Bio-Lectura: Jurnal Pendidikan Biologi,
Vol. 10, No. 1, April 2024, 41-56

EXPLORING THE FEEDING PATTERNS OF SIAMANGS: BEHAVIOR AND FOOD PREFERENCES IN ZOO ENVIRONMENTS AND THEIR CONTRIBUTION TO BIOLOGY EDUCATION

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ABSTRACT

The siamang (*Symphalangus syndactylus*), an endemic primate of Indonesia, is critically endangered due to hunting and habitat destruction and is now predominantly found in conservation areas. This study aims to analyze the feeding behavior and food preferences of siamangs in the zoo, evaluate the suitability of the ex-situ diet composition compared to their natural diet, and assess its contribution to biology education. The research methods included 480 hours of feeding behaviour observation using scan sampling, descriptive data analysis, and Pearson correlation tests. The results indicate that the siamang's diet in zoos is dominated by fruit (53.88% for males and 56.38% for females), followed by leaves and supplementary foods such as tubers and biscuits. The dietary composition is similar to studies conducted in their natural habitat, although the variety of zoo food is more limited. Adjustments to the feeding menu, such as hanging food at elevated locations and increasing the variety of local fruits, could support the siamangs' natural feeding behaviours. In conclusion, the feeding patterns of siamangs in zoos largely align with their natural behaviour as frugivores, although improvements in feeding methods and dietary variety are needed. The implications of this study emphasize the importance of aligning ex-situ conditions with natural habitats to support animal welfare and conservation programs while also strengthening the role of zoos as centres for education and biodiversity preservation.

ARTICLE HISTORY

Received 14 January 2025
Revised 08 April 2025
Accepted 24 April 2025

KEYWORDS

Siamang,
Feed Composition,
Feeding Behavior,
Feeding Preferences,
Zoo

Introduction

The siamang (*Symphalangus syndactylus*) is one of Indonesia's endemic primate species whose existence is endangered due to hunting and the destruction of its natural habitat (Hankinson et al., 2021). This species is listed as *Endangered* on the International Union for Conservation of Nature (IUCN) Red List and is protected by various international regulations, such as CITES Appendix I (Rasyid et al., 2024). Its population is predominantly found in conservation areas on Sumatra Island and some Southeast Asian regions. As an arboreal primate, the siamang exhibits unique feeding behaviours that are vital for its survival and contribute to ecosystem regeneration through seed dispersal (McConkey, 2018). However, in

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ISSN 2339-241X (print/ISSN) 2598-2427 (online ISSN)

ex-situ conservation settings, such as zoos, the primary challenge is ensuring that the diet aligns with its biological needs to maintain the animal's welfare.

Providing an appropriate diet poses a significant challenge in ex-situ conservation, particularly for species with specific dietary preferences like the siamang. Siamangs consume various fruits, young leaves, and insects in their natural habitat (Adyn et al., 2022; Harrison et al., 2021). However, in conservation settings, the limited availability of natural food sources often leads to dietary changes that may disrupt the siamang's nutritional balance and natural behavior (Sherwen & Hemsworth, 2019). Moreover, comprehensive studies on the feeding behaviour of siamangs in ex-situ environments are still scarce, creating an information gap that could impact the success of conservation strategies for this species.

The issue that often arises, particularly in relation to public education efforts—especially biology education for children and the general public (*citizen science*)—is the evolving role of zoos. Zoos are no longer merely places of entertainment or animal exhibitions; they now function as centers for learning that allow people to directly engage with biodiversity. In this context, the feeding behavior of siamang can serve as a highly effective educational tool for introducing fundamental biological concepts such as adaptation, ecology, food chains, and ecosystem balance (Jensen, 2013; Zakaria & Hua, 2024). By presenting accurate and engaging information about the siamang's dietary habits, children can learn about the importance of species conservation through meaningful, firsthand experiences. This knowledge not only fosters early conservation awareness but also encourages empathy towards other living beings, which is a crucial foundation for environmental character education.

By observing feeding behaviour and analyzing the suitability of the provided diet with their natural diet, this study aims to produce practical guidelines for animal management in ex-situ conservation environments. This approach is relevant for zoos and can be applied in similar conservation settings to enhance the effectiveness of siamang conservation and overall animal welfare. The study is based on animal behaviour theory, emphasizing the importance of understanding feeding patterns as a fundamental aspect of animal ecology (Kymäläinen et al., 2021). As Dugatkin (2019) noted, animal behaviour is influenced by internal and external factors, including food availability. As frugivorous and folivorous primates, Siamangs have a complex feeding pattern highly dependent on nutritional availability (Adyn et al., 2022). The animal welfare theory, particularly the Five Freedoms principle, also underpins the design of feeding strategies that support the physiological and psychological needs of siamangs in conservation environments (Davey, 2006; Keeling et al., 2019). Through this research on the dietary composition of siamangs in zoos, significant contributions are made to the development of evidence-based dietary management guidelines. By examining the alignment between the provided food and their natural preferences, this study offers practical solutions to enhance animal welfare and support the overall success of ex-situ conservation. This approach benefits not only zoo managers but also educators, as it can serve as a concrete example in contextual and applied biology learning.

