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The Effect of Habitat on Density, Feeding Behaviour and Activity of Heller's Vervet Monkey (*Chlorocebus pygerythrus arenarius*): A Case Study in Arba Minch Forest, Ethiopia

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Abstract: Heller's vervet monkey (*Chlorocebus pygerythrus arenarius*) is one of the African savannah monkeys found in East Africa including Ethiopia. This study was carried out from September 2012 to April 2013 to provide data on the effect of habitat on density, feeding and activity of the Heller's vervet monkey in Nech Sar National Park and its adjacent areas, in Ethiopia. The study area constituted underground water forest, riverine forest, savannah bushland, bush with *Eucalyptus* plantation and tree dominated bushland. Five line transects of 3-4 km were made in all habitats to estimate the population density of Heller's vervet monkey. Five selected troops were also followed using focal animal sampling to study the activity patterns and feeding behaviour. The highest population density of Heller's vervet monkey was recorded in underground water forest and riverine forest habitats. The overall diet composition of Heller's vervet monkey was dominated by leaves, which accounted for 37.87%. Foraging on bark, fruit and flowers constituted 21.19%, 19.56% and 13.90%, respectively. They also fed on shoots (4.70%) and unknown food items (2.78%). The activity in different troops showed significant variations in resting behaviour, whereas active behaviours did not show significant variations between the troops.

Keywords: Behaviour, Diet, Ecology, Effect, Heller's Vervets, Nech Sar National Park

1. Introduction

The survival of a species is dependent on the availability of critical resources such as food and protection [23]. Quality of habitat is a major factor for species survival in an area [18]. The existence of primates in different habitats varies depending on the local heterogeneity of ecological resources and environmental conditions [11]. The distribution patterns of different available resources affect primates' existence [19]. Differences in structure and composition among habitat types generate differences in habitat use by primates [15].

Savannah monkeys of the genus *Chlorocebus* are the most widely distributed non-human primates in Africa [32, 27]. They occur from Senegal to Ethiopia, Djibouti and Somalia, as well as southward over much of southern Africa [16]. Heller's vervet monkey (*Chlorocebus pygerythrus arenarius,* Heller, 1913) is one of the savannah monkeys found in East Africa including Ethiopia. In Ethiopia, they exist around the shores of the low lying rift valley lakes Abaya and Chamo of central Ethiopia [6].

Heller's vervets show characters such as preference for plant matter mainly leaves, and high variability in occupying the various habitats in Nech Sar National Park. They occupy a wide range of habitats from riverine and underground water forests to savannah bushland in the area. They are also observed in bush with *Eucalyptus* plantation forest habitat.

The study of Heller's vervet monkeys in different habitats provides useful information about the interactions between this species and their habitats [35, 26]. Studies conducted at small spatial scales are particularly important because they permit investigation of the effects of variation in some ecological conditions [7]. As Heller's vervets in the study area occupy diverse habitats, the present study considers

three questions. 1. What is the extent of Heller's vervets density in different habitats? 2. What does feeding behavior of Heller's vervets look like? 3. Do Heller's vervets alter their behaviour in response to habitat variations? In order to address the above three questions, this study aims to provide data on the effect of habitat on density, feeding behaviour and activity patterns of Heller's vervet monkey in Nech Sar National Park and its adjacent areas, in Ethiopia.

2. Methodology

2.1. The Study Area

Nech Sar National Park is located in the eastern edge of Arba Minch town, at about 500 kms south of Addis Ababa. The Park lies within the floor of the Ethiopian Great Rift Valley and extends from 5°51'N to 6°50'N and from 37°32'E to 37°48'E with an elevation varying between 1,108-1,650 meters above sea level. It covers an area of 514 km^2 of which 85% is land and 15% is water. The study area comprised the western part of Nech Sar National Park, Arba Minch forest and the northern parts of Arba Minch forest, and the adjacent areas (Figure 1). It has an area of 60 km^2. The temperature of the area ranges between (17-30°C). Rainfall distribution is bimodal mostly occurring in March, April and May and between September and November. Annual rainfall averages around 900 mm. The wet season includes March, April, May, September, October and November and the dry season includes December, January and February.

