ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Behavioral Ecology of the Patas Monkey (*Erythrocebus patas*) and Conservation Challenges in Alatish National Park, Northwest Ethiopia

By

Mezgebu Ashagrie Demissie

A Thesis Presented to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Biology (Ecological and Systematic Zoology Stream)

Advisor: Dr Solomon Yirga (D.Sc.)

June 2015

Addis Ababa

Ethiopia

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Approved by Examining Board:

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DECLARATION

I, hereby confirm that this thesis is my original work and has not been presented for a degree in any other University and that all sources of material used for this thesis have been duly acknowledged.

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Behavioral Ecology of the Patas Monkey (*Erythrocebus patas*) and Conservation Challenges in Alatish National Park, Northwest Ethiopia

By: Mezgebu Ashagrie Demissie, PhD thesis (2015)

Abstract

The results of both qualitative and quantitative investigations on the behavioral ecology of the patas monkey (*Erythrocebus patas*) and conservation challenges at Alatish National Park are presented in this dissertation. The study aimed at the behavioral responses of patas monkeys to their seasonal lowland habitats and evaluating the taxonomic status of the patas monkeys found in Ethiopia as well as the conservation threats the park faces. The field study was carried out from November 2011 to April 2013 in two wet seasons and two dry seasons. Behavioral data were collected through 15 minutes scanning samples of 10 hours and 30 minutes field observations a day, particularly on feeding, activity time budget and ranging patterns. Morphological features of all age groups and sexes were also noted during both wet and dry seasons. Seasonality in feeding behavior was tested through Schoener's dietary niche overlap index and Levins' dietary niche breadth index. Effects of seasonal changes on activity time budgets were statistically tested by MANOVA; ecological factors that determine activity time budget were statistically analyzed by MANCOVA. Daily range length and home range size were estimated using OpenJump toolbox (MOVEAN), and statistically tested by t-test and Wilcoxon test. Kernel density (95%), MCP (95%), and grid cell home range estimation methods were also used to estimate home range sizes. Conservation threats were studied through field observations and Landsat Satellite Imagery Analysis. *Erythrocebus patas* found in Ethiopia have some distinctive morphological features compared with *E. p. pyrrhonotus*. The adult males face is fully black without a white spot on their nose. Adult females also have a white frontal band. Food items such as gum (39%), fruits and flower buds (32.7%), Acacia pod (0.6%), crop seed (8.1%), herb stem pith (3.5%), corm/tuber (14.8%), and insect (1.3%) contributed to their annual diet composition. Patas show dietary switching in response to seasonal changes. The diet similarity between wet season and dry seasons was only 15.5%. Dietary niche breadth of patas was also narrow during dry seasonal. Moreover, this study found that within their daylight activity time budget, Patas monkeys spent 16.71% feeding, 22.75% moving, 11.26% social activity, 32.03% resting, 14.93 % vigilance and 2.33% other activity. The results of multivariate analysis reveal that season has a statistically significant effect on activity time budget, Wilks' $\lambda = 0.21$, $F = 17.14$, $df = (6, 27)$, $p < 0.001$, $\eta^2 = 0.79$. Analyses on the effect of ecological factors in activity time budget also show that food availability or dietary niche breadth, temperature, ectoparasite infestation and predation risks significantly determine seasonal changes in activity time budgets. Patas monkeys respond to seasonal environmental changes in their ranging behavior. Day journey lengths varied between wet and dry seasons ($t = -8.4$, $df = 28$, $p < 0.001$) with long (1,512.8m (±466.18) daily travel length during the dry season. Home range size of the wet season was 36.19651 hectares (±15.5196), whereas in the dry season it was 105.29439 hectares (±104.7916). Wildlife dwelling in the Park have been affected by habitat degradation caused by human induced fire and dry season water and food resource scarcity. The land cover change analysis found that woodland cover of the Park is highly altered. Finally, based on morphological features and feeding behavior, the study suggests that patas monkey in Northwest Ethiopia is distinct enough from *E. P. pyrrhonotus* and warrant designation as a new and distinct subspecies.

Key words: *Erythrocebus patas*, feeding, activity time, ranging behavior, Alatish National Park, conservation challenge

Acknowledgement

In conducting this study, many people and institutions helped me in different ways. Especially, I am grateful to my research advisor, Dr. Solomon Yirga for his valuable advice, comments, criticisms, insights and suggestions as well as for his encouragement and material support that contributed much to the success of this study. He supported me by sharing his office, and providing reference books, field guide books and equipments. He was also concerned and helped me in all ups and downs I faced starting from the time of admission to the final step of the study.

My gratitude goes to Addis Ababa University for research funding and to Department of Zoological Sciences for logistic support. I would also like to express my deep gratitude to Idea Wild for supporting this study by providing digital recording binoculars. I also got free access for satellite imagery from the European Space Agency and United States Geological survey. I thank them for their support in free satellite imagery access. I also thank the Ethiopian Wildlife Conservation Authority for granting research permission. I am grateful to Alatish National Park Office and staff for providing me logistic support (car) to work in the park and for their field assistance. I thank the Ethiopian Mapping Agency and Meteorological Agency for providing me with a topographic map and meteorological data for the study area. My gratitude goes to the staff members of National Herbarium, Addis Ababa University for their support in plant herbarium preparation, and I thank Assefa for his assistance in identifications of some of the food plant species. I am very much indebted to the Federal Democratic Republic of Ethiopia Ministry of Education for providing me a full scholarship for the entire study period.

I thank Mr. Mesfine Sahle and Mr. Engida Asfaw for their kind cooperation in mentoring me in basic GIS and Remote sensing analysis. My friends: Agegnehu Wassie and Abrham Aynekugnim, I thank you for your information sharing in accessing articles, and handling computer manipulation. I am also thankful to Maningerew Shenkut and my wife Birtukan Ayalew for their help in editing and emotional supports. My deep and sincere gratitude goes to my family for all the support they provided me for my academic achievements.

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Acronyms

ANOVA.....Analysis of Variance

ANP.....Alatish National Park

ANPMP.....Alatish National Park Management Plan

EMA .....Ethiopian Mapping Agency

ESA.....European Space Agency

ETM+.....Enhanced Thematic Mapper

EWCA.....Ethiopian Wildlife Conservation Authority

GCP.....Ground Control Points

GLM .....Generalized Linear Models

GPS.....Geographical Positioning System

HoRAE.....Home Range Analysis and Estimation

IBC .....Institute of Biodiversity

KDE ……Kernel Density Estimation

LSCV.....Least-Squares Cross Validation

MANCOVA.....Multivariate Analysis of Covariance

MANOVA.....Multivariate Analysis of Variance

MCP.....Minimum Convex Polygon

NDVI .....Normalized Difference Vegetation Index

TNC.....Total Non-structural Carbohydrate

USGS.....United States Geological Survey

UTM.....Universal Transverse Mercator

WGS .....World Geodetic System

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Erythrocebus is a genus of the Cercopithecinae that has only one species, *E. patas,* and it is commonly termed as the Patas monkey. Patas monkeys have a shaggy reddish (reddish–brown) coat coloration with gray-white ventral parts. The short fur is reddish except that the lower half of the limbs is white in males and pale brown in female and young (Hall, 1965; Groves, 1972). The male is much brighter than the female (Groves, 2001). The fur is comparatively coarse-rusty tan on the back and smooth bright off-white on the four legs and the underside of body and tail. The shoulders are also covered with a spotted gray long fur (Hall, 1965; Groves, 1972; Ankel-Simons, 2007).

In its skull and dentition, the patas monkey is remarkably similar to *Cercopithecus,* but its limb morphology is very different being specialized for running in a savanna environment (Groves, 1972). Hall (1965) also suggested that patas monkeys resemble the highly terrestrial baboon in their locomotor behavior and mode of existence. Patas monkeys have narrow hands and feet with short digits and a reduced pollex and hallux (Fleagle, 2013). During quadrupedal locomotion, the hands are usually held in a digitigrade position (Ankel-Simons, 2007). Patas monkeys have long and slender limbs. The tail is shorter than in *Cercopithecus*, even though it is long. The scrotum of patas is turquoise blue as that of the *Chlorocebus pygerythrus*(Hall 1965; Groves, 1972).

The muzzle of patas monkeys is comparatively long and their eyes set close to each other (Ankel-Simons, 2007). Patas monkeys are highly sexually dimorphic species. Male patas monkeys are considerably larger than females with an average body length of 65 to 88 cm and

tails of about the same length. Females are on average 50 cm long and their tails also measuring about 50 cm (Ankel-Simons, 2007). Average body weight of adult male patas monkeys is around 12-13 kg and that of the females it is around 6-7 kg (Hall, 1965; Bonadio, 2000). The patas monkey has a slender body with a long tail (Fleagle, 2013).

Besides the above generic characterizations, Hill (1966as cited in Groves, 1972) and Dandelot (1971 as cited in Groves, 2001), *Erythrocebus patas* has been grouped in to four subspecies and characterized based on their facial and body coloration and geographical distribution. *Erythrocebus. p. patas* occur in western savannah from Senegal to Chad; *E. p villiersi* occur from Air (Asben) massif in the Sahara and north of the bend of the Niger River; *E. p. pyrrhonotus* has been reported to occur from Cameroon through southern Sudan, western Ethiopia to localized areas of Kenya, northern Uganda and Tanzania, and *E. p. baumstarki* is restricted to northern Tanzania (Isbell and Chism, 2007). The distinguishing facial colorations and other characteristics have been described as West African *E. p. patas* with pale pink face and black nasal spot; *E. p. villiersi* differs only in its size from *E. p. patas*; East African *E. p. pyrrhonotus* is distinguished with its blackish face , adults develop a white nasal spot, and a black fronto-temporal line; *E.p. baumstarki* is paler than *E. p. pyrrhonotus* without black fronto-temporal bands (line),
; otherwise it is similar to *E. p. pyrrhonotus.*

Groves (1972) pointed out that there are also patas monkeys on the Athi plains, south-east of Nairobi and east of the Rift valley, which are different from the four sub-species described above. These distinct groups have a pink face with a blue nasal spot. However, they have not been given a subspecific name or identified at any taxonomic level so far.

Patas monkeys are native to Africa and adapted to ground living in open habitat. As a result of their predominant terrestrial adaptation, they are widely distributed in grasslands and woodland savannah habitats south of the Sahara desert and north of the tropical forest belt from northwest Senegal through Sudan to western Ethiopia, central Kenya, northern Uganda, northern Tanzania and Cameroon (Figure 1). They are typically found in savanna grassland, dry and dense woodland margin habitats with tall grass, and on grass steppe with thicket clumps. Patas monkey can tolerate arid conditions and some of them have been found close to the southern edge of the Sahara desert (Hall, 1965). In general, patas preferentially established their home range in grassland and preferred woodland to grassland as sleeping sites possibly as a means of to predation avoidance (Hall, 1965; Nakagawa, 1999).

In the case of woodlands, following deforestation, patas monkeys have been observed in man-made clearings in the forest. In addition, they have also been observed in the zone of flooding in the delta of the Senegal River (Bonadio, 2000). An area such as a river basin can provide water for patas monkeys to survive. In the drier areas in which patas monkeys typically live, water can be a limiting factor (Isbell *et al*., 2013). Mostly, patas monkeys avoid areas with dense cover and this may be due to potential exposure to predators. Patas generally occur in agricultural areas, natural forests, secondary/disturbed forest, range/grasslands, riparian zones, scrub/shrublands and wetlands (Nakagawa, 1999; Bonadio, 2000; Isbell and Chism, 2007).

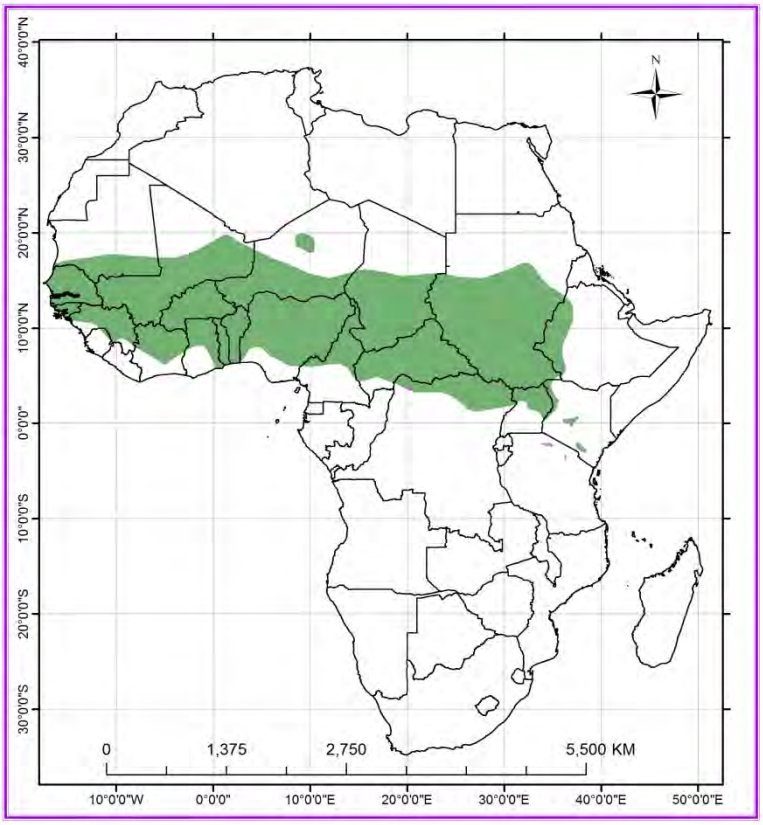


Figure 1. Distribution map of Patas monkeys in Africa.

Patas monkeys are active during the day and climb onto trees in the evening where they spend the night to avoid large predators (Ankel-Simons, 2007). Although, they usually sleep in trees at the edge of the forest, most of their diurnal activities like foraging take place in the open grasslands where they move by quadrupedal walking and running (Fleagle, 2013). They are extremely alert, fast runners (55 km/h), and they frequently stand bipedally to look over the tall grass for potential predators or other interspecific/intraspecific groups (Napier and Napier, 1967;

Fleagle, 2013). The day activity pattern of patas monkeys comprised two main feeding periods with a rest period of one to three hours in the hottest time (Hall, 1965; Nakagawa, 1989).

The bulk of their diet has been described as grass seeds, new shoots, and acacia gums and seeds. They also eat the beans of tamarind trees and a variety of other tough savannah fruits, seeds and berries (Bonadio, 2000; Fleagle, 2013). They supplement their herbivorous diet with insects (like ants and grasshoppers) and various other prey items (Nakagawa, 2000a; Ankel-Simons, 2007; Isbell and Young, 2007). Patas monkeys primarily feed on fruits, seeds, pods, tubers, and insects. They are opportunistic omnivores and eat whatever is available, including leaves, branches, eggs, and small animals. They normally pick up bits of food items to eat as they walk (Fleagle, 2013).

Patas monkeys live in groups. Their group size ranges from 5 to 40 individuals of mostly related females and their young with a single adult male. Indeed group size ranges vary from place to place (Hall, 1965 and Struhasker and Gartlan, 1970; Bonadio, 2000; Fleagle, 2013). The lone adult male patas functions as the guard or sentry of the group, whereas females are group leaders and engage in territorial disputes (Chism *et al*., 1984). On the other hand, subordinate males often live together in all-male satellite bands, but there is considerable turnover of males in patas heterosexual groups during a breeding season.

In patas, threat-attack is mainly a task of adult females, but very rarely it can be made by the adult male. The adult male patas monkey plays a part in the group as watchdog. Whenever the group is disturbed or approaches new areas, the male explores from a high point several hundred meters away from the group. In the group local position, adult male is spatially peripheral, except when day resting, mating and grooming. Otherwise, females will harass the male if it is in close

proximity (Hall, 1965). In addition to securing territory, the adult females habitually initiate directions and times of group movement. Basically, activities of adult females targeted in looking after themselves, their infants and the juveniles, while that of the adult male is very prominently watching for predators or other patas groups or other sympatric species (Hall, 1965). The observation of Hall (1965) indicates that vocalizations of patas are audible at about 100 m and occur very infrequently (about two to four times a day) compared with baboon groups (25 to 50 times a day).

Both the daily travel distance and the home range size are greater in patas than other members of Cercopithecid monkeys. This can be attributed to its higher preference for grassland with low habitat quality in the case of patas (Nakagawa, 1999). Day range lengths of patas are extraordinarily variable from group to group and from season to season, ranging from 700 m to nearly 12,000 m, with an average tendency of between 2,000 and 2,500 m. Sometimes the group forages cohesively and other times members of a group are separated by as much as 800 m (Hall, 1965; Fleagle, 2013). The estimated home ranges are over 5,000 ha, which is the largest known home range from any non-human primate species (Fleagle, 2013). The population density of patas monkeys in most parts of its distribution range is approximately 1.5 individuals per km^2 (Bonadio, 2000). However, in Puerto Rico, introduced patas populations are found to have much smaller home ranges and be much more densely populated. This smaller home ranges, and dense population have been considered as indicator of higher resource availability in the area. Puerto Rican populations also exhibit territorial behavior with groups having well established boundaries, while African groups have large and highly overlapping home ranges (Enstam and Isbell, 2004). In the African groups intergroup contacts are very common at the water holes during the peak of the dry season; otherwise they are extremely rare (Hall, 1965; Struhsaker and

Gartlan, 1970). At this time the frequency of agonistic encounters increased remarkably, especially between members of different groups (Struhsaker and Gartlan, 1970).

Timing of reproduction seems to vary somewhat with geography. In most populations, mating takes place in June through September, and young are born between November and January (Bonadio, 2000; Nakagawa, 2000b). The patas monkeys mostly give birth in the dry season as opposed to guenons that give birth in the wet season (Nakagawa, 2000b and Struhasker and Gartlan, 1970). Infants less than three months old occurred only up to June, and commonly seen in March and April (Hall, 1965). In the birth season, the monkeys have to obtain a larger amount of energy and gross protein than in their mating season. In other words, the birth season appears to be the time when the monkeys obtain more surplus energy. Thus, the dry season birth giving of patas can be attributed to its widely exploitative foraging adaptation supported by their locomotive ability, which enables them to obtain more energy from seeds, fruits and gums of Acacia, and more protein from grasshoppers or other insects in the dry season (Nakagawa, 2000a).

Patas monkeys play both negative and positive roles in human livelihoods. In most localities, patas monkeys are considered as pests at various levels (Bonadio, 2000). They frequently invade and damage crop, and fruit farms as well as cotton plantations. Their size, strength, and aggressiveness make them a potential threat to humans and domestic animals. Furthermore, they may carry diseases that can be transmitted to humans. Patas monkeys are sometimes hunted for meat, and they sometimes can be used in medical research as laboratory animals (Bonadio, 2000).

Conversely, patas monkeys can benefit or be threatened by different human activities. For example, in Laikipia, Kenya, relative stability of a patas population has been observed as a result of beneficial co-existence of patas with large-scale cattle ranching. Such landuse provides patas monkeys with water and broad expanses of *Acacia drepanolobium* woodlands, the habitat to which patas are restricted in Laikipia. Patas monkeys, on the other hand, can also be at increased risk of local extinction due to habitat alterations especially from increasing human populations that cause expansion of agricultural activities and hunting in most habitats outside national parks and reserves (Isbell and Chism, 2007). As a result, patas monkeys are of particular interest for conservationists seeking to determine the sustainability of its populations and design possible conservation plans.

1.2. Comparison of Alatish with other East and West African Patas study sites

Patas monkeys have been studied in East Africa (Kenya, Tanzania, and Uganda) and West Africa (Cameroon and Senegal). When comparing Patas behavior in Alatish with other patas living in East and West Africa, their biogeography might contribute a significant difference in their behavior. For this purpose, I have chosen the Kenyan Likipia site and Cameroon's Kala Maloue study sites for two reasons. First, these two study sites of patas are well studied sites, and thus provide information on patas monkeys feeding behavior, activity pattern, ranging behavior and social behavior. Second, these two sites are biogeographically closer in latitude and longitude with Alatish National Park. Alatish is closer to Likipia in longitude and also with Kala Maloue in latitude.

According to Isbell (1998) and Enstam and Isbell (2002), the Laikipia Plateau of north-central Kenya is located at 36°50'E longitudeand 0°15'N latitude with an elevation of 1,800 m asl. Climatically, Laikipia is a semiarid ecosystem and has an estimated total annual rainfall (1992-1993) of about 568mm. Despite the amount of rainfall varying from month to month and from year to year, the rainfall is year round. The peak rainfall months are April and May (Isbell, 1998) with an average of 43.4 mm of rainfall per month and monthly rainfall ranged from 0 to 144mm. But in 1999, the study area's mean annual rainfall was estimated approximately 600–700 mm. The mean minimum and maximum temperatures were estimated as 12.0°C and 28.3°C, respectively. Soil of Likipia was described as poorly drained, seasonally waterlogged ("black cotton") vertisolic soils. Its vegetation is wooded grasslands dominated by *Acacia drepanolobium* in the overstory and *Pennisetum* spp. and *Themeda triandra* in the understory (Isbell, 1998). Enstam and Isbell (2002) estimated that within the patas home range *A. drepanolobium* comprises over 97% of the woody species. *Acacia drepanolobium* has swollen thorns that harbor several mutualistic ant species. Colonies of ants live in the swollen thorns. In addition, numerous other invertebrates and small vertebrates occur on *A. drepanolobium,* mainly inside swollen thorns (Isbell, 1998).

The West Africa Kala Maloue patas study site is located in the northern part of Cameroon, south of Lake Chad (12°09'N, 15°53' E) (Nakagawa, 1989). Topographically, Kala Maloue is a lowland flat plain at an altitude of 293 m asl (Ohsawa, 2003). In contrast to Likipia of Kenya, Kala Maloue is climatically characterized by two sharply defined seasons. In this site the wet season is from mid-May to September, and the dry season encompassing the rest of the year. The mean annual rainfall vary from year to year with range of 497 mm to 710 mm (Nakagawa,

1989,1999; Ohsawa, 2003). According to Nakagawa (1999) the mean monthly temperature was 33.7^{o}C in May to 22.7^{o}C in January. But, Nakagawa (1989) pointed out that during the rainy season (July to September), the maximum temperature reached 37^{o}C and minimum temperature was 19^{o}C. Vegetationally, Kala Maloue belongs to seasonally flooded Sahelo-Sudanian lowland (Nakagawa, 2000a). Its open woodland distant from the rivers is dominated by *Acacia seyal*, *A. nilotica*, and *Balanites aegyptica.* The grassland is also dominated by *Gramineae* spp. (*Zornia glochidata*, *Panicum* sp., *Echinochloa colona*, etc.), and herbaceous species (*Sida* sp., *Abutilon* sp., *Cassia tora*) (Nakagawa, 1999; 2000a).

The present study area, Alatish is biogeographically closer to the West African Kala Maloue than the East Africa Kenyan Laikipia site. Both Alatish and Kala Maloue lie in the same latitude. Both these areas they are also low land plains with the Sudan-Guinea Savanna Biome/ecological zone. These two sites share similar vegetation like *Acacia seyal, Balanitus aegypticus* in their open wood land and *Acacia sieberiana, Tamarindus indica* in the riverine woodland (Nakagawa, 1999). *Combretum* spp are also common in Alatish as in the West African site in Senegal (Henty and McGrew, 2014). In addition to the geographic and vegetation similarities, Alatish is climatically more similar to Kala Maloue than Laikipia. Both Alatish and Kala Maloue are highly seasonal with high temperature, but Laikipia is not seasonal and its temperature is lower relative to Alatish and Kala Maloue. Overall Alatish is far from Laikipia in latitude (Alatish is 12^{o} north whereas Laikipia is 0^{o} north) and Alatish is lowland at $\leq$ 650m asl but Laikipia is 1800m asl. In relation to these latitude and altitude differences, Alatish is distinct from Laikipia in its climate and vegetation composition. As a result of these differences, patas in Alatish are expected to be distinct in their behavior and morphology from patas in Kenya and Cameroon.

1.3. Justification of the Study

The patas monkey, which is widely distributed over the grass and woodland savannah regions of West and East Africa, appears to be unique in some of its physical and social adaptations. For example, the patas groups tended to use a different area of the home range each night, and individuals dispersed far apart in taking up night resting positions in trees (Hall, 1965). Besides this behavioral feature, the patas adaptations of fast locomotion, silence, disguise, dispersal, coat color and morphology make it to be different from other monkeys of the family.

Among the four patas monkey subspecies, the patas found in Ethiopia has been recorded as *E. p. pyrronotus* (Yalden *et al*., 1977; Heckel *et al*., 2007). This subspecies is distinguished from the other subspecies with its angled black stripe above the eyes that offsets the rusty tan skullcap of fur, white mustache, blackish face and a white spot of almost bare skin around the pitch-black nostrils. Except for the small bare areas that also extend around the eyes where the skin turns dark gray, the face is hairy. Moreover tufts of long hair, which is gray on the cheeks and above as well as in front of the ears give the face a broader appearance than it actually is.