This study shares some similarities with previous research. For instance, similar to the study by Asyi et al. (2022), this research focuses on siamang behaviour, particularly feeding behaviour. However, the scope of daily behaviour in Asyi et al.'s study is broader. Both Ningsih et al. (2023) and Asyi et al. (2022), this study highlight the importance of siamang conservation in Sumatra as a preservation effort, although this study emphasizes diet management in ex-situ conservation. Meanwhile, Dewi et al. (2023) share similarities with this study in examining feeding behaviour and dietary preferences of siamangs in ex-situ conservation, including dietary adjustments resembling their natural habitat to support siamang welfare.

This study differs from Asyi et al. (2022), which primarily focuses on the daily behaviour of siamangs, whereas this research concentrates on feeding behaviour and dietary preferences. The focus of Ningsih et al. (2023) is the distribution patterns of siamangs in their natural habitat, while this study was conducted in an ex-situ conservation setting and does not discuss population distribution. Unlike Dewi et al. (2023), this study does not statistically analyze differences in feeding behaviour based on age or gender. Instead, it emphasizes the suitability of dietary composition with their natural habitat. Additionally, this research provides detailed information on the proportion of nutritional components (fruits, leaves, tubers) in the feeding patterns of adult male and female siamangs.

This study aims to analyze the feeding behavior and food preferences of siamangs in a zoo setting and to assess the compatibility of the provided diet with their natural food sources, as well as its contribution to biology education. The research offers new insights by examining the compatibility between the diet of siamangs in captivity and their natural diet in the wild. Unlike previous studies, which mainly focused on daily behavior, distribution patterns, or specific food preferences, this study demonstrates that the frugivorous feeding behavior of siamangs remains consistent with their natural characteristics, even in ex-situ conservation environments.This information is crucial for optimizing ex-situ conservation efforts, particularly in providing appropriate diets to support the welfare and sustainability of siamangs. The uniqueness of this study lies in its contribution not only to conservation science and wildlife management but also to biology education—especially for children and the general public. In the context of biology education, siamangs can serve as a real-life example for teaching about biodiversity, tropical ecology, animal adaptation, and the importance of ecosystem balance. The findings of this study are expected to provide practical contributions for zoo managers in designing more effective and efficient feeding strategies, while also offering new insights for primate conservation research. Furthermore, this study aims to enhance animal welfare in ex-situ conservation environments, support the sustainability of the siamang species, and promote broader biodiversity conservation efforts. By integrating science, conservation, and education, we not only work to preserve species like the siamang but also help shape future generations to be more environmentally conscious, animal-loving, and scientifically literate.

Methods

This study was conducted over approximately 480 hours of observation. The research location was at Gembira Loka Zoo (GLZ), at Jl. Kebun Raya No. 2, Rejowinangun, Kotagede District, Yogyakarta City, Special Region of Yogyakarta. The objects of observation were a population of Siamangs (*Symphalangus syndactylus*) consisting of one adult male and one adult female. The tools used included writing instruments, a camera, and a timer.

Procedure

Habituation and Identification

Before starting the observation of feeding behaviour, habituation was carried out using the ad libitum sampling method to familiarize the subjects with the observer's presence and vice versa. During habituation, the observer stood in the exact location near the enclosure and wore consistent and non-flashy clothing, as recommended by Hanson and Riley (2018). Individual identification was based on physical characteristics such as body size, body hair colour, facial hair colour, and morphological defects. Additional information was obtained from the keepers, and relevant references were used to support identification, including records of food composition and consumed parts (Farida et al., 2019; Herdian et al., 2020).

Feeding Behavior Observation

Feeding behaviour was observed daily from 08:00 AM to 04:00 PM WIB. At GLZ, food for the Siamangs was provided once in the old enclosure and twice in the new enclosure, with varying times in the morning and afternoon. The food, prepared by the GLZ nutrition team, included fruit with the skin intact and was given after the keeper arrived at the enclosure. Observations were conducted using the scan and instantaneous sampling methods at one-minute intervals, as recommended by Martin & Bateson (1986). The chewing duration for each type of food was also recorded (Riptianingsih et al., 2015).

