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Diurnal Activity Paflerns And Feeding Habits Of Free-Ranging Colobus Monkey (*Colobus guereza* Ruppell 1835) In Kafa Biosphere Reserve, Southwest Ethiopia

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Activity patterns; diet composition; feeding habits; habitat type; seasonality

Abstract

Understanding primate behavioral ecology is essential for developing effective conservation strategies and promoting sustainable forest management. This study investigated the diurnal activity patterns and feeding habits of free-ranging *Colobus guereza* in Kafa Biosphere Reserve (KBR), southwestern Ethiopia, during 2021. Data were collected in both dry and wet seasons using a scan sampling method, which involved instantaneous behavioral observations of visible individuals at fixed intervals. Focal groups included individuals of different sex and age classes, and observations were conducted systematically throughout the study periods to capture seasonal variation. Each scan lasted 5–10 minutes, yielding a total of 1,303 scans in the dry season and 1,191 scans in the wet season. Behavioral data were categorized into feeding, resting, and traveling activities. A Chi-square test of independence was applied to assess associations between activity type and habitat type within each season, while the Cochran–Mantel–Haenszel test was used to control for seasonal effects. Results indicated that *C. guereza* allocated the largest proportion of its daily activity budget to resting (45.3%), followed by feeding (42%). Significant differences in activity patterns were observed among sex and age classes ($p < 0.05$). Adult females spent more time feeding and resting compared to adult males, sub-adults, and juveniles, whereas younger individuals engaged more frequently in play behavior. Dietary analysis identified 13 tree species, with *Milletia ferruginea* (33%), *Sapium ellipticum* (25%), and *Olea welwitschii* (24%) as the most frequently consumed. Seasonal variation significantly influenced diet composition ($p < 0.05$), with increased consumption of leaves and flowers during the dry season and leaves and fruits during the wet season. Overall, the distribution and persistence of *C. guereza* in Kafa Biosphere Reserve are closely linked to food resource diversity and habitat integrity. The findings highlight the ecological flexibility and apparent resilience of *Colobus guereza* in the Kafa Biosphere Reserve; however, this resilience should not be interpreted as immunity to environmental change. They also emphasize the critical importance of conserving forest ecosystems to sustain primate populations in Ethiopia.

1 Introduction

Primates are among the most ecologically significant and behaviorally complex mammals inhabiting tropical and subtropical forests worldwide. Their relatively large body size, social organization, and diverse feeding strategies make them particularly sensitive to habitat alteration, while also positioning them as important indicators of forest ecosystem health (Estrada et al., 2017; Fashing et

al., 2012). Understanding primate feeding habits and activity patterns is therefore essential for elucidating species-environment interactions and for designing evidence based conservation and habitat management strategies, especially in regions experiencing rapid environmental change.

Colobine monkeys are a distinct subfamily of Old World monkeys distributed mainly across Africa and Asia and are characterized by their specialized foregut fermentation system, which enables efficient digestion of fibrous plant material (Kirkpatrick, 2011; Matsuda et al., 2020). African colobines are currently classified into three genera: *Piliocolobus* (red colobus), *Procolobus* (olive colobus), and *Colobus* (black-and-white colobus) (Groves, 2001, 2007; Zinner et al., 2019). The genus *Colobus* comprises five recognized species: *Colobus guereza*, *C. satanas*, *C. polykomos*, *C. vellerosus*, and *C. angolensis* (Kingdon, 2015). Among these, *Colobus guereza* is the most widely distributed and abundant, occurring across East and West Africa, including extensive portions of Ethiopia (Kingdon et al., 2008; Zinner et al., 2019).

Ethiopia harbors two subspecies of *Colobus guereza*: the nominate subspecies (*C. g. guereza*) and the gallarum subspecies (*C. g. gallarum*), both primarily associated with highland and montane forest ecosystems (Mekonnen et al., 2021; Zinner et al., 2019). These forests represent important refugia for colobines but are increasingly threatened by anthropogenic pressures. Despite the ecological importance and relative abundance of *C. guereza*, detailed behavioral ecological studies remain unevenly distributed across its range, with notable information gaps in southwestern Ethiopia.

Colobus monkeys are predominantly folivorous, feeding primarily on leaves, particularly young leaves that are higher in protein and lower in fiber and secondary compounds (Chapman et al., 2002; Fashing et al., 2007). However, their diet is flexible and may include mature leaves, leaf buds, flowers, fruits, seeds, bark, petioles, and occasionally soil or invertebrates, depending on habitat characteristics and seasonal food availability (Hanya & Chapman, 2013; Kibaja, 2014; Matsuda et al., 2020). Recent studies emphasize that dietary composition in colobines is strongly influenced by temporal variation in plant phenology, forest structure, and human disturbance, which in turn affects their activity budgets and ranging behavior (Mekonnen et al., 2021; Twinomugisha et al., 2018).

The diurnal activity patterns of *Colobus guereza* are shaped by ecological, physiological, and social factors, including food distribution, habitat quality, group size, and age–sex composition (Wijtten et al., 2012; Zhou et al., 2011). Typically, their daily activity budget is dominated by resting and feeding, with relatively limited time allocated to movement and social interactions. High resting time is often associated with the need for prolonged digestion of leaf material and energy conservation strategies linked to a low-quality but abundant food source (Smith et al., 2013; Zhou et al., 2013). Variations in activity budgets across habitats have been documented, particularly in fragmented or disturbed forests, where primates may adjust feeding and movement patterns to cope with altered resource availability (Estrada et al., 2017; Fashing et al., 2007; Onderdonk & Chapman, 2000).