In Ethiopia, the patas monkey is found along the western border in deciduous savanna-woodland habitats. In the North West they are found in Kafta-Humera, around Metemma, and Quara. In the West patas also found in Benishangul-Gumuze region from Gubba to Bambesi (Solomon Yirga *et al*., 2010) and in Gambela south of the Gilo River and Akobo River. It is also reported that patas was observed in south part of the country around northern limit of the Omo National park and eastern part of the Omo River (Bolton, 1973; Yalden *et al*., 1977). The wildlife inventory of Kafta-Humera also indicated that the range of patas monkeys extends to the northwestern

extremes of the country (Heckel *et al*., 2007). The altitudinal range of patas monkey does not appear to extend much above 1000m, and mostly it is 500-1000m (Bolton, 1973; Yalden *et al*., 1977; Yalden *et al*., 1996). Concerning the conservation status of the Ethiopian patas monkeys, as their geographic distribution indicates, most of the country's patas monkeys are dwelling outside of the natural reserve areas. Unless continuous survey on its population status, habitat quality, interference of human activities and conservation status can be conducted, perhaps local extinction is likely to occur due to anthropogenic factors.

In determining population status and habitat preferences of patas monkeys, studies on range utilization pattern play an important role because it is often closely linked to factors such as food availability, predation risk and anthropogenic influences that affect animals' behavior and survival. At present, no systematic field data have been available on the population status, human-patas interactions, behavior and ecology of Ethiopian *E. patas*. In general, even though Ethiopia is one area of the species world geographic range of distribution, detailed studies on the Ethiopian patas have not yet been conducted other than a survey of geographic distribution done several decades ago (Yalden *et al*., 1977) and our recently conducted preliminary survey (Solomon Yirga *et al*., 2010). Thus, conducting a study on this group's morphological descriptions, behavioral ecology and patas-human interactions will contribute to our understanding about the proximate factors involved in determining behavior, habitat preferences and utilizations as well as threats of patas. It will also add new information for assessing their taxonomic status and future conservation plans of patas in the country. Moreover, in combination with the other African biogeographic groups/races of the species, this study will add knowledge on the patas monkey geographical variation in behavioral and ecological adaptations.

1.4. Objectives of the Study

The general objective of this study was to investigate *E. patas* behavioral ecology, taxonomic status and conservation challenges in Alatish National Park.

The specific objectives of the study were:

- To investigate feeding behavior of patas and any seasonal variation.
- To examine their activity time budget in relation to seasonal habitat changes.
- To study ranging behavior and identify ecological determinants influencing their ranging pattern.
- To evaluate their taxonomic status based on behavioral and morphological features in comparison with previously described geographic races.
- To assess conservation challenges in Alatish National Park.

1.5. Research questions

How does seasonality affect the patas's feeding ecology and do patas respond to the dry season food scarcity?

How does seasonality affect the patas activity pattern and what factors determine activity patterns of patas?

How does the spatio-temporal distribution of resources influence ranging behavior of patas monkeys?

Are patas monkeys in Northwest Ethiopia behaviorally and morphologically distinct from the East African *E. p. pyrrhonotus*?

What are the conservation challenges of patas and other wildlife in Alatish National Park and how are conservation threats are affecting the park?

CHAPTER 2 STUDY SITE DESCRIPTION

2.1. Topography

The present study was conducted in Alatish National Park (ANP), located in the Quara District of north Gonder Zone, northwestern Ethiopia, located between 11°47' - 12°21'N latitude, and 35°16' - 35°47'E longitude (Fig 2). Alatish is a lowland area with an elevation ranging between 528 and 654 m asl. Topographically, Alatish National Park consists of extended flat plains with a few scattered mountain cliffs. Almost 97% of the area is flat plain and the few mountain cliffs are scattered throughout (Abraham et.al. 2008). It is about 1123 km northwest of Addis Ababa and 324 km southwest of Gonder and covers an area of 2600 km^2. The park was established legally as a National Park in 2006, but it was delineated as a priority forest area since 1941 during Emperor Haile Selassie's regime. It shares boundaries with Sudan (Dinder National Park) in the west, Benshangul Gumuz National Regional State of Ethiopia through Ayima River in the south, and 7 different peasant associations of Quara Woreda in the east (Anonymous, 2006).

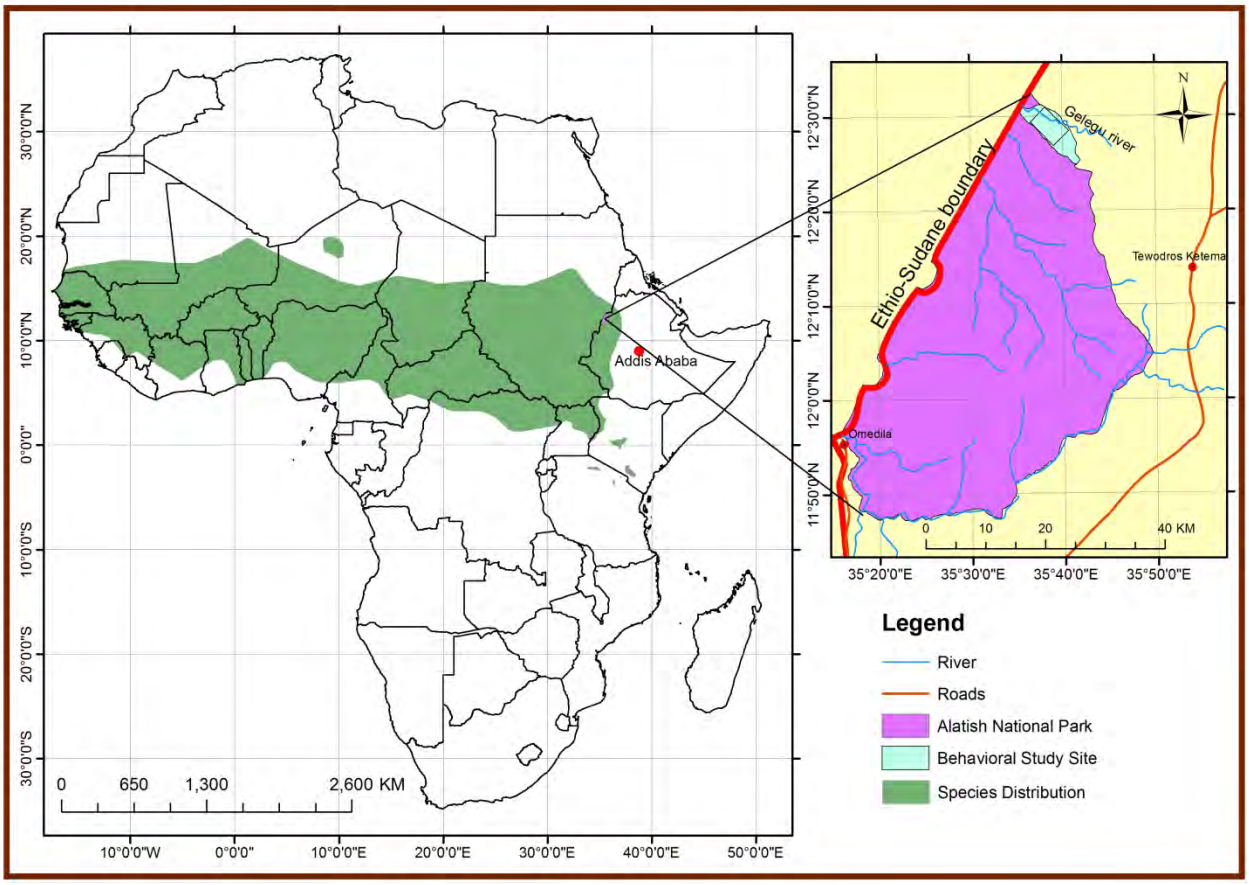


Figure 2. Location map of study area

2.2. Climate

The climate of Alatish is characterized by two extremes, moist-wet and dry-hot seasons. This is a tropical semi-arid zone, characterized by rainy months from May to October with highest rainfall from July to September with August as the peak rainy month (Fig 3a). The mean monthly rainfall range extends from 0 mm in dry season months to a 266.8 mm in August. In present study period (e.g. 2012) the rainfall may extend from about 2.7 mm in November to a maximum rainfall record of 354.4 mm in August (2013). The total annual rainfall ranges between 798.4 mm and 1162.6 mm, and the mean annual rainfall is 970.2 mm. The mean monthly minimum temperature ranges between 15.4 ^{o}C in January and 23.1 ^{o}C in May, and the

mean monthly maximum temperature ranged between 30.8°C in the heavy rainy month (August) and 41.7 °C in dry hottest month (April).The relative humidity also showed variation among months (Fig 3b). The lowest relative humidity was recorded in April, while the highest humidity was scored in August. Thus, cold wettest and hot driest months of the area were August and April, respectively. Agro-ecologically, it falls in the hot-to-warm submoist zone (Abraham Marye *et al.*, 2008).

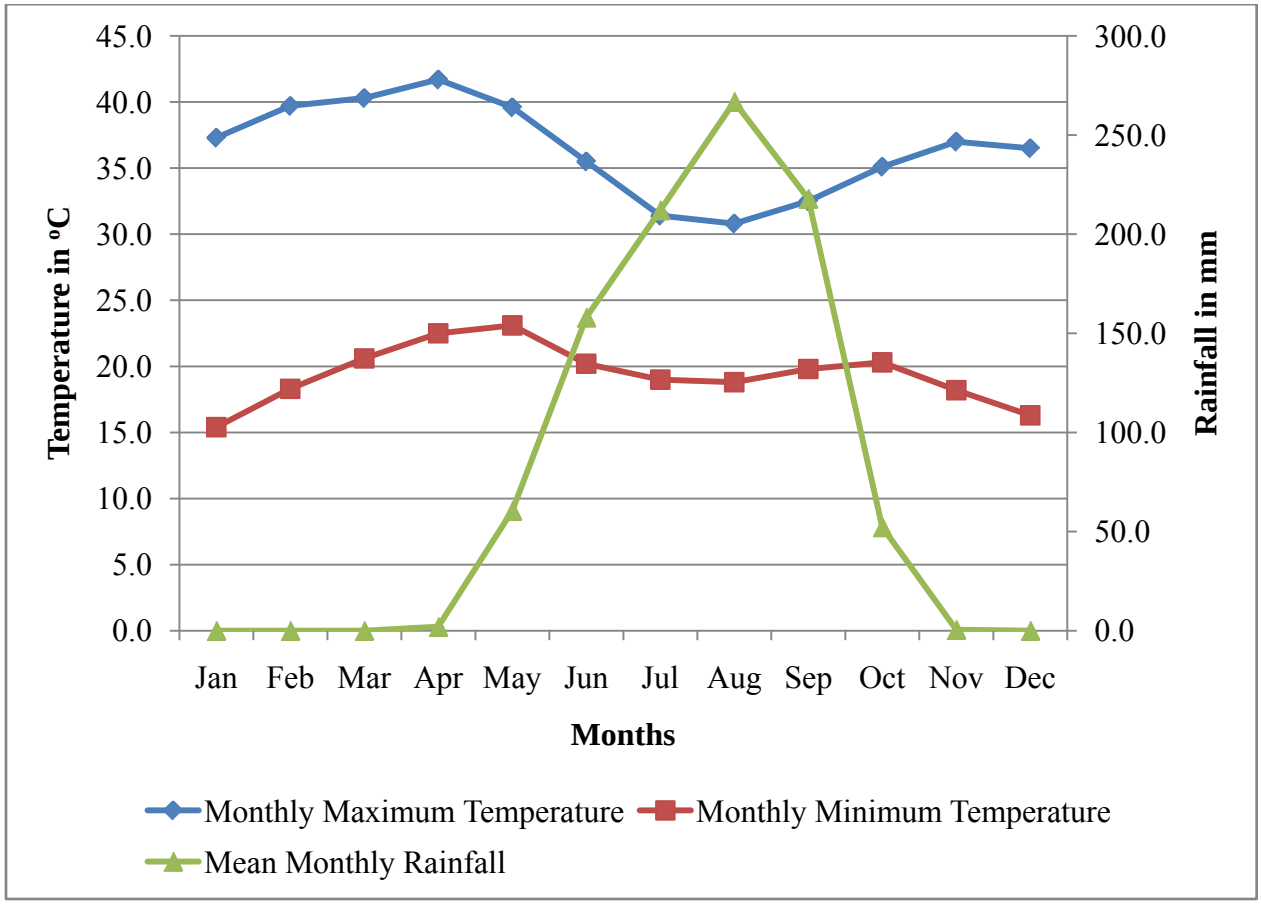


Figure 3a. Mean monthly maximum and minimum temperatures and rainfall distribution of the study area (2009-2013).

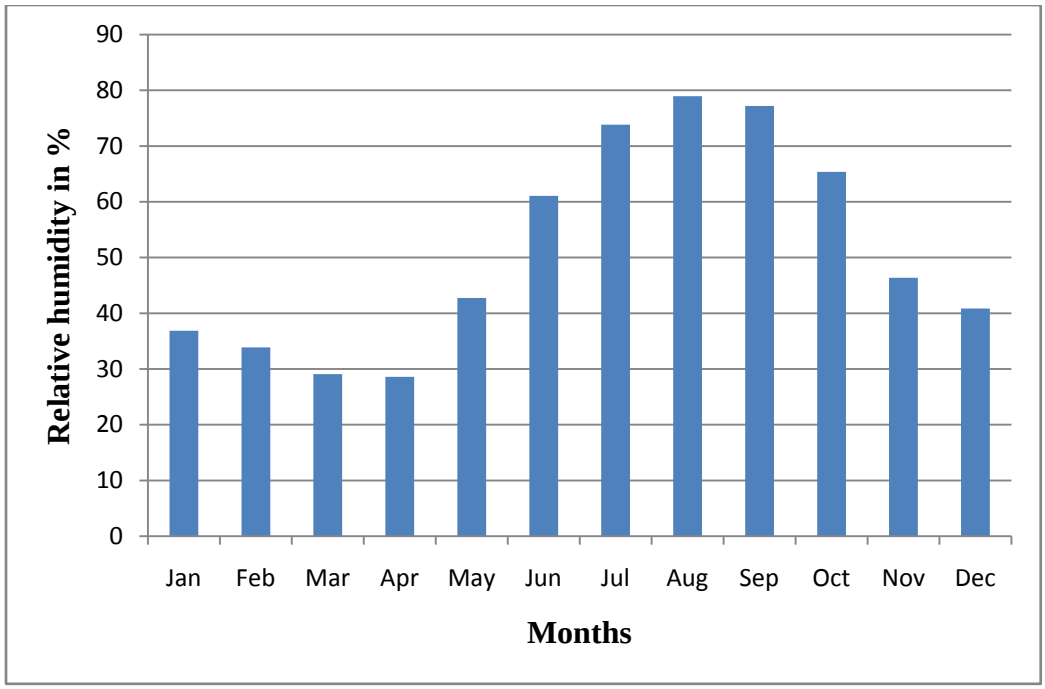


Figure 3b. Mean monthly relative humidity of the study area

2.3. Soil and water sources

The dominant soil types of ANP are ventisols, lentisols and alluvial deposits. Ventisols are described as the dark heavy cracking clays of the plains occur scattered throughout the Park's plains, but is more dominant in the north and south east of the Park. The soil of the wetlands mainly consists of heavy, dark cracking vertisols broken near the rivers and streams (khors), with areas of sand, sandy loam (azaz) and sandy entisols. The black cotton soil usually cracks deeply during the early dry season. The entisols dominate the eastern limits of the Park towards the foothills. This soil type occurs in patches of sandy loam and sandy clay. Entisols occur in patches of sandy loam and sandy clay in scrub land. Alluvial deposits are dominant in the central flood plains along Alatish and Galegu rivers. Cone-shaped low lying hills and rocky outcrops are scattered throughout the park and the escarpment ranging towards the south eastern limits.

As shown in Figure 2, Alatish is drained by different rivers, which include rivers Ayima, Alatish, Galegu, Demir, Anbessa Sheleko, and their tributaries. Ayima, Alatish and Galegu are prominent rivers in the Park with many tributaries and seasonal floods from the surrounding upper highland areas. Alatish is within the Nile drainage system. From Alatish various rivers like Gelegu, Ayma and Alatish, and different streams drain into Sudan, and these are important tributaries of the Nile. These rivers flow to the west of the Park and then to Dinder National Park of Sudan. Ayma river drains in the south east to south and south western part; Alatish river begins from south east escarpments and flows to the west of the Park passing through the centre of the Park; and Galegu river drains the northern part of the Park. Ayima river is the largest in terms of water discharge. All of these rivers hold a large volume of water in the wet season, but do not flow throughout the year. River beds of these rivers are mostly sandy soils, which have the capacity to carry water below the surface of the river course. As a result most water sources including the rivers, dry up during the hot dry season from December to mid June. But, some water pool patches may remain along the rocky bed of the river courses and hold water throughout the year (Plate 1a & b).


a

Plate 1a &b. Water pools remain on the river bed of Gelegu river.

Besides rivers, seasonal flood plain water pools also supply water for wildlife in the wet to the mid-dry season (January to February), even after the sandy rivers dry up in November - December (Plate 2). Seasonal wetlands/floodplain pools are found along the rivers in the Park and have been formed due to overflow of water in the river channel and flood flows from hills to down hills. These wetlands are significantly important for wildlife as source of water and forage. During early to mid dry season, they provide best feeding sites for ungulates and primates in the area.

Plate 2. Water pool in a seasonal flood plain in the study area.

In the dry season, water shortage is a serious problem in Alatish National Park and wild animals in the area suffer because of it. Even though, surface water is scarce during peak dry periods, water is available at about one meter to two meters depth under the sand bed throughout the river courses. In exploiting this potential, local nomadic pastoralists dig water holes on the Gelegu river course and use water troughs. In some cases, these artificial water holes are also water sources for wild animals including primates.

2.4. Vegetation and Habitat Type

Biogeographically, Alatish falls in the Guinea Sudan Biome Region of Tropical Savanna (Heckel *et al*., 2007). According to White (1983), the flora of the western Ethiopian escarpment including Alatish is considered as undifferentiated woodlands of Ethiopian type and it is linked most closely to the flora of the West African-Sudanian region. Like other western Ethiopian lowland parts, Alatish has been included with the Sudanian Regional Centre of Endemism (White, 1983). Vegetation of Alatish could also be considered as a transition zone or ecotone between the

Afromontane Region in Ethiopia and the Sudanian Region in the Sudan. As a result, the biological attributes of the Park are thought to be diverse and unique. As the western biogeographic region of Ethiopia, Alatish is low in its floral diversity. Nevertheless, it has a higher rank of local endemism than most of the Ethiopian regions (Sebsebe Demissew *et al*., 2005). Alatish has characteristic vegetation, which consists mainly of deciduous woodland, with combretaceous trees; *e.g. Combretum hartmannianum,* or *Acacia seyal* and dense thickets of the lowland bamboo (Sebsebe Demissew *et al*., 2005). Other vegetation types are wooded grassland, riverine forest and swamps. Thus, ecosystem of Alatish is classified in to four major ecosystem components or communities. The major communities are Riverine woodland, Seasonal Wetland/flood plains, mixed deciduous Woodland and Wooded grassland ecosystem.

2.4.1. Riverine Woodland Ecosystem

The riverine ecosystem is found in the alluvial river banks of Alatish, Galegu, and Ayima and other streams and tributaries of these rivers in both sides from the river course (Plate 3). It contains tall tree cover with interlocked canopy. This ecosystem provides shelter and food for wildlife during wet and dry seasons. It is highly dominated by tall trees of *Terminalia, Ficus* spp, *Stereospermum kunthianum, Tamarindus indica, Accacia sieberiane, Adasonya digitata* and *Comberetium* spp. and associated with *Ziziphus spina-christi, Cardenia ternifola* and *Pilostigma thonniingii*. This ecosystem comprises flora on the river banks. On both sides of the river banks, there are also tall grasses including *Bekeropsis uniseta, Eragrosis tremula* and *Sorghum sudanenis* with different species of herbs and climbers.

Plate 3. Riverine woodland in the river bank of the Gelegu River

2.4.2. Woodland Ecosystem

This ecosystem covers vast area of the Park and mixed vegetation composition (Plate 4). This ecosystem is dominated by moderately sized deciduous mixed trees with at least 40% canopy cover, but their crowns are not densely interlocked (White, 1983). Tree species of the genus such as *Terminalia* spp., *Combretum* spp., *Acacia* spp., *Pterocarpus* and *Lannea* with understory grass coverage dominated the ecosystem.

Plate 4. Effect of fire on woodland ecosystem. Left: Woodland cover in the beginning of rainy season. Right: Fire burned woodland photo captured during late dry season

2.4.3. Wooded Grassland Ecosystem

The wooded grassland ecosystem is mixed trees and grasslands with less than 40% of tree cover (White, 1983). Grasses with scattered trees dominate the ground covers (Plate 5). This ecosystem is found in shallow soils of sandy to dark cracking clay soils (vertisols). Variation in the vegetation and soil types resulted in mixed and pure stands of grasses. This ecosystem is represented by shrubs, and small to tall trees of different species such as *Acacia seyal, Balanites aegyptica*, and *Comberetum* spp scattered in patches of open grasslands.

Plate 5. Wooded grassland before fire (top) and after fire burn (bottom)

2.4.4. Seasonal Wetland Ecosystem

Seasonal ponds and wetlands are formed in the flood plain. It extends from central to northern extremes and western flat lands bordering Dinder National Park in Sudan. Seasonal wetlands remain as pool for months dominated by excessively growing water loving grasses or *Ipomia aquatic* herbs (Plate 6). Many seasonal ponds in different parts of the Park are surrounded by woody vegetation and shrubs of *Acacia seyal*, *Ziziphus* sp. and *Balanites aegyptica*. Seasonal wetlands reserve huge floods in the rainy season until the mid dry season and dried later in the

dry season. This ecosystem serves as range land as well as water source for wildlife. In the dry season, this ecosystem is the only area where green ground cover can be observed next to the riverine woodlands. The seasonal flood plain locally known as 'Sambre' is suitable for wildlife as a feeding area. Especially patas monkeys use seasonal wetlands as source of water and feeding sites when *I. aquatica* is grown in the ecosystem. *Ipomia aquatica* fruit is a preferred food of patas monkeys. Warthogs also spend most of their foraging and resting time in this area. In the long dry season, warthogs use it heavily by digging up the soil in search of tubers and roots.

Plate 6. Seasonal wetlands covered with *I. aquatica* herb (top), and tall (middle) and short grass (bottom).

It is a feeding area of Oribi, Bushbuck, Warthog and Kudus as it is the only foraging site during forage scarce dry season (Abraham Marye *et al*., 2008). This ecosystem is visited by carnivores such as lion and serval. All eco systems of Alatish are largely threatened by fire and water shortage in dry season.

Based on its vegetation cover, the potential of Alatish in combating climate change is considered to be significant. According to Vreugdenhil *et al*. (2012), Alatish National Park has the largest carbon stock estimates (carbon sequestration potential) among the six selected national parks of Ethiopia which is 20,132,576 tons of CO_2e within its vegetation source.

2.5. Fauna of Alatish National Park

Alatish National Park harbors 20 large mammalian species including endangered and rare species like Elephant (*Loxodonata africana*), Leopard (*Panthera pardus*), Lion (*Panthera leo*) and also the low risk but conservation dependent Lesser kudu (*Tragelaphus imberbis*) and Greater kudu (*Tragelaphus strepsicero*) (Girma Mengesha and Afework Bekele, 2008). It is also anticipated as a potential site to shelter Tora hartebeest (*Alcelaphus buselaphus tora*) which has a historic biogeographic distribution range in eastern Sudan, north-western Ethiopia and northern Eritrea (Heckel *et al*., 2007). Among mammalian species some primates such as patas monkey, Anubis baboon and grivet monkeys are found in the Park. In addition to the presence of large mammals, 204 species of birds, 23 species of rodent, 6 species of insectivores (Tadese Habtamu and Afework Bekele, 2008), at least 15 species of reptile (Mezgebu Ashagrie, unpublished), 23 species of fish (ANPMP, 2009; Dereje Tewabe *et al*., 2009) and a few amphibians are inhabiting in the Park. Tadese Habtamu and Afework Bekele (2008) reported some endemic rodent species of the Ethiopian highland forest and three shrew species were found in Alatish. As Alatish is also a trans-boundary Park which is adjoined with the Dinder National Park of the Republic of Sudan. Thus, it has huge potential to conserve rich wildlife resources. Abraham Marye *et al*. (2008) and ANPMP (2009) described that Alatish serves as a migratory route for Elephants, which traverse from Dinder National Park in the Sudan.