Data Analysis

Data analysis was performed descriptively and quantitatively. The percentage of feeding behaviour duration for each type of food was calculated using the formula:

$$\% \text{ Types of Feed} = \frac{x}{y} \times 100\%$$

Where X is the duration of specific behaviour, and Y is the total duration of behavioural observation (Altmann, 1974). The data were then processed using Microsoft Excel, and the results were descriptively compared between the male and female individuals. Pearson's correlation test, with a significance level of 0.05, was also performed to assess the relationship between the feeding behaviour of Siamangs at GLZ and in their natural habitat. Statistical analysis was conducted using IBM SPSS Version 25.

Results

Individual Identification

The siamang population (*Symphalangus syndactylus*) at Gembira Loka Zoo (GLZ) used as the subject of this research consisted of two individuals: one adult male and one adult female (Table 1). The siamangs at GLZ were obtained due to a confiscation carried out by Yogyakarta's Natural Resources Conservation Agency (BKSDA). Both siamangs observed were in healthy condition and are currently undergoing a breeding program managed by GLZ. Siamangs are social animals that live in groups in their natural habitat, typically consisting of a family group made up of an adult male and female pair and up to four offspring (Gittins & Raemaekers, 1980).

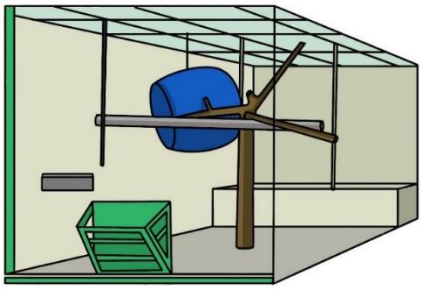
Table 1. Identification of Siamangs at Gembira Loka Zoo Yogyakarta

Sex	Age Category	Physical Characteristics	Images
Male	Adult (± 9 years)	Weight ± 11 kg, tall and large body, dark black and neat fur, elongated (oval-shaped) face with flat hair on the head.	

Female	Adult (± 15 years)	Weight ± 9 kg, black and coarse fur (clumped in the lower arm area), round face, and a defect on the left-hand index finger.	

Condition of Enclosure

During the observation period, the two Siamang individuals were housed in a single enclosure in two separate areas. Their previous enclosure was next to the Bornean Orangutan (*Pongo pygmaeus*) enclosure, located behind and above the Sumatran Elephant (*Elephas maximus sumatranus*) enclosure. The primates in this area were not included as display animals in the Gembira Loka Zoo. The siamang enclosure measured approximately 2.5 meters in length, 4 meters in width, and 2.5 meters in height (Figure 1). Walls bordered the enclosure's sides and back, while the roof's front and half were made of iron pipes and wire mesh. The front section of the enclosure was equipped with a feeding station made of iron plates, while the siamang's drinking container was made of aluminium. The siamang enclosure was directly adjacent to two other enclosures, one of which served as a temporary activity area for the siamang during cleaning by the keeper. Additional components were provided in the siamang enclosure, including wooden logs, iron pipes, climbing ropes, rubber, and a hanging plastic drum, which served as areas for locomotion and resting.



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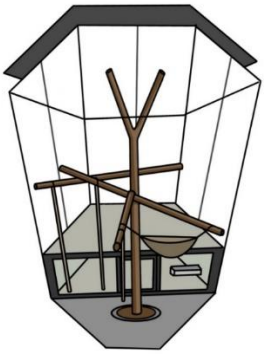

(2)

Figure 1. Illustration of the Interior of the Siamang Enclosure at Gembira Loka Zoo; Old Enclosure (1), New Enclosure (2)

The siamangs were relocated to the Gibbon (*Family Hylobatidae*) area during the second month of observation. The enclosure is hexagonal, made of iron wire mesh, with approximate dimensions of 3 m in length, 3 m in width, and 5 m in height (Figure 1). The roof is covered with a canopy. Inside the display enclosure is a smaller cage serving as a sleeping area for the siamangs, measuring approximately 3 m in length, 1 m in width, and 2 m in height. The siamangs are released from the sleeping cage in the morning and returned in the evening after the visitors have left. The feeding area is located inside the sleeping cage. The water container for the siamangs is a box made of aluminium. The enclosure has additional components such as tree branches, rope, and burlap sacks used as hammocks. These enrichment facilities inside the enclosure improve the success of conservation efforts for the animals (Nugroho & Ihsan, 2013).

