Dietary composition and feeding preference of Colobus monkey *Colobus guereza* in Maze National Park, Ethiopia (#99661)

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Dietary composition and feeding preference of Colobus monkey *Colobus guereza* in Maze National Park, Ethiopia

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Knowledge of primate ecology is essential for effective conservation and identification of its food. Examining temporal change in a species' diet and comparing it to variation in feed resource availability can help us better understand evolution and socio-ecology. This is critical to a species' survival can lead to more targeted habitat conservation and management. There was no data on the diets of *Colobus guereza* in the Maze National Park (MzNP) ~~up to date~~. Thus, the aim of this study is to identify dietary composition and feeding preferences of ~~the study species~~ in the area. The scan sampling method was used to collect feeding data during October 2021-September 2022. This refers keeping a fixed 10-minute watch on the target groups every five minutes interval. Depending on how far we were from the Colobus, we used binoculars or the naked eye for the observation. Descriptive statistical analyses were held to compute the feeding data, and presented in tables, figures and narrative means. We compared the ~~mean~~ difference among diet components utilized by the study species using one sample t-test at 95% confidence interval. The preference of diet components between seasons was computed using χ2-test. Of the 750 feeding observations, 369 were took place during the dry and 381 were during the wet season ~~including three targeted groups~~. Eight plant types and non-identified invertebrates have been identified as essential food sources in the study region. We found young leaves were preferred first during the wet, and the matured one during the dry season based on their availability. We observed significant difference among diet components used between seasons. This might be due to the difference in availability and quality of feed components between seasons. Our results suggest that maintaining the riverine habitat along the Maze River was crucial for the conservation of Colobus, where most of essential plant types and feeding activities were recorded.

Title: Dietary Composition and Feeding Preference of Colobus Monkey *Colobus guereza* in Maze National Park, Ethiopia

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ABSTRACT

Knowledge of primate ecology is essential for effective conservation and identification of its food. Examining temporal change in a species' diet and comparing it to variation in feed resource availability can help us better understand evolution and socio-ecology. This is critical to a species' survival can lead to more targeted habitat conservation and management. There was no data on the diets of *Colobus guereza* in the Maze National Park (MzNP) up to date. Thus, the aim of this study is to identify dietary composition and feeding preferences of the study species in the area. The scan sampling method was used to collect feeding data during October 2021-September 2022. This refers keeping a fixed 10-minute watch on the target groups every five minutes interval. Depending on how far we were from the Colobus, we used binoculars or the naked eye for the observation. Descriptive statistical analyses were held to compute the feeding data, and presented in tables, figures and narrative means. We compared the mean difference among diet components utilized by the study species using one sample t-test at 95% confidence interval. The preference of diet components between seasons was computed using $\chi 2$-test. Of the 750 feeding observations, 369 were took place during the dry and 381 were during the wet season including three targeted groups. Eight plant types and non-identified invertebrates have been identified as essential food sources in the study region. We found young leaves were preferred first during the wet, and the matured one during the dry season based on their availability. We observed significant difference among diet components used between seasons. This might be due to the difference in availability and quality of feed components between

seasons. Our results suggest that maintaining the riverine habitat along the Maze River was crucial for the conservation of Colobus, where most of essential plant types and feeding activities were recorded.

Keywords/Phrases: *Colobus guereza*, Conservation, Dietary composition, Feeding Preference, Habitat, Maze National Park, Matured leaf, Maze river, Season, Young leaf

INTRODUCTION

The *Colobus guereza* is a large, strong black-and-white colobus monkey. The majority of the body is coated in glossy black fur, which contrasts with short white hair around the face and a long white mantle that forms a U shape across the lower back and shoulders (*Arkive, 2011; Groves, 2001*). From tip to base, the tail is yellow or white, with a large white tuft at the end (*Kim, 2002*). Its face is bald and grey. In sharp contrast to the adult guereza's mainly black fur, the young guereza's hair is completely white at birth (*Arkive, 2011*). According to the IUCN Red List of Threatened Species, the *Colobus guereza* is among the least concerned primates (*de Jong et al., 2019*).