CHAPTER 3 DESCRIPTION OF THE PATAS MONKEY

The behavioral study site of patas was located in the northern part of Alatish, particularly at Amjale/Anbesa Wuha site camp at 35° 38' E, 12° 30' N and 519 m asl. The vegetation composition of the site includes *Acacia seyal* and *Combretem hertmanium* dominated wood land, mixed wooded grassland (*Acacia seyal, Acacia polycantha* and *Balanitus aeypticus*), *Ipomia aquatica* covered the floodplain/wet land. The study patas group used a home range partly at the park and park buffer zone where patas raid crops in the adjacent farmland during the wet season, and obtain water access from cattle water troughs during the water scarce dry season. Cattle herders came adjacent to the study site on the Gelegu river during the dry season in search of forage and water holes for their cattle. However, as the study site is located about 11 - 12 km from the nearest settlement (Mar Wuha), human interference was minimal for the patas. The existence of cattle in the dry season was beneficial to the patas for accessing water from cattle water troughs. But, both cattle and cattle herders imposed negative effect for other wildlife. Cattle compete with grazers like Oribi for food and cattle herders sometimes hunted wildlife such as warthog and introduced fire in to the park for wild honey collection. Climate data were collected from the closest meteorological station at Gelegu town of Quara district where the head office of the park is located.

The present study was conducted on one selected group of patas with 27 individuals. The group was composed of 10 adult females, 9 infants, 7 yearlings and 1 adult male. Morphologically, this study group has some distinct features, especially in the coat coloration. As described in Solomon Yirga *et al* (2010), the adult male has long black hair/fur from its shoulder to its arm. In addition, adult males and juveniles have a black face without a white nose spot. It is only adult

females that have a white nose spot. When adult male patas of this study group in Alatish and those in Bambesi (Solomon Yirga *et al*., 2010) were compared with the photo of an adult male of *E. patas pyrrhonotus,* at Laikipia Kenya, the patas found in Ethiopia is distinct from Kenyan patas in facial coloration. The adult male patas in Laikipia Kenya has a white nose spot like adult females (see photo in de Jong *et al*., 2008), but in Ethiopia the adult males of patas both in lone males and heterosexual group do not have a white nose spot. Moreover, the facial long white tuft of adult males, adult females and juveniles of this study extends to the temporal black band, but the white facial tuft does not extend to the temporal black band and is limited to perpendicular to their ear (see Plate 7, 8 and Figure 4). Similar to *E. p. pyrrhonotus* adult female patas in Ethiopia have black face with white nose spot, but white frontal band make them different (Plate 9).

Plate 7. Picture of adult male Patas monkey in Ethiopia. Leftside:Adult male Patas monkey in Alatish National Park (photo capture in dry season, April 2013 at nomad's water hole by Mezgebu Ashagrie); right side: Adult male Patas monkey in Bambesi Anbesa chaka Benishangul-Gumuz (Photo captured in wet season June, 2009 by Demisew Sertse)

Plate 8. *Erythrocebus patas pyrrhonotus* in Kenya. Right side picture is from de Jong *et al*., 2008; left side picture is taken from Wikipedia

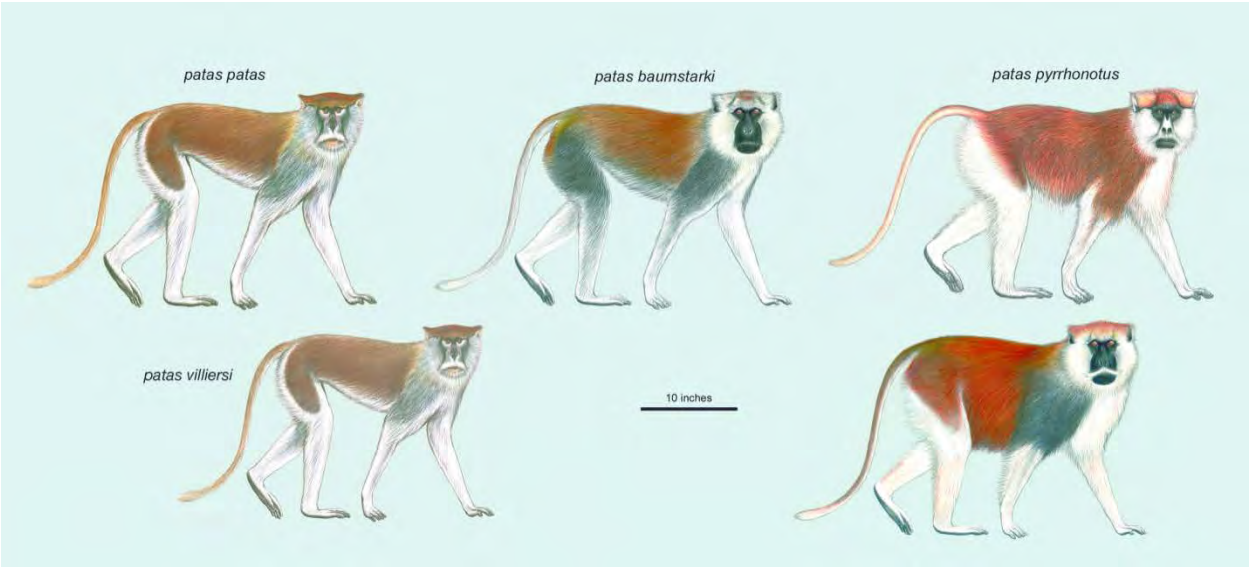


Figure 4. Comparative drawing of the patas monkeys subspecies, (Drawn by Stephen Nash)

Plate 9 . P icture o f ad ult f emale p atas m onkeys i n wet s eason, J une 2009 i n B ambesi Benishangul-Gumuz, wet Ethiopia, (Photograph captured by Demisew Sertse).

Despite so me d istinct m orphological f eatures, the social or ganization of t he s tudy gr oup is similar t o p atas st udied el sewhere. I t was co mposed o f si ngle ad ult male, multifemales w ith subadults and infants throughout the year. Like patas in other places, males disperse from their natal gr oups when t hey be come s ubadults, w hereas f emales r emain i n t heir na tal gr oups. Extragroup males were solitary and sometimes they formed small associations with other males. Extragroup males ap proached t he o ne m ale-multi f emales group dur ing w et s easons. I n J une, kidnapping of a single adult female by two adult males and another wounded adult male were

observed. Thus even though group takeover was not observed, this might show an attempt to replace the resident male in the mating season. In the two consecutive study years (November 2011 to April 2013), it was observed that females gave birth from November to December. Except for a few aggressive interactions among females and rare calls of adult male, patas were relatively quiet. Three vocalizations in females and two sounds in the adult male were detected. The three sounds of females were:- 1. When an adult female lags far apart from the group members, she makes a call that might be used to communicate with other group members. This sound resembles the domestic cat's squeal ("nyom call) as reported in (Entam and Isbell, 2002). The other two sounds were detected in t intragroup and intergroup aggressive interactions. One of the two sounds was like a growl "(g) rrr" sound described by Henty and McGrew (2014) in Senegal. The third call was a loud chutter call during active defense. The wet season call of the adult male was a low pitched call "quaf-quaf" whereas its dry season call was loud barking ("bark grunt") as reported in (Enstam and Isbell, 2002). The study group also shared its home range with another patas group, baboons (*Papio anubis*) in both wet and dry seasons, and rarely with the grivet monkey (*Chlorocebus aethiops*) during the dry season. When patas and grivet monkeys encountered around a water location, they did not show any interaction; but when patas and baboon groups encountered around a water location, the baboons chased the patas monkeys and patas left the area without defense. However, on one occasion when one adult male baboon and one adult male patas encountered at the water point, they drank at the same water source without any aggressive interaction. Beyond the interactions at water point, inter-specific competition among the three species seems to be minimized by their different habitat and food preferences. Baboons and grivetsusually prefer riparian habitat, whereas patas prefer non-riparian *Acacia* and *Combretum* woodlands as well as *Balanitus* mixed wooded grassland.

CHAPTER 4 MATERIALS AND METHODS

4.1. Ecological Data

4.1.1. Phenology as indicator of food availability

The phenology of vegetation in different habitat types and seasons were considered as factors of primate food availability. Phenological data sampling were carried out through selected tree method (Haugaasen and Peres, 2005). Tree species were selected based on information on plants to provide fruits, flowers, pods and gum consumed by primates. Seasonal monitoring of the selected plants was conducted in three 2 km transect lines by direct crown inspection of the plant parts with the help of binoculars in 2 days, one day before starting behavioral observation and another one day at the end of the behavioral observations during every field study (Haugaasen and Peres, 2005). Transect lines were laid 100 m apart. Phenological data were collected in terms of the number and percentage as potential food items and species composition in the diet of the study group. To investigate the effect of phenological patterns on activity time budget, ranging behavior and feeding behavior, phenology of potential food items were considered as indicators of food availability. This helps to understand how food availability influences behavior in patas.

In addition to the field phenological observations, seasonality in plant productivity at spatial and temporal scales were estimated from satellite images in the form of Normalized Difference Vegetation Index (NDVI) data (Tucker and Seller, 1986; Willems *et al*., 2009; Pettorelli *et al*., 2011). The NDVI values were estimated as a spectral index from earth surface reflectance patterns in the red and near-infrared band of the image through EARDA IMAGINE 10 remote sensing software. The NDVI index was estimated as, NDVI= (NIR-Red)/ (NIR+Red), where NIR and Red are the amount of near-infrared and red light, respectively, reflected by a surface

and measured by satellite sensors. The NDVI value ranges from +1 and -1, where low values correspond to an absence of photosynthetic active vegetation/poor photosynthetic activity and higher positive values signify more active vegetation cover in photosynthesis. Calculated seasonal plant productivity by NDVI metrics over the home range area was compared temporally to analyze the relationship between food availability and habitat use of wildlife. The scale of analysis was further refined by assessing NDVI values over the home range for their food availability estimation by comparing field observation records on habitat productivity and plant phenology throughout the home range. Seasonal plant productivity from NDVI was used to evaluate temporal variation in behavioral ecology parameters (activity time, size of home range and core area, average day journey length) in relation to food availability estimations derived from calculated NDVI values over the home range of focal group of patas.

Analysis of monthly plant productivity index (NDVI) shows a positive correlation with monthly rainfall and relative humidity with $r= 0.68$, $P <0.05$ and $r= 0.78$, $P <0.01$, respectively. Figure 5a and 5b show patterns of association between climate (rainfall and relative humidity) and habitat productivity. As shown in these figures, habitat productivity showed a seasonally changing trend. Habitat productivity was medium in June and October to November, but productivity was highest from July to September. New shoot flush in June and fruits availability was highest around the end of the wet season (September - December). However, the productivity started to drop in December, and from January to May the habitat was driest and poorest in productivity, and wildlife food resources were also scarce.

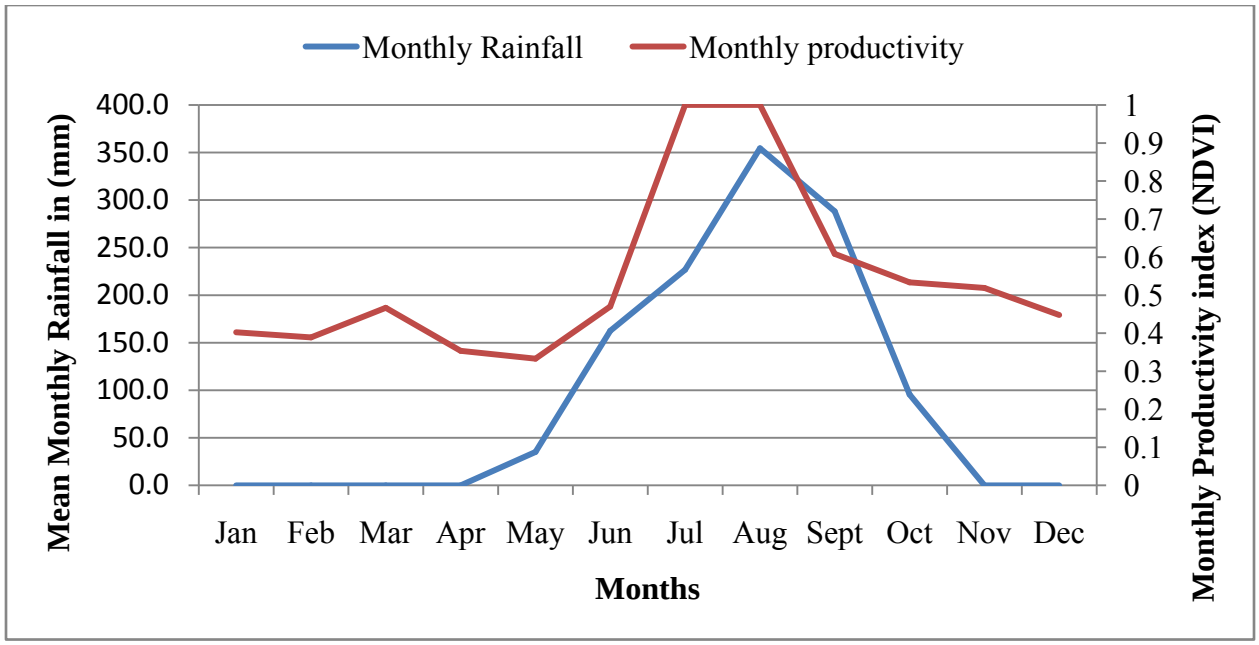


Figure 5a. Trend of annual rainfall and habitat productivity as inferred from NDVI

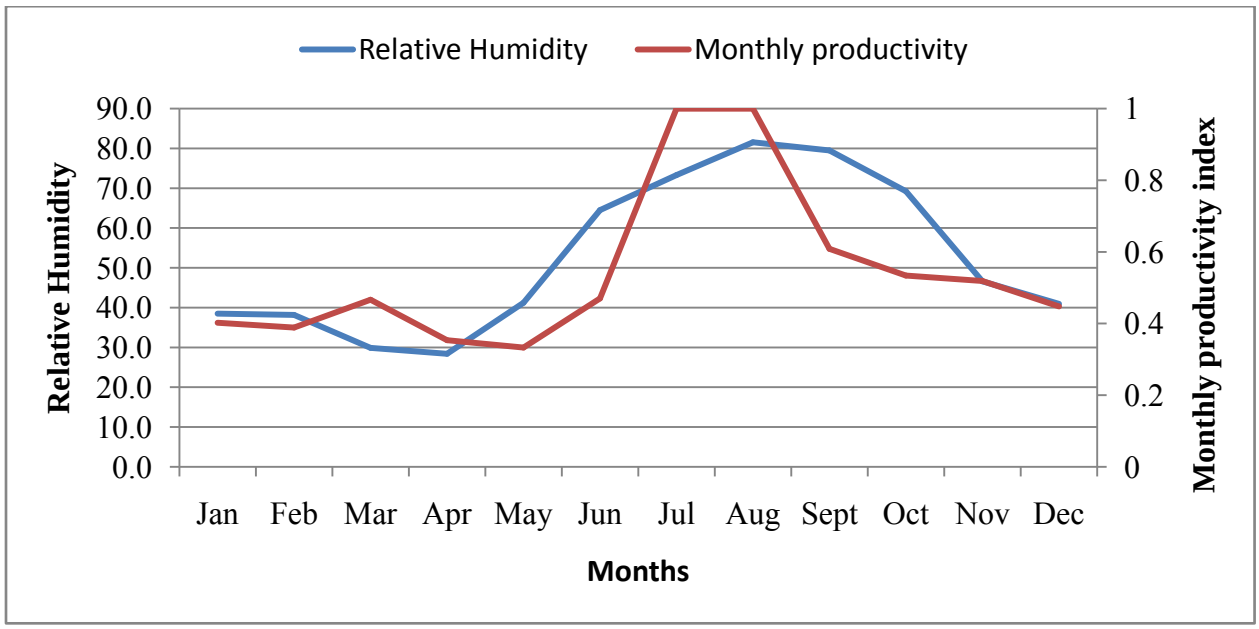


Figure 5b. Trend of annual relative humidity and habitat productivity as inferred from NDVI

In addition to the above described remotely sensed habitat productivity, qualitative field phenological observations indicate that in November and December, woody plants such as

Balanites aegyptiaca and *Lannea fruticosa* as well as different herbaceous plants including *Ipomia aquatica,* which usually grow in seasonal flood plains, provide significant amount of flowers and fruits for patas monkeys. After January most above ground vegetation covers except woody plants were dried and additionally removed by fire. In this season, all above ground parts of grasses, herbs and forbs vanish entirely. Thus, flowers, fruits, seeds and pith of herbaceous plants, which were abundant during the wet season were unavailable in the dry season. Moreover, since most woody plants are deciduous, they shed their leaves in the dry season. So, during the dry season (January - May), except the riverine habitat, Alatish National Park loses its green vegetation coverage and it is extremely poor in plant productivity. In some riverine trees, potential food resources like *Ficus* sp fruit and *Stereospermum kunthianum* (local name: Zana) flowers were observed from February to April. Nevertheless, patas monkey did not use this riverine habitat. The overall information suggests that the highly seasonal climatic pattern of Alatish influenced its habitat productivity. As a result Alatish is highly seasonal in its habitat productivity and food availability.

4.1.2. Estimating Predation Risk

In the habitat of patas monkeys, the presence of terrestrial predators like lion, serval, hyena, snakes and python were observed. Lion was identified by the presence of pugmarks, dung and roaring (Plate 10), hyena was identified by hearing their night barking, while others were directly observed. Encounter of these potential predators were noted along with the number of individuals, and habitat types in the study area. Predator presence is summarized in Table 1. To analyze effects of perceived predation risk on activity time budget (vigilance), predation risk was included as an ecological factor in the MANOVA. The effect of habitat structure on the

probability of risk of predation was also estimated by odds ratio as a function of vegetation cover.

Table 1. Detection of potential predators during November 2011– April 2013 in the home ranges of the study groups of patas monkeys.

Predator Species	Direct observation	Indirect observation	season
Lion (*P. leo*)	0	6	wet
Serval (*F. serval*)	11	0	Wet=10, dry=1
Hyena (*Crocuta*)	0	3	dry
Snake (Black mamba & Egyptian cobra)	15	0	Wet=11, dry=4
African rock python	1	0	wet
Total	27	9	

Plate 10. Pugmark and semi-buried dung of lion on mud and sand on the river course of Gelegu river.

4.1.3. Vegetation Cover

Seasonality of vegetation cover was considered as an ecological variable that affects the behavior of patas monkey in their activity time budget. The grass vegetation cover within the group's

home range was sampled with 20 quadrats of 10 x 10 m^2 plots in woodland, wooded grassland and flood plain habitat types. In each plot, measures of vegetation cover particularly height and density of grass cover were obtained by estimating whether a 2 m vertical pole was visible to an observer standing 10 m away from it. The heights of plants were categorized into small (0- 0·5 m), medium (0·5 m- 2·0 m) and tall (> 2 m). Human disturbances and the structural complexity of the vegetation in the area were recorded using qualitative ranking procedures (Chapman, 1985). Open flood plains received the lowest rank for structural complexity, while areas with tall and dense understories received the highest rank. In addition, the percentage of each quadrat covered by any vegetation and the amount of open ground was also estimated.

4.1.4. Estimating the Risk of Ectoparasite /Tick Infestation

Collecting tick on patas was difficult in the field, as it requires the animals to be trapped. As a result, incidents of tick attack of the researcher and two field assistants were considered to estimate level of tick load in the patas monkeys' habitat. This method was taken as mechanism of studying patas monkeys' vulnerability to tick infestation as we followed the animals and were exposed to ticks as the monkeys were. We also experienced tick bites and associated effects of inflammation and irritation from tick bites, itching, and allergic responses (swelling of tick bite sites). Most ticks spend the bulk of their life on or near the ground, waiting for a suitable host animal. Thus, ticks were collected and counted from each of us on each behavioral field study day in the evening when we completed daily field observations. In addition to counting ticks, I recorded feeding events while patas were grooming. Here time spent feeding while grooming was taken as proxy of removing the ectoparasite/tick load during grooming. Finally,

susceptibility of patas to tick infestation in the wet and dry seasons was estimated as mean count of tick and proportion of feeding during grooming activities.

4.1.5. Climate

Physical variables, especially rainfall and temperature, can adequately influence temporal (seasonal and annual) variations in the availability of resources (food and water availability). Thus, to trace these effects in the study, monthly data on rainfall and temperature during the whole study period (July 2011 to July 2013) were collected from the Ethiopian National Meteorological Agency. Weather data were used to characterize temperature and rainfall of the study area as well as to carry out statistical analysis for testing the effect of climate on behavioral patterns particularly rainfall and temperature variations in temporal scale, i. e. annual and seasonal variability.

4.2. Behavioral study Design and Data Collection

The field study was carried out from November 2011 to April 2013 in two wet seasons and two dry seasons on a single study group. As the study area is remote and inhospitable to stay for a long continuous field study time due to water shortage, the wet and dry season studies were represented by two sample months in each season. November and December were taken as sample of the wet season studies and March and April were sampled as dry season. The study was conducted for a total of 140 field study days.

In the first year dry season natural water pointes were dried out and there were no cattle water trough on human dag water hole around their home range. Thus, the study patas monkeys were

migrated about 11km from their wet season home range and the study camp site. During this season walking to and from the study site to the camp took 3 to 4 hours. As I spent more time in travel to reach in their new home range of the study group, full daily data were not collected. As a result of this fact, comparative analyses were made between seasonal change (wet season versus dry season) within the second year of the study and wet seasons of the two years. Actually, except the human interference on the habitat, differences in the habitat condition between dry seasons of two consecutive years were not observable.

A single study patas group was selected for this behavioral study the fact that the study aimed at investigating effects of ecological factors on their behavior in relation to seasonal and annual environmental changes. Conducting this study on a sing group was designed to control confounding effects of group size and habitat differences on the study. Other previous detailed behavioral studies were also conducted in a single group (Bronikowski and Altman, 1996). In the study design I included seasonal changes and annual changes as factors because Alatish is highly seasonal in its climate and plant phenology. Earlier studies (Bronikowski and Altman, 1996; Albert et al., 2005) show that ecological changes in relation to seasonal and yearly variation in amount of rainfall and possibly changes in other ecological changes in the home range of study group are factors in studying behavioral ecology of savannah baboons.

The amount of time spent for different activities depend on habitat condition (with specific features in food availability (Chapman, 1985; Isbell *et al.*, 1998), predation risk (Cowlishaw, 1998), and seasonal climatic variation like temperature (Hill, 2006; Campos and Fedigan, 2009).

Thus, analyses of activity budgets were made by considering the effect of habitat conditions in temporal change (seasonal and/annual) aspects.

To collect intensive data on the activity budget, feeding, and range use pattern of the patas group, scan sampling on a selected single group as focal animals was used (Altmann, 1974; Lehner, 1996). Data were collected on each visible individual of a group through instantaneous scan sampling, which was conducted for 1- 5 min in every 15 min sample interval from 7:30 to 18:00 (Cohn and MacPhail 1996; Isbell, 1998; National Research Council, 2003). The scan samples were conducted on every quarter hour, i.e., at 0, 15, 30 and 45 minutes for daylight 10 hours and 30 minutes per day. Activity budget and feeding data collected through scan sampling were scored as proportion/percentage spent for each activity and food item/species per daily and seasonal samples, respectively.

4.3. Feeding ecology Data collection and Analysis

Data on feeding ecology were collected together with activity time budgets. As noted in activity time budget data collection, feeding behavior was studied in feeding activity scan samples. In the scan sample when dietary items were known, the types of food items with corresponding species names were recorded. But, when food items could not be identified from a distance, description of the motor patterns used to forage the foods were noted and I checked the type of food items and species when the feeding animals left the feeding site or guess the item based on the way the animals foraged (Isbell, 1998). In addition, some difficult feeding observations were recorded by evo-sony digital recording binoculars and replaying the record to identify the food items after completing the daily field data collection. However, when identification of food species was the

only difficulty in recording food items, the species were recorded with specific codes and sample specimens were collected for further identification. The collected plant specimens were identified in Addis Ababa University Herbarium. Identifications of species were confirmed by curators working in the Herbarium.

The annual food type composition was computed based on scan sample feeding records collected during the two wet season months and dry season months observation hours of the study. To test seasonal variation in feeding behavior, records for different food items were calculated as proportions of the seasonal diet composition. Then, Chi-square test was used to test whether feeding behavior of patas is associated with seasonal variation. Moreover, to quantify the degree of seasonal variation in the diet composition as a behavioral response to changes in seasonal food resources, dietary overlap and dietary breadth between wet and dry seasons were computed.