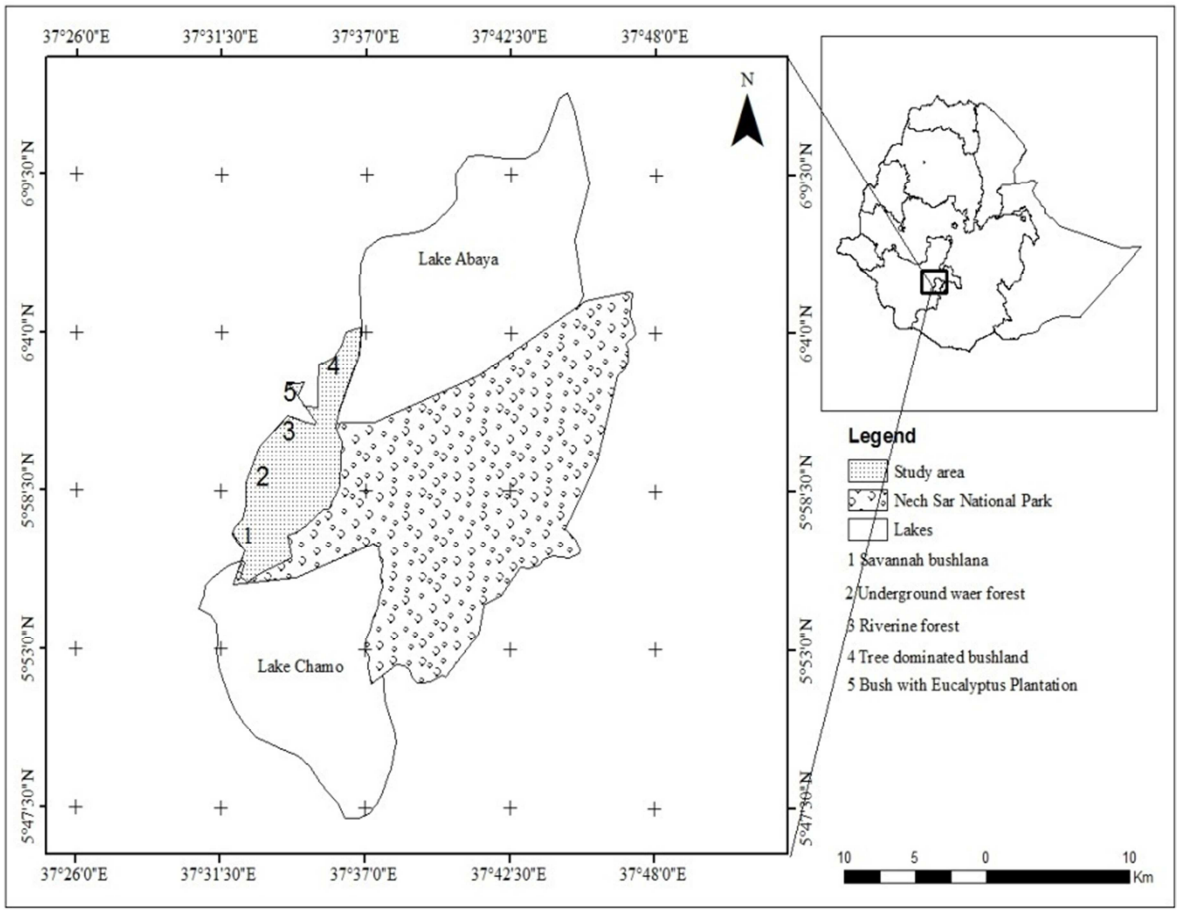

Figure 1. *Map of the study area.*

2.1.1. Habitat Structure

The study area had five habitats. These included riverine forest, underground water forest and savannah bushland in Nech Sar National Park and bush with *Eucalyptus* plantation and tree dominated bushland in the adjacent areas. Underground water forest is dominated by tall trees of over 30 meters high. The species characterizing this habitat include *Cordia africana, Diospyros abyssinica, Croton macrostachyus, Ficus vasta, Syzygium guineense, Lecanodiscus fraxinifolius* and *Ficus sycomorus.* Riverine forest is dominated by woodland. The vegetation communities of this habitat include *Balanites rotundifolia*, *Tamarindus indica, Dicrostachys cinerea, Balanites aegyptiaca, Diospyros abyssinica* and *Ficus sycomorus*. Savannah bushland is composed of grass, *Acacia* trees and bushes. *Acacia seyal*, *Acacia senegal*, *Acalypha fruticosa*, *Pterolobium stallefum*, *Euphorbia tirucalli* and *Acacia tortilis* are major vegetation of the habitat. Bush with *Eucalyptus* plantation is somewhat disturbed, encompassing *Eucalyptus* trees, *Acacia tortilis*, *Acalypha fruticosa* and *Balanites aegyptiaca*. Tree dominated bushland is composed of tall *Acacia* trees and bushes. The major vegetation of this habitat include *Acalypha fruticosa*, *Acacia seyal*, *Acacia tortilis*, *Ficus vasta* and *Balanites aegyptiaca*.

2.1.2. Fauna

Nech Sar national Park possesses different species of large mammals including, but not limited to Bush pig (*Potamocherus larvatus*), Spotted hyena (*Crocuta crocuta*),

Aardvark (*Orycteropus afer*), Greater kudu (*Tragelaphus strepsiceros*), Warthog (*Phacochoerus africanus*), and primates such as Black and white colobus monkey (*Colobus guereza*) and Anubis baboon (*Papio anubis*). Because of its wide varieties of ecological conditions, Nech Sar National Park also supports a range of birds, amphibians and reptiles. The Park lies within the Somalia-Massi Regional Center of Endemism, one of the major floristic regions in Africa [10]. Due to the presence of vast birdlife in the Park, Birdlife International has declared the Park as an Important Bird Area of Ethiopia [12].

2.2. Methods

A preliminary survey was made for ten days during 15–25 August 2012 in the study area to identify sites and familiarize ourselves with the habitat for detailed studies. During this survey, layout of transects and selection of focal study troops of the Heller's vervet monkey were made. The main data collection activities were carried out during September 2012-April 2013.

2.2.1. Line-Transect Method