In Ethiopia, forest ecosystems are increasingly threatened by anthropogenic pressures, including agricultural expansion, human settlement, overgrazing, fuelwood collection, timber extraction, and infrastructure development (Nune, 2008; Tolla et al., 2017; Yakob & Fekadu, 2016; Yirga et al., 2019). These drivers of deforestation and forest degradation significantly impact primate populations by reducing habitat quality, fragmenting forest landscapes, and altering plant community composition. The Kafa Biosphere Reserve (KBR), encompassing the area formerly known as Bonga Forest, represents one of the largest remaining moist Afromontane forests in southwestern Ethiopia. It is recognized as a national forest priority area and supports high biodiversity, including populations of *Colobus guereza* (NABU (Nature and Biodiversity Conservation Union), 2017; Vreugdenhil et al., 2012).

Despite its conservation significance, empirical data on the behavioral ecology of *Colobus guereza* in the Bonga Forest remain scarce. Previous studies in other parts of Africa have demonstrated that fine-scale information on feeding habits and activity patterns is critical for understanding species adaptability to habitat change and for informing sustainable forest management (Chapman et al., 2010; Mekonnen et al., 2021; Twinomugisha et al., 2018). However, such baseline ecological data are largely lacking for the KBR.

Therefore, the present study investigated the diurnal activity patterns and feeding habits of free-ranging *Colobus guereza* in Kefa Biosphere Reserve, southwestern Ethiopia. The study placed particular emphasis on diet composition (including plant species and plant parts consumed), diurnal activity time budgets, and the influence of habitat condition (disturbed and undisturbed forest), across groups with different sex–age categories and between seasons.

Specifically, the objectives of the study were to: (1) quantify the diurnal activity time budgets (feeding, resting, moving, and social activities) of *Colobus guereza*; (2) determine the diet composition and major food plant species consumed by the species, including the relative contribution of different plant parts (leaves, fruits, flowers, and others); (3) assess seasonal variation in diurnal activity patterns and feeding habits of *Colobus guereza* between the dry and wet seasons; and (4) compare activity patterns and feeding behavior among different sex–age categories of *Colobus guereza*.

2 Materials and Methods

2.1 Description of the study area

The study was conducted in 2021 in Kafa Biosphere Reserve (KBR), located in the Kaffa Zone of the South West National Regional State (SWNRS), Ethiopia (Figure 1). The Kafa Biosphere Reserve (KBR) covers an area of approximately 760,000 hectares (7,600 km²) in southwestern Ethiopia. It is one of the country's largest remaining tracts of moist Afromontane forest, recognized for its exceptional biodiversity and ecological significance.

The reserve includes a mix of dense forest, wetlands, and agricultural landscapes, and is globally important as the center of origin of wild *Coffea arabica*. Designated as a UNESCO Biosphere Reserve in 2010, KBR supports diverse wildlife, including endemic and threatened species, while also promoting sustainable use of natural resources by local communities The forest lies along the southern boundary of the Reserve, a nationally and internationally important conservation landscape (NABU (Nature and Biodiversity Conservation Union), 2017). The area covers five Woredas of Chena, Gimbo, Menjiwo, Tello, and Decha, but this study was limited to Gimbo and Decha districts, which represent key forest habitats within the KBR. The study area is situated between 7°14′24″ N and 7°16′48″ N latitude and 36°09′36″ E and 36°13′12″ E longitude, approximately 470 km southwest of Addis Ababa and 12 km from Bonga town.

The landscape is dominated by rugged ridges and valleys, forming a predominantly mountainous terrain that gradually levels out toward the Gojeb River (Deraro et al., 2003). The area experiences a humid climate, with mean annual temperatures ranging between 15°C and 22°C (Ethiopian Meteorological Service Agency (EMSA), 2019; Kebede, 2011). The warmest period occurs from February to April, while the highest rainfall is recorded between June and August, with total annual precipitation ranging from 1,401 to 2,000 mm. The Kafa Biosphere Reserve comprises moist evergreen montane forest that supports rich biodiversity, including around 100 bird species and at least 48 mammal species, among which *Colobus guereza* is prominent (Bekele, 2003; NABU (Nature and Biodiversity Conservation Union), 2017).