4.3.1. Analysis of Seasonal Dietary Niche Overlap

Numerous methods have been used to assess dietary overlap (Holmes and Pitelka, 1968; Schoener, 1968; Rose, 1976; Feinsinger *et al*., 1981; Post, 1982; Irwin, 2008; Oueda *et al*., 2008; Warren *et al*., 2008; Dantas *et al*., 2013). Here seasonal estimation of diet niche overlap between wet season and dry season was calculated using the niche overlap O(w,d) metric as:

$O(w,y) = 1\text{-}0.5(\sum | P_{iw} - P_{id} |)$

Where, O(w,y) is index of diet overlap between wet season and dry season; P_{iw} is proportion of food item i during wet season; P_{id} is proportion of food item i during dry season. This metric varies between 0 (no overlap) and 1 (complete overlap). The niche similarity test addresses whether the dietary niche utilized in wet season is more similar to the dry season than would be

expected by chance. The index value is generally considered biologically significant overlap when O (w,d) >0.6 (Wallace 1981 as cited in Dantas *et al*., 2013). To express the diet overlap index in percentage, the value was multiplied by 100.

4.3.2.Analysis of seasonal dietary niche breadth

Similar to diet overlap analysis conducted in many studies, this study used Levins' index of dietary niche breadth (Colwell and Futuyama, 1971; Feinsinger *et al*., 1981; Oueda *et al*., 2008; Warren *et al*., 2008; Vandercone *et al*., 2012; Irwin, 2008, Mwasi *et al*., 2013). Niche breadth for diet composition was calculated using index B:

$B= 1/\sum P^2_{ij}$

Where, Pij = proportional use of food item i in season j.

To standardize dietary niche breadth index and express it on a scale from 0 to 1.0, (Krebs, 2014) formula was used as:

$B_A=B-1/n-1$

Where,
B_A= Levins' standardized dietary niche breadth

B= Levins' measure of dietary niche breadth

N= Number of possible food items

4.4. Data Collection on Activity Time Budget

The group was scanned each time from left to right to avoid potential biases toward behaviors such as grooming and fighting (Dunbar, 1988; Isbell, 1998). In the visible individuals of each scan sample, the first activities lasting for more than five seconds were recorded. Recording of activity time budgets included feeding, moving, resting, social activities (allogrooming, aggression, social play/friendly interactions and infant care), vigilance/scanning and

autogrooming. Feeding was recorded when an individual was observed eating, ingesting or placing an item in the mouth and chewing. Moving was recorded when an individual was observed walking, loping, running, climbing, or leaping. An individual observed chewing while moving was recorded as moving. Social behavior was noted while animals were playing, allogrooming and aggressively interacting. Vigilance was recorded when an individual was scanning intently into a distance while moving head from side to side or a head lift and standing on hind legs on the ground and while moving head from side to side in a tree for brief inspection of the surrounding area (Alberts, 1994; Enstam and Isbell 2002). When an animal was both feeding and moving, the activity was considered as feeding, and hence moving time was underestimated. Therefore, in the analysis, an additional variable, foraging time, as time spent feeding, and moving, or doing both simultaneously was considered separately.

The amount of time spent for different activities depends on habitat condition with specific features of food availability, predation risk, and seasonal climatic variations like temperature. Thus, to analyze effects of ecological factors that determine activity budgets, the habitat conditionsw such as food availability, predation risk, vegetation cover, presence of ectoparasites and temperature were considered.

4.4.1. Analyses on Effects of Season on Activity Time Budget

A total of 3544 scan samples were collected for analysis of activity patterns. Out of these total scan samples, 65 recorded samples were discarded as these samples were taken in incomplete daily activity time records. Analyses of activity time budgets were made based on 3479 scan samples. The daily proportion of time budget for each activity was calculated to give equal

weighting to seasonal habitat condition. Percentage of time spent in each activity was determined daily, each day counts as one sampling point; and the overall mean was determined from these daily data (Doran,1997). Daily percentages of activity time budgets were averaged to obtain overall percentages of time devoted to different activities over seasonal and annual analyses. The overall activity time budgets were estimated by averaging daily proportion of time spent in each of the six activity categories during both wet and dry seasons of the single study year. Moreover, in order to examine the effects of seasonal changes in ecological conditions on behavioral adaptation, analyses were carried out on activity time budgets of wet and dry seasons. Before running the analysis, the daily time proportions for each of the activity categories were tested for normality and homogeneity. Then to test effects of seasonal changes (wet season versus dry season) on activity time budget of different behavioral responses (feeding, social, resting, moving, vigilance and autogrooming) one way Multivariate Analysis of Variance (MANOVA) was used for mean comparison. Animals were expected to respond behaviorally in some correlated manner that would be of interest to cope with their seasonal ecological changes. As a result of this, instead of using multiple separate t-tests, analyzing activity time budgets by MANOVA is appropriate for this study (Scheiner, 2001; Warne, 2014). Dependent variables of the study which are behavioral responses to seasonal changes are potentially correlated. MANOVA enables to control potential correlation among activity time budgets of different behaviors. MANOVA also helps to reduce the likelihood of committing type I error (rejecting true null hypothesis), which cannot be achieved in using multiple separate ANOVA/t-tests (Scheiner, 2001). Moreover, MANOVA helps to determine whether the independent variable (season) are related to combinations of dependent variables (activity time of different behaviors), which is more useful information for this behavioral study with

correlated dependent variables (Warne, 2014). Multivariate significant test for main effects of season and year were tested at 95% level of confidence ($\alpha = 0.05$). After confirmation of significant effects of season and year on time budgets, the univariate F tests were done for each activity time budget of behaviors to explore how seasonal variations influence specific patterns of behavioral response on the activity time budget. In these tests of specific effects of season on activity time budget, six tests on each factor (season and year) were done with an experiment-wise alpha of 0.008 ($\alpha = 0.008$). Experiment-wise level of $P < 0.008$ were set by dividing significance level of the main effect ($\alpha = 0.05$) by six to get an acceptable significance level for each of the six tests.

Moreover, when two activities cannot be scheduled simultaneously, animals which are forced to choose between activities incur costs in terms of reduced opportunities engage in other biologically important activities. Dunbar (1992) and Dunbar *et al* (2009) have suggested that as the biological/survival demands of an activity rise, an animal's time budget becomes increasingly compressed until it is forced to give up time from one or more other activity categories to fulfill time demand of the required activity. Thus, to analyze the pattern of how patas monkeys allocated their activity time budget in constrained extreme seasonal habitats of Alatish, Pearson correlation analysis was used. On the other hand, ecological determinants of seasonal variation in the activity time budget were also analyzed by multiple GLM (generalized linear models/MANCOVA. Ecological factors such as food availability, vegetation cover and predation risk were recorded as categorical data and recoded as dummy variables. Regression model with dummy variables is fundamentally the same as conducting a t-test on the post test means for two groups or conducting Analysis of Variance (ANOVA). So, multiple

GLM/MANCOVA was used to identify/predict which factors contributed to the difference in the seasonal activity time budget. In the model with dummy variables, the estimate of the difference between the (treatment and control) groups is β_1.

4.5. Ranging Pattern Data Collection and Analysis

Ranging data were generated from the GPS data of the study group scan samples of full day (7:30 – 18:00) follows recorded at every 15-minute interval (Wallace, 2006; Hoffman and O'Riain, 2011). The GPS data were recorded starting from the location of the group in the morning before the group left their previous night resting site, to the late evening when the group moves to a sleeping site of the day. Home range sizes were estimated using 95% Kernel density (KDE), 95 % minimum convex polygon (MCP) and grid cell methods, which are the most common home range estimators (Grueter *et al.*, 2008; Nilsen *et al.*, 2008; Grueter *et al.*, 2009; Steiniger and Hunter, 2012). The KDE was implemented with fixed smoothing using least-squares cross-validation bandwidth determination and 25 cell size grid resolution. In the MCP method, home range size was considered as the area contained inside the straight line connections among all the peripheral sightings of the group. Daily range lengths (travel distances) were estimated from the sequence of coordinates taken at every 15 minute location record from early morning to the late evening (Hoffman and O'Riain, 2011). Daily travel distances were calculated as the sum of distances between each set of location coordinates by the software. Both the area of the polygons (home range sizes) and daily range lengths were computed with OpenJUMP Home range Analysis and Estimation (HoRAE) free GIS Toolbox software (Steiniger and Hunter, 2012). In addition to the home range and daily range length estimations, OpenJUMP was used to evaluate the pattern of seasonal habitat use of the group

from all GPS data points of seasonal group locations imported to it (Steiniger and Hunter, 2012). Test of whether patas shift their home range in response to resource changes between wet and dry seasons within a year and the same wet seasons of two consecutive years were analyzed through polygon overlay. Home range overlap analysis was also used to analyze overlap between heterosexual group and all males group. Core areas were also estimated from LSCV KDE by creating core area from density raster layer.

The patterns of range use were plotted and evaluated by superimposing a 100 m x 100 m grid on top of a map of each season's set of location records using ArcGIS10. The frequency of GPS location records that fell into each 1-ha grid was counted for analyzing grid utilization patterns (Grueter *et al.*, 2008). Percentage of use for each grid in each season was estimated and then percentage scores were categorized into the nearest quartile or 25% of seasonal range use (Wallace, 2006). The overall intensity of grid use across the home range was represented by using four use-intensity categories: 25% overall use, 25% - 50% use, 50 –75% use, > 75% use. Greater than 50% of grid uses were considered as core areas of range use. Moreover, the degree of range use evenness was estimated by the Shannon-Weaver evenness index J (Help *et al.*, 1998). This evenness index was computed as:

J = H'/H' maximum= H' / logS

Where J provides a measure of how evenly the 100 m x 100 m grid cells were represented in the range utilization of the patas in each season; H' is Shannon-Weaver diversity index ($H' = -\sum p_i \log p_i$, where p_i is the proportion of quadrat/grid utilization in grid i); S is the number of grids in the season. In this analysis the index approaches to 1 as the range use evenness increases, but it approaches to 0 as the evenness of grid use decreases in the range use pattern.

4.5.1. Statistical Analysis

To test whether home range sizes of patas changed in response to seasonal change in resource availability Wilcoxon signed-ranks tests were used. However, test of daily range lengths were analyzed by paired sample t-test. Here, for the sake of seasonal change analyses, November and December were considered as wet season and March and April as dry season. Thus, wet versus dry season comparison was made for 2012 wet season and 2013 dry season. Wet season of 2011 was considered to compare interannual difference of the same season.

4.6. Habitat Alteration and Anthropogenic Effect Assessment Methods

4.6.1. Field Survey

During the field observations, data on habitat alterations were collected through randomly selected five 3 km long transect surveys in the behavioral study Amjale site. These transects were laid 100 m apart. In addition, survey was conducted on vehicle in the northern part of the Park from Bermil to Jabra, from Bermil to Amjale and from Amjale to Alga sites. Types of habitat alterations were noted and photographs were taken. During the survey, types of habitat alterations were recorded. To quantify effects of fire on vegetation cover, landcover was estimated by analysis of satellite imagery.

4.6.2. LandCover Change Analysis

The study used moderate resolution (30 m) landsat and high resolution (4 m multispectrum and 1 m panchromatic) kompsat satellite images accessed from United States Geological Survey (USGS) and European Space Agency (ESA), respectively. Enhanced Thematic Mapper (ETM+) Landsat-7 and Landsat-8 satellite images of 1999 and 2013 on path 171 and row 51 and 52 were

used to analyze temporal landcover changes in the study area. Whereas, high resolution Kompsat imagery of 2012 was used for referring the patterns of landcover in the study area, as it enables to observe detailed nature of vegetation pattern to the extent of a single tree canopy. The Ethiopian Mapping Agency (EMA) toposheet of 1:250,000 scale locating the study area was used for geo-referencing the satellite images. Landsat satellite images and kompsat satellite images were radiometrically and geometrically processed using ERDAS Imagine 10.0 (Ortho-rectification with WGS 1984 UTM Zone 36 N). The ground truth of the area was sampled by direct observation to verify image classification.

The ground truth information was collected during the field survey by GPS on 44 ground control points (GCPs) in the study area. These GCPs were collected through stratified sampling from each of the landcover types (riverine woodland, *Combretum-Terminalia* Woodland, *Acacia* woodland, wooded grassland, bamboo woodland and water body/flood plain). When recording GPS points during the field survey, the current landcover classes were noted in the field. The GPS points were downloaded and overlaid on the imagery and used for refinement of the landcover map interpretation. For landcover mapping, visual interpretation technique was employed. Based on the extensive ground truth samples and detailed information obtained from high resolution (4 m multispectrum and 1 m panchromatic) Kompsat satellite image, training samples and signature generation (interpretation keys) were developed. The mapping trial was carried out first on the datasets of the 2012 Kompsat imagery. Same vector layer was overlaid upon the 2013 and 1999 landsate dataset, and the polygons were modified wherever changes were found. Land-cover classification was made by supervised classification method. In the process of classification, training area was taken on each of the land-cover classes, based on the

reflectance signature of different features on the false color composite 4-3-2 (FCC) band combinations. Maximum likelihood classifier technique was used for image classification, and a 3 x 3 pixel moving windows majority filter was employed to smoothen the classification. Accuracy test for the prepared land-cover classification was computed by taking the field collected 44 points from the six land-cover classes through ENVI software. Change detection statistics matrix of land-cover and rate of change were also computed by ENVI software. The rate of land-cover pattern changes during the period 1999–2013 were estimated as the difference in the respective land-cover type in hectare divided by duration in years. The prepared supervised land-cover images were exported to ArcGIS 10.0, and LC maps were prepared for the years 1999 and 2013.

CHAPTER 5 RESULTS

5.1. Feeding Behavior

5.1.1. Diet of Patas Monkeys

Overall, 16 plant species and one animal species were consumed as food by patas monkeys during 2011 and 2012 wet seasons and 2013 dry season. Among these food species six were trees/shrubs, eight were herbs (2 crop herbs, 2 climbing herb and 4 ground herbs), and two were grass. Out of total 19 food items, 7 food categories were recorded from plants and insect items (full list in Table 2). Among the total proportion of food items 56.3% were tree/shrub (flower, fruit, pod and gum), 30.3% were herb/grass (flower, fruit and pith), 12.6 % were crop (flower, fruit/seed and pith) and only 0.8% were animal food (insect). In the annual diet composition different food items such as gum (39%), fruits and flower buds (32.7%), *Acacia seyal* pod (0.6%), crop seed (8.1%), herb stem pith (3.5%), corm/tuber (14.8%), and insect (1.3%) contributed as sources of food (Table 3).

Table 2. Summary of food items in the overall diet composition of Patas monkeys in relation to their overall proportion, importance and seasonal utilization.

Food item	Seasonal use
Acacia polycantha gum	W
Acacia seyal gum	W>D
Acacia seyal pod	D
Balanites aegyptiaca fruit	W
Combretum hartmannianum gum	W>D
Cotton flower bud	W
Cucumis ficifolius fruit	W
grass (*Rottboellia cochinchi*) stem pith	W<D
Cricket/insect	W
Ipomia aquatica fruit /flower	W
Lannea fruticosa flower/fruit	W
Murdannia simplex stem	W
Sorghum seed	W
sorghum stem pith	W
Zizipus sp. Fruit	W
4 Unidentified spp. (2 bulb like root, 1 grass corm & 1 tuberous root)	D

W=wet season, D= dry season

Table 3. Contribution percentages of food species in patas annual diet

Food species	Percentage
Acacia polycantha	3.144654
Acacia seyal	27.98742
Balanites aegyptiaca	2.830189
Combretum hartmannianum	8.490566
Gossypium sp. (cotton) Malvaceae	6.918239
Cucumis ficifolius	3.459119
grass sp *(Rottboellia cochinchi*)	2.201258
Gryllus sp./cricket(Gryllidae)	1.257862
Ipomia aquatica	17.92453
Lannea fruticosa	1.257862
unidentified tubers/ corms	14.77987
Sorghum sp	9.433962
Zizipus sp	0.314465

As observed in Table 3 the woody plants species, *Acacia seyal* (27.99%) had the highest proportion in the diet of patas. This was followed by the herbaceous plant, *I. aquatica* and tubers/corms, which contributed for 17.92% and 14.78% of the patas annual diet, respectively. Out of their annual food items, patas depended on 44.03% woody plants and 54.72% herbaceous plants. The role of woody plant food items, which were 50.58% of the wet season diet components, was limited during the dry season diet. During the dry season, woody plants accounted only for 15.25% of patas diet. However, herbaceous plants contributed significantly both in wet and dry seasons. In the wet season, 47.88% of patas diets were above ground herbaceous plant parts (flower, fruit, seed, and tem pith), and these diets were substituted by underground parts in the dry season. In food scarce dry season, herbaceous plants contributed for about 84.75% of feeding time.

The proportion of time spent feeding on the ground and on the tree show seasonal variations. During the late wet season, the time spent feeding on the tree and on the ground was 50.58% and 49.42%, respectively. In the wet season the proportion of time spent feeding on tree and on the ground was nearly equal. During the dry season, patas monkeys in Alatish also spent very high proportion of feeding time (84.75 %) on the ground, whereas feeding on trees was only 15.25%.

As described in phenology, during the late wet season, there were some tree species that contributed gums, flowers and fruits to the patas diet. However, during the dry and hot months of the season (March, April and May), all woody plants except *Balanitus aeyptica* and riverine trees shed their leaves and did not provide flowers and fruits. Despite *Balanitus aeyptica* remaining green, its fruiting season is during the wet season. In addition, during the late dry season, gum of Acacia trees were also dried and hardened to be eaten. Asthey rapidly grow and bloom during the wet season, they were unavailable during the dry season. Thus, except small proportion of *Combretum hartmannianum* trees that produce gum, in the late dry season, patas depend on food resources available on the ground. These facts imply that the terrestrial mode life of patas monkeys is seasonal response to changes in availability of food resources.

5.1.2. Test of seasonal and annual variation in diet composition

The dietary composition of patas during the dry season was different from their wet season diet (figure 6 and 7). Feeding behavior of patas monkeys showed a highly seasonal pattern of consumption of major food items.

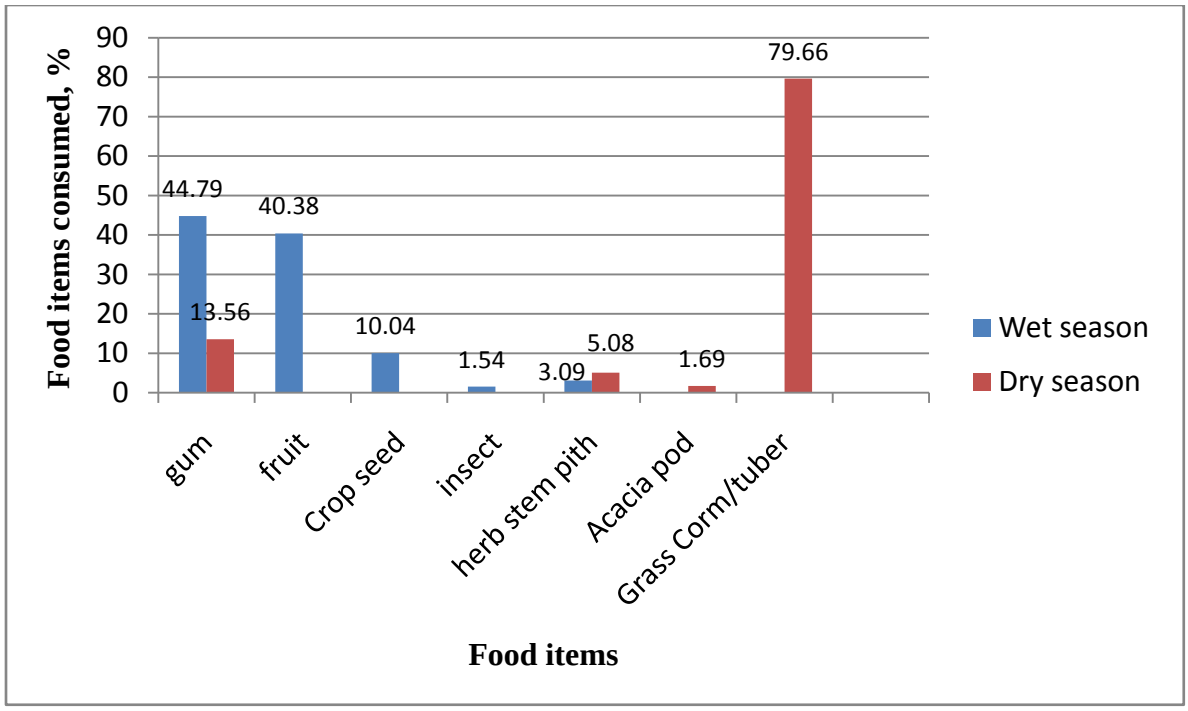
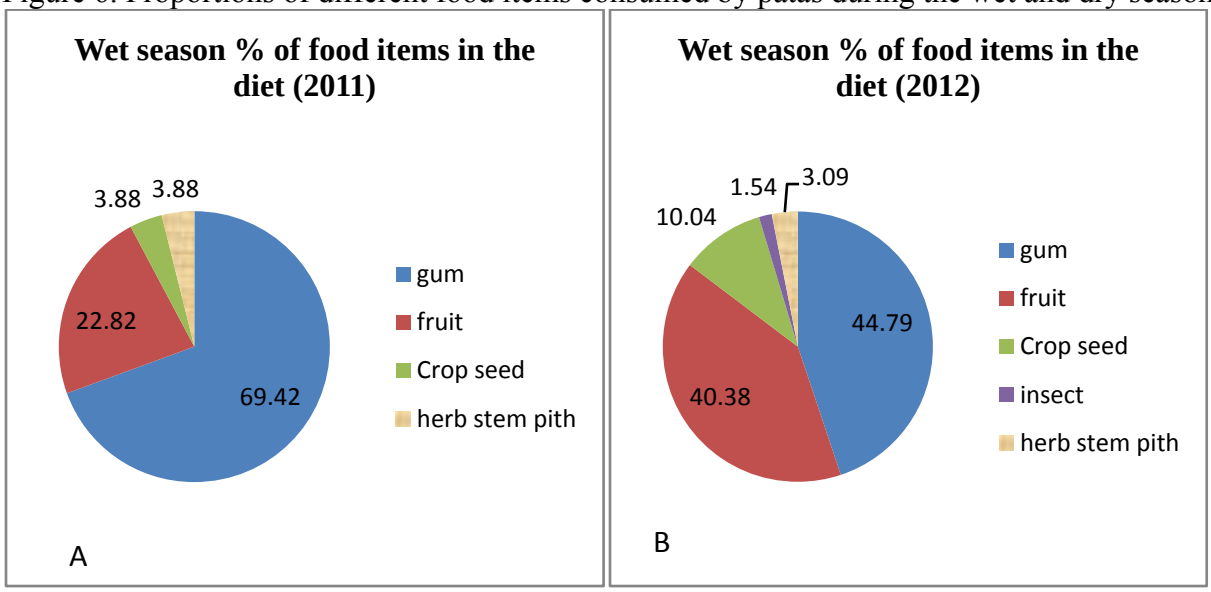


Figure 6. Proportions of different food items consumed by patas during the wet and dry seasons.



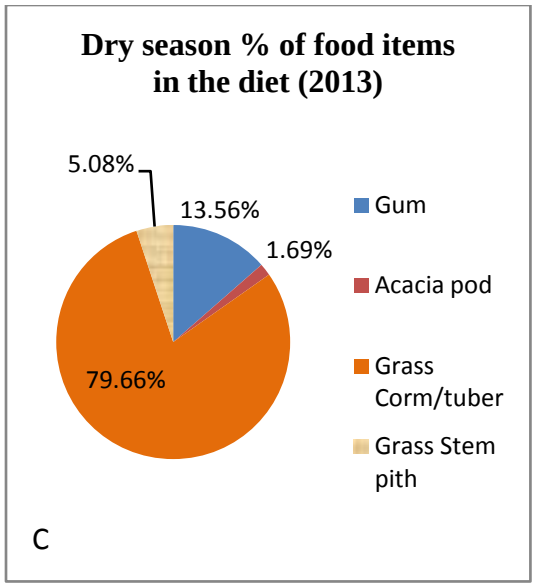


Figure 7. Percentage of different food items consumed in the wet and dry seasons of two consecutive years. A= wet season diet of 2011, B= wet season diet of 2012, and C= dry season diet of 2012.

Except Acacia pod, stem pith and insect, seasonal variation in consumption of most of the food items were statistically significant. In the wet season, diet compositions of patas monkeys in their order of proportion were gum (44.79%), fruit (40.38%), crop seed (10.04%), stem pith of herbaceous plants (3.09%), insect (1.54%), and Acacia pod (0.4%) (Table 4). In the dry season, however, significant proportion of patas diet was corms and tubers (79.66%). The highest proportion of their wet season diet such as gum accounted only for 13.56% in the dry season. Fruit/flower bud and crop seed food items were completely lost in their dry season diet. Instead small proportion of grass stem pith (5.08%) and Acacia pod (1.69%) supplement its dry season diet. Peak fruit, flower buds and crop seed consumptions were observed towards the end of the wet season and early dry season before seasonal flood plain herbs and crops dried. Patas spend significantly more time feeding on fruits and seed in the late wet season than during the dry season (χ^2 = 35.2, df= 1, p < 0.05 and χ^2 = 6.45, df=1, p =0.01). Seasonal flood plains as a wetland provides water and food resources for patas monkeys.