~~Studies show~~ primates are one of the most threatened mammal groups worldwide due to a variety of anthropogenic pressures *(Estrada et al., 2017; Estrada et al., 2020; Estrada & Garber, 2022; Garber, 2022*). About 65% of primate species are threatened with extinction, and ~75% have declining populations as a result of persistent human pressures on natural environments leading to widespread loss and degradation of tropical forests *(Estrada et al., 2017; Rudran, 2019*). Many primates are poached for bush meat and traditional medicine and captured live for the pet trade (*Ripple et al., 2016; Estrada et al., 2017*). Therefore, it needs urgent conservation interventions to protect their habitat (*Sushma et al., 2022*). Ethiopia has a high diversity of primates, but increasing human pressure has negatively impacted their distribution and abundance across the country, primarily due to deforestation *(Kifle & Beehner, 2022*). The country has experienced significant current forest loss due to agriculture and grazing land expansion, monoculture plantations, and unsustainable and overexploitation of resources (*Ameha et al., 2014; Mekonnen et al., 2020)*.

Diet is integral to understanding the behaviour and adaptations of extant and extinct primate species alike (*van Casteren et al. 2018*). Primates feed on a diverse array of plant items and

animal tissues to meet their nutritional needs (*Coiner-Collier et al., 2016*). In response to habitat changes, they can develop ecological and behavioural flexibility (*Arroyo-Rodríguez & Fahrig 2014; Mekonnen et al., 2018*). The studies show species display microhabitat preferences, occupying specific forest strata or habitat types (*Campbell et al., 2018; Matsuda et al., 2022*). Ecological factors such as forest structure, habitat area, and spatial and temporal resource availability are critical in determining the distribution of primate species. Thus, Colobus showed specific habitat preferences (riverine) in the present study area. This is due to the preference of forest habitat to get food and protection; thus, relatively better forest patches are present along the Maze River. This illustrates a result of seasonal variation in food availability; primates may show a dietary shift to optimize nutrient intake (*Jarvey et al., 2018*). The food availability in an animal's diet is influenced by seasonal variations as well as environmental factors *(Chouteau, 2006*). This in turn influences animals' diet choices. Dietary shifts typically correspond with seasonal resource scarcity (*Yiming, 2006; Hanya & Chapman, 2013)*. A shift in an individual's diet should reflect the most profitable foods available at a specific time and place, which may also mean the most nutritious, the easiest to find, or the easiest to process (*Lambert & Rothman, 2015*).

~~Moreover,~~ the aim of this study was to look at dietary composition, and examine the feeding preferences of *Colobus guereza* between seasons in the study area. Here, we hypothesized that seasonal change affects feed availability, which in turn determines the feeding preference of the study species. ~~Thus,~~ our findings suggest that season affects the accessibility of diet components and consequently governs feeding preferences of the *Colobus guereza*. Based on the results of this study, we highly recommend that the riverine habitat contribute valuable diet components and provide protection to the *Colobus guereza*, where almost all of the food plants were recorded during this survey. Furthermore, this could offer an opportunity to create and implement successful habitat conservation strategies, thereby preserving important feed components in the particular habitat of the Park.

METHODS AND MATERIALS

Study area

We conducted this study at the Maze National Park (MzNP) along the Maze River, which is major habitat of target species. The area is located between Gamo and Gofa Zones, Southern

Ethiopia. It is surrounded by five districts, such as Daramalo in the south and southeast, Qucha in the east, Qucha Alfa in the northwest, Zala in the southwest and Kamba zuria in the south. The Park is located between 06°18'30 and 06°29'00" N latitude and 37°7'30" to 37°22'30" E longitude (Figure 1). The elevation ranges between 900 and 1200 meters above sea level (*Befekadu & Afework, 2006*). The area is one of semi-arid agro-ecological zone of Ethiopia. The annual rainfall varies between 843 to 1321mm. Maze area experiences a rainy season that extends from March to October, while the dry season is from November to February. The lowest temperature recorded during the wet season is 15.3°C in June and the highest during the dry season is 33.5°C in February *(Mamo, 2012; Tekalign & Bekele, 2011*). The Park has remarkable population of mammalian fauna such as orbi (*Ourebia ourebi*), bohor red buck (*Redunca redunca*), buffalo (*Bubalus bubalis*), warthog (*Phacochoerus africanus*), bush buck (*Tragelaphus scriptus*), greater kudu (*Tragelaphus strepsiceros*), lesser kudu (*Tragelaphus imberbis*), Water buck (*Kobus Ellipsiprymnus*), bush pig (*Potamocherus larvatus*), anubus baboon (*Papio anubis*), vervet monkey (*Chlorocebus pygerythrus*), colobus monkey (*Colobus guereza*), lion (*Panthera leo*) leopard (*Panthera pardus*), wildcat (*Felis silvestris*), serval cat (*Leptailurus serval*), ~~are the common wild animal species~~. In addition to varied floral composition. It comprises varieties of bird species, reptiles, amphibians and insects. Moreover, 39 larger and medium sized mammals and 196 bird species have been recorded in the Park (*Tekalign & Bekele, 2011; MzNP annual office report, 2018*).