A census of Heller's vervet monkey in the study area was carried out by line-transect method. Transects were established based on a stratified random sampling approach within different habitats. A total of five transects ranging from three to four kilometers in length were walked in all habitats.

Each transect was walked a minimum of 10 times during both wet and dry seasons [27]. Altogether, transects were walked a minimum of 50 times. Surveys were conducted during 06:30–10:30 h in the morning and 14:00–18:00 h in the afternoon at an average speed of 1km/hr in the forest and 2km/hr in the plantation [31, 9]. During the transect walks, when Heller's vervet monkeys were encountered, GPS location, group size, perpendicular distance usually from 30° and habitat type where the troop was spotted were recorded [14]. No surveys were done when it was rainy and strongly windy, as such weather conditions reduce visibility leading to bias [4]. The population density of Heller's vervet monkeys in different habitats of the study area was calculated using the King estimator [25]: $d = n / 2La$.

Where:

n is the number of Heller's vervet monkeys counted on each transect,

L is the length of the transect walked, and a is the average perpendicular distance of the individuals observed to the transect.

2.2.2. Sample Design

Behavioural data were collected on five troops of Heller's vervet monkeys. The behavioural study was carried out for six months during both the wet and dry seasons. Troop one (TRF) was found in the riverine forest, troop two (TUWF) in the underground water forest, troop three (TSB) in the savannah bushland, troop four (TBEP) in the bush with *Eucalyptus* plantation and troop five (TTB) in the tree dominated bushland habitat. There were 16 individuals in troop I, 20 in troop II, 5 in troop III, 9 in troop IV and 10 in troop V. Troops were chosen that ranged a minimum distance of 2 km apart to ensure habitat differences among them.

During the behavioural observations, individuals in each group were identified at the level of age-sex classes as they were not well habituated with the observers. Systematic behavioural data for the study were collected during the wet season between September and November 2012 and the dry season between December and February 2013. Different social groups were sampled on different days. Each troop were followed by a trained of researcher and of local field assistant. Each individual in the troop was categorized into its respective age and sex category. The categories used were adult male, adult female, sub-adult male and sub-adult female. Identification of sex and age categories was carried out using relative body size and external genitalia [2]. Adult females with infants were considered as adults, but individuals of undefined sex and immatures were excluded from the behavioural study.