Table 4. Statistical summary of effect of season on consumption of different food types

Season		category of food types consumed by patas							Total
		Gum	Acacia pod	Fruit/flower	Crop seed	Insect	Stem pith	Corm/tubers	
Wet	% within season	44.8%	.4%	40.2%	10.0%	1.5%	3.1%	0.0%	100.0%
	% within category of food types	92.8%	50.0%	100.0%	100.0%	100.0%	72.7%	0.0%	81.4%
dry	% within season	15.3%	1.7.0%	0.0%	0.0%	0.0%	5.1%	79.7%	100.0%
	% within category of food types	7.2%	50.0%	0.0%	0.0%	0.0%	27.3%	100.0%	18.6%
	% within annual	39.3%	.3%	32.7%	8.2%	1.3%	3.5%	14.8%	100.0%
Chi-square test	X^2	19.67	1.3	35.2	6.45	0.92	0.57	236.1	
	df	1	1	1	1	1	1	1	
	p	< 0.001	0.25	< 0.001	0.01	0.34	0.45	< 0.001	

In addition to inter-seasonal variation in the diet composition, wet season (November to December) of two consecutive years (2011 and 2012) also showed some inter-annual variation in feeding of food items (Figure 7). Particularly variations in time spent feeding food times were significant in fruit and gum proportions. In 2011, gum consumption was high (69. 42%) whereas in this season the contribution of fruit was low (22.82%). Conversely, in 2012 fruit composition

in the diet increased (40.38%) almost twice of the previous year and the proportion of gum decreased to 44.79%. In these two consecutive study years, annual proportion of fruit consumption in the diet of patas monkeys also revealed strong positive correlation with annual rainfall (r_s= +1, P < 0.01, N = 2) and proportion of gum consumption was negatively correlated with rainfall (r_s = -1, P < 0.01, N = 2). These inter-annual difference in gum and fruit diet composition is linked to temporal variation in rainfall and fruit availability.

5.1.3. Seasonal Dietary Niche Breadth and Switching

In the analysis of the effect of seasonal changes on feeding behavior, the Schoener's dietary niche overlap index estimation indicated that dietary niche overlap between wet season and dry season was 0.155. As 0.155 is less than 0.6, which is the standard of niche similarity index (Wallace 1981 as cited in Dantas *et al*., 2013), dietary niche overlap between wet and dry seasons of this study is not biologically significant. This estimation of niche overlap also agrees with the estimation made by adding the common minimum percent occurrence of food items in the wet and dry seasons, which is 15.49%. This small percentage of dietary niche overlap between wet and dry seasons shows that patas monkeys used dietary switching as behavioral adaptation mechanism to survive in highly seasonal savannah habitat of Alatish National Park.

In addition to dietary switching, patas monkeys show seasonal variation in the dietary niche breadth. Dietary niche breadth of 2012 wet season was 5.5, and number of food items was 14. Therefore, the wet season standardized niche breadth is 0.35. However, in the subsequent dry season (2013), dietary niche breadth is 1.55 and the number of food items consumed was 5. Thus, its dry season standardized niche breadth is 0.14. This points out that even though patas

monkeys general dietary niche breadth is narrow, its dry season dietary niche breadth was extremely narrower than its wet season dietary niche breadth.

5.2. Activity Time Budget

5.2.1. Overall Activity Time Budget

In their overall annual activity time budget, Patas monkeys spent 16.71% of their activity time feeding, 22.75% moving, 11.26 social activity, 32.03% resting, 14.93 % vigilance and 2.33% for other non-social activity (Table 5). This activity pattern shows that patas monkeys spent more time in foraging (feeding + moving = 39.45%), followed by resting and less time spent in social activities.

Table 1. Descriptive Statistics of annual activity time budget of patas

Activity category	Range	Mean	SE	SD
Social time	30.77	11.27	1.52	8.84
Feeding	27.75	16.71	1.17	6.83
Moving	29.33	22.75	1.30	7.58
Vigilance	27.08	14.93	1.10	6.41
Autogrooming	10.34	2.33	.48	2.81
Rest	55.54	32.03	2.22	12.95

5.2.2. Seasonality in Activity Time Budget

The null hypothesis in this study was that wet season and dry season behavioral observations are equal on all activity time budgets. Thus, MANOVA was conducted to determine the effect of season on the overall six behavioral activity time budgets. The analysis indicates that season has a statistically significant effect on the overall activity time budgets.

Seasonal changes in the environment had a major influence on the activity time budgets of patas monkeys. Analysis of activity time budgets revealed that Patas monkeys show behavioral adjustment in response to seasonal environmental changes (Table 6a,b and Figure 8). The result of multivariate analysis make clear that season has statistically significant effect on activity time budget, [Wilks' $\lambda = 0.21$, $F = 17.14$, $df = (6, 27)$, $p < 0.001$, partial $\eta^2 = .79$. This high effect size (partial $\eta^2 = .79$)] implies, season has strong effect on changes in the activity time budget of different behavior between wet season and dry seasons. Thus, activity time budgets of patas monkeys in Awash are significantly influenced by season. In other words, season has statistically significant effect on the difference in the activity time budget of different behaviors between wet season and dry seasons.

Specific tests of effects of seasons in activity time budget have revealed that the effect was significant for social behavior ($F(1,32) = 66$, $p<0.001$), partial $\eta^2 = 0.67$; moving ($F(1,32) = 28.9$, $p<0.001$), partial $\eta^2 = 0.39$; resting ($F(1,32)=17.88$, $p<0.001$), partial $\eta^2 = 0.48$; vigilance ($F(1,32)=11.22$, $p= .002$, partial $\eta^2 = 0.26$ and autogrooming ($F(1,32)=8.79$, $p=0.006$, partial $\eta^2 = 0.22$). Effect sizes of statistical tests revealed, social behavior and resting were highly influenced by seasonal changes compared to other activities. During the dry season, there was little time for

social activities, whereas resting time increased much in the heat stressed dry season. But, effect of season on the time spent in feeding was not statistically significant ($F(1, 32) = 1.56$, $p=0.22$, partial $\eta^2 = 0.05$). In addition, when both moving and feeding were combined and termed as foraging (Bronikowski and Altmann, 1996; Alberts *et al*., 2005), seasonal difference in foraging was not significant ($F(1, 32)= 4.83$, $P= 0.044$, $\eta^2 = 0.12$) with reference to Bonferroni correction $\alpha= 0.01$.

Table 2a. Results of multivariate analysis to test the effect of season on activity time budget.

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Intercept	Pillai's Trace	.998	2721.774[b]	6.000	27.000	.000	.998	16330.645	1.000
	Wilks' Lambda	.002	2721.774[b]	6.000	27.000	.000	.998	16330.645	1.000
	Hotelling's Trace	604.839	2721.774[b]	6.000	27.000	.000	.998	16330.645	1.000
	Roy's Largest Root	604.839	2721.774[b]	6.000	27.000	.000	.998	16330.645	1.000
Season	Pillai's Trace	.792	17.144[b]	6.000	27.000	.000	.792	102.863	1.000
	Wilks' Lambda	.208	17.144[b]	6.000	27.000	.000	.792	102.863	1.000
	Hotelling's Trace	3.810	17.144[b]	6.000	27.000	.000	.792	102.863	1.000
	Roy's Largest Root	3.810	17.144[b]	6.000	27.000	.000	.792	102.863	1.000

a. Design: Intercept + Season

b. Exact statistic

c. Computed using alpha = .05

Table 6b. Result of statistical test on effect of season in specific activity time budget

Tests of Between-Subjects Effects									
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[g]
Season	Social behavior	1000.479	1	1000.479	66.041	.000	.674	66.041	1.000
	Resting behavior	2628.559	1	2628.559	28.928	.000	.475	28.928	.999
	Moving behavior	679.721	1	679.721	17.880	.000	.358	17.880	.984
	vigilance behavior	352.077	1	352.077	11.216	.002	.260	11.216	.901
	Autogrooming behavior	55.969	1	55.969	8.786	.006	.215	8.786	.820
	Feeding behavior	72.556	1	72.556	1.585	.217	.047	1.585	.231

a. R Squared = .674 (Adjusted R Squared = .663)

b. R Squared = .475 (Adjusted R Squared = .458)

c. R Squared = .358 (Adjusted R Squared = .338)

d. R Squared = .260 (Adjusted R Squared = .236)

e. R Squared = .215 (Adjusted R Squared = .191)

f. R Squared = .047 (Adjusted R Squared = .017)

The proportions of time spent in the six activity time budgets form a mutually dependent set of patterns in which time spent in one activity is necessarily unavailable for the performance of others. Hence, the statistically significant correlations between time spent in one activity with the other might have some behavioral implication. Despite interseasonal difference in feeding and foraging activity, time budgets were statistically insignificant, the proportion of time spent in feeding was higher and conversely time spent in moving was lower during the wet season, and the opposite was true during the dry season. Higher proportion of time spent in moving during the dry season implies that patas monkeys spent more time in searching for food during dry season than during the wet season. The group spent more time in resting and moving during the hotr and food scarce dry season, whereas social behavior such as allo-grooming and non social activities like vigilance and self grooming (autogrooming) occurred more frequently in the wet season.

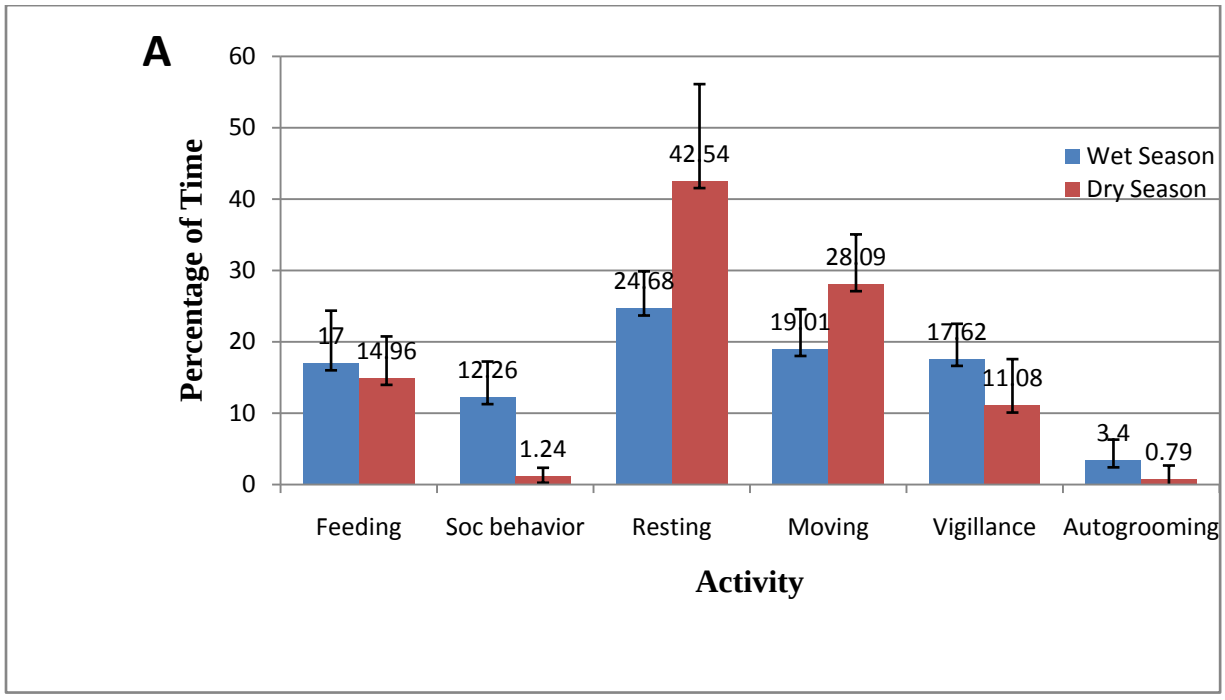


Figure 8. Comparison of activity time budget between the wet and dry seasons

The dry season activity time budget showed a significant increase in the time spent on moving and resting with proportional decrease pattern in the time spent in social and other non-social activities (Figure 8). On an average, the time spent in social activities was reduced by 11% from 12.26% to 1.24% corresponding to seasonal change from wet season to dry season. Vigilance and autogrooming also fall by 6.54% and 2.6%, respectively, during thedry season. On the other hand, the time spent in resting was increased by 17.87% and moving was increased by 9.1% of the activity time. Foraging was increased only by 6.12% as feeding was decreased by 2.97% . These tradeoffs in the activity time budget are also supported by correlation analyses (Table 7).

Table 3. Results of correlation analysis among activity time-budgets

Activity time	Social	Resting	Moving	Feeding	Foraging	Vigilance
Social	—					
Resting	-.525**	—				
Moving	-.680**	.171	—			
Feeding	-.051	-.433*	-.256	—		
Foraging	-.814**	.295	.825**	.070	—	
Vigilance	.310	-.771**	-.129	.121	-.277	—
Autogr.	.294	-.490**	-.274	.152	-.377*	.279

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

The proportion of time spent in resting and socializing in wet and dry seasons are strongly negatively correlated (Table 7, r = - 0.525, P = 0.01). Resting time was also negatively correlated with other non-social activities like vigilance at r = -.771** (p = 0.01) and autogrooming at r = -.490** (P = 0.01). Even though time spent in feeding did not show significant difference between

seasons, resting was negatively correlated with feeding at r = -.433* (P = 0.05). But, resting was not correlated with moving (r= 0. 171, p = 0. 33). Similarly when feeding and moving are combined as foraging, resting is not correlated with foraging (r = 0.295, P = 0.09). Thus, this study suggest that resting time in this patas group is an enforced resting but not spare time that could be allocated for other activities like foraging when foraging demand was increased.

In contrast to resting, time spent in social activities was strongly negatively correlated with moving at r = -.594** (p = 0.01). Foraging was also strongly negatively correlated with time spent in social activities (r = -0.814, P < 0.001). However, social activity was positively correlated with other non-social activities such as vigilance (r = 0 .365*, p = 0.05) and autogrooming (r = 0.417*, p = 0.05). An increase in resting and foraging time during ecologically stressed season together with inverse pattern in the need for social activity and vigilance showed significant seasonal tradeoffs in the activity time budget. These imply that time budget for social activity and other non-social activities were sacrificed for resting and foraging. This finding substantiates the hypothesis of dispensable social time. The findings of this study also support this dispensable social time hypothesis in which social time could be scarified for activity adjustments in response to the survival strategy of the animal. Patas monkeys reduced their social activity time budget in response to the need for foraging time during food scarce dry season.

Within foraging, proportion of feeding and moving time was weakly or not correlated (r= -0.26, P= 0.14). This weak negative correlation and increased demand for foraging during the dry season imply that the increase in the proportion of time spent moving in the dry season may be a result of scarcity for food or scattered food distribution, and have their own need for searching

food items spending time during the dry season. These findings suggest that the habitat quality was degraded during the dry season which resulted in an ecological challenge for survival of patas in the present study area.

Within the social activity categories, allogrooming was strongly positively correlated with aggression ($r = 0.577$, $P < 0.001$). Both allogrooming and aggression were significantly observed in the wet season as compared with their occurrence during the dry season. The mean proportion of time spent in allogrooming was higher (17± 6.68%) during the wet season than during the dry season (3 ± 2.87%, $t = 7.4$, $df = 32$, $P < 0.001$). Similarly, aggression was relatively frequent during wet season (3.7 ± 2.7%) than during the dry season (0.3 ± 0.79%, $t = 4.5$, $df = 32$, $P < 0.001$). Autogrooming also showed the same pattern of seasonal variation as allogrooming, which was also higher during the wet season (3.4 ± 2.89%) than during the dry season (0.79 ± 1.87%, $t = 2.9$, $df = 32$, $P < 0.01$). These two forms of grooming were also positively correlated ($r = 0.488$, $P < 0.01$).

However, the above mentioned relationships among activity budgets are not strictly independent as the sum of time proportions of all activity pattern of each season must be equal to 100%. Therefore, the significance of this correlation was difficult to understand without considering environmental variables. In analyzing the effect of seasonal environmental variation, a significant correlation (Spearman rank correlation) was found between the average monthly proportion of time spent in resting activity and mean monthly maximum temperature ($r = 0.929$, $P < 0.05$). This suggests that increasing temperature accounted for a significant increment in the proportion (17.87%) of the average monthly time spent in resting.

5.2.3. Ecological Factors that Determine Seasonality in Activity Time

Analyses of time budgets are expected to show that time budgets broadly reflect the choices that animals make about the relative importance of various activities in different seasons. But, unless the nature of influence of seasonal variability in ecological factors and their effects on the animals' behavior are well understood, the pattern and importance of seasonal variability in the proportion of time spent in different activities may be difficult to interpret. Thus, this section of the study attempted to analyze effects of ecological factors that explain seasonal variations in activity time budgets or behavioral responses.

Analyses on ecological factors (Table 8a, b) show that seasonal changes in ecological factors such as food availability or dietary niche breadth, temperature, ectoparasite infestation and predation risks significantly determine seasonal changes in the activity time budgets. As observed in their effect sizes, seasonal change in food availability has the highest effect (0.83) for seasonal behavioral changes. Food availability is typically considered as the main ecological factor for variation in time spent on different activities. The general model summary (Table 8) showed that the ecological factors significantly explain variations in social time (80.9%), resting (61.9%), moving/travel time (66%) and the time spend onvigilance (37.9%).

Specific analyses of determinants of each behavior revealed the following patterns of relationship between activity times and associated ecological factors. Variation in resting time was determined by predation risk ($p = 0.001$, $\eta^2 = 0.32$), food availability ($p= 0.001$, $\eta^2 = 35.6$) and temperature ($p= 0.008$, $\eta^2 = 0.22$). Seasonality in social time was also influenced by food availability ($p < 0.001$, $\eta^2 = 0.73$) and ectoparasite infestation ($p < 0.001$, $\eta^2 = 0.45$). Among the

ecological factors, seasonal change in food availability ($p< 0.001$, $\eta^2 = 0.51$) and temperature ($p< 0.001$, $\eta^2 = 0.36$) determine time spent in moving. The effect of predation risk was also statistically significant to determine seasonal changes in the time spend on vigilance ($p = 0.008$, $\eta^2 = 0.36$).

In addition to predator encounter, seasonal ground vegetation cover is also a confounding factor that affects vigilance. An interaction effect analysis of seasonal ground vegetation cover with predator encounter on vigilance was statistically significant at $P< 0.05$ and $R^2 = 0.17$. Results of predation risk estimate analysis also supports vegetation cover as an ecological factor for seasonal variation in the time spend on vigilance.

Parameter estimates of the MANOVA predicted that an increase in the temperature influenced animals to spend more time in resting. The model also revealed that an increase in the level of ectoparasite infestation caused increase in social time of patas monkeys. Increasing in the level of tick load might force patas to spend more time in grooming. According to this MANOVA parameter estimates, reduction in food availability and increase in the temperature resulted in an increase in time spent moving.

Table 4a. Results on general linear model of effect of ecological determinants on activity time budget

Effect		Value	F	df	Sig.	Partial Eta Squared	Observed Power[c]
Predation risk	Wilks' Lambda	.468	4.350[b]	6,23	.004	.532	.940
Food availability	Wilks' Lambda	.169	18.798[b]	6,23	.000	.831	1.000
Temperature	Wilks' Lambda	.538	3.294[b]	6,23	.017	.462	.848
Ectoparasite	Wilks' Lambd	0.494	3.923b	6,23	.008	.506	.911

Table 8b. Summary of ge neralized l inear m odel on t he e cological de terminants of specific activity time budget

Source	Dependent variables	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[g]
Summarized Model	Social	2401.324[a]	5	480.265	23.676	.000	.809	1.000
	Resting	3424.829[b]	5	684.966	9.084	.000	.619	.999
	Vigilance	514.366[c]	5	102.873	3.420	.015	.379	.841
	Autogrooming	62.301[d]	5	12.460	1.766	.152	.240	.520
	Feeding	217.941[e]	5	43.588	.925	.479	.142	.280
	Moving	1252.076[f]	5	250.415	10.887	.000	.660	1.000
Risk_pred	Social	158.153	1	158.153	7.796	.009	.218	.769
	Resting	988.411	1	988.411	13.108	.001	.319	.937
	Vigilance	285.227	1	285.227	9.482	.005	.253	.844
	Autogrooming	9.847	1	9.847	1.396	.247	.047	.207
	Feeding	77.576	1	77.576	1.647	.210	.056	.236
	Moving	99.452	1	99.452	4.324	.047	.134	.519
Food_availab	Social	1534.453	1	1534.453	75.644	.000	.730	1.000
	Resting	1166.241	1	1166.241	15.466	.001	.356	.967
	Vigilance	184.537	1	184.537	6.135	.020	.180	.667
	Autogrooming	48.645	1	48.645	6.896	.014	.198	.717
	Feeding	.147	1	.147	.003	.956	.000	.050
	Moving	673.937	1	673.937	29.300	.000	.511	.999
Temperature	Social	19.436	1	19.436	.958	.336	.033	.157
	Resting	606.230	1	606.230	8.039	.008	.223	.781
	Vigilance	42.918	1	42.918	1.427	.242	.048	.211
	Autogrooming	2.036	1	2.036	.289	.595	.010	.081
	Feeding	4.344	1	4.344	.092	.764	.003	.060
	Moving	359.515	1	359.515	15.630	.000	.358	.968
Tick load	Social	471.848	1	471.848	23.261	.000	.454	.996
	Resting	55.685	1	55.685	.738	.397	.026	.132
	Vigilance	.199	1	.199	.007	.936	.000	.051
	Autogrooming	.679	1	.679	.096	.759	.003	.060
	Feeding	9.146	1	9.146	.194	.663	.007	.071
	Moving	117.791	1	117.791	5.121	.032	.155	.589

a. R Squared = .809 (Adjusted R Squared = .775)

b. R Squared = .619 (Adjusted R Squared = .551)

c. R Squared = .379 (Adjusted R Squared = .268)

d. R Squared = .240 (Adjusted R Squared = .104)

e. R Squared = .142 (Adjusted R Squared = -.011)

f. R Squared = .660 (Adjusted R Squared = .600)

Table 5. Estimation of perceived predation risk on vegetation cover/risk estimation of vegetation cover for perceived predation risk

		95% Confidence Interval	
	Value	Lower	Upper
Odds Ratio for habitat tree canopy and understory vegetation cover (very low / high)	15.889	1.732	145.788
For cohort Occurence of perceived predation risk = abcent	2.063	1.244	3.422
For cohort Occurence of perceived predation risk = present	.130	.019	.895
N of Valid Cases	34		

*Note:- high vegetation cover is vegetation with dense ground cover taller than 1.5m grass and trees with its full canopy cover

-low vegetation cover is vegetation with sparse ground cover or shorter than 1m or bare ground cover and trees shade their leaves of canopy cover

The odd of absence of risk of predation for low vegetation cover is about 16 times that of high vegetation cover. In other words, the likelihood of high risk of perceived predation for high vegetation cover is higher and is about 16 times higher than low vegetation cover. The 95 % confidence (1.732, 145. 788), interval doesn't include one, which means there is significant association between vegetation cover and risk of perceived predation. The risk of predation was higher for high vegetation cover to the minimum by about 73% and to the maximum the likelihood of the risk was about 145 fold (Table 9).

5.2.4. Comparison of Activity Time Budget of the Wet Seasons of the Consecutive Years

In addition to effects of seasonal changes on activity time budget, patas monkeys also showed variation in activity patterns (Wilks' $\lambda = 0.56$, $F (6, 40) = 5.1$, $p = 0.001$, $\eta 2 = 0.43$) between two successive years at the same study site, study group and season. When differences in the activity time budget between successive years of the same seasons (wet) is compared with differences

between wet season and dry season within the same year, the differences between successive years of the wet seasons were very weak. There were, however, overall marked differences between the seasons within the year. Effect size of seasonal variation (partial $\eta^2 = .79$) on activity time budget is higher than effect size of annual changes between the same season, ($\eta^2 = 0.43$). Significant effect of change of years in activity patterns was also limited only for feeding ($F(1, 45) = 8.03$, $p = 0.007$, partial $\eta^2 = 0.15$). Test of differences across the years for the other activity patterns were not significant [moving $F(1, 45) = 6.6$, $p = 0.013$; social activity $F(1, 45) = 0.62$, $p = 0.44$; resting $F(1, 45) = 2.09$, $p = 0.16$; vigilance $F(1, 45) = 3.49$, $p = 0.068$, and autogrooming $F(1, 45) = 0.66$, $p = 0.422$]. Effect size of annual variation in feeding time was also very weak, $\eta^2 = 0.15$.