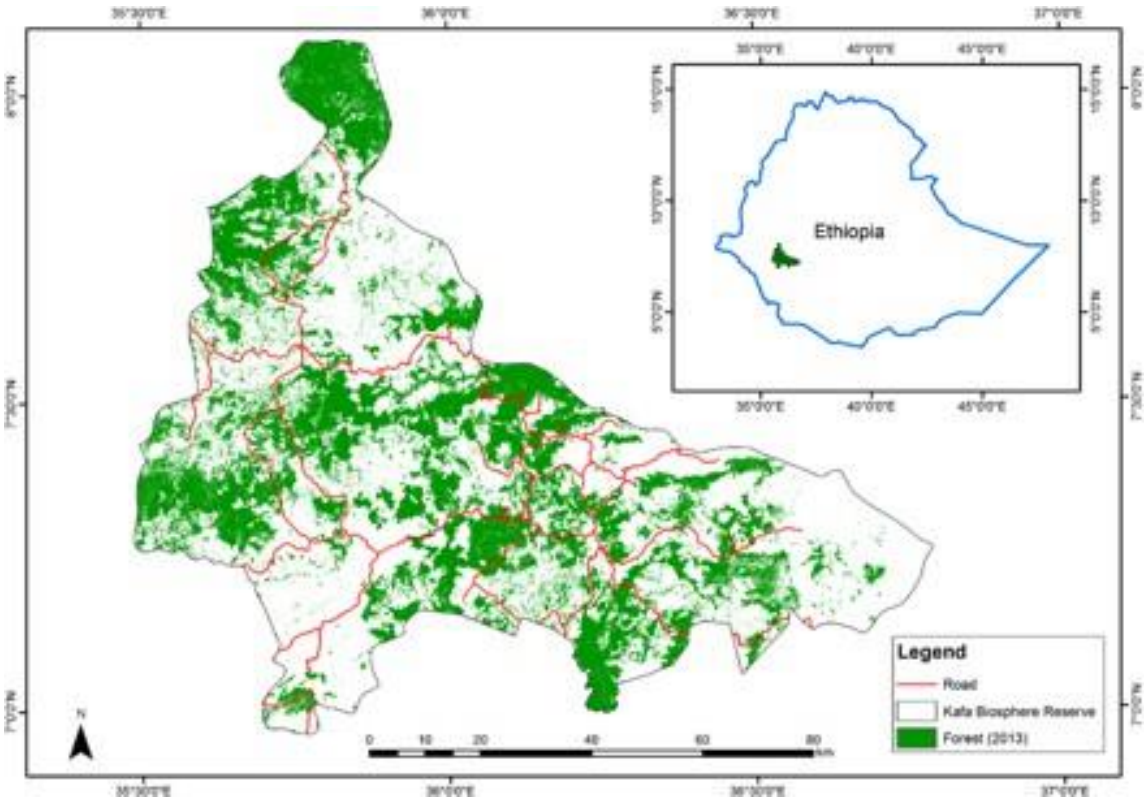

Figure 1: Overview of the UNESCO Kafa Biosphere Reserve location, where five Woredas the study area were located within the reserved. (SOURCE: GOOGLE EARTH; ETHIO-REGION AND ZONE, 2021; USING QGIS VERSION 3.8).

The map presented in this study above (Figure 1) illustrates only the overall extent of the Kafa Biosphere Reserve, highlighting the general distribution of forest cover and major road networks. It does not specifically delineate the boundaries of Gimbo and Decha woredas, which constitute the focal study areas. Furthermore, no spatial classification was applied to distinguish core (relatively undisturbed) and buffer (disturbed) zones. At the time of data collection, clear and consistent demarcations of woreda boundaries and biosphere reserve zonation were not available; therefore, these categories were not incorporated into the map.

2.2 Sampling Method

2.2.1 Preliminary Survey and Study Site Selection

Before formal data collection, a one-week reconnaissance survey was conducted to gather essential information on site accessibility, climate, topography, vegetation types, general faunal presence, and the distribution and preliminary behavior of *Colobus guereza*. Reconnaissance surveys are widely recommended in primate ecological studies to optimize sampling design, identify logistical constraints, and reduce observer bias in structurally complex tropical forests (Jones & Perelman, 2019; Rovero et al., 2018). This initial phase allowed the research team to familiarize themselves with the forest environment, assess the relative abundance and spatial distribution of *C. guereza*, and determine safe and effective observational approaches that minimize disturbance.

During the survey, key habitat types were identified based on vegetation structure, disturbance levels, and topographic variation, following stratification approaches used in forest primate studies (Nielsen et al., 2018; Tokuda et al., 2020). Preliminary observations revealed a mosaic of habitats and complex terrain within the study area. The site was subsequently stratified into disturbed and undisturbed forest zones using a framework adapted from Girma et al. (2018), previously applied for habitat classification in Ethiopian montane forests and have been widely applied in Ethiopian montane forest studies. Specifically, disturbed forests were identified based on evidence of human activities such as selective logging, firewood collection, grazing, trails, and proximity to settlements, combined with structural characteristics such as reduced canopy cover, lower tree density, and a higher proportion of secondary vegetation. In contrast, undisturbed forests were characterized by minimal human interference, continuous canopy cover, intact tree composition, and the presence of mature trees and native under-

story vegetation.

GPS coordinates for each habitat type were recorded using a Garmin GPSMAP 64st receiver to ensure spatial accuracy. These coordinates were imported into QGIS (version 3.8) to digitize habitat strata, estimate their areas, and generate spatially explicit sampling units. GIS-based stratification enhanced the representativeness of sampling across habitat gradients and reduced potential bias from unequal habitat coverage (Sabater Pi et al., 2021; Willi et al., 2019).

2.2.2 *Field Data Collection*

Field data were collected on free-ranging *Colobus guereza* during both the dry season (March–June 2021) and the wet season (July–October 2021) through direct observation. Observations were carried out in two daily sessions: morning and afternoon using established primate behavioral protocols. Behavioral data were recorded at three-minute intervals per hour using instantaneous scan sampling, which involved observing all visible individuals at fixed intervals.

Each scan lasted 5–10 minutes, resulting in a total of 1,303 scans during the dry season and 1,191 scans during the wet season. Observations included individuals from different sex and age classes and were conducted systematically to capture seasonal variation. Behavioral activities were categorized into feeding, resting, and traveling.

To assess activity budgets, scan sampling was consistently applied at regular intervals. In addition, focal animal sampling was used to examine feeding behavior in detail, including identification of plant species, plant parts consumed, foraging duration, and frequency of feeding observations. Plant species were identified using key informants and identification keys. For each observation session, one focal individual per group was randomly selected, with replacement if the individual could not be relocated, while avoiding resampling within the same scan period.

Two focal groups were studied, representing disturbed and undisturbed forest habitats, with group sizes ranging from 3 to 13 individuals. Data collection was conducted by a primary researcher and a trained local assistant to ensure representation of all sex-age categories.

All observations were made using Nikon 10×50 Aculon A211 binoculars, allowing accurate identification of feeding behavior and plant items from a safe distance without disturbing the animals.

2.2.3 *Data Analysis*

All data were analyzed using SPSS version 23. To compare differences in time allocated to various activity patterns across sex–age categories, we used MANOVA. Independent-sample t-tests were applied to examine differences in activity budgets between disturbed and undisturbed habitats. Associations between habitat types and seasonal variations, as well as differences in the proportion of time spent consuming specific plant parts, were evaluated using Chi-square tests. Seasonal variation in plant consumption was assessed with the Mann–Whitney U-test.