The Park is covered by savannah grassland with scattered deciduous broad leaved trees. Most of the Park area is plain, and is covered by open *Combretum* and *Terminalia* wooded vegetation. The river Maze begins from the surrounding highlands of the Park and drains in to the southern part of the area along with different tributaries, and traverses the Park from the northern to southern end of the area. This makes an important riverine habitat to primates, particularly for colobus monkey, in which no feeding activity has been detected rather than the riverine habitat over the study period (Figure 1).

Ethical permit

The Office of Executive Research Directorate and the Biodiversity Research and Conservation Center were approved the field survey with permissions (AMU/TH2/BRCC/09/2014). Hereby, we can guarantee that no animal capture and tissue or blood sample was taken from the subject species, with the exception of field data collecting by scan sampling to watch feeding activities.

Data collection

Feeding ecology

During the 12-month period (October 2021–September 2022), we collected feeding activity data from individuals using prompt scan sampling (*Altmann, 2009*). For the dry season, we collected data from October 2021 to February 2022, and for the wet season, from April 2022 to August 2022. The feeding data were collected through direct observation from proper viewpoints (*Altmann, 2009*). This was watching of the *Colobus guereza* for a fixed period of 10 minutes with 5 minutes interval from 6:30 to 10:30 with~~in~~ naked eye and binocular depending on the distance between the observer and targeted group of the study species (*Fashing et al., 2007*).

Target groups

Three groups of *Colobus guereza* were targeted for this study. One group with three individuals at Maze camp site (group-1); another group with two individuals at Domba site (group-2); and the third group with three individuals at Lemasse site (group-3); were selected along the River Maze. We monitored those groups in their home ranges for the duration of the study, with a research team assigned to each group to look at dietary ecology and potential differences in feeding activities.

In each exploration interval, the feeding activity of the study species, the plant type, parts of the plant, growth patterns, and the diet components other than the plant materials were noted *(Fashing et al., 2014; Jarvey et al., 2018; Mekonnen et al., 2018*). We categorized the feed components as young leaf, matured leaf, shoot, flower, fruit, bark and unidentified invertebrates. Most of the diet components consumed were distinguished in the field, while some unidentified plant species were taken to Arba Minch University, and later identified to their taxonomic level.

Data analysis

All the data were combined into one XLSTAT 2023.1.3 (1407) and SPSS software version 22 were used for analysis. ~~To compute the data, descriptive statistics were used.~~ The total amount of each feed consumed over the study period was calculated using percentage value. The chi-square test was employed to show the seasonal variation and monthly difference in the diet components used by the study species. We compared the mean difference among diet components utilized by the study species using one sample t-test at 95% CI. $P < 0.05$ was deemed significant for all analysis.

RESULTS

We illustrated that seven tree plants and one shrub species, those grouped in to eight families comprised the major plant species identified as colobus feed sources in the area; of these, six plant sections were utilized by colobus as food and consumed in different proportions depending on the availability across seasons (Table 1). Nonetheless, we found no differences in the three research groups' feeding behaviors.