The analysis shows that feeding rate was higher in 2012 when annual rainfall and associated flood plain herb fruits were relatively more available than in 2011. In the relatively lower annual rainfall year (2011), the time spent in feeding was 12.82% ± 1.22(x ± S.E), whereas in the subsequent relatively higher rainfall year (2012), feeding time was increased by 5.43%. Conversely, in 2011 time spent in moving was higher than in 2012 (Figure 9). Time spent in moving was reduced by 5.24% in 2012 as compared to the moving time in 2011. The correlation analysis result ($r = -0.387$, $p = 0.007$) also shows inverse relation of time spent in feeding and moving between the two wet seasons study years. Possibly due to inverse relationship between feeding and moving across years, foraging time did not show variation across the two subsequent years both in t-test analysis ($t = -0.05$, $df = 46$, $P = 0.96$) and MANOVA ($F(1, 46) = 0.003$, $P = 0.96$). The difference in time spent foraging between the two years was only 0.12%. Activity time of feeding and moving were not also correlated with any other activity time. Thus, the

limited year to year differences in activity time observed within the two components of foraging behavior and absence of relation with any other behavior activity time suggest that the year to year changes in activity budget might be due to the variation in the rainfall and associated food availability across years. This again implies that yearly differences in the activity time budget was related to feeding, which was dictated by yearly differences in the rainfall and associated food availability.

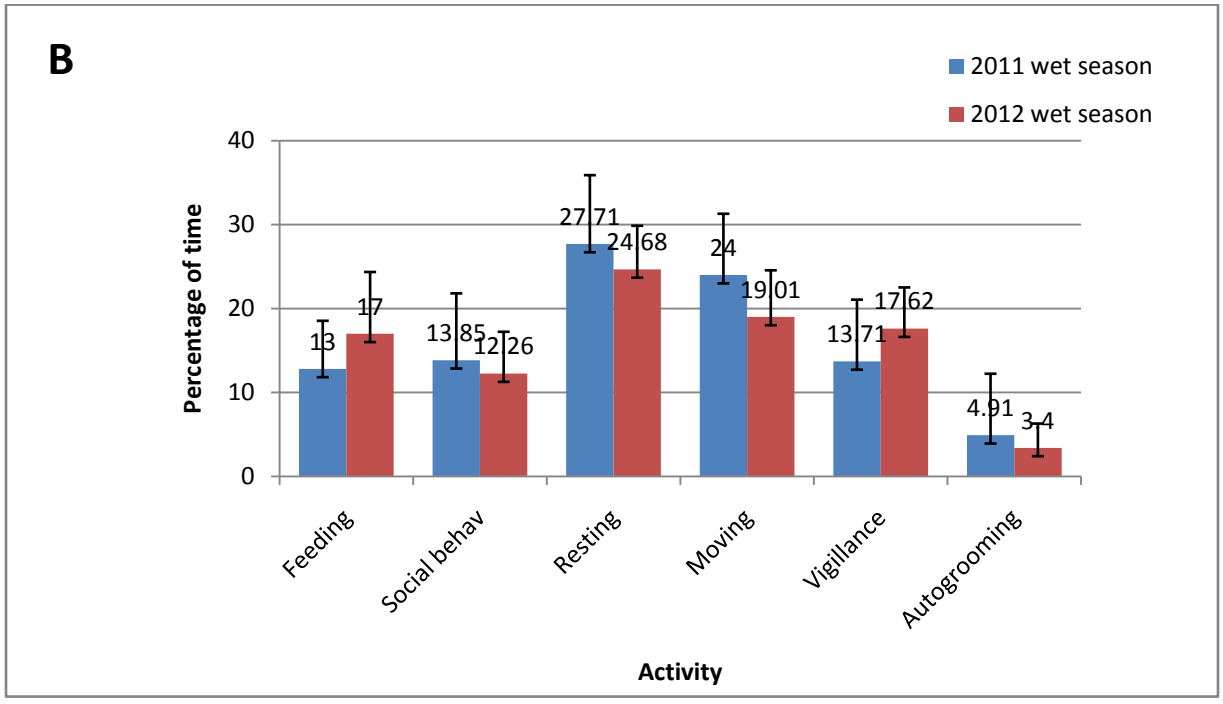


Figure 9. Activity time budget of 2011 and 2012 wet seasons

5.3. Ranging Behavior

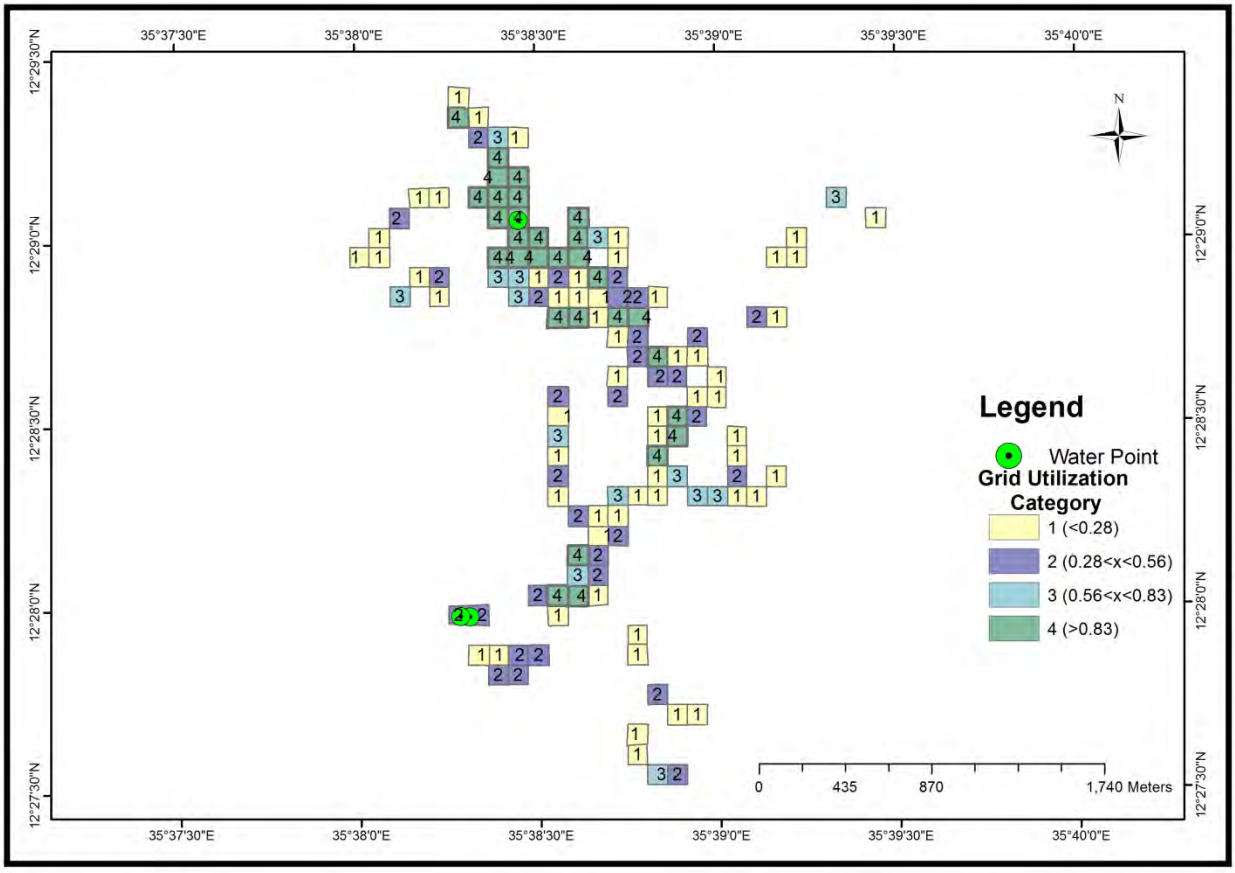
Day journey lengths varied between wet and dry seasons ($t = -8.4$, $df = 28$, $p < 0.001$). The estimated average day range length of the wet season was 479 m (± 179.5 SD), whereas that of the dry season was 1,512.8 m (±466.18). In the wet season, the minimum and maximum range lengths were 235.34 and 801.24 m, respectively. The longest daily range length in the dry season was 2249.6 m and the shortest was 779.5 m. Thus, the shortest daily range length in the dry

season was almost equivalent to the longest daily range length of the wet season. Comparison of daily range length between the two wet seasons of consecutive years (2011 and 2012) also showed statistically significant variation ($t=3.97$, $df = 33$, $p < 0.001$). The mean daily range length of the first year wet season was 1165.57 m (±690.25), and the second year wet season was 479 m (± 179.5). The longest daily range length in the first year wet season was 2310.28 m.

In contrast to the daily range length, home range size of patas did not show statistically significant variation between wet and dry seasons ($z = -1.069$, $p = 0.285$). Indeed, size of the seasonal home ranges had significant difference. Home range size of the 2012 wet season was 36.20 hectares (±15.52) with core area of 9.55 hectare, whereas home range size of the dry season was 105.29 hectares (±104.79) with core area of 28.96 hectare. Wet seasons of the two consecutive years also did not show statistically significant variation ($z = 0$, $p=1$). Home range size of the 2011 wet season was 90.21 hectares (±49.39) and its core area was 4.88 hectare. All these home range statistics were based on LSCV KDE home range estimator. But, when home ranges were estimated with 95% MCP, home range sizes were higher than KDE estimates. Home range size of 2013 dry season was 227.026 hectares; the 2012 wet season was 231.12 hectares and size of 2011 wet season home range was 485.08 hectares. On the other hand, in using grid cell method, the home range sizes were 133 hectare, 57 hectare and 104 hectare in 2011 wet season, 2012 wet season and 2013 dry season, respectively (Figure 10). In the grid cell method, if 50% of grid utilization is considered as core area, the study group spent 50% of their 2013 dry season, 2012 wet season and 2011 wet season ranging time in 38 hectare, 12 hectare and 24 hectare, respectively.

In the first year, the home range area was estimated only for its wet season. During dry season search of the study group in their wet season home range site and surrounding potential area failed to locate them. In the late dry season, the study group of patas monkeys was seasonally migrated far from their wet season home range. In May the study group had moved elsewhere about 11km away from the previous wet season home range and during this period only a brief sighting was observed. But, annual home range size of the patas group in the second year of study estimated by MCP was 548.00 hectares.

Analysis of range utilization distribution revealed that range use was more evenly distributed during the dry season than during the wet seasons. The range utilization distribution evenness index value for the 2013 dry season was 0.96; and evenness value for 2012 and 2011 were 0.92 and 0.93, respectively. As shown in Figure 10, during 2013 dry season the lowest quartile of grid utilization (0.58%) accounted for 63.5% (66 hectares), 1.16% grid utilization covers 22.1% (23 hectares) and from 1.73% to 4.62% grid utilization cover (15 hectare) 14.5% of the total seasonal range use. In contrast to the dry season, the 2012 wet season grid utilization was more heterogeneous. The lowest quartile of grid utilization (0.51%) accounted only for 26.3% of the total home range use; the second, third and fourth quartiles of grid utilization accounted for 31.6%, 17.5% and 24.7% of the total home range, respectively. Grid utilization pattern of the 2011 wet season was intermediate between the two home range use patterns. In this season, the lowest quartile grid utilization was 0.28%, which accounted for 42.9% of the total range use; the highest quartile of grid utilization covered 22.7% of the range use pattern.


35°37'30"E
35°38'0"E
35°38'30"E
35°39'0"E
35°39'30"E
35°40'0"E
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12°29'0"N
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12°28'0"N
12°27'30"N
N
Legend
Water Point
Grid Utilization Category
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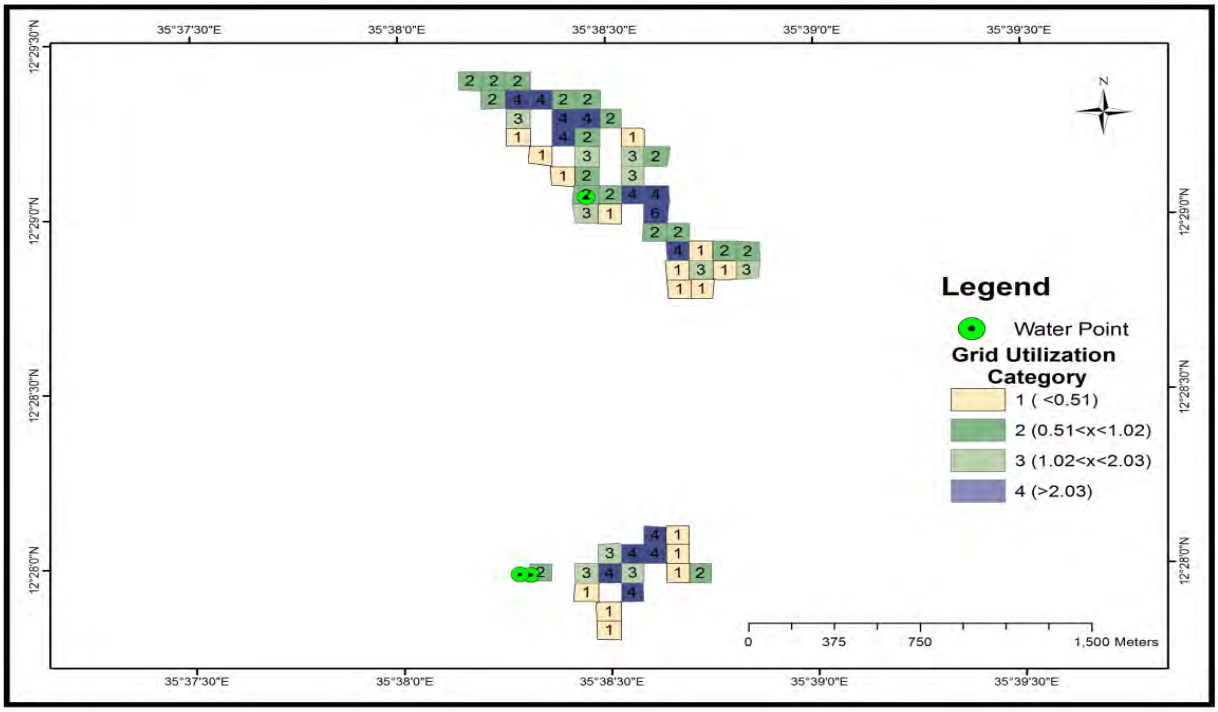
2 (0.28<x<0.56)
3 (0.56<x<0.83)
4 (>0.83)
0
435
870
1,740 Meters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35°39'0"E
35°39'30"E
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12°29'0"N
12°28'30"N
12°28'0"N
12°26'0"N
N
Legend
Water Point
Grid Utilization Category
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3 (1.02<x<2.03)
4 (>2.03)
0
375
750
1,500 Meters

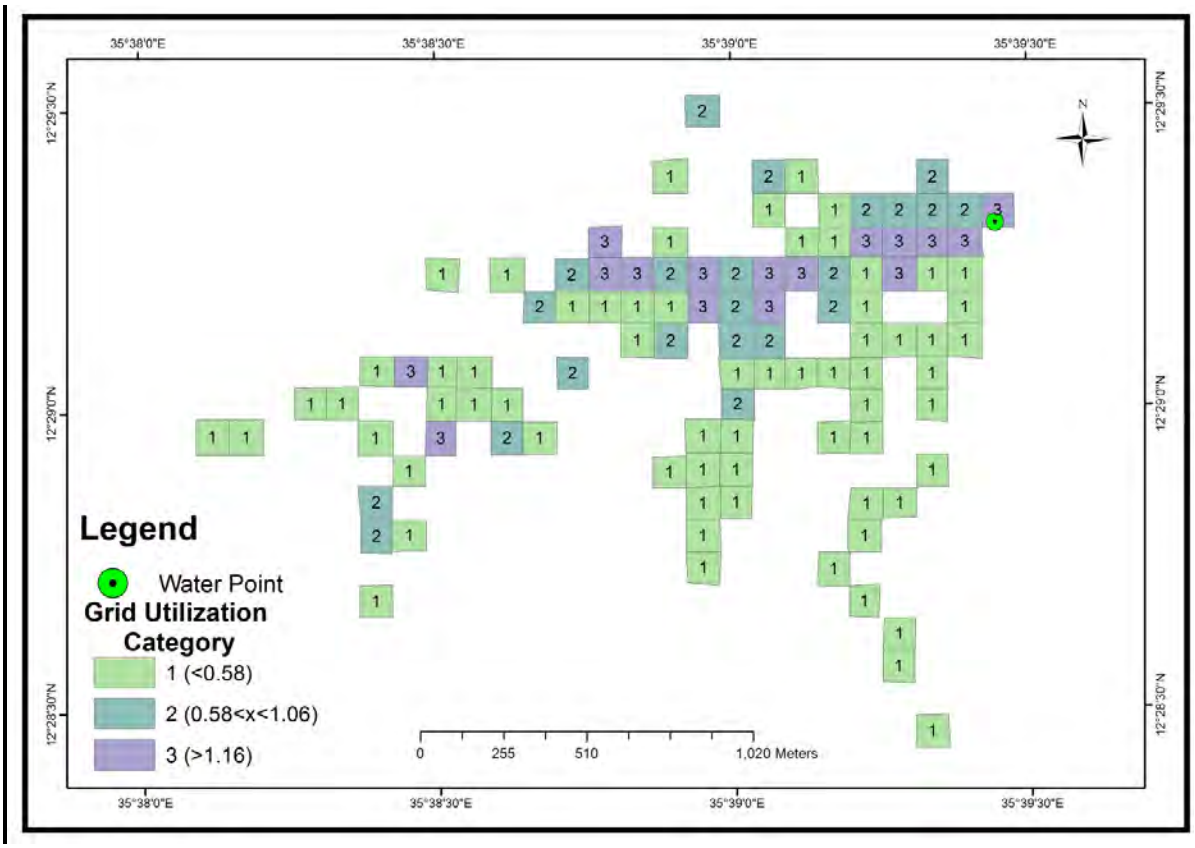
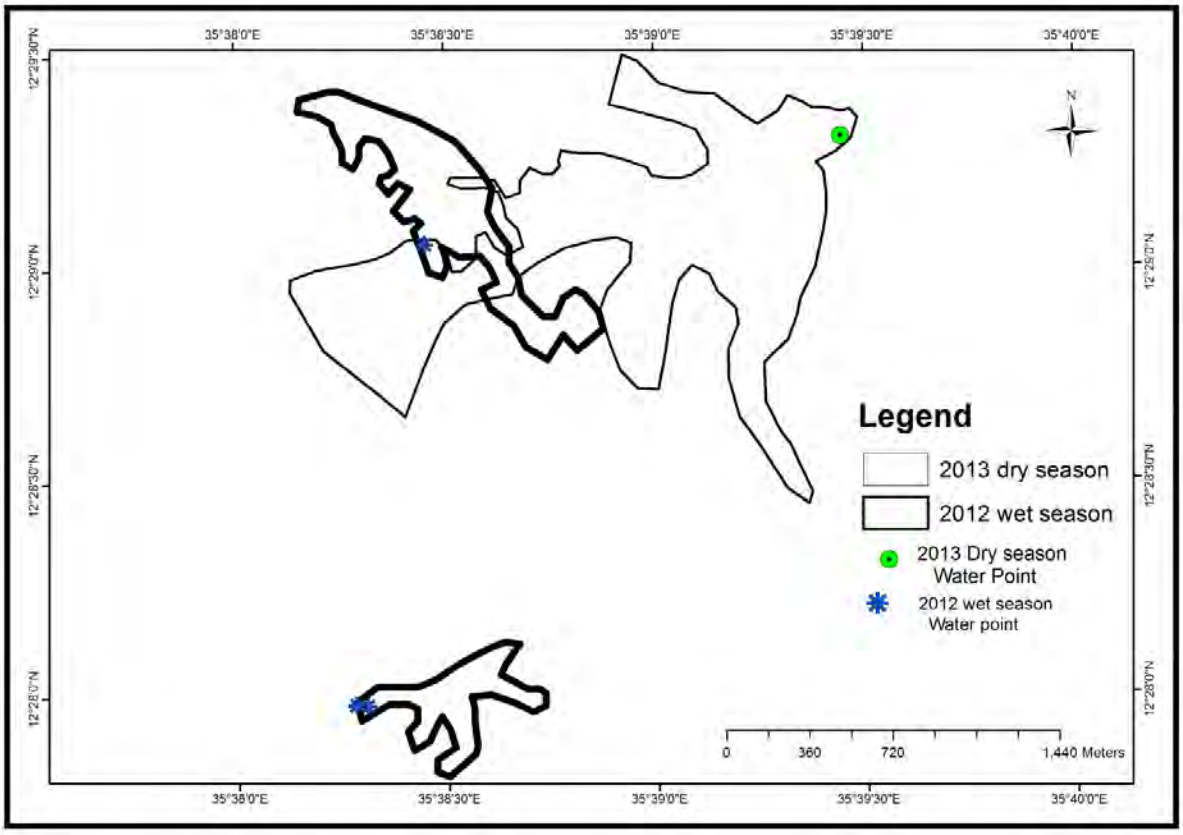


Figure 10. Map of grid utilization in the seasonal range use pattern. Top Fig: 2011 wet season, middle Fig: 2012 wet season, bottom Fig: 2013 dry season.

The overlap between home range areas of consecutive wet and dry seasons of a year was 134.75 hectares. This home range overlap was over estimated when the overlap was estimated by MCP. But, as shown in Figure 11 the overlap of wet and dry seasons home range of patas using grid cell method was smaller. Patas used different water points in wet and dry seasons. In the wet season, patas never approach the Gelegu river for searching water, instead they used flood plains/wetlands as water sources. However, when flood plains dried after the mid dry season starting from January, patas shifted their home range towards the Gelegu river and used either water pools left on rocky river bed in the case of adult males or cattle water troughs in Gelegu river in the case of the one male-multi-female group. As a result of change in water availability and desiccation of the associated flood plains food resources like *I. aquatica,* patas abandoned most of their wet season home range parts. Thus, in the dry season, patas monkeys shifted their

home range to areas near the river, which were not visited in the wet season. In the wet seasons of the two consecutive years, however, the degree of home range overlap was high (Figure 11). This significant home range overlap shows that patas revisited the area, which was abandoned in the previous dry season. Home range of adult males was also overlapped with that of the one male-multi female study group during the wet season, but they did not share common home range during the dry season (Figure 12).



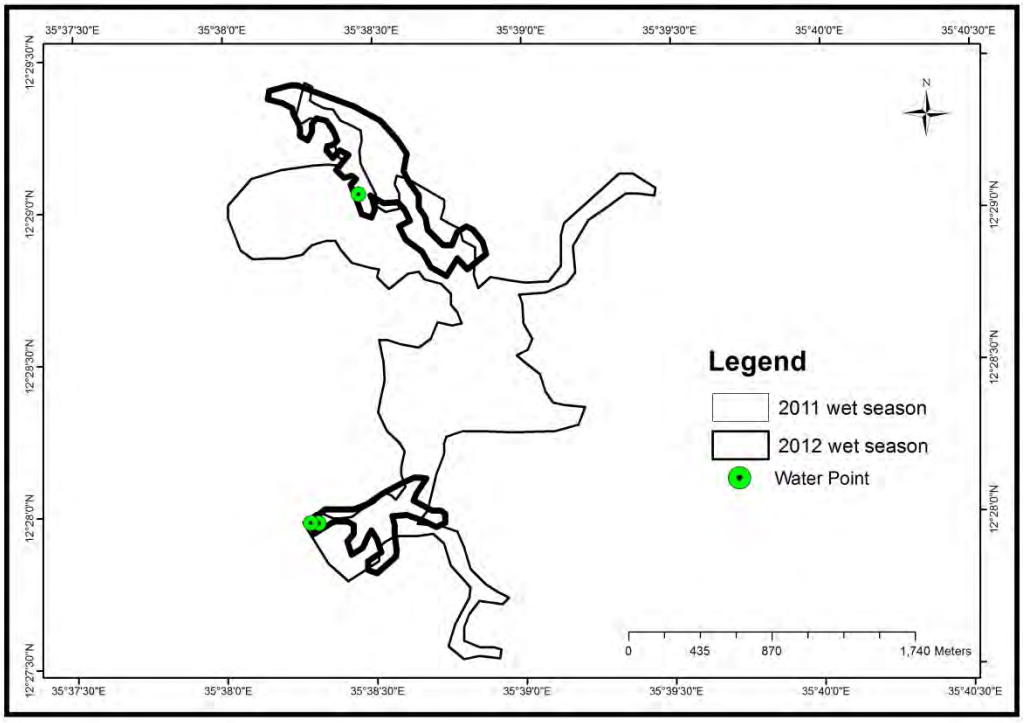


Figure 11. Map of range use pattern showing seasonal and annual home range overlap and shifting

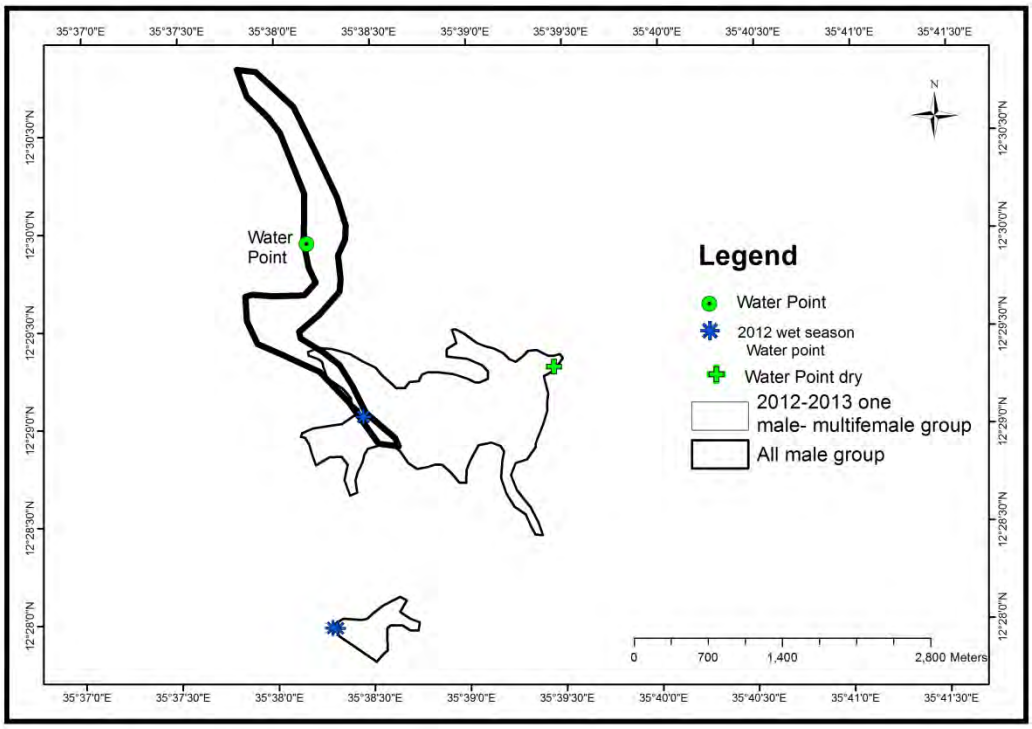


Figure 12. Home range overlap map in the spatial utilization of adult male group and one male-multi female group.