To control for multiple comparisons when analyzing multiple categorical variables (activity type, habitat type, and season), we first applied MANOVA to assess the overall effect of habitat type on behavior across dependent variables, avoiding inflation of Type I errors. For categorical variables, the Stratified Chi-square test was used to evaluate relationships while accounting for stratification by season and habitat type.

Feeding behavior was quantified by calculating the percentage of time devoted to specific plant species and plant parts, providing a measure of dietary preferences. Overall dietary composition was expressed as the proportion of each food type consumed during foraging bouts, offering a detailed view of seasonal and habitat-related foraging strategies. These analyses allowed identification of patterns in activity allocation and diet that may reflect ecological adaptations and habitat influences on *Colobus guereza* behavior.

3 RESULTS

3.1 Overall Frequency of Diurnal Activity Paflerns of Colobus Monkeys

At the study site, five major activity categories of *C. guereza* were recorded: feeding, resting, jumping, playing, and grooming, across both Undisturbed Forest (UDF) and Disturbed Forest (DF) habitats. A total of 1,191 activity records were obtained during the wet season and 1,303 during the dry season.

As illustrated in Figure 2, grooming accounted for the smallest proportion of observed activities in both habitats during the dry season. In the disturbed forest (DF), individuals spent a greater proportion of their time resting (25%) and feeding (24%). In contrast, in the undisturbed forest (UDF), jumping was more frequent (22%), followed by resting (21%).

During the wet season, playing behavior was observed less frequently in both habitat types, while resting constituted the largest proportion of the activity budget.

A stratified chi-square test was conducted to evaluate the relationship among activity type, habitat type, and season. The results indicated no statistically significant difference in the overall frequency of activities between habitat types across seasons ($\chi^2 = 4.000$, df = 3, $p > 0.05$)

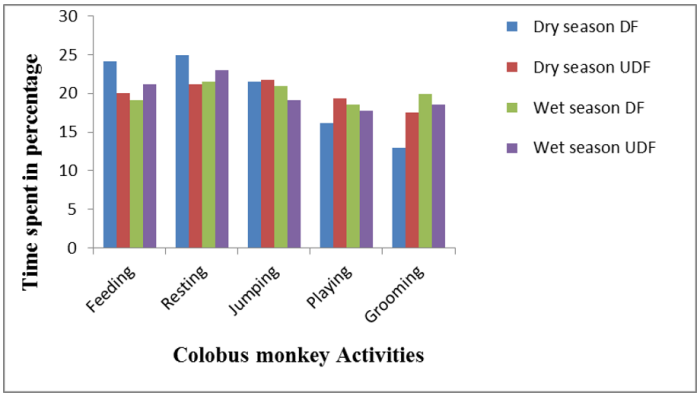

Figure 2: The proportion (%) of the total feeding budget or bout spent on a specific behavior by *Colobus guereza*.

3.2 Morning and Afternoon Variation of Activity Patterns

During the dry season, the frequency of *Colobus guereza* activity patterns observed during morning and afternoon sessions in both habitat types is presented in Figure 3. In the Disturbed Forest (DF), individuals allocated more time to feeding and grooming in the morning than in the afternoon, whereas resting was more frequent in the afternoon. In contrast, in the Undisturbed Forest (UDF), guerezas spent more time on all recorded activities in the afternoon compared to the morning.

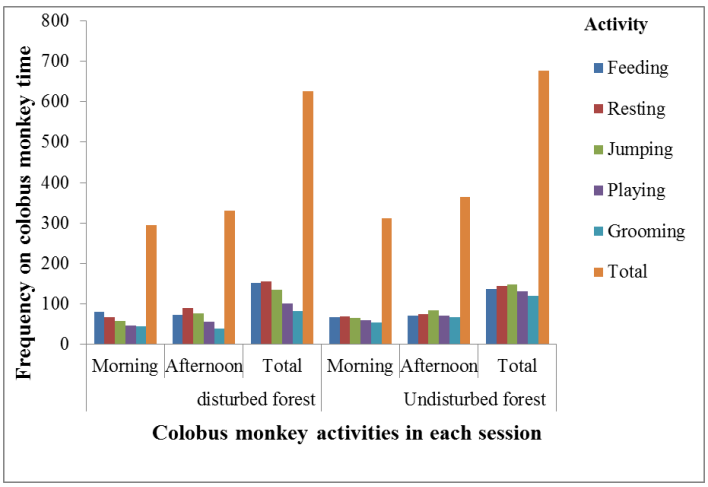

Figure 3: Frequencies of the total feeding bout spent on a specific behavior of *Colobus guereza* during morning and afternoon in disturbed and undisturbed forest in the dry season.

To evaluate differences in activity budgets between habitat types, a multivariate analysis of variance (MANOVA) was conducted, with habitat type (DF vs. UDF) as the independent variable and time spent feeding, resting, and jumping as dependent variables. The MANOVA results indicated a statistically significant overall effect of habitat type on activity patterns during the dry season ($p < 0.05$). Follow-up univariate analyses revealed that time spent feeding, resting, and jumping differed significantly between disturbed and undisturbed forests ($p < 0.05$). However, no significant differences were detected for playing and grooming activities between the two habitat types ($p > 0.05$).