2.2.3. Activity Patterns and Feeding Ecology

Data on the activity pattern of Heller's vervet monkey in the study area was recorded for different troops. Troops were studied using focal animal sampling for a continuous period of 10 minutes with 5 minutes intervals between samples [3]. Behavioural records such as resting, travelling, feeding, social and other behaviours were examined for each troop. Activity patterns were calculated using the proportion of points for each behavior between the troops, and considering the numbers of records of behavioural changes during the study. Totals for focal samples were used for analyzing the activities of the troops. Twenty days were devoted each month to study the activity pattern, following each of the troop for four days. The 4 focal animals of each troop were followed in a day for a total of 40 minutes. Troops were observed on alternate days to ensure that hours of data collected were similar between troops. In observation periods when, the focal animal disappeared from the sight before the 10 minute mark, the record was discarded and substituted with the observation of another individual of the same age and sex category. Resting was categorized as inactive behaviour, whereas all others were categorized as active [13]. Behaviour are grouped in to feeding, travelling, resting, social behaviour and other behaviours [33]. The definition and types of each of the above behavioural activities are given in (Table 1).

Table 1. *Major behavioural categories observed and definition.*

Behaviour	Operational definition
Resting	The state at which individuals are inactive. e.g. sitting, sleeping
Travelling	Moving from one place to another or changing location within one tree or between trees without involving in other activities. e.g walking, running, jumping
Social behaviour	Interactions among individuals. e.g. playing, aggression, mating, calling
Feeding	Searching, chewing, eating, breaking or handling of food items. e.g. fruit, leave
Others behaviours	Activities displayed by individuals as a response to internal and external stimuli, and not encompassed above. e.g. defecating, urinating, scanning, auto-grooming

The feeding behaviour of the Heller's vervet monkey was studied along with the observation on behavioural activities. During the focal animal sampling, the feeding activities of Heller's vervets were observed and the different types of food items such as leaves, shoots, flowers, fruits, barks and unknown items consumed were recorded. The data analysis on feeding behaviour was carried out as feeding events on observation time [3] and computing the percentage of foraging devoted to a specific plant part. Each time they switched food items were used for this feeding analysis. The percentage of foraging frequency devoted to a specific plant part was calculated as the total feeding events that item consumed divided by the total amount of feeding events recorded [8]. Diet selection of the study troops was determined from the relative proportion of the feeding events on different food items.

2.3. Data Analysis

Descriptive statistical methods such as percentages were used to analyze the feeding behaviour and activity of Heller's vervet monkey whereas density was estimated using values calculated with the king estimator. SPSS 20.0 version software was used to test significant variation between groups. Statistical tests used were two-tailed with 95% confidence intervals. Chi-square tests were used to compare the food items of Heller's vervet monkey between the wet and dry seasons. One-Way ANOVA were used to compare activities in different troops, and analyze the effect of group size on activities of different troops.

3. Results

3.1. Density

During the transect survey of Heller's vervet monkeys in different habitats, a total of 184 individuals of Heller's vervets in 17 groups were encountered. The mean group size of Heller's vervet monkey ranged from 3-24 individuals and averaged 10.82±4.48, with a 95% (CI) of 8.52-13.12. In total, 50 surveys were conducted covering a distance of 180km. The average density of Heller's vervet monkey in the area was 131.40±133.11individuals/km^2 whereas the average abundance of Heller's vervet monkey was 10.87±9.79 individuals/km. The results of population density in the area also indicated that underground water forest had the highest density, followed by riverine forest. Tree dominated bushland had the third highest population density of Heller's vervet monkey followed by bush with *Eucalyptus* plantation. Savannah bushland had the lowest density of all habitats. Population density of Heller's vervet monkeys in different habitats with total distance covered and perpendicular distances are given in (Table 2).