Siamang Feeding Behavior

The feeding behaviour of the siamangs at Gembira Loka Zoo includes selecting food, plucking fruit or leaf stalks, bringing them close, and inserting them into their mouths. This behaviour aligns with similar studies, stating that feeding begins with placing food in the mouth, chewing, and swallowing (O'Brien & Kinnaird, 1997). However, a notable difference observed is that the siamangs occasionally sit on the floor while eating since the feeding area is at the bottom of the enclosure. Nonetheless, they spend more time eating on branches or hanging from the iron mesh and ropes. This does not fully comply with one of the animal welfare principles (Veissier et al., 2021), which states that animals should be free to express natural behaviours. Therefore, Gembira Loka Zoo should consider revising feeding methods, such as hanging food or water above the enclosure or placing them on branches inside. Typically, the siamangs begin their feeding activities in the morning after waking up. The observed siamangs were likely only able to consume leftover food from the previous day before being provided with fresh daily food. In the previous enclosure, feeding was conducted once daily in the morning or afternoon between 9:00 and 11:00 AM. However, after being moved to the Gibbon area enclosure, feeding was conducted twice daily: from 8:00 to 10:00 AM and 3:30 PM. The feeding duration decreases toward the afternoon as the siamangs rest more. According to Tiyawati (2015), feeding should be conducted earlier, around 6:00 AM, to maintain the siamangs' natural feeding behaviour. The siamang diet at Gembira Loka Zoo consists of primary and supplementary foods. Additionally, the food types are categorized based on feeding frequency over 60 days: (1) Always: 60 days, (2) Often: <60 days, and (3) Rarely: <15 days. Based on the frequency of each food type provided, the composition of the siamangs' diet at GLZ consists of fruits (57.14%), leaves (23.81%), and tubers (14.29%) as primary foods. In comparison, the supplementary food includes specialized primate biscuits (4.76%) (Table 2).

Table 2. Feeding Frequency of Siamangs at Gembira Loka Zoo

Local Name	Species	Family	Frequency (days)	Frequency (%)
Tomat (1)	*Solanum lycopersicum*	Solanaceae	60	100
Cucumber (1)	*Cucumis sativus*	Cucurbitaceae	60	100
Carrot (3)	*Daucus carota*	Apiaceae	60	100
Pakcoy (2)	*Brassica rapa*	Brassicaceae	60	100
Corn (1)	*Zea mays*	Poaceae	60	100
Long Bean (1)	*Vigna unguiculata*	Fabaceae	60	100
Celery (2)	*Apium graveolens*	Apiaceae	60	100
Banyan (2)	*Ficus benjamina*	Moraceae	39	65
Sweet Potato (3)	*Ipomoea batatas*	Convolvulaceae	26	43,33
Orange (1)	*Citrus sinensis*	Rutaceae	24	40
Banana (1)	*Musa paradisiaca*	Musaceae	20	33,33
Jamaican Cherry (2)	*Muntingia calabura*	Mutingiceae	19	31,67
Radish (3)	*Raphamus sativus*	Cruciferae	8	13,33
Bitter Melon (1)	*Momordica charantia*	Cucurbitaceae	6	10
Pepaya (2)	*Carica papaya*	Caricaceae	5	10
Melon (1)	*Cucumis melo*	Cucurbitaceae	4	6,67
Papaya (1)	*Carica papaya*	Caricaceae	3	5
Pear (1)	*Pyrus pyrifolia*	Rosaceae	3	5
Primate Biscuits (4)	-	-	2	3,33

Water Apple (1)	*Syzygium aqueum*	Myrtaceae	1	1,67
Grape (1)	*Vitis vinifera*	Vitaceae	1	1,67
Notes: (1) Fruits, (2) Leaves, (3) Tubers, (4) Others				

Siamang feeding behaviour can be determined based on the duration spent consuming each type of food. Male siamangs spend more time than females in all food groups except fruits. Out of 21 types of food provided, there is no significant difference in food preferences between adult male and adult female siamangs. Both individuals consume fruits the most, followed by leaves, with tubers being the least consumed (Table 3). This is consistent with Rosyid (2007), who stated that ripe fruits are the leading preferred food of siamangs in the wild.

Table 3. Composition of Siamang Diet Based on Feeding Duration at Gembira Loka Zoo

Food Type	Adult Male		Adult Female	
	Feeding Duration (minutes)	Percentage (%)	Feeding Duration (minutes)	Percentage (%)
Fruits	2130	53,88%	2086	56,38%
Leav	1353	34,23%	1195	32,30%
Tubers	446	11,28%	405	10,95%
Others	24	0,61%	14	0,38%
Total	3953	100%	3700	100%

The dietary preferences of the siamangs were determined based on the top 10 food types consumed with the highest feeding durations. Both siamangs share similarities in their top 10 food preferences, differing only in the order of feeding durations from highest to lowest. Both individuals spent the most time consuming corn (*Zea mays*), which is categorized as a fruit. The top 10 food types include 5 types of fruits, 4 types of leaves, and 1 type of tuber (Figure 2). For the male siamang, the top 10 food types by feeding duration were corn, fig leaves, long beans, carrots, cucumbers, jamaica cherry leaves, celery, and oranges. Meanwhile, for the female siamang, the top food types started with corn, followed by fig leaves, long beans, carrots, cucumbers, jamaica cherry leaves, celery leaves, oranges, pak choi leaves, and tomatoes. The fruits consumed by the siamangs are generally visually appealing and have flavors that are enjoyable, sweet, sour, or mildly astringent (Atmanto et al., 2014).