Food classes used by colobus between seasons

We found in the dry season, matured leaf accounted for the majority (34.69%) of colobus' diet, followed by young leaf (27.64%), while the sprout (shoot) contributed the least. During the wet season, the young leaf had the highest share (47%) followed by the matured leaf (18.63%), with unidentified invertebrates contributing the least (Table 2)

Significant variations were observed among diet components used by colobus in both seasons (Dry: $\chi2 = 230.136$, df = 6, $p = 0.000$; Wet: $\chi2 = 375.643$, df = 6, $p = 0.001$). Substantial difference was observed between seasons for young and matured leaf (Young leaf: $\chi2 = 21.100$, df = 1, $p = 0.002$; Matured leaf: $\chi2 = 16.327$, df = 1, $p = 0.000$) and non-significant variation was recorded for other feed components (Fruit: $\chi2 = 0.653$, df = 1, $p = 0.419$; Flower: $\chi2 = 1.373$, df = 1, $p = 0.241$; Bark: $\chi2 = 1.653$, df = 1, $p = 0.199$; Shoot: $\chi2 = 0.500$, df = 1, $p = 0.480$; Non-identified invertebrates: $\chi2 = 0.500$, df = 1, $p = 0.480$) consumed.

Diet components' proportion consumed among months in the study year

The proportion of diet components used by the study species in months of the year were varied significantly (Table 3). Thus, November: $\chi2 = 37.253$, df = 6, $p < 0.05$; December: $\chi2 = 20.283$, df = 6, $p < 0.05$; January: $\chi2 = 33.293$, df = 6, $p < 0.05$; February: $\chi2 = 48.141$, df = 6, $p < 0.05$; March: $\chi2 = 78.741$, df = 6, $p < 0.05$; April: $\chi2 = 69.212$, df = 6, $p < 0.05$; May: $\chi2 = 74.286$, df = 6, $p < 0.05$; June: $\chi2 = 97.778$, df = 6, $p < 0.05$; July: $\chi2 = 135.429$, df = 6, $p < 0.05$; August: $\chi2 = 119.000$, df = 6, $p < 0.05$; September: $\chi2 = 104.990$, df = 6, $p < 0.05$; October: $\chi2 = 96.081$, df = 6, $p < 0.05$.

In the other hand, with the exception of the young leaves, that Colobus ate among months of the year, none of the diet's constituents changed considerably during the course of the study month However, there was a significant increase in the young leaf used along the study months ($\chi2 = 31.841$, df = 11, $p = 0.001$) (Table 3). In addition, we found a considerable variation between the mean differences of diet components consumed by *Colobus guereza* through the study period (Dry: t = 30.076, Mean difference= 2.63415, SE = 0.08758; Wet: t = 26. 685, Mean difference = 2.35696, SE = 0.08832).

DISCUSSION

We made a total of 750 feeding observations through the survey period. Of these, 369 were during the dry and 381 were in the wet season (Table 2). We found that the riverine forests beside the Maze River provide the vital food groups, and that *Colobus guerezas* consume a wide range of dietary components. Thus, population biology and ecology depend heavily on the species' feeding patterns. To make up the majority of herbivore's diet, it is necessary to assess the quantity and quality of the most and least desired plant species (*Ego et al., 2003*). The largest selection ratio for plant parts shows a desire for the food items offered by the plant species, whereas a low selection ratio implies a dislike *(Mekonen & Hailemariam, 2016; Fashing et al, 2007*). Many colobine species, have increased dietary extent during times and areas with low availability or quality of resources (*Hu, 2011; Clink et al., 2017*). The present study depicted, the dietary preference of *Colobus guereza* included young and matured leaves of diverse tree species, shoots, some of tree fruits, flowers, bark and unidentified invertebrates (Table 2).

Similar to other colobines, the *Colobus guereza* primarily prefer young leaves followed by the matured leaves. We found young tree leaves were the most important food sources for the study species in the MzNP, southern Ethiopia. We observed the study species use young leaves and matured leaves interchangeably during the wet and dry seasons. In line with this, studies shown

that leaves accounted for high proportion (42–49%) by folivorous-frugivorous monkeys (*Lima et al., 2024*). Another study shown that Bale monkeys spend more time munching on new bamboo tree leaves in Southern Ethiopia (Mekonnen *et al*., 2018). Similarly, the leaves accounted for highest proportion of *Colobus guereza's* food items; (71.6%) in Borena-Sayint National Park, Northern Ethiopia (*Hussein et al., 2017*) and 82% in Bale Mountains National Park, Ethiopia (*Petros et al., 2018*). These all illustrate that plant leaves, particularly leaves from tree plants are the highly preferred feed by the study species followed by fruits (Figure 2).