Table 2. *Population density of Heller's vervet monkey in different habitats.*

Habitat type	T L	PD	RHV	Density (Individuals/km^2)	Abundance (Individuals/ km)
RF	3.4 km	41	58	208.03	17.06
UWF	3.2 km	38	80	328.95	25
SB	4.0 km	56	8	17.86	2
BEP	3.8 km	54	17	41.42	4.47
TDB	3.6 km	48	21	60.76	5.83
Mean ± (SD)	3.60 ± (0.32)	47.40 ± (7.86)	36.80 ± (30.77)	131.40 ± (133.11)	10.87 ± (9.79)

RF: Riverine Forest, UWF: Underground Water Forest, SB: Savannah Bushland, BEP: Bush with *Eucalyptus* Plantation, TDB: Tree Dominated Bushland. TL: Transect length, PD: Perpendicular distance in meters, RHV: Record of Heller's vervet monkeys on each transect, (Figures in brackets show standard deviation).

3.2. Feeding Ecology

The overall diet for all troops of Heller's vervet monkeys was 37.87% leaves, 21.19% barks, 19.56% fruits, 13.90% flowers, 4.70% shoots and 2.78% item unidentified. The most commonly consumed plant species also include *Ficus sycomorus, Euclea divinorum, Ficus vasta, Diospyros abyssinica, Tamarindus indica, Terminalia browni, Acacia seyal, Croton mycrostacheous, Acacia tortilis, Eucalyptus* species*, Syzygium guineense, Cordia gharaf* and *Cordia africana.*

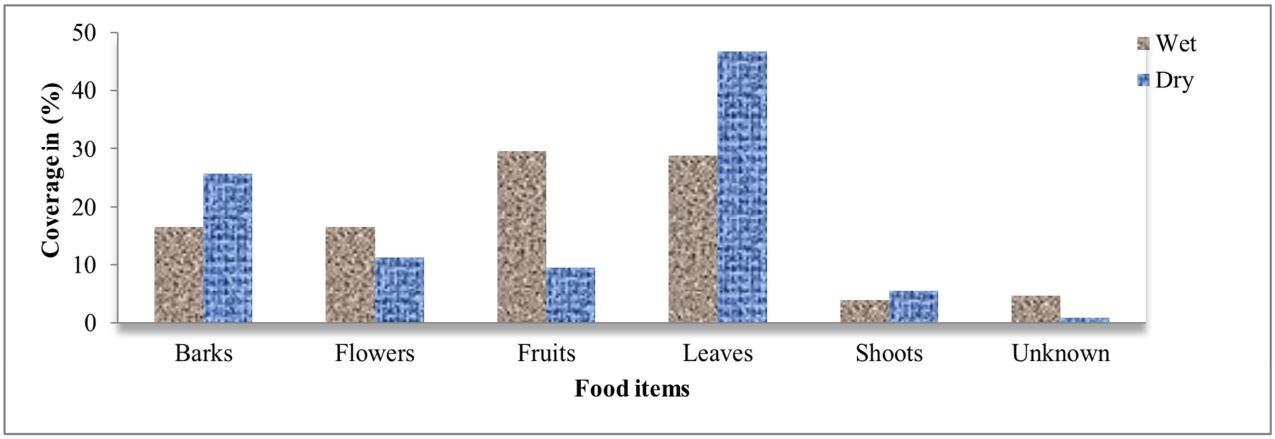

Figure 2. *Food items of Heller's vervet monkey in the wet and dry seasons.*

The seasonal percentage contribution of different food items is given in (Figure 2). During the wet season, Heller's vervets consumed more fruits, flowers and unknown food items, but during the dry season they consumed more leaves, barks and shoots. The Chi-square test showed that there were significant seasonal differences for feeding on leaves (X^2 =22.848, df=1, p=0.000), fruits (X^2 =53.020, df=1, p=0.000), barks (X^2 =10.864, df=1, p=0.001), flowers (X^2 =5.028, df=1, p=0.025) and unidentified food items (X^2 =12.448, df=1, p=0.000). However, there were no significant seasonal differences for feeding on shoots (X^2 =1.653, df=1, p=0.199).