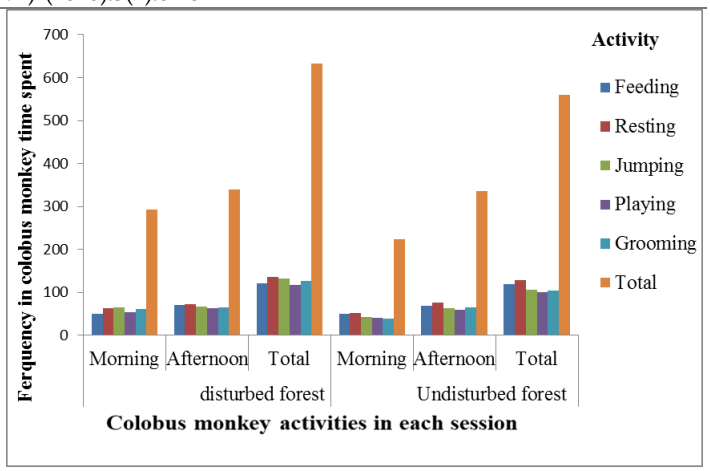

Figure 4: Frequencies of the total feeding bout spent on a specific behavior of *Colobus guereza* during morning and afternoon in disturbed and undisturbed forest in the wet season

Similarly, during the wet season (Figure 4), *C. guereza* in both DF and UDF exhibited higher activity levels across all behavioral categories in the afternoon compared to the morning. A MANOVA was performed to assess habitat-related differences in activity patterns. The analysis showed a significant multivariate effect of habitat type on the combined activity variables ($p < 0.05$). Subsequent univariate tests indicated that time spent feeding, resting, and playing differed significantly between the two habitats ($p < 0.05$), whereas no significant differences were observed for jumping and grooming activities ($p > 0.05$).

Table 1 above shows the time spent by *Colobus guereza* in different activity categories during the dry season, broken down by sex-age groups. Adult males spent less time grooming and more time resting, while adult females spent less time playing and more time feeding. Sub-adults devoted less time to grooming and more time jumping, while young individuals spent less time eating and more time jumping. Among adults, feeding was the most commonly performed activity, followed by resting, whereas for young individuals, feeding was the least frequent activity. Jumping was the most common activity for both young individuals and sub-adults, while playing was the most frequently performed activity by young monkeys compared to the other age groups. Adult females engaged in more activities overall than any other age group.

Table 1: The proportion (%) of the total feeding bout spent on a specific behavior of *Colobus guereza* across different sex and age groups during the dry season.

Activities	Adult males	Adult females	Sub-adults	Young's	Total
Feeding	6.4	8.2	4.4	3.0	22.3
Resting	6.9	7.8	4.9	3.4	23.0
Jumping	3.9	3.9	6.4	7.3	21.5
Playing	3.5	3.1	4.7	6.4	17.7
Grooming	2.5	5.3	3.4	3.9	15.1
Total	23.2	28.3	23.8	24.0	100

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The statistical analysis (ANOVA) revealed that groups containing different sex-age categories significantly influenced the amount of time spent on various activity patterns ($F = 2.790$, $df = 3$, $p < 0.05$). Notably, the mean differences between adult females and sub-adults ($p < 0.05$), adult females and young individuals ($p < 0.05$), and adult males and adult females ($p < 0.05$) were all significant. However, no significant differences were found between adult males and sub-adults ($p > 0.05$), adult males and young individuals ($p > 0.05$), or sub-adults and young individuals ($p > 0.05$) during the dry season.

3.3 Diurnal Variation in Activity Paflerns

Clear diurnal patterns in activity allocation were observed, with differences between habitats and seasons. During the dry season, morning and afternoon activity budgets showed habitat-specific contrasts. In disturbed forest, monkeys devoted more time to feeding and grooming during morning hours, while resting increased markedly in the afternoon. This pattern suggests that individuals may exploit cooler morning conditions for energetically demanding activities and reduce activity later in the day. In undisturbed forest, overall activity levels were higher in the afternoon, reflecting greater behavioral flexibility and possibly better resource availability. Independent sample t-tests demonstrated significant differences between habitats in time allocated to feeding, resting, and jumping during the dry season ($p < 0.05$). However, no significant differences were detected for playing or grooming ($p > 0.05$), indicating that these social behaviors were relatively stable across habitats.

During the wet season, *C. guereza* in both habitats showed increased activity during afternoon sessions. Feeding, resting, and playing differed significantly between disturbed and undisturbed forests ($p < 0.05$), suggesting that habitat quality influenced how monkeys responded to seasonal environmental changes. In contrast, jumping and grooming did not differ significantly between habitats ($p > 0.05$), again highlighting the consistency of certain behaviors irrespective of habitat condition.

3.4 Activity Paflerns by groups containing different Sex-Age Categories

Behavioral time allocation varied markedly among sex–age categories, reflecting differences in energetic requirements, social roles, and developmental stages. During the dry season, adult males spent a greater proportion of time resting and comparatively little time grooming. Adult females devoted more time to feeding and less to playing, emphasizing the importance of energy intake, likely linked to reproductive demands. Sub-adults were characterized by high levels of jumping, while young individuals focused primarily on jumping and playing, with relatively little time spent feeding. Overall, feeding was the dominant activity among adults, whereas locomotor and play behaviors predominated among sub-adults and young monkeys.

Analysis of variance (ANOVA) confirmed that sex–age category significantly influenced activity budgets during the dry season ($F = 2.790$, $df = 3$, $p < 0.05$). Significant differences were detected between adult females and sub-adults, adult females and young individuals, and between adult males and adult females ($p < 0.05$). In contrast, no significant differences were observed between adult males and sub-adults, adult males and young individuals, or between sub-adults and young individuals ($p > 0.05$). These findings indicate that adult females differ most strongly from other groups in their activity allocation, particularly with respect to feeding and resting.