5.4. Conservation Threats and Landcover Change

5.4.1. Conservation Threats

The establishment of Alatish as National Park has been considered as a conservation initiative to protect declining threatened and endangered wildlife as well as the ecosystem. However, this field study (2011-2013) has recognized that biodiversity resources including wildlife of the Park, its potential vegetation cover and ecosystem services have been facing challenges of sustainability. Among the factors that threaten the Park, adverse pressures being exerted by activities of livestock grazing as well as wild honey collectors (Plate 11) were the major anthropogenic threats. The cattle-raising nomads usually encroach seasonal wetlands and river banks in Alatish, which are the potential water sources of wildlife and center of wildlife diversity during the dry season. In addition, fire induced by them is a severe problem in degrading habitat quality and tree coverage of the Park to the extent that burnt trees cannot be regenerated (Plate 12).

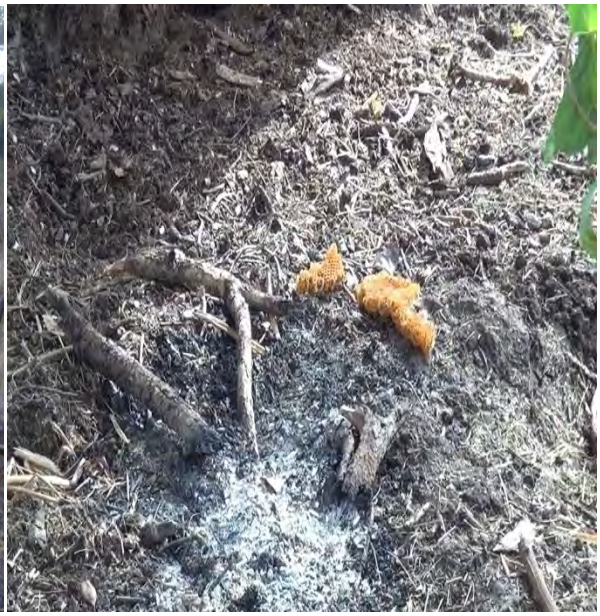


Plate 11. Threats of Alatish by honey collectors and nomadic pastoralists. Top left: destructive honey collection practice in tree holes by cutting of trees. Top right: fire in the park to collect honey in tree holes. Bottom: Pastoralist nomads cattle grazing in the Gelegu river bank when new grass shoots respout after fire near Alga site.

Plate 12. Intense fire burn removes trees including roots.

In addition, in the two years field study hunted warthog and African civet were observed. Besides, sounds of gunshot were detected near water sources around the Gelegu River. The study has revealed that fire remove vegetation covers annually, and the effect of fire on vegetation covers were severe.

5.4.2. Landcover Change

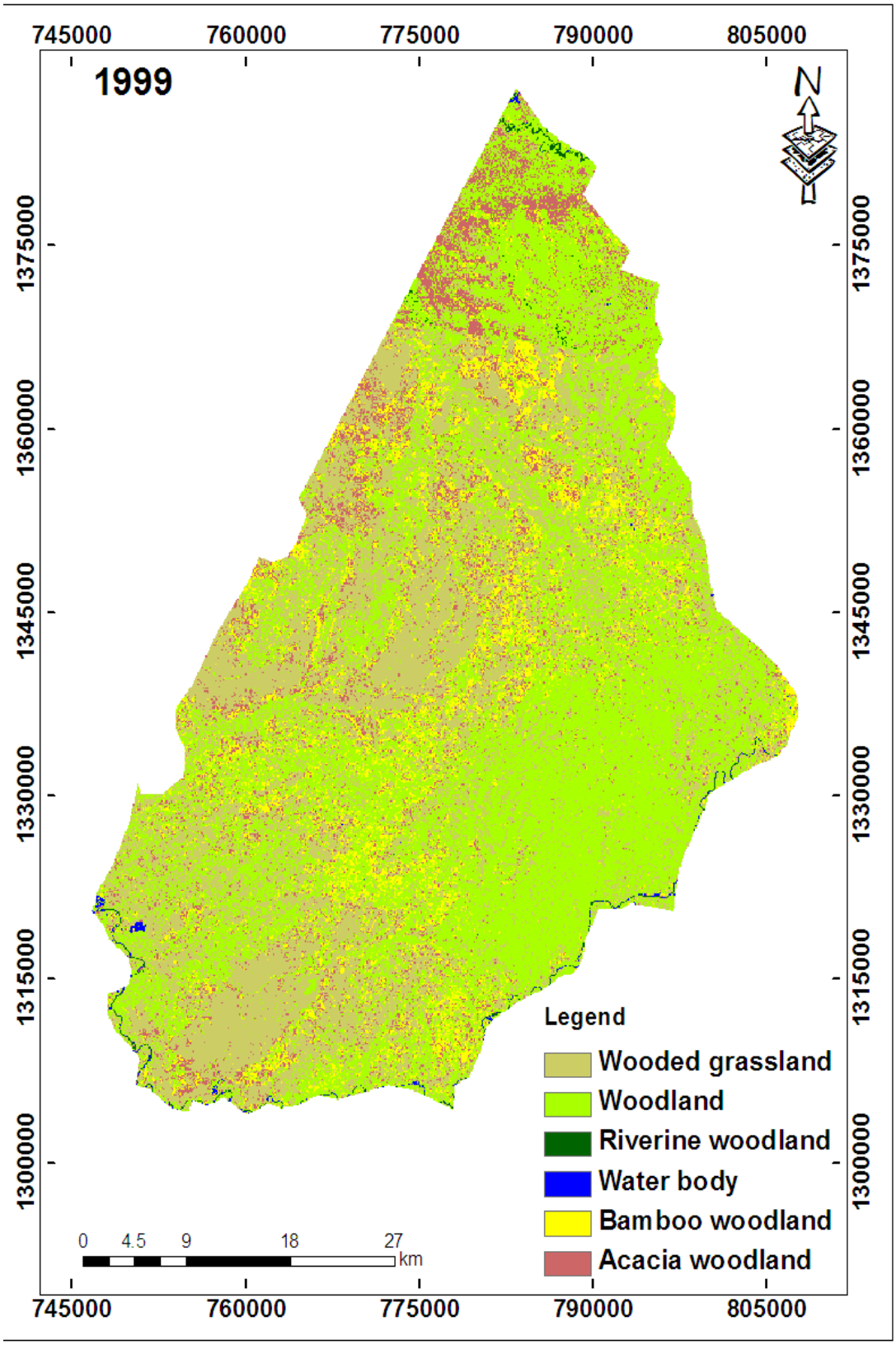
In Alatish National Park there are six major landcover classes both in 1999 and 2013. The land covers include riverine woodland, *Acacia* woodland, deciduous woodland, bamboo woodland, wooded grassland, and seasonal flood plains/water body. As observed in Figure 13 and Tables 10 and 11, the landcovers mentioned show changes in area coverage between 1999 and 2013. Deciduous woodland was the highest landcover (46.55%) in 1999, but this landcover was reduced by 26.7% with a rate of 5231.4 hectare per year. The woodland cover in 2013 was only 19.8% of the Park. As observed in Table 10 most of the deciduous woodland landcover was changed in to wooded grassland and Acacia woodland. Bamboo woodland is another landcover, which was reduced during this time. Bamboo woodland, which was 9.34% in coverage in 1999, was extremely shrunk to below 1% in 2013. Most of the bamboo woodland was converted into wooded grassland. However, wooded grassland, which was the second highest landcover (35.4%) in 1999 was highly increased with a rate of 5689.98 hectare annually. In 2013 wooded grassland covered 64.5% of the total landcover. *Acacia* woodland also showed increasing trend with the rate of 1222.1 hectare per year; from 1999 to 2013 *Acacia* woodland increased by 6.25%. Riverine woodland and seasonal flood plains/wetlands are generally small in their extent, and did not show noticeable changes. Even though, riverine woodland cover is small in total proportion, it seems to be increasing in coverage from 1999 to 2013.

Table 6. Landcovers and change matrix between time periods of 1999 – 2013 in Alatish National Park.

		1999 ha						
2013 ha		*Acacia* woodland	Water body/Flood plains	Riverine woodland	Wooded grass-land	Bamboo woodland	Deciduous Woodland	Class total
	Acacia woodland	**4291.8**	111.12	131.99	12832.9	3497.84	18551.8	39417.45
	Water body/Flood plain	10.58	**210.72**	357.39	6.52	0.89	94.91	681.01
	Riverine woodland	24.83	5.73	**124.48**	1211.31	46.64	1435.98	2848.97
	Wooded grassland	16011	141.84	9.46	**71769.6**	18215	70423.1	176570.4
	Bamboo woodland	2.38	0.26	0.06	12.87	**3.78**	13.72	33.07
	Deciduous Woodland	1967.1	164.16	191.81	11077.5	3879.34	**36920.5**	54200.4
	Class total	22308	633.83	815.19	96910.7	25643.5	127440.01	
	Class change	18016.3	423.11	690.71	25141.1	25639.71	90519.51	
	Image difference	17109.4	47.18	2033.78	79659.7	-25610.4	-73239.61	

Table 7. Proportion of land covers of Alatish National Park during 1999 and 2013 and annual rate of change.

Land cover class	Extent in1999		Extent in 2013		Rate of change(ha/year)
	Area (ha)	%	Area(ha)	%	
Acacia woodland	22308.08	8.15	39417.45	14.40	1222.10
Water body/Floodplain	633.83	0.23	681.01	0.25	3.37
Riverine woodland	815.19	0.30	2848.97	1.04	145.27
Wooded grassland	96910.7	35.40	176570.4	64.50	5689.98
Bamboo woodland	25643.49	9.37	33.07	0.01	-1829.32
Deciduous Woodland	127440	46.55	54200.4	19.80	-5231.40
Total	273751.3	100	273751.3	100	


1999
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1315000
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Wooded grassland
Woodland
Riverine woodland
Water body
Bamboo woodland
Acacia woodland
0
4.5
9
18
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km

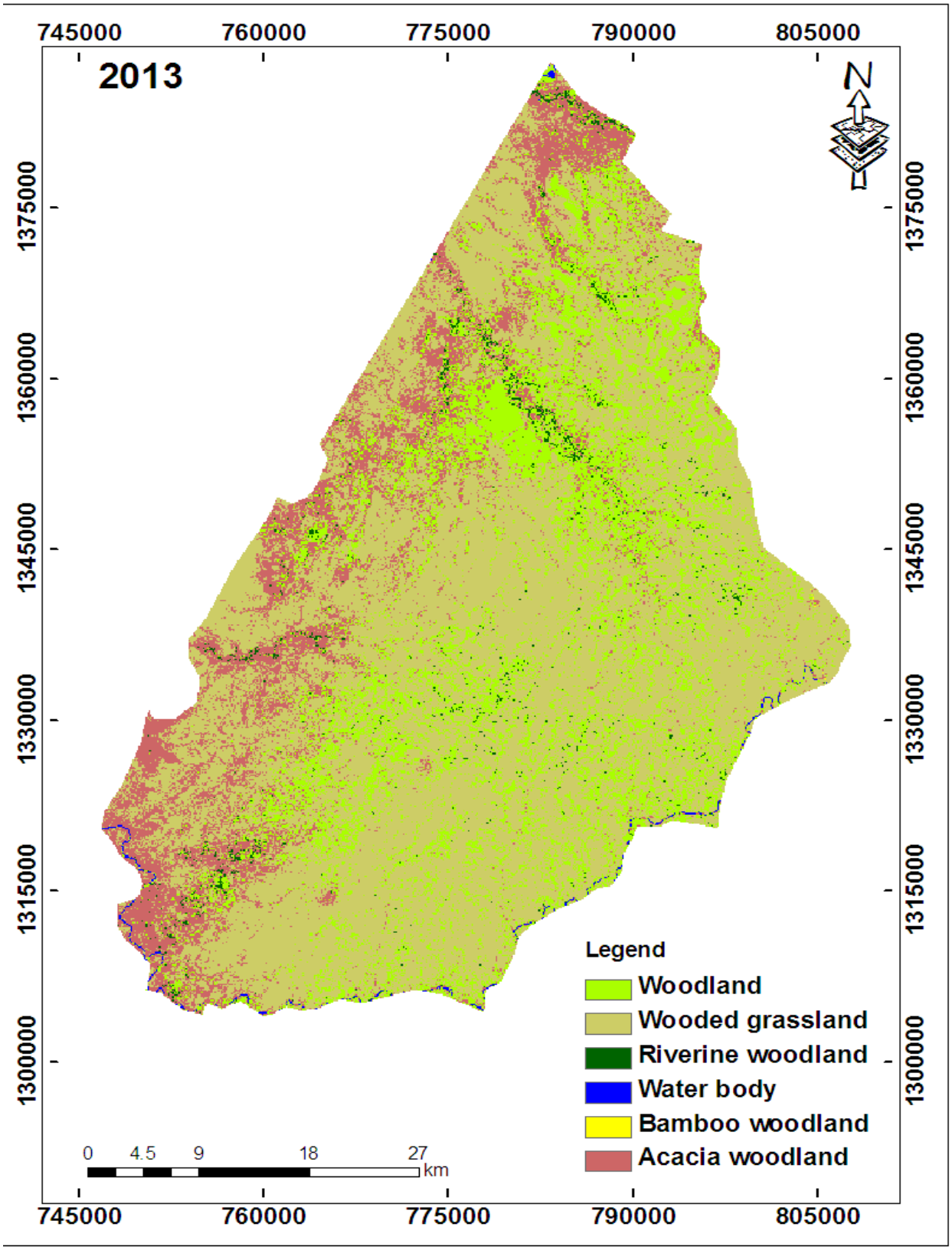

Figure 13. Land cover maps of 1999 and 2013

CHAPTER 6 DISCUSSIONS

6.1. Feeding Behavior

6.1.1. Overall Diet composition

The present study revealed that diet of patas in Alatish is limited to few food species. The overall food species observed in the two wet seasons and one dry season was 17 species and 19 food items. Among these food species 16 were plant species while animal matter was represented by only one species. Out of their food species, only three species (*A. seyal*, *C. hartmannianum* and *I. aquatic*) covered 60.5% of the patas' feeding time. Similarly, in the other East African site, Isbell (1998) show that diet of patas in Kenya Laikipia composed of fourteen plant species and eight animal species. Patas monkeys at Laikipia obtained the majority of their food (83%) from *A. drepanolobium* trees (Isbell, 1998). However, in only one wet season study of patas in Cameroon Kala Maloue of west Africa, (Nakagawa, 1989) pointed out that patas monkeys fed on 27 species (32 items) of plant food and at least 12 species of animal food (11 insect spp., and 1 bird sp. eggs). Another study in Cameroon, indicated that patas exploited a relatively wider range of food items than the East African Patas (Nakagawa, 2003). This same author showed that the variety of patas' diet include about 49 food items in Kala Maloue.

When the number of food species of patas in Alatish (Ethiopia) is compared to patas in Kenya and Cameroon, the number of food species in Alatish is narrow like diet of patas studied in Kenya. Dietary breadth of patas in the two East African countries is narrower than the West African patas' diet. However, the total number of food species of this study might be underestimated as data were not collected during the heavy rainy season. During the rainy season, crossing Gelegu river was difficult to reach at "Amjale" the study camp site.

Nevertheless, in the rainy season, patas are expected to feed on different herbaceous plant foods (Nakagawa, 1989).

Compared to sympatric forest dwelling guenons and savanna baboons, patas monkeys generally have narrow dietary niche breadth (Post, 1982; Isbell, 1998; Nakagawa, 2000, 2003; Swedell, 2008, Schreier 2010; Johnson *et al*., 2012). The general nature of low dietary breadth of patas monkeys relative to other savanna primates can be attributed to differences in their habitat preference. Previous studies pointed out the sympatric tantalus (*Chlorocebus tantalus*) monkeys preferred woodland, especially gallery forest, whereas patas preferentially established their home range in grassland and/or woodland (Nakagawa, 1999; Enstam and Isbell 2002; Enstam, 2007). The highly preferred habitats of patas monkeys are low in habitat productivity, highly seasonal and prone to extremely poor productivity during the dry season.

It is known that gallery forest and open woodland or savanna habitats have differences in vegetation composition and structure. Differences in the floristic composition and species richness of these two habitat types could likely influence food supply of the habitats (Chapman, 1985; Chapman *et al*., 1999). Chapman *et al*. (1999) stated that if one habitat had higher tree species richness than another habitat, the primates in the richer habitat would likely have more foraging options. In this condition, primates would less likely experience periods of food scarcity than the animals at the more degraded habitat, as there would be more types of alternative resources to depend on. Thus, relative to patas, primates such as tantalus monkeys and baboons in a forest with higher food-species richness would likely have more food options and be less likely to experience periods of food scarcity than patas monkeys at a more seasonal savanna

habitat. Alternatively, differences in dietary diversity may also be explained by seasonal variations in plant productivity of these primates' habitat.

Selectivity of high quality food can also be a possible explanation for primates to possess either wide or narrow dietary breadth. But, the high degree of dietary species overlap between tantalus monkeys and patas monkeys in Cameroon revealed that diet breadth differences between the two monkeys cannot be explained by food selectivity (Nakagawa, 2003). Lack of difference in the available energy of plant foods between patas and tantalus monkeys and high dietary diversity of tantalus relative to patas (Nakagawa, 2003) also strengthened effects of habitat type on their dietary diversity.

6.1.2. Comparison in Diet composition of Patas in Alatish with East African and West African Patas

The diets of patas monkeys include food items from different plant parts and species (Tables 1 and 2). Within their annual diet, 98.7% of food sources were plant species. The top three food sources were obtained from woody plant species *Acacia seyal* (27.99%), herbaceous plant *Ipomia aquatica* (17.92%) and underground plant parts (tubers/corms) (14.78%) in their rank of contribution to the patas annual diet. Annual food items of patas in Alatish revealed herbaceous plants constituted the highest proportion (54.72%) of patas diet than woody plants (44.03%).

In terms of food types, gum (39%), fruits and flower buds (32.7%), and corm/ tuber (14.8%) were the three major food types that cover 86.5% of their food composition. The high proportions of herbaceous plant (fruits/flower bud and corm/tuber) foods in Alatish makes feeding behavior of this population distinct from patas studied at Laikipia in Kenya. In addition

to herb fruits, patas consumed fruits of *B. aegyptiaca* and *L. fruticosa* woody plants. Besides this high fruit diet, patas also supplement their food with crop seed (8.18%). Thus, when proportion of fruits and seeds are added, fruit and seed food items accounted for 41.51% of their annual diet. However, the highest contribution of herbaceous plants in the diet of Laikipia patas was *Commelina* spp. (fruit/seed), which was 3.3% and total non-Acacia plant flower, fruit and seeds, accounted for not more than 5% of their diet (Isbell, 1998). According to Isbell (1998), the diet of patas monkeys in Laikipia consisted primarily of gum of *A. drepanolobium,* arthropods (both free-living and concentrated in the swollen thorns of *A. drepanolobium*), and other animals. In Laikipia gum and swollen food items contributed for 37% and 36% of the diet of patas (Isbell, 1998). Based on the observations of ants and other animals inside the swollen thorn, Isbell (1998) and Isbell et al. (2013) suggested that patas ingested more animals in their diet. High proportion of fruit diet in Alatish and Kala Maloue compared to Laikipia supports the biogeograhic variation of diet reported in *C. mitis* (Coleman and Hill, 2014). Similar to *C. mitis,* biogeographic dietary pattern, proportion of fruit in diet of Patas increased in areas where seasonality in climate increased. In rainfall distribution, Laikipia is less seasonal compared to Alatish and Kala Maloue. Thus, variation in fruit diet proportion among these patas sites may reflect the availability of animal matter in the environment.

Patas in Alatish share food plants and plant parts with the West African patas in Cameroon, Kala Maloue (Nakagawa, 1989, 2003). Based on the food lists of patas monkeys in Kala Maloue (Nakagawa, 1989, 2000b, 2003) and Lakipia Kenya (Isbell,1998), the diet of patas monkey in Alatish more resemble the West African patas than patas in Kenya. These two populations share food plant sources like Ipomoea, commelina, *Acacia seyal*, *Balanitus*

aegyptica, sorghum, cucurbitacea and Ziziphus. High proportion of fruit, flower and non-Acacia seeds strengthen the similarity in their feeding behavior (Nakagawa, 1989, 2003). Even though gum as a food accounted for a larger proportion of diet in Alatish and Lakipia than Kala Maloue, the gum diet of patas in Alatish was foraged from *A. seyal, A. polycantha* and *C. hartmannianum,* whereas Laikipia patas foraged gum from*A. drepanolobium.* As pointed out in Isbell (1998), *A. drepanolobium* occurs in Laikipia as a virtual monoculture that covers over 98% of all woody species in the area. The similarity of plant diets between patas in Alatish and Kala Maloue as well as their differences with Laikipia were suggested to be due to their available foods in the habitat. As described in introduction part of this thesis, vegetation and climate of Alatish are closer to that of Kala Maloue than Laikipia. Thus, their feeding ecology determines their similarity in feeding of plant food items or species.

However, insect and other animal matter diet of patas monkeys in Kala Maloue (Nakagawa, 1989 and 2003) and Laikipia (Isbell, 1998 and 2013) were higher, whereas the animal matter diet of patas in Alatish was very low in terms of the proportion of feeding time and species composition. In their animal diet component, patas in Alatish differ from the east and West African patas. Thus, differences in dietary components and dietary breadth among these biogeographic populations reflect the availability of different food types across their geographic distribution. This study confirms observations of variations in the foraging behavior and dietary composition of patas monkeys across their geographic ranges.

6.1.3. Seasonality in the Feeding Behavior

Seasonal change has significant effect on feeding behavior of patas in the consumption of different food items during different seasons (Table 2). In their wet season diet, composition of gum, fruit and crop seeds were the first, second and third highly utilized food types, respectively. When the proportion of fruits/flower buds and seeds were added together, the dietary contribution was 50.2% of the patas total feeding time and this is greater than the proportion of gum food item (44.8%). The fruit food items were foraged in wild plants such as *Ipomia aquatica, Cucumis ficifolius, Balanites aegyptiaca, Lannea fruticosa,* and *Zizipus* sp. These fruit food items were supplemented by crop raiding on *Gossypium* sp. (cotton) flower buds and *Sorghum* sp seeds. Patas also fed gum food in *A. seyal, Combretum hartmannianum* and *A.polycantha* plant species. These fruit and gum food providing plant species are listed in their top-down diet contribution.