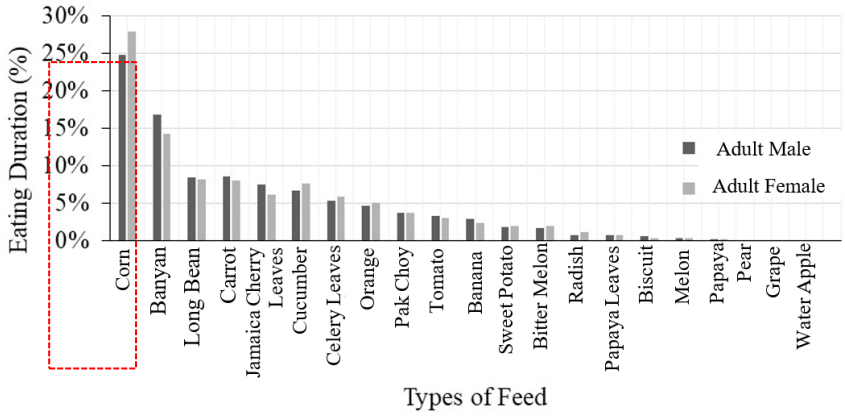

Figure 2. Percentage of feeding duration for adult male and female siamang at Gembira Loka Zoo

The feeding preferences of Siamang at Gembira Loka Zoo can be observed through the relationship between feeding frequency and eating duration for each individual. The high consumption of certain food types correlates with the frequency at which they are provided. However, other types of food that are not regularly offered are often finished by the Siamang, including bananas, sweet potatoes, bitter melon, melons, papayas, pears, grapes, and water apples. According to Tiyawati (2015), the first type of feed chosen by male Siamang is bananas, while female Siamang prefers vegetables or leaves at Taman Agro Satwa dan Wisata Bumo Kedaton (TASWBK).

Based on feeding duration, male Siamang consumed more banyan leaves, long beans, carrots, jamaica cherry leaves, pakcoy, tomatoes, bananas, biscuits, melons, and pears compared to female Siamang. Meanwhile, female Siamang consumed more corn, cucumbers, celery leaves, oranges, sweet potatoes, bitter melon, radishes, papayas, pears, and water apples than males. Papaya leaves were the type of feed with similar feeding durations for both male and female Siamang. There was no significant difference in feeding duration for each type of feed between adult male and female Siamang. When the keeper provides feed, both Siamang individuals typically run or swing closer to the feeding spot and compete to grab fruits first, such as bananas, sweet potatoes, tomatoes, cucumbers, carrots, corn, and bitter melon. The Siamang will then consume other types of feed when they feel hungry again. The differences in feeding preferences between captive male and female Siamang are presumed to be influenced by their previous feeding patterns, daily behaviours, and physiological factors (Clink et al., 2017). In this context, the differences in feeding duration for Siamang at Gembira Loka Zoo are caused by one individual consuming most of the feed.

Comparison of Siamang Feeding Behavior at Gembira Loka Zoo and in the Wild

Animal welfare is defined as efforts to adjust the environmental conditions for animals to improve their psychological and physiological well-being (Nurhayati et al., 2018). Feeding can be one of the methods used to ensure the welfare of zoo animals since feeding is a vital activity for their survival. The suitability of feed for wild Siamang can be adopted as the feed provided to Siamang at Gembira Loka Zoo. Based on feeding duration, the composition of the feed consumed by Siamang at Gembira Loka Zoo consists of fruit: 53.88% (male), 56.38% (female); leaves: 34.23% (male), 32.30% (female); and others: 11.89% (male), 11.33% (female). The "other" feed category includes tubers and supplementary feeds since these are not part of the Siamang's natural diet and are grouped into the same category. Several references were used to determine the composition of Siamang feed in their natural habitat (Table 4).