Dietary flexibility

Primates consume more secondary successional species in response to habitat loss (*Dunn JC et al., 2012; Chaves et al., 2019*). We found seasonal change in the diets of Colobus monkeys in the present study. They consumed a lot of young leaves during the wet season and matured leaves and fruits during the dry season. Throughout the study months, there was a considerable increase in young leaves but not a significant change in the remaining diet groups (Table 2). This is attributed to seasonal variations in the availability of diet compositions. When young leaves are insufficient, the Colobus monkey changes their diet and increases their consumption of matured leaves. This demonstrates the seasonal variability in the availability of food components and across months of seasons (Table 3). This is consistent with the previous study where resource availability is highly variable; leaf monkeys eat more leaves during periods of low fruit availability *Hanya & Bernard (2012).* This In line with this, Bale monkeys changed their diet by eating more fruits, stems, petioles, insects, and leaves from plants other than bamboo (*Mekonnen et al., 2018*). Many Colobine species are more affected by food availability and distribution, and employ multiple strategies to survive during periods of food shortage (*Feilen & Marshall, 2020*). This was evidenced that high records of feeding activity along Maze River indicated ample distribution of food plants in the particular area. Research outputs found, proboscis monkeys varied in response to monthly changes in food availability, but did not vary among forest types (*Feilen & Marshall, 2020*). In addition, the influence of seasonality on the diet reported at Tanjung Putting National Park, thus fruits comprised high proportion of the diet from January to May, while young leaves consumed the highest proportion of the diets from June to December (*Yeager, 1989*). This might be attributed the fact, that the season contribute to the availability and even the quality of diet components and this determines the feeding preference of the species. However, *Colobus guereza* consumed high amount of young leaf during the study period, in

riverine habitat of the Park, the percentages were higher for studies of another Colobine in elsewhere; in the Lower Kinabatangan River found large proportion (66%) of young leaves in the diet of proboscis monkeys than the present study (*Matsuda et al., 2009*). A study in the rubber forest in South Kalimantan, Indonesia (80.9%) as mentioned by *Feilen & Marshall (2020*) for *Soendjoto et al. (2006)* and a study from the river's edge in mangrove forest and riverine forest performed in Klias Peninsula in Sarawak, Malaysia, also found higher percentages of leaves in the diet (91.6%) (*Bernard et al., 2018*) comprising 35% young leaves, in West Kalimantan, Indonesia (*Feilen & Marshall, 2020*). In addition, the Omo River guereza (*Colobus guereza guereza*) feed a wide range of diets in populations with varying degrees of habitat conditions *(Tesfaye et al., 2021*). Similarly, studies have shown that primates can exhibit ecological and behavioural flexibility in response to changes in habitat (*Arroyo-Rodríguez & Fahrig, 2014; Mekonnen et al., 2018*). These might be suggested that there may be considerable dietary variation among the study areas, forest types, duration of sampling period, method of sampling, and the survey effort. Preferred foods are generally high quality foods that are easy to process and are eaten more often than would be predicted based on their availability (*Leighton, 1993*). Studies indicated that dietary shift is opportunistic rather than desired food availability, which is controversial to the current study, thus we examined *Colobus guereza* shift from its first preference to the other type based on the availability of the particular feed type. However, Lima et al. (2024) mentioned that the opportunistic consumption probably contributed only minor amounts of energy to the species. Mountain gorillas used agricultural and anthropogenic foods opportunistically in Uganda's Bwindi Impenetrable National Park (*Seiler & Robbins, 2016*). The primary motivations for macaques switching from natural feed to anthropogenic foods were considered to be either natural food scarcity or dependency on the anthropogenic foods (*Sha & Hanya, 2013*). On the other hand, *Cancelliere et al. (2018)* suggested that feeding effort variation in Vervet monkeys has been linked to behavioural characteristics. However we selected three separate groups of the study species for this study, we found no change among those groups for feeding preferences throughout the study period. This might be attributed to the habitat homogeneity where the *Colobus guereza* permanently live and its feeding activities were recorded in the riverine habitat during this survey.

