* consume a range of fruits and supplement their diet with foliage when fruit availability declines, demonstrating dietary flexibility that supports survival in fluctuating environments (Marcé-Nogué et al., 2017; Choi et al., 2023). Studies also highlight the dietary diversity of gibbons and their ecological role as seed dispersers, which contributes to forest regeneration and biodiversity (Clink et al., 2017). Their diets in the wild are largely frugivorous, with composition influenced by seasonal changes and habitat-specific resource availability (Kim et al., 2012; Marcé-Nogué et al., 2017).

This behavioral pattern aligns with previous zoo-based observations of Müller's gibbons in Yogyakarta, which noted that ex-situ environments and human-mediated feeding schedules significantly shape their daily activity patterns (Apitalau et al., 2026). However, the structured feeding system in managed care, which includes fruits, vegetables, and alternative food items, may reduce some of the dietary variability normally encountered in natural habitats and can influence aspects of foraging behaviour and social interactions (Choi et al., 2023).

Overall, the feeding practices support the ecological and nutritional requirements of Müller's gibbons. Because diet is closely linked to health and reproductive success, integrating ecological knowledge into captive management is important. Providing a balanced and varied diet can help maintain natural feeding tendencies while supporting animal welfare, conservation

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goals, and educational efforts in ex situ settings (Mishra & Saudagar, 2024; Zhang & Zang, 2018).

This study provides valuable educational implications for biology instruction in Indonesia by serving as a localized contextual learning resource and empirical case study for ecology, animal behavior, and conservation biology curricula. By utilizing the quantitative data on primate diets and ex-situ management, educators can demonstrate to students how scientific observation supports evidence-based wildlife conservation. Additionally, the paper's scan sampling methodology and statistical framework offer a practical training example for teaching field research methods, effectively bridging the gap between theoretical biology and real-world ecological research.

4. CONCLUSION

The study indicates that the feeding practices meet Müller's gibbons' ecological and nutritional requirements. Fruits constitute the majority of their diet, followed by tubers and leaves. These findings highlight the importance of providing a balanced and varied diet in captivity that reflects natural feeding behaviors. Incorporating ecological knowledge into zoo feeding practices is essential to maintain the health and overall well-being of gibbons, thereby supporting long-term conservation goals and enhancing public education efforts.

5. STUDY LIMITATION

The small sample size (two individuals) limited statistical analysis; therefore, the results are presented descriptively and should be interpreted as preliminary observations.

6. ACKNOWLEDGEMENTS

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