During the wet season, similar but not identical patterns emerged. Adult males spent more time feeding and less time playing, while adult females increased time devoted to feeding and grooming. Sub-adults allocated a greater proportion of time to resting, suggesting reduced locomotor activity during wetter conditions. Young individuals prioritized playing over feeding, consistent with developmental needs and lower energetic constraints. Resting was the dominant activity for sub-adults, whereas playing remained the most frequent behavior among young monkeys. Adult females engaged more frequently in feeding and grooming than any other group, underscoring their central role in maintaining energy balance and social cohesion.

Statistical analysis again demonstrated a significant effect of sex–age category on activity time during the wet season ($df = 3$, $p < 0.05$). Significant differences were observed among adult males, adult females, and young individuals ($p < 0.05$). However, no significant differences were found between adult males and adult females or between sub-adults and young individuals ($p > 0.05$), indicating partial convergence in activity patterns under wetter environmental conditions.

Table 2: The proportion (%) of the total feeding bout spent on a specific behavior of *Colobus guereza* across different sex and age groups during the wet season.

Activity pattern	Adult males	Adult females	Sub-adults	Young's	Total
Feeding	5.4	7.3	4.4	3.2	20.3
Resting	5.1	4.6	6.9	5.6	22.2
Jumping	4.8	3.1	5.9	6.1	19.9
Playing	2.6	3.4	5.0	7.1	18.3
Grooming	3.5	6.1	4.5	5.1	19.2
Total	21.4	24.5	26.7	27.1	100

3.5 Feeding Time Budget and Diet (plant types) Composition of Colobus Monkey

Feeding Behavior and Dietary Composition

A total of 528 feeding events of *Colobus guereza* were documented through scan sampling during both the dry and wet seasons, providing a detailed overview of dietary composition and plant species use across disturbed forest (DF) and undisturbed forest (UDF) habitats. These feeding records comprised 13 tree species belonging to nine plant families, indicating a moderately diverse but selective feeding strategy. Despite this diversity, feeding was strongly concentrated on a small subset of preferred species, reflecting dietary specialization within the available forest resources.

Across both seasons and habitats, *Olea welwitschii*, *Sapium ellipticum*, and *Cupressus lusitanica* emerged as consistently important food plants, together accounting for a substantial proportion of total feeding observations (Figure 5). This pattern suggests that these species provide reliable and nutritionally suitable resources throughout the year. However, seasonal and habitat-specific variations in relative consumption frequencies were evident. During the dry season, feeding activity in disturbed forest was dominated by *Ficus vasta*, which recorded 22 feeding occurrences, followed by *Cordia africana* with 16 occurrences. These species likely serve as critical fallback resources in disturbed habitats when food availability is reduced. In contrast, *Sapium ellipticum* was least consumed in disturbed forest during this season, with only three records, indicating either lower availability or reduced preference in that habitat.

In the undisturbed forest during the dry season, *Millettia ferruginea* was the most frequently consumed species, accounting for 38 feeding records, followed by *Sapium ellipticum* (29). The dominance of *Millettia ferruginea* in UDF highlights its importance as a key dietary component in relatively intact forest conditions, while *Allophylus abyssinicus* was rarely consumed (two records), suggesting marginal dietary importance. Similar patterns persisted during the wet season. In disturbed forest, *Cupressus lusitanica* (14 occurrences) and *Croton macrostachyus* (12 occurrences) were most frequently consumed, whereas *Eucalyptus grandis* was least consumed (five occurrences). In the undisturbed forest, *Millettia ferruginea* again dominated the diet with 44 records, followed by *Olea welwitschii* (22), while *Croton macrostachyus* remained the least utilized species.

When feeding data were aggregated across seasons, *Millettia ferruginea* emerged as the single most important food species, contributing 30% of feeding records in the dry season and 36.6% in the wet season. This strong and consistent reliance underscores its year-round dietary significance. *Sapium ellipticum* and *Olea welwitschii* ranked next in importance, whereas *Prunus africana* (5.8%) and *Eucalyptus grandis* (4.1%) contributed minimally to overall feeding activity. Importantly, statistical analyses revealed no significant differences in plant species selection between disturbed and undisturbed forests (χ^2 = 0.000, df = 12, $p > 0.05$), indicating similar dietary composition across habitat types. Likewise, the Mann–Whitney U-test showed no significant seasonal differences in dietary ranks (U = 23.500, Z = −0.128, $p > 0.05$). Together, these results demonstrate a stable feeding strategy characterized by consistent reliance on a few key plant species, despite seasonal changes and habitat disturbance, highlighting the ecological importance of these species for the conservation of *Colobus guereza*.

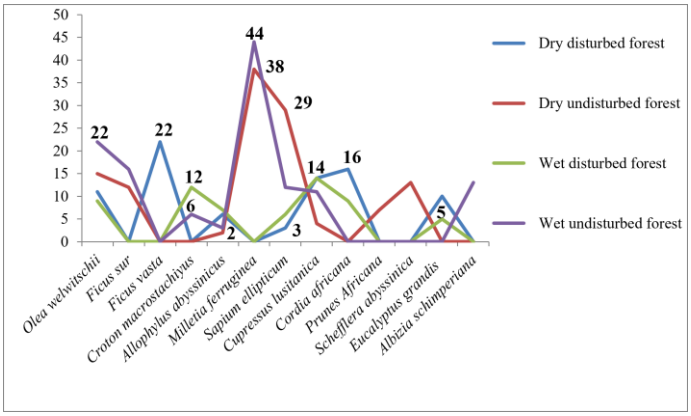

Figure 5: Feeding time spent or frequencies (shown in x-axis) by Colobus monkeys on each plant type

As shown in Table 3 below, *Millettia ferruginea* was the most commonly consumed food item by *Colobus guereza* during both seasons. In the dry season, *Millettia ferruginea* accounted for 30% of the feeding activities, followed by *Sapium ellipticum* at 26.6%. During the wet season, *Millettia ferruginea* remained the most frequently consumed food item, constituting 36.6% of the total feeding time, followed by *Olea welwitschii* at 25.8%. In contrast, *Prunus africana* (5.8%) and *Eucalyptus grandis* (4.1%) were the least consumed food items during the dry and wet seasons, respectively. These findings highlight the prominence of a few plant species in the *Colobus guereza* diet across both seasons. Despite the variation in the proportions of time spent consuming different plant species between the dry and wet seasons, statistical analysis revealed no significant difference in the rank of dietary contributions of plant species consumed by the *Colobus guereza* across the two seasons (Mann-Whitney U test; U = 23.500, Z = -0.128, $p > 0.05$). This suggests that the relative importance of different plant species in the monkeys' diet remains consistent, regardless of seasonal changes in food availability or plant abundance.