CONCLUSION

Analyzing and comprehending the diet of primates is a crucial aspect of species ecology, with significant consequences for conservation. Our research showed that the habitat found in rivers plays a significant role in providing all food plants and a suitable place for the species to live. In addition, we found that all plant species' leaves, young and matured, could be a viable food source nearby. Based on the results of this study, we strongly suggest that emphasizing the protection of the riverine habitat will result in effective conservation of the species. Specifically, we looked at seasonal fluctuations in the diet composition used by the *Colobus guereza* during the study period. In fact, we illustrated this there is the difference in the availability of diet items over months of the year. As a result, this limits feeding preference of the species.

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

Abraham Tolcha: conceived and designed the all research work, led the project, performed the experiments and field data collection, analyzed the data, prepared the draft manuscript, reviewed the draft manuscript and enriched, and approved the final version.

Matewos Masne: conceived and designed the experiments, performed the field data collection, analyzed the data, reviewed the draft manuscript, and approved the final draft.

Belayneh Ayechw: conceived and designed the experiments, performed the field data collection, analyzed the data, reviewed the draft manuscript, and approved the final draft.

Data Availability

The all data for this study will be accessible with the corresponding author in reasonable requirement and at the database of this journal.

Supplemental Information

Supplemental information for this work can be found online at web site of this journal.

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Table 1(on next page)

Result section of table data

Tables

Table 1 Plant species and parts consumed by Colobus during the study period

Scientific name	Family name	Local name: (Gamotho/ Gofatho)	Growth habit	Food items consumed	Season	
					Wet	Dry
Carissa spinarum	Apocynaceae	Lade	Shrub	Fruit	FR	FR
Millettia ferruginea	Fabaceae	Zage	Tree	FR, Fl	-	FR, Bk
Syzygium guineense	Myrtaceae	Ocha	Tree	FR, Fl	YL	FR, YL
Moringa stenopetala	Moringaceae	Yalaga halako	Tree	L, Sh	YL, Sh	YL, Sh
Trichilia emetica	Meliaceae	Demo	Tree	FR, L, Sh	YL, Sh	FR, Sh
Ficus sycomorus	Moraceae	Eatha	Tree	FR	-	FR
Grewia villosa	Tiliaceae	Ogaade	Tree	L, Fl	YL, ML	ML
Acacia polyacantha	Leguminosae Mimosoideae	Dawala	Tree	Bk, L	YL	Bk

Note: FR=fruit, Bk=bark, L=leaf, ML= matured leaf, YL= young leaf, Fl= flower, Sh= shoot

Table 2 Overall contributions of various food classes of Colobus monkeys between seasons in the study area.

Dry season	Total diet components consumed over seasons							
Components of diet	Young Leaf	Matured leaf	Fruit	Flower	Bark	Shoot	Non-identified invertebrates	Total
Dry season								
Feeding observation	102	128	53	25	29	14	18	369
% of diet	27.64	34.69	14.36	6.77	7.86	3.80	4.88	100%
Wet season								
Feeding observation	179	71	45	34	20	18	14	381
% of diet	47.00	18.63	11.81	8.92	5.25	4.72	3.67	100%

Table 3 Proportion of diet components used by Colobus monkeys for each month during the study period

No.	Food components	Diet components consumed by Colobus monkey over months of the year (%)											
		Nov. 2021	Dec. 2021	Jan. 2022	Feb. 2022	Mar. 2022	Apr. 2022	May 2022	June 2022	July 2022	Aug. 2022	Sep. 2022	Oct. 2022
1	Young leaf	20	21	25	27	38	39.5	41	46	49.5	46.5	43	40
2	Matured leaf	28.5	24	27.5	31	28	23.5	21.5	19.5	27	28	29.5	31
3	Fruit	21	17.5	15	10.5	7.5	12	8.5	13.6	6	8	9.75	9
4	Flower	14	10	9.3	8.5	6.5	9	10.5	4.5	2.5	3.5	6	4
5	Bark	3.5	4	3.45	3	2.5	2.3	3	3.4	1.2	2	1.5	4
6	Shoot	4	12.5	9	7	6	5.7	9	7	4.3	5.5	3	2.5
7	Unidentified invertebrates	9	11	10.75	13	11.5	8	6.5	6	9.5	6.5	7.25	9.5