The feeding behaviour of Heller's vervet monkey was also recorded in different habitats during the wet and dry seasons. A total of 1043 sample records were obtained from different habitats. These include, Riverine Forest (n=207), Underground Water Forest (n=284), Savanna Bushland (n=101), Bush with *Eucalyptus* Plantation (n=237) and Tree dominated Bushland (n=214). In both RF and UWF, the highest records of feeding on fruits were observed during the wet season, but highest records of leaf feeding were observed during the dry season. SB comprised the highest record of leaf and fruit feeding during the wet, but bark was the highest record during the dry season. Leaves comprised the main food component for BEP and TDB in both wet and dry seasons. The feeding records of Heller's vervet monkeys in different habitats for the wet and dry seasons are given in (Table 3).

Table 3. *The feeding records of Heller's vervets in different habitats during the wet and dry seasons.*

Habitats	Seasons	Food items, %					
		Leaves	Barks	Fruits	Flowers	Shoots	Unknown
Riverine Forest	Wet	29.13	13.59	38.84	14.56	2.91	0.97
	Dry	67.31	21.15	5.77	0.96	3.85	0.96
Underground Water Forest	Wet	33.00	7.00	45.00	11.00	4.00	0.00
	Dry	39.13	38.59	7.61	11.41	2.72	0.5
Savannah Bushland	Wet	28.54	17.86	28.57	12.50	10.71	1.79
	Dry	24.44	26.67	17.78	17.78	11.11	2.22
Bush with *Eucalyptus* Plantation	Wet	25.19	23.70	19.26	25.19	2.96	3.70
	Dry	42.16	15.69	14.70	20.59	5.88	0.98
Tree Dominated Bushland	Wet	29.37	18.25	21.43	15.08	2.38	13.49
	Dry	55.68	15.91	7.95	9.09	10.23	1.14

3.3. Activity Patterns

The activity patterns for different troops of Heller's vervet monkey were recorded in terms of frequency of activities per observation time. A total of 5389 sample records were obtained from different troops. These include, TRF (n=1447), TUWF (n=1528), TSB (n=655), TBEP (n=877) and TTB (n=882). TRF had the highest record of travelling while TUWF had the highest record of other behaviours. Travelling was the dominant activity for TSB and TTB. However, in TBEP, feeding was most frequent of all activities. The activities by all troops of Heller's vervet monkeys in different habitats are given in (Table 4).

Table 4. *The activities of different troops of Heller's vervet monkey in different habitats.*

Troops	Activities, %				
	Resting	Travelling	Social	Feeding	Other
Troop Riverine Forest	25.78	26.26	15.20	14.30	18.45
Troop Underground Water Forest	22.90	21.01	9.36	18.59	28.14
Troop Savannah Bushland	21.22	34.35	13.13	15.42	18.88
Troop Bush with *Eucalyptus* Plantation	25.88	20.07	10.72	27.02	16.31
Troop Tree Dominated Bushland	19.95	24.49	19.05	24.26	12.24

The result from One-Way ANOVA test for activity pattern of troops indicated that there was significant differences in resting in different troops of Heller's vervet monkey, F (4, 15) = 5.311, p =.007. But, all other active behaviours such as, travelling, social behaviour, feeding and other behaviours did not significantly differ in different troops of Heller's vervet monkey in different habitats. The result from One-Way ANOVA test also indicated no significant effect of group size on all activities of different troops of Heller's vervet monkey (p>0.05).

4. Discussion

4.1. Density

The present study area is described as lowland and categorized into riverine forest, underground water forest, savannah bushland, bush with *Eucalyptus* plantation and tree dominated bushland. Of these habitat types, underground water forest and riverine forest support the highest density of Heller's vervet population. This might be due to the high availability of water and vegetation composed of tall trees and woodlands in these habitats. Vervet monkeys rely on habitats with high rainfall, considerable proportion of forest cover and numerous fruit bearing trees. Troops of vervets whose ranges centre on local rivers are significantly larger than those found away from rivers [17, 30]. Lower elevations and woodland habitats seemed to be the preferred habitats of vervet monkeys [22].