Table 3: Plant species consumed by Colobus monkeys and their frequencies and percentages with ranks

Plant species	Dry season			Wet season		
	Frequency	Percentage	Rank	Frequency	Percentage	Rank
Millettia ferruginea	38	30.0	1st	44	36.6	1st
Sapium ellipticum	32	26.6	2nd	28	23.3	3rd
Olea welwitschii	26	21.6	3rd	31	25.8	2nd
Ficus vasta	22	18.3	4th	-	-	-
Cupressus lusitanica	18	15.0	5th	25	20.8	4th
Croton macrostachiyus	-	-	-	18	15.0	5th
Cordia africana	16	13.3	6th	9	7.5	8th
Schefflera abyssinica	13	10.8	7th	-	-	-
Ficus sur	12	10.0	8th	16	13.3	6th
Albizia schimperiana	-	-	-	13	10.8	7th
Eucalyptus grandis	10	8.3	9th	5	4.1	9th
Allophylus abyssinicus	10	8.3	9th	-	-	-
Prunus africana	7	5.8	10th	-	-	-

Where '-' indicates no record, when the Colobus monkey consumed the plant species.

The plant parts consumed by the study species as a diet and the frequency of feeding time scans for each plant part during feeding activity are illustrated below (Table 4). During the dry season, the diet of Colobus monkeys was primarily made up of leaves, followed by flowers. During the wet season, colobus monkeys favored leaves, followed by fruits. During both seasons, stems/woods/barks were the least consumed food item from other plant parts. The feeding records of plant parts consumed by Colobus monkeys differed statistically across seasons ($\chi^2 = 16.00$, df = 4, $p < 0.05$).

Table 4: Overall food item selection of Colobus monkeys as diet during both seasons

Plant Parts	Dry season		Wet season	
	FSP	DSI=FSP/TSP	FSP	DSI=FSP/TSP
Leaves	84	0.7	97	0.80
Flowers	49	0.40	37	0.30
Fruits	28	0.23	41	0.34
Steams	14	0.11	6	0.05

Where DSI = Diet Selection Index, FSP = Frequency Scanning Period per plant part, and TSP = Total Scanning Period (120 for each season).

4 DISCUSSION

4.1 Activity Paflerns of *Colobus guereza*

At the study site, *Colobus guereza* devoted the majority of its daily activity budget to resting and feeding, while comparatively little time was allocated to social behaviors such as grooming and play. This pattern is consistent with previous studies conducted in Ethiopia and other parts of Africa, which have similarly identified resting and feeding as dominant activities in guereza monkeys (Hussein & Ejigu, 2017; Shumet & Yihune, 2017; Yazezew, 2018; Yemane, 2018). However, in contrast to Agnes (2019), the present study recorded slightly reduced resting time and relatively higher engagement in play behavior, suggesting a more balanced allocation between maintenance and social activities. Such variation may reflect local ecological conditions, group composition, or differences in disturbance levels.

Seasonal variation had a pronounced effect on activity patterns. During the dry season, guerezas spent more time feeding and resting compared to the wet season. This trend likely reflects the combined influence of reduced food availability and higher ambient temperatures. Increased feeding time during the dry season may enable individuals to compensate for the lower quality or patchy distribution of food resources, while extended resting periods help conserve energy and reduce thermoregulatory stress. In addition, the folivorous diet of *C. guereza*, which is rich in cellulose, requires prolonged digestion, thereby necessitating longer resting periods for efficient fermentation and nutrient absorption (Abraham Eustace et al., 2015).

Differences in activity patterns were also observed between seasons and among sex–age categories. Seasonal shifts are likely driven by fluctuations in resource availability, including food, water, and shelter, which vary with climatic conditions (Yazezew, 2018; Yemane, 2018). Significant variation among age–sex classes ($p < 0.05$) revealed that adults allocated more time to feeding and resting, whereas juveniles and sub-adults engaged more frequently in social activities, particularly play. This distinction likely reflects differing energetic and developmental requirements: adults prioritize energy conservation and reproductive fitness, while younger individuals invest in social interaction and motor skill development (Abraham Eustace et al., 2015; Shumet & Yihune, 2017).

Overall, although the general activity budget of *C. guereza* appears relatively stable, fine-scale variation is influenced by seasonal conditions, habitat characteristics, and group composition. Adults predominantly engage in energy-conserving behaviors such as feeding and resting, whereas juveniles are more active socially. This behavioral flexibility likely enhances the species' capacity to cope with environmental variability and contributes to its persistence across both disturbed and undisturbed habitats.

4.2 Feeding Ecology and Diet Composition

The present study demonstrates that *Colobus guereza* exhibits considerable dietary flexibility, feeding on thirteen plant species during the study period. The diet consisted mainly of leaves, supplemented by fruits, flowers, and occasionally bark, stems, and wood. This diversity is supported by the species' specialized digestive system, characterized by a multi-chambered stomach that enables efficient breakdown of fibrous plant material (ARKive, 2011; Gron, 2009). These findings are consistent with earlier studies describing *C. guereza* as a predominantly folivorous but adaptable feeder capable of exploiting a range of plant resources (Fashing, 2001a; Matsuda et al., 2020).