Table 4. Composition of Siamang Diet in Their Natural Habitat Based on Food Consumption

Feed Composition (%)				Location	Reference
Fruit	Leaves	Flowers	Others		
Symphalangus syndactylus					
63	48	5	6	Ulu Sempam, Malaysia	(Chivers, 1974)
63	31,4	0,4	4,5	Krau Wildlife Reserve,Kuala Lompat	(MacKinnon & MacKinnon, 1980)
61	17	1	21	Krau Wildlife Reserve, Kuala Lompat	(Raemaekers, 1977)
56	32	12	0	Way Canguk, Taman Nasional Bukit Barisan Selatan	(Lappan, 2005)

63	25	12	0,1	Way Canguk, Taman Nasional Bukit Barisan Selatan	(Nurcahyono, 2001)
36	43	6	15	Ketambe, Sumatera Utara	(Ryne Arthur Palombit, 1992)

The Pearson Correlation test was conducted by comparing the diet of siamangs in Gembira Loka Zoo (GLZ) with several research references from siamangs' natural habitats (Table 5). The results indicate that the diet composition of siamangs in GLZ shows similarities with some of the references used. For adult male individuals, the diet composition has a significant correlation with the diet composition reported in studies by Chivers (1974) and MacKinnon & MacKinnon (1980), with $P<0.05$. Meanwhile, for adult female individuals, the diet composition has a very significant correlation with the composition reported by MacKinnon & MacKinnon ($P<0.01$) and a significant correlation with the composition from Chivers' study ($P<0.05$). These findings reveal that siamangs in GLZ and their natural habitats share similar feeding preferences, primarily consuming fruits and leaves. However, no similarities were found between the types of fruits provided in GLZ and their natural diet. It was noted, however, that siamangs tend to prefer fruits with appealing colours and flavours, including sweet, sour, and astringent tastes, as well as varying sizes (Atmanto et al., 2014). While siamangs are frugivores, they also consume leaves in the wild. Among the diet types provided, only one type of food in GLZ shares the same genus as their natural diet, namely Ficus. In certain conditions, small primates such as gibbons also consume insects and young leaves as a complement to their fruit-dominated diet (Ryne Arthur Palombit, 1992; Raemaekers, 1977; Whitten, 1982). The management of Gembira Loka Zoo should reevaluate the feeding menu to ensure that the siamangs' feeding behaviour in GLZ remains consistent with their natural behaviour.

Table 5. Pearson Correlation Analysis of the Comparison of Siamang Diet Composition

Correlations

		(Chivers, 1974)	(MacKinnon & MacKinnon, 1980)	(Raemaekers, 1977)	Lappan (2005)	(Nurcahyono, 2001)	(Ryne Arthur Palombit, 1992)	Adult Male	Adult Female
(Chivers, 1974)	Pearson Correlation	1	.967*	.770	.955*	.901	.911	.972*	.964*
	Sig. (2-tailed)		.033	.230	.045	.099	.089	.028	.036
	N	4	4	4	4	4	4	4	4
(MacKinnon & MacKinnon, 1980)	Pearson Correlation	.967*	1	.899	.966*	.961*	.799	.983*	.990**
	Sig. (2-tailed)	.033		.101	.034	.039	.201	.017	.010
	N	4	4	4	4	4	4	4	4
(Raemaekers, 1977)	Pearson Correlation	.770	.899	1	.784	.852	.562	.884	.908
	Sig. (2-tailed)	.230	.101		.216	.148	.438	.116	.092
	N	4	4	4	4	4	4	4	4
(Lappan, 2005)	Pearson Correlation	.955*	.966*	.784	1	.981*	.754	.917	.925

Correlations

		(Chivers, 1974)	(MacKinnon & MacKinnon, 1980)	(Raemaekers, 1977)	Lappan (2005)	(Nurcahyono, 2001)	(Ryne Arthur Palombit, 1992)	Adult Male	Adult Female
	Sig. (2-tailed)	.045	.034	.216		.019	.246	.083	.075
	N	4	4	4	4	4	4	4	4
(Nurcahyono, 2001)	Pearson Correlation	.901	.961*	.852	.981*	1	.643	.893	.914
	Sig. (2-tailed)	.099	.039	.148	.019		.357	.107	.086
	N	4	4	4	4	4	4	4	4
(Ryne Arthur Palombit, 1992)	Pearson Correlation	.911	.799	.562	.754	.643	1	.874	.841
	Sig. (2-tailed)	.089	.201	.438	.246	.357		.126	.159
	N	4	4	4	4	4	4	4	4
Adult Male	Pearson Correlation	.972*	.983*	.884	.917	.893	.874	1	.998**
	Sig. (2-tailed)	.028	.017	.116	.083	.107	.126		.002
	N	4	4	4	4	4	4	4	4
Adult Female	Pearson Correlation	.964*	.990**	.908	.925	.914	.841	.998**	1
	Sig. (2-tailed)	.036	.010	.092	.075	.086	.159	.002	
	N	4	4	4	4	4	4	4	4