The study area comprised a considerable density of Heller's vervet monkey population though there is variation in densities from habitat to habitat. The reason for this may be their ability to tolerate different types of environmental conditions and the presence of wide dietary diversity particularly for food items from plants. The diet of savannah

or green monkeys is dominated by plants of secondary growth [28].

4.2. Feeding Ecology

The dietary preferences of Heller's vervets in the study area includes leaves, fruits, barks, flowers, shoots and few unidentified items. Heller's vervet monkeys in the study area rely less on fruits than leaves and the main food sources of Heller's vervet monkeys was leaves (37.87%), followed by barks, (21.19%) and fruits, (19.56%). This is similar to the diet of some species of forest guenon, in which leaves form as much as a third of the diet (e.g. *Cercopithecus preussi* 41%, [5], *Cercopithecus lhoesti* 35%, [24]. However, it contradicts with the findings of the majority of guenons or savannah monkeys in which fruits constitute 24.5%-91% of their diet [21] and they have dietary preferences of consuming leaves, flowers, and small animals.

Seasonal comparison of feeding by Heller's vervet monkeys showed significant variations in consumption of leaves, fruits, barks, flowers and unidentified food items but in consumption of shoots no significant variation was observed. Probably, this is due to the abundance of fruits, flowers and unidentified food items available during the wet season. The trees in the area bear fruits and flowers when rain starts and maintain them until it ends. The unidentified foods might be small animals associated with rain as the monkeys were observed feeding them on the ground. During the dry season, however, leaves, barks and shoots were highly consumed by Heller's vervets because they are abundant throughout the year. The wide dietary diversity in wet and dry seasons for Heller's vervets might signal a strategy to reduce competition from other monkeys such as Anubis baboon and *Colobus guereza* on preferred food items when they are seasonally scarce [34].

The comparison of feeding by Heller's vervet monkeys in different habitats revealed that fruits were highly consumed in UWF and RF during the wet season while leaves dominate during the dry period. This could be due to the availability of trees such as *T. indica and Ficus spp* that give fruits throughout the year particularly when water is abundant [29]. Troops of Heller's vervets in SB habitat consumed a small amount of fruits and leaves during the wet season, but bark was highly consumed during the dry season. This may be due to absence of adequate fruit bearing trees in dry periods. Leaves compose the main food component for BEP and TDB in both wet and dry seasons. Fruit and flower bearing trees in these habitats are not well distributed as in UWF and RF. Moreover, because they are habitats outside the park, there was selective logging for different trees that may lead to reduction of fruit bearing trees.

4.3. Activity Patterns of Different Troops

The activity patterns in different troops of Heller's vervet monkey are characterized by a significant difference in inactive behaviour. The possible reason may be the variation of habitat type and water availability by which troops that easily access these resources rest more than others that access the resources insufficiently. Although frequently consumed plant species were available in all habitats of Heller's vervets in the study area, their abundance was higher in riverine and underground water forest habitats. This might have affected resting behaviour of different troops. Differences in the resource availability between habitats likely lead to variation in the behavioural patterns [13]. Moreover, these two habitats have water sources such as streams and rivers. This availability of water could have also contributed for troops in these habitats to rest more by making life easier for them just by improving food availability and quality of the forage. The activity pattern of most primates is also dependent on water availability [1]. Group size did not affect any of the activities in different troops of Heller's vervet monkey in the study area.

Unlike resting, active behaviors were not significantly different between troops. There were consistencies in the travelling, feeding, social and other behaviours. This might be due to the uniform temperature in different habitats and consistency in dietary strategy of Heller's vervets. Active behaviours appeared related to temperature because all troops were active in the morning and late afternoon when there was no extreme heat. Extreme temperature can cause evaporative water loss in primates; hence can affect their activity [20].

5. Conclusion

Heller's vervet monkey is one of the savannah monkeys restricted to Eastern Africa. The present study revealed that Heller's vervet monkeys were seen in a variety of environment. However, their density was higher in habitats where tall trees and woodlands exist, and permanent water sources are found. The dietary diversity of Heller's vervet monkeys in the study area included leaves, fruits, barks, flowers and shoots. But, leaves constituted the most consumed food that accounted a third of the overall diet. The activity in different troops of Heller's vervet monkeys showed significant variation in resting.

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