Among the plant species consumed, *Millettia ferruginea*, *Sapium ellipticum*, and *Olea welwitschii* were the most frequently utilized. Their prominence in the diet likely reflects both their relative abundance and nutritional value. Similar preferences have been reported in other Ethiopian populations, including those inhabiting fragmented habitats along the Omo River, where *Millettia ferruginea* is consistently selected (Tesfaye et al., 2021). In contrast, species such as *Eucalyptus grandis* and *Ficus sur* were rarely consumed, possibly due to limited availability or lower palatability (Hussein & Ejigu, 2017). These patterns suggest that guerezas make foraging decisions based on a combination of resource availability and nutritional quality.

Feeding time allocation further indicated a strong reliance on leaves, which comprised the majority of the diet. This finding contrasts with studies from Kakamega Forest, Kenya, where fruit consumption was more prominent (Fashing, 2001b), but aligns with other Ethiopian studies emphasizing folivory (Ibrahim et al., 2017; Shumet & Yihune, 2017; Yazezew, 2018). Leaves offer several nutritional advantages, including relatively high protein content, lower levels of secondary compounds, and greater year-round availability compared to fruits and flowers (Chapman et al., 2002; Kaplin & Moermond, 2000). Consequently, reliance on leaves provides a stable and predictable energy source, particularly in environments where fruit availability is highly seasonal.

4.3 Seasonal Variation in Diet and Effects of Disturbance

The study revealed clear seasonal variation in dietary composition. During the dry season, guerezas relied more heavily on mature leaves, likely due to the scarcity of young leaves. In contrast, the wet season was characterized by increased availability of young leaves and fruits, leading to greater dietary diversity. Fruit consumption increased during the wet season, while bark and stems were more frequently consumed in the dry season, possibly serving as alternative sources of moisture and nutrients when preferred foods were limited (Ibrahim et al., 2017). These findings highlight the species' capacity to adjust its diet in response to seasonal changes, thereby maintaining nutritional balance and energy intake.

Despite these seasonal shifts, the study found that habitat disturbance did not have a statistically significant effect on the primary behavioral activities of *C. guereza*, including feeding, resting, and traveling. This result contrasts with previous research indicating that anthropogenic disturbance can alter primate behavior, often leading to increased vigilance and reduced feeding efficiency (Estrada et al., 2017; Kokou et al., 2020).

Several factors may explain this discrepancy. First, *C. guereza* may exhibit a relatively high degree of ecological and behavioral adaptability. Although primarily folivorous, the species demonstrates flexibility in both diet and habitat use, which may buffer it against moderate levels of disturbance (Fashing, 2011; Tesfaye et al., 2022). Such adaptability is particularly advantageous in mosaic landscapes where natural and human-modified habitats coexist.

Second, the temporal scope of the study may have limited the detection of disturbance effects. Although both dry and wet seasons were included, the study represents a relatively short time frame. Long-term impacts of disturbance such as habitat degradation, resource depletion, and cumulative human pressure may not be immediately reflected in observable behavior (Chapman et al., 2019).

Third, the categorization of habitats into "disturbed" and "undisturbed" may oversimplify the complexity of anthropogenic influences. Disturbance varies in intensity, frequency, and type, including activities such as selective logging, grazing, and fuelwood collection. More detailed and quantitative measures of disturbance could provide a clearer understanding of its effects on primate behavior (Arroyo-Rodríguez et al., 2017).

Thus, the findings underscore the ecological flexibility and apparent resilience of *Colobus guereza* in the Kafa Biosphere Reserve. However, this resilience should not be interpreted as immunity to environmental change. Conservation efforts should prioritize the protection of key food species, such as *Millettia ferruginea*, *Sapium ellipticum*, and *Olea welwitschii*, as well as the maintenance of habitat heterogeneity. Long-term monitoring and more refined assessments of disturbance are essential to ensure the continued survival of this species in increasingly human-modified landscapes.

5 CONCLUSIONS

The study demonstrates the ecological flexibility and relative resilience of *Colobus guereza* in the Kafa Biosphere Reserve, while highlighting that this resilience does not imply immunity to environmental change. The species spent most of its time resting and feeding, reflecting its energy-conserving, folivorous lifestyle. Behavioral differences among age–sex classes were evident, with adults especially females focusing more on feeding and resting, while juveniles engaged more in social activities such as play. Seasonal variation strongly influenced both activity patterns and diet, with increased feeding during the dry season likely compensating for reduced food availability and higher temperatures. Leaves constituted the primary diet, particularly from *Millettia ferruginea*, *Sapium ellipticum*, and *Olea welwitschii*, while shifts in fruit and bark consumption across seasons indicated dietary adaptability. Although disturbance did not significantly affect core behaviors, this result should be interpreted cautiously due to potential long-term impacts. Overall, the species' persistence depends on diverse food resources and intact forest habitats, emphasizing the importance of conservation and continued ecological monitoring.

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Authors' contribution

Belaynew Asmamaw and Melkamu Adamu: Writing the original draft, review & editing, investigation, data collection, analyzing with software, methodology. Yosef Mamo: review & editing and formatting, validation, supervision, methodology, conceptualization.

Conflict of interest

The authors declare that they have no conflict of interest.

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Data availability Statement

All data generated or analyzed during this study are included in this manuscript [and its supplementary information files].

Ethical Clearance

As the study involved observing free-ranging colobus monkeys in their natural habitat without any physical interaction, such as capturing, tagging, or handling, no ethical clearance was required for this research. The data collected was solely through non-invasive field observations.

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