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Discussion

The feeding behaviour of gibbons at Gembira Loka Zoo (GLZ) exhibits distinct patterns influenced by their captive environment. Both individuals, one adult male and one adult female, show similar dietary preferences, with fruit consumption dominating their diet (male: 53.88%; female: 56.38%), followed by leaves (male: 34.23%; female: 32.30%) and supplemental foods such as tubers and biscuits (male: 11.89%; female: 11.33%). The feeding duration indicates that the male consumes more leaves and tubers than the female, while the female consumes fruit more frequently. This pattern aligns with the characteristics of gibbons as frugivores, relying primarily on fruit as their primary food source, as reported by Raemaekers (1977) and Chivers (1974).

A comparison of the diet composition of gibbons at GLZ with their natural habitat shows similarities in the preference for fruits and leaves. However, the variety of fruits provided at GLZ does not fully reflect the diversity found in their natural diet. Of the food items offered, only the *Ficus* genus matches their natural diet. References such as MacKinnon & MacKinnon (1980) and Chivers (1974) support the finding that fruits dominate the gibbon diet in the wild, with leaves serving as a supplement, especially during fruit scarcity. Additionally, studies by Whitten (1982) and Palombit et al. (1997) highlight that wild gibbons also consume young leaves and insects to meet their nutritional needs.

The suitability of the dietary composition at GLZ with the natural diet of gibbons still requires improvement. A Pearson correlation test shows significant similarity between the diet

composition at GLZ and the findings of MacKinnon & MacKinnon (1980) and Chivers (1974). However, differences remain in the types of food provided. For instance, supplementary foods like primate biscuits and tubers are not part of a gibbon's natural diet. Moreover, the fruits provided at GLZ tend to be selected based on human preferences (sweet taste or attractive colour). In contrast, gibbons consume various fruits in the wild, including those that are less visually appealing.

The feeding behaviour of gibbons at GLZ, such as eating on the enclosure floor or hanging from ropes while eating, reflects adaptation to their captive environment. However, providing food that is not suspended or placed at lower positions can reduce the expression of natural feeding behaviours. This approach conflicts with animal welfare principles, emphasizing the freedom to express natural behaviours (Browning & Veit, 2021). Previous research by Tiyawati (2015) suggests that providing food earlier in the day, around 6:00 AM, helps maintain the natural feeding behaviour of gibbons. To better align with natural feeding behaviours, GLZ could review the feeding menu by incorporating a greater variety of local fruits and simulating natural feeding conditions, such as suspending food at higher positions or adding young leaves as supplements. These steps would enhance the welfare of gibbons and support conservation goals by preserving their natural feeding behaviours.

Compared to previous research, the strength of this study is its holistic approach to feeding behaviour, dietary preferences, and the suitability of gibbon diets in captivity with their natural habitat, conducted specifically at Gembira Loka Zoo. This study integrates feeding behaviour analysis with aligning ex-situ and natural dietary patterns, providing in-depth insights into ex-situ conservation practices that prioritize animal welfare. Compared to research by Asyi et al. (2022), which focused on the daily behaviour of gibbons at Pematangsiantar Animal Park, this study specifically examines feeding behaviour and dietary preferences. Meanwhile, the study by Ningsih et al. (2023) emphasizes the distribution patterns of gibbons in their natural habitat without discussing feeding behaviour. Although Dewi et al. (2023) addressed feeding behaviour and dietary preferences at Taman Safari Indonesia, they did not explicitly evaluate the suitability of ex-situ nutritional composition with the natural diet.

The findings of this study support previous research, particularly Dewi et al. (2023), which also highlights the dominance of fruit in gibbon diets. However, this study adds value by showing that the proportion of food provided at Gembira Loka Zoo aligns with their natural feeding patterns, allowing gibbons to maintain their frugivorous behaviours. The absence of significant differences in dietary preferences between male and female gibbons in this study is also consistent with Dewi et al. (2023), which found that gender-based nutritional differences are insignificant. This underscores the importance of adjusting ex-situ diets to support effective ex-situ conservation.

This research also makes a significant contribution to biology education, particularly in the context of animal ecology, adaptive behavior, and species conservation. In biology learning, these findings can be used as a concrete case study to understand the interactions between animals and their environments, including how habitat changes and food provision in artificial environments can influence feeding behavior. This knowledge aligns with core competencies in the biology curriculum that emphasize understanding organismal adaptation and the importance of ecosystem balance (Kusuma & Arifin, 2021; Meidamayani et al., 2021). In the context of education for children, an inquiry-based approach through the case study of the siamang can help students concretely grasp the concepts of adaptation and ecosystem balance. The application of project-based learning or scientific inquiry models allows students to develop critical thinking, collaboration skills, and empathy toward living beings. For instance,

students can be encouraged to design a simulation of siamang feeding or create a model of the tropical forest ecosystem in which siamangs live.