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Figure 1

Figure data

(1) Study area map of the Maze National Park

(2) Feeding observations carried out on various diet components between seasons

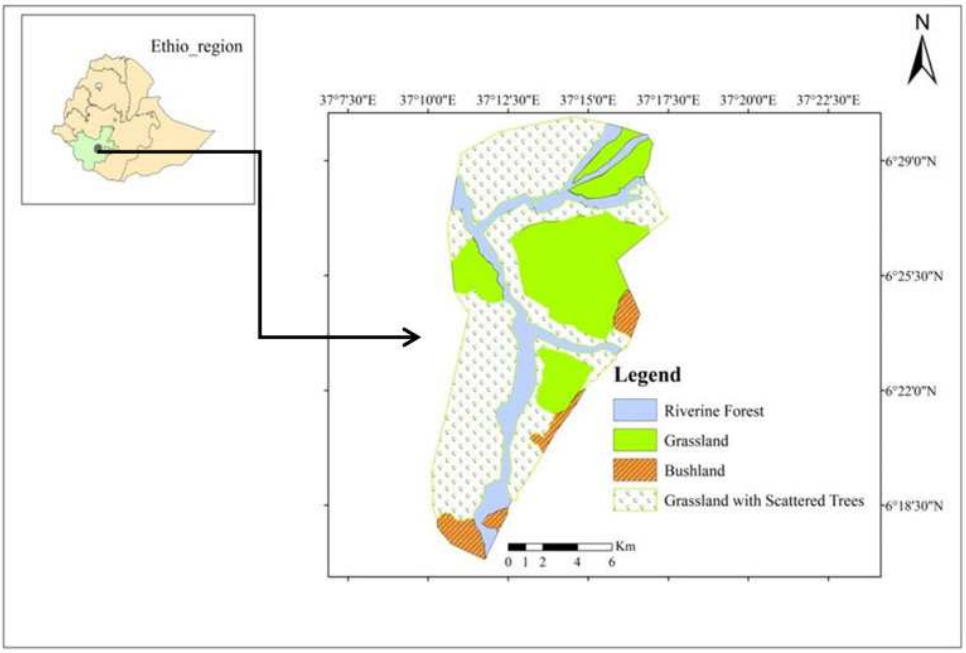

Figure 1 Study area map of the Maze National Park

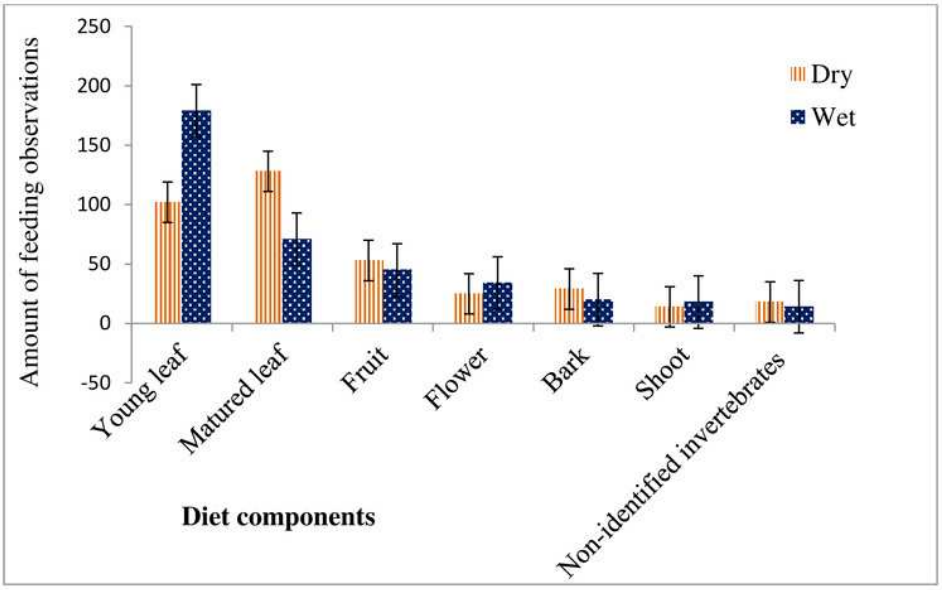

Figure 2 Feeding observations carried out on various diet components between seasons