Through this research, students can learn that siamangs, as arboreal primates, exhibit a consistent food preference for fruits and leaves, which not only meet their nutritional needs but also play an important ecological role in seed dispersal in their natural habitats (Harrison, 2019). Findings on the suitability of food composition between the zoo environment and the siamang's natural habitat introduce the concepts of animal welfare and conservation principles, which can serve as valuable discussion topics to raise students' awareness about the preservation of Indonesia's endemic wildlife. For public education (citizen education), zoos have the potential to serve as powerful centers for informal learning. By providing interactive information about siamang behavior and nutritional needs, zoos can enhance public ecological awareness. Activities such as educational tours, data-driven informational panels, and family conservation workshops can strengthen community engagement in preserving Indonesia's endemic species (Suhardono et al., 2024).

The emphasis on the importance of modifying feeding methods to resemble natural feeding behavior also offers an entry point into behavioral biology education, where students are encouraged to explore the relationship between environmental structure and the expression of natural animal behavior (Earley, 2009). Thus, the results of this study not only enrich biology teaching materials through an inquiry-based learning approach but also play a role in shaping students' ecological awareness and fostering appreciation for biodiversity. This study can also be adapted into contextual and interdisciplinary teaching materials combining biology and environmental education and developed into learning media such as documentary videos or case-based worksheets that incorporate aspects of animal welfare, conservation, and animal feeding behavior. By incorporating this study into biology lessons, teachers can build students' understanding of the importance of maintaining ecosystem balance and conserving endangered species, while also instilling values of environmental responsibility from an early age (Ahirwar, 2024; Børresen et al., 2023).

The implications of these findings show that ex-situ conservation efforts, such as those conducted at Gembira Loka Zoo (GLZ), have great potential to support the preservation of the siamang (*Symphalangus syndactylus*) if carried out using approaches that closely mimic their natural conditions. Adjusting the diet and feeding methods—such as hanging food in higher places or providing young leaves and a greater variety of fruits—can enhance animal welfare by allowing the siamang to express its natural feeding behaviors. Moreover, the success of conservation efforts depends on a deep understanding of the siamang's food preferences, both in captivity and in the wild, to ensure the sustainability of reintroduction programs into their native habitats. By fulfilling nutritional needs and supporting natural feeding behaviors, zoo management can promote the welfare of individual siamangs and strengthen the role of zoos as effective centers for education and wildlife conservation. Furthermore, these findings carry important implications for biology education, as they can be utilized as contextual learning resources to understand concepts of ecology, animal behavior, adaptation, and biodiversity conservation. The study of siamang feeding behavior and its compatibility with natural habitats provides a concrete example of how scientific approaches are used to analyze the relationships between organisms and their environments, as well as the importance of animal welfare principles in ex-situ animal management. This information can be integrated into biology learning through project-based learning models or case studies that not only train students' critical thinking skills but also foster concern for the preservation of Indonesia's endemic wildlife. Zoos, as open learning laboratories, can also become strategic partners in supporting outdoor learning activities that strengthen holistic and contextual understanding of biological

concepts. Therefore, this study not only strengthens ex-situ conservation practices but also has the potential to serve as a bridge between science and public education. Through an integrative approach grounded in animal welfare, the management of GLZ can enhance the effectiveness of conservation efforts while making a meaningful contribution to the development of more contextual and inclusive biology education.

Conclusion

This study shows that the feeding patterns of siamangs at GLZ reflect their natural frugivorous characteristics, with a dominant consumption of fruits (53.88% for males and 56.38% for females), followed by leaves and tubers as supplementary food sources. Identified challenges include the limited variety of food resembling their natural habitat, feeding methods that do not sufficiently support the expression of natural behaviors, and individual differences in food preferences. The study recommends adjusting the diet by incorporating a wider variety of local fruits, providing young leaves, and utilizing suspended feeding methods to enhance the well-being of the siamangs. From the perspective of biology education, a key limitation lies in the lack of direct integration of these research findings into concrete teaching materials. In the future, further research is needed to evaluate the long-term impact of dietary modifications on siamang behavior and health, as well as to support the success of reintroduction programs into the wild. From an educational standpoint, it is important to develop learning materials based on these findings that can be used in biology teaching, particularly in topics related to ecology, adaptation, animal behavior, and conservation.

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