Patas monkeys were feeding moreplant reproductive parts of plants (fruit, flower bud and seed), during the wet season, which these food items were absent in their dry season diet. In addition to switching off from fruit, flower bud and seed diets during the time of food scarce dry season, time spent feeding on gum was also reduced. Out of the total gum feeding record, 92.8% was observed during the wet season, but in the dry season, gum feeding was limited to 7.3% only. Significant reduction of gum feeding in response to high temperature (De la Fuente *et al*., 2014) supports seasonal gum feeding of patas in the present study. In case of gum food, seasonal changes were both in its amount of total food contribution and species composition. Among the three gum providing plant species in the wet season, *A. polycantha* was not included as a source of gum in patas diet during the dry season. Dry season switching of plant reproductive part food

items and reduction of gum feeding were complemented by high proportion of ground corms or tuber. Ground corms accounted for 79.7% of patas monkeys' dry season food items.

Observation of high corm food item consumption in Alatish patas supports the view that feeding behavior of a taxon may differ in different biogeographic areas (Hemingway and Bynum, 2005; Coleman and Hill, 2014). Hemingway and Bynum (2005) noted that primates inhabiting the margins of their ranges particularly in latitudinal or elevational extremes consume ''unusual'' food items. Underground corm feeding is not commonly reported in the feeding behavior of patas, but patas in Alatish, their north east extreme biogeographic range, use corm as critical food resource for their survival during food scarce season.

Thus, the highly seasonal feeding behavior and observation of significant proportion of corm foods make patas in Alatish distinct from patas in East and West Africa. In Kenya Laikipia, patas monkeys did not show seasonality in their feeding behavior. According to Isbell (1998) and Isbell and Young (2007) ants and gum provide patas monkeys a consistent supply of food throughout the year. As a result of these abundant and reliable resources, patas monkeys did not show major seasonal fluctuations in their feeding behavior (. Rather, high seasonal feeding behavior and dry season corm feeding of patas in Alatish made them share behavioral features with savanna baboons. Different feeding behavior studies show that baboons are highly seasonal in their feeding behavior and they usually depend on subterranean items like corms during the food scarce dry season (Post 1982; Hill and Dunbar, 2002; Alberts *et al*., 2005).

The overall dietary switching analysis shows that the dietary overlap between wet season and dry season was only 15.5%. This means seasonal change generates a change of 84.5 % of in patas food composition. Seasonal variation or switching of food items and types is a behavioral response in relation to the resource availability relative to searching time and the amount of food available, which in turn is available to the energy expense and gained daily in the foraging activities. As described in the climate and phenology of this study, Alatish is an extremely seasonal environment with short plant flushing and fruiting peaks interval. So, food resources are seasonally synchronized in their availability. In the wet season, the availability of different herbaceous and woody plant food items (fruits, flowers, buds, seeds and gums) were higher than availability of potential food items in the dry season. During the dry season, all herbaceous plants were desiccated and cease to provide food source. Even woody plants were limited in their productivity. None of the riverine woody plants shed their leaves and only their stems remain dormant until the next rainy season. Besides desiccation, the above ground herbaceous plants were removed by fire. But, the bare land created more opportunity for ground foraging patas to feed on exposed subterranean foods like roots, tubers and corms. Thus, corms of different forms were the only alternative food resources, which contributed to the highest proportion of the patas monkeys' diet during the peak resource scarce dry season. The reduction in dietary breadth of patas during the dry season is also attributed to lower food species availability in the habitat.

Hemingway and Bynum (2005) have made it clear that resource availability and preference determine dietary switching in primates. In this theoretical framework, the resources that primates switch to should be available while preferred resources are abandoned. These authors also pointed that overall diet variability or switching decreases as dietary breadth increases. This implies that incorporating many species into the diet on a regular basis appears to mitigate

dramatic and frequent changes among food types. The pattern of dietary switching and dietary breadth of patas monkeys in this study support such view. High seasonal dietary switching and narrow dietary breadth in patas are consistent with expectations in their highly seasonal environments with limited food species and synchronized plant phenology. Patas monkeys have no option to increase their diet breadth during the dry season. The diet-breadth model predicts that if a highly valuable item becomes too scarce to be exploited profitably and alternative items are available with much lower ratios of net energy value to acquisition time, then dietary diversity is expected to increase when higher-ranked foods are scarce (Hemingway and Bynum, 2005). Some highly fruit specialized primates such as Chimpanzees (Wrangham *et al.,* 1998) and Gibbons (Kim *et al*., 2012) consume only preferred high quality fruit foods in the fruit abundant season. This leads them to have low dietary breadth in the fruit available season, whereas during periods of food scarcity these primates consumed different food types to obtain sufficient nutrients. In this case, these primates increase their dietary breadth as behavioral response to food scarcity. Nevertheless, selectivity of food items does not seem to have significant effect on Patas feeding behavior.

Actually different nutritional studies of primates (Altmann *et al*., 1987; Nakagawa, 2000 and 2003; Johnson *et al*., 2012; Isbell *et al*., 2013; Irwin *et al*., 2014), show that average water and macronutrient contents of foods varied considerably among food types. Within the food types included in patas diet, flowers or flower buds are rich in water and carbohydrates (Altmann *et al*., 1987); fruits of *Cucumis* contain nonstructural carbohydrate and protein, which provide more energy (Johnson *et al*., 2012). In reproductive plant part foods, patas get a significant amount of non-structural carbohydrate, moderate protein and small amount of fat contents. Nakagawa

(1999) found that *A. seyal* gum contains protein nearly equal to that of *Ipomia* seeds and higher than that of *Zizipus* fruit.

The other patas food, gums are complex carbohydrates and primarily a source of energy and minerals (Power, 2010) . For example, nutrition analysis of *A. drepanolobium* gum shows digestible fiber (71–76% of dry weight) and total nonstructural carbohydrate (TNC) (15–19%), which are the two major nutrient component of the gum (Isbell *et al*., 2013). *Acacia depanolobium* gum is considered as a good source of gross and metabolizable energy and mineral of the diet of patas in Kenya (Isbell, 1998; Isbell *et al*., 2013). Nevertheless, compared to *A. drepanolobium* gum, *A. seyal* gum, which is major food of patas in Alatish has some better nutrient content such as ash content and hydrolyzed sugar contents (Methylglucuronic acid and rhamnose) as well as equal galactose contents (Anderson, 1978). *Acacia seyal* and *A. polycantha* gums are also important sources of minerals (Na, Ca, K, Mg, Fe, Zn) (Mhinzi, 2003; Ali *et al*., 2012). Mhinzi (2003) showed that *A. seyal* gum meets the maximum limit of total ash content required for a food standard. In addition, *A. seyal* and *A. polycantha* gums contain flavonoid substances (Seigler, 2003). Nash and Whiten (1989) suggested that flavonoid substances have nutritional or hormone like function. As Nash and Whiten (1989) reviewed, flavonoids are given the status of vitamins and found to be indispensable growth factors in some species of insects and promoters of growth in mammals. Despite all these nutritional substances, like other Acacia species, the bark of *A. seyal* (13.3%) and *A. polyacantha* (9.3%) contain relatively high tannin substance (Seigler, 2003). Mhinzi (2003) indicates that tannin content of *A. seyal* and *A. polyacantha* gums are higher than *A. Senegal*. Moreover, gums of these Acacia species have

lower moisture content than fruits and flower/buds (Altmann *et al*., 1987). Moisture content of *A. seyal* and *A. polyacantha* were 10.4% and 9.4-11.6%, respectively (Seigler, 2003).

The moisture content of gums varies with age and climate. In the dry season field study, it was observed that old gum was harder and drier. As the function of gum to plants is sealing wound sites, gum usually hardens fairly rapidly. As more time elapses after the gums are produced on the tree, the tannin content of gums is also supposed to increase (Mihinzi, 2003). Thus, age of gums are assumed to induce different digestive challenges and in turn affect foraging selectivity. During the dry season, low moisture content of gum diets may pose problems of water balance for patas monkeys. In the patas' habitat, natural water sources are normally rare during the dry season. They usually get water access in cattle water holes after cattle drink and cattle herders have left the site. In the water stress season, water absorption by the non-digestible portion of the gum could cause dehydration. Thus, dehydrating effect resulted from low moisture contents and tannin of gums may be the reason for reduction of gum consumption during the dry season. Alternatively, seasonal reduction of gum consumption may be explained by the indirect effect of season on gum production. Patas monkeys do not have morphological adaptation to stimulate gum production and they may depend on gum produced by insect damage. Thus, the effect of season on the activity of insects may indirectly affect the consumption of gum in patas diet.

Underground storage organ (tubers) food items eaten during periods of food scarcity are also high in their protein content (Altmann *et al*., 1987). Post (1982) suggested that the amount of stored materials and the nutritive value of corms increase during the dry season. Most of the subterranean items are tubers and sheath covered dried corms. Their storage organ sizes are larger than grass corms, but they are not available like grass corms. Thus, except their scarce

availability, their nutritional content helps patas monkeys as critical resource to survive on overall resource limited dry season.

6.1.4. Annual Variation in Diet Composition

In addition to variation in the seasonal diet composition, patas also show variation in the proportion of food types between the same wet seasons of two consecutive years. Especially, gum contributed more in the 2011 wet season than in the 2012 wet season. By contrast, the proportion of fruits was the reverse of gum consumption. More fruit feeding time was recorded in the 2012 wet season than in the 2011 wet season. This diet contribution tradeoff between gum and fruit is explained by rainfall variations between the two consecutive years and associated abundance of the aquatic plant, *Ipomia aquatica*. As stated in the diet composition of patas in this study area, *I. aquatica* fruit is the the second most important food plant species. In 2012, the amount of rainfall was greater than in 2011 and water covered flood plains before grass grew in 2012. As a result, large flood plains were covered with *I. aquatica* in 2012. In 2011 as water contents of flood plains were low, flood plains were covered with tall grass, and *I. aquatica* were limited in availability in the home range of patas monkeys.

The proportion of feeding time spent on fruits is a positive function of rainfall, a fact that probably reflects the way in which herb cover responds to rainfall. As herb cover is a positive function of rainfall, the increased proportion of fruits and seeds in the diet must be due to the increased availability of these food items as herb cover increases. The positive relationship between the proportions of feeding time spent on fruit and the phenology of food plant species further suggests that fruits and seeds are being selected preferentially when they become

available. The proportion of herbaceous ground covers which contain a significant proportion of fruits and seeds declines in the low-productive months. Thus, both seasonal and annual variation in the diet composition suggest that the influence of climate on feeding behavior of patas can be explained by considering responses of plant food species to the phonological changes in the habitat.

6.2. Activity Time Budget

The findings confirm that season has effect on behavior of patas monkeys and patas are able to adjust their behavior such as activity patterns, feeding behavior and ranging pattern to cope with high temperature, food and water scarcity during the dry season. Patas monkeys are highly flexible in their activity patterns and capable of adaptively responding to seasonal habitat variations. The nature of seasonal variability in environmental factors like food availability, ambient temperature, ectoparasite, and predation risk are major factors for the observed seasonal variability in the proportion of time spent in different activity categories.

6.2.1. Feeding and Moving

Patas monkeys show seasonal variation in the proportion of moving time in response to seasonal change in food availability and distribution, but this seasonal change did not show significant effect on feeding time. The proportion of moving time increased during food scarce dry season compared to the wet season; however, the time spent feeding did not show significant change between seasons. Previous studies on primates also demonstrated that differences in resource distribution or abundance can influence time spent in moving (Isbell and Young, 1993; Doran, 1997; Isbell *et al.*, 1998b). Isbell *et al.* (1998b) showed that patas monkey feeding on

smaller food patch size with short food site depletion time have greater moves per unit time than vervet monkeys feeding on dense and large food patch size with long food site depletion time.

In the dry season of this study, the overall food availability was scarce and during this period, there was a decrease in the diet breadth of patas monkeys. In food scarce dry season, most food sources of wet season were unavailable and about 79 % of their feeding time was spent feeding on corms. In contrast to baboons which increase the proportion of time spent feeding on corms, patas did not show significant change in their feeding time between wet and dry seasons. The increase in baboons' feeding time during a period of lower food availability has been explained as the increased time required to harvest a given volume of food when underground corms constitute a high proportion of their diet (Post, 1981). Isbell and Young (1993) also supported the trend of increasing in feeding time when primates depend on food items that need greater handling time. But, in patas this was not observed perhaps the habitat they forage corms is of vertisoil which is self ploughed and most corms were found exposed for easy picking while foraging.

However, scanty distribution of food items like corms during the dry season affected moving time. In the wet season, fruits like *I. aquatica* were available in large patches with high density. Even within a tree, patas can spent a long feeding time in many gum feeding sites. Unlike available clumped fruits and gums that contributed as major food during the late wet season, in the dry season corms were scarce and scattered in their distribution throughout the habitat. As the nature of distribution and availability of food resources determine the distance patas have to move between feeding sites, proportion of time spent moving is a consequence of the need to

change between feeding sites. While feeding on large patch size and clumped foods during the late wet season, patas spent long feeding bouts in a single feeding site and was not forced to move frequently between feeding sites. Nevertheless, in the dry season, due to scattered distribution and limited availability of corms, searching for corms and distances between feeding sites need more moving time. Thus, the proportion of time spent moving was high during the dry season with the need of relatively high food searching time. This agrees with the prediction that assumes animals allocate more time to foraging when resources are scarse until they meet their daily energy requirement (Robinson, 1986; Defler, 1995; Isbell *et al.*, 1998). The finding of this study again agrees with those of the earlier studies that have showed increase in moving time during the resource scarce dry season (Isbell *et al.*, 1998b). A reduction in the ground cover may also contribute for the increases in moving time.

In contrast to the above assumption, another prediction assumes because traveling is an energetically costly activity, the reduction of time spent in moving is expected as an energy saving strategy to cope up with the resource limitations in food scarce condition (Doran, 1997; Chaves *et al.*, 2011). Particularly during the dry season, when foraging is constrained by limited availability of food resources, the energetic costs of moving for foraging are expected to outweigh the benefits of food eaten. Nevertheless, as demonstrated by Mahoney (1980), the travel cost of patas is lower than for mammals of similar weight. Thus, the metabolic adaptation of patas that enable them to conserve energy imply that in patas the energy demands of moving for foraging might not constrain the proportion of moving time.

During the effect of thermal stress, patas were expected to minimize their movement time during hot dry season (Mahoney, 1980; Korstjens *et al.*, 2010). Moving is assumed to exacerbate heat stress in the hot season. Earlier studies (Stelzner, 1988; Hill, 2006; Campos and Fedigan, 2009; Korstjens *et al.*, 2010) had shown that at higher temperature, the proportion of time spent traveling decreased. Actually patas minimize their activity, particularly movement, in the hottest time of the day. In contrast to this daily activity pattern and earlier studies, patas spent more time moving during the hot dry season than during the wet season in their seasonal activity pattern. This implies that the effect of temperature on seasonal variability in moving time is primarily an indirect impact that arises from the effect of weather on food availability rather than a direct effect of temperature on travel activity (Bronikowski and Altmann, 1996). During the hot dry season, understory or herbaceous cover of the habitat is observed to be low in density or bare and all herb food items were completely absent. In a semiarid tropical habitat like Alatish, non-woody vegetation often dies during the dry season due to a combination of lack of water and high radiation loads. Even the woody plants faced water and heat stress and shed their leaves. The relationship between seasonal temperature and herbaceous plant food resources can be interpreted as the drier season, with less or no herbaceous food resources is available. Thus, effect of temperature on seasonal moving time reported in this study might be due to its indirect effect that dessicated food resources and scarcity of food resources caused patas to move more time in search of food during the hottest months compared to resource rich heat stress free wet season months.

6.2.2. Resting

Seasonal changes affected resting time and the patterns of change in activity time show that time spent resting was greater during the dry season than during the wet season. In contrast to the

assumption of resting time in activity time budget (Dunbar, 1988; Dunbar, 1992; Alberts *et al*., 2005), seasonal variation in resting time is not determined by the need of feeding time. The study found higher temperature during the dry season contributed to the observed high resting time because monkeys extend their midday resting time to reduce heat load avoiding solar radiation. In Alatish the mean monthly maximum temperature was generally higher in the dry season months than in the wet season. According to Ivlev *et al*. (2011), the average air temperature of Alatish during late dry season (March and April) was 35°C with a peak of 47°C at daytime in the shade. The temperature also exceeded 38°C for more than 9 hours a day. The thermoneutral zone of patas ranges from 18 °C up to about 40°C and at ambient temperature above 38-40°C patas face additional heat stress from the environment in addition to that generated metabolically (Mahoney, 1980). This shows that patas in Alatish experienced thermal stress at the highest temperature of 47°C. This necessitates for for complete inactivity when shade temperatures impose significant thermal constraints. Thus, extending of resting time during the dry season is a behavioral adaptation to cope with the dry season thermal stress.

In primates like patas monkeys that inhabit open habitats, solar radiation intensity and high ambient temperature contribute to heat load. As a result, high thermal stress is expected during the hot dry season. However, substantial vegetation covers in forests likely to reduce the impact of solar radiation. During the dry season in the hottest hours of the day from 11:00 to 16:00h, patas spent time resting in the shade of *B. eagyptica* trees, mostly near riverine habitat with water holes to avoid heat stress. Long midday resting periods in patas are also reported in earlier studies (Hall, 1965; Nakagawa, 1989). Struhasker and Gartlan (1970) also noted that patas spent long periods of time near water holes (Struhasker and Gartlan, 1970). The findings of different

studies support that the time spent resting is more determined by the high temperature (Stelzner, 1988; Bronikowski and Altmann, 1996; Hill, 2006; Campos and Fedigan, 2009; Dunbar *et al.*, 2009; Korstjens *et al.*, 2010; Chaves *et al.*, 2011; De la Fuente *et al.*, 2014). All these studies pointed out that when ambient temperatures rise significantly above the species' thermoneutral zone, an animal may be forced to take shelter or at least reduce heat-generating activities like feeding and travelling, and even social interaction in order to avoid thermal overload. These revealed that primates adjust their behavior in response to high temperature like prolonging their resting time and reducing other activities that aggravate heat stress.

There are evidences that patas can adapt to heat stress through physiological responses (Mahoney, 1980; Gisolfi *et al.*, 1982; Kolka and Elizondo, 1983). In patas monkeys, the overall heat load above their body temperature can be lost by evaporation, particularly sweating (Mahoney, 1980; Gisolfi *et al.*, 1982; Kolka and Elizondo, 1983). Sweating rate or total evaporative water loss of patas is closer to the sweating rate of humans. This evaporative heat loss in the tissues of patas could provide additional cooling effect during the hottest time of the day. However, lower relative humidity and high temperature of Alatish during the dry season might lead patas to lose more water. In Alatish, water is also scarce in the dry season and this can cause patas to face another water stress challenge. Different observational studies of patas confirm that water is scarce in their habitat, and seeking shelter and resting are the most effective behavioral solution among adaptations that enable patas to avoid high heat load (Hall, 1965; (Nakagawa, 1989); Isbell *et al.*, 2013). Thus, a long resting time during the dry season is enforced behavioral response to avoid overheat load and conserve evaporative water lose. This implies resting time during the dry season is not a free time to be allocated to other more useful

activities. Resting time in patas is biologically important by itself. This suggests that patas monkey relied on behavioral adjustments and scheduling of their activity pattern to maintain body temperature in dry and hot environment.

The effect of food availability on resting time might be explained by the indirect effect of temperature on vegetation cover, which influences food availability. As shown in the feeding behavior of this study, seasonal climatic change negatively affects food availability of patas. During hottest and dry season, patas faced food scarcity. In a food scarce condition, patas may not be able to sacrifice energy requirements for non-sedentary activities. Thus, the effect of food availability on resting time can be a metabolic response to save energy by minimizing ecologically less important activities in the dry season. The negative correlation between resting and social activities (grooming, playing) as well as feeding also support resting as an energy conservation mechanism.

The activity time budget tradeoff between resting and vigilance implies that reduction in the time spent for vigilance also contributed for increasing in resting time in the dry season. Resting can be primarily taken in low predation risk habitat conditions. As described in vigilance risk of predation, it is low during the dry season when resting time is high. Removal of ground vegetation cover by fire in most parts of their home range, and low probability of predator encounter during the dry season supports the assumption of low predation risk in the dry season. The findings of this study revealed that resting time is subjected to environmental constraints, and it is time that can be drawn from other biologically less essential activity time in the season.

6.2.3. Social behavior

Like other activities discussed, social behavior is not a random activity. Activity time spent in social behavior shows significant seasonal difference. Social behavior activity time was high during the wet season, whereas it was highly reduced in the dry season. As the analysis revealed, social time is strongly affected by seasonal changes compared to other activities. Corresponding to wet *versus* dry season change, social time was reduced by 11%. This significant seasonal change in social time is influenced by ecological factors mainly food availability and ectoparasite/tick infestation.

Among strategies that establish, maintain and reinforce social interaction between group members, allogrooming is the major behavioral activity. Reduction in social time of patas monkeys during the dry season happened because the rate of allo-grooming was highly minimized and playing was not observed among group members. In the wet season, ground cover was high. This dense ground cover and wet environmental conditions favor the outbreak of tick load in the habitat. As a result, patas faced high ectoparasite/tick infestation in this season. Exchanging of altruistic allo-grooming behavior reciprocated benefits immediately or at a later time. Thus, in response to high tick load, patas used to allo-groom to avoid cost of blood loss and associated disease caused by tick ectoparasite. Nevertheless, during the dry season, in addition to natural seasonal desiccation effect, fire burn removed tick loads in the habitat and patas were free from ectoparasite infestation. In relation to this seasonal change in tick load, time demand in social activity was reduced in the dry season. This finding corroborates earlier field and experimental studies that demonstrate the relationships between grooming behavior and tick load

(Sánchez-Villagra *et al.*, 1998; Madden and Clutton-Brock, 2009; Akinyi *et al.*, 2013; Godinho *et al.*, 2013).

An experimental study conducted to test the effect of ectoparasite load on grooming demonstrated that a reduction in ectoparasite loads generated a substantial reduction in grooming rate (Madden and Clutton-Brock, 2009). Comparative field studies also show that primate groups with high ectoparasite load have higher grooming rates than groups in less ectoparasite infested habitats (Sánchez-Villagra *et al.*, 1998). This study on patas also strengthened the previous experimental and field study findings. The relation between activity time patterns of allo-grooming and auto-grooming of this study also support the effect of ectoparasite on all-grooming rate. Both allo-grooming and auto-grooming were higher during the wet season when ectoparasite load was high. These two forms of grooming, however, decreased when ectoparasite/tick infestation was less during the dry season. Moreover, contrary to the social glue prediction, this finding revealed overall aggression did not increase following reduction in allo-grooming.

In addition to ectoparasite load, social activity time of this study was affected by seasonal changes in food availability. Food availability was high in the wet season, but during the dry season overall food availability and the diet breadth was reduced. Parallel to this environmental factor change, social activity time was also reduced during dry season. This agrees with the previous finding that show reduction of social time in poor habitat quality or scarce food availability (Chapman, 1985; Isbell and Young, 1993). The findings suggest that primates living in food riche habitats might have more time to groom because they were able to obtain food more quickly than individuals in groups living in poorer quality habitats.

6.2.4. Vigilance

In the activity time budget, it is observed that vigilance behavior is highly seasonal. The time spent in vigilance was higher in the wet season, while it was less during the dry season. The analysis has revealed that this seasonal change in vigilance behavior is a result of interaction effect of seasonal vegetation cover and predator encounter. Previous studies on vigilance also demonstrated that rate of vigilance is influenced by vegetation cover, predation risk, and social monitoring (intragroup and intergroup interaction) (Alberts, 1994; Cowlishaw, 1998; Hirsch, 2002; Jaffe and Isbell, 2009; Macintosh and Sicotte, 2009). During the wet season, when vigilance time was high, both vegetation cover and predator encounter rate were high. In this season, most parts of the patas habitat except some flood plains were covered with dense tall grass of about 1.5 to 2 m height and trees with their full canopy cover. Even the flood plain short herbs less than 1m height can hide reptile predators during the wet season. However, in the dry season, almost in all parts of their home range, tall grass covers were removed by fire besides seasonal effects on desiccation and falling of grasses, herbs and tree canopy covers. This shows habitats of patas monkeys differ seasonally in their nature of vegetation cover, including tree canopy cover and tall grass ground cover.

Seasonal changes in vegetation, mainly grass covers in the home range of patas monkeys, influence their behavioral activity patterns, particularly vigilance. Predation risk estimation in relation to the seasonal vegetation cover of patas home range demonstrated that in high vegetation cover, the risk of predation was high. As Enstam (2007) noted that predation risk is the probability of an individual or group encountering a predator, the analysis shows tall grass vegetation covers might provide refuge for mammalian predators. Observations of both

mammalian and reptile predators were high in the wet season when vegetation cover was tall and dense. During the wet season, the study found tracks and dung of lion, and direct encounters of serval and more reptile predators like python, black mamba and Egyptian cobra. These mammalian predators such as lion, serval, and hyena (Enstam and Isbell, 2002), and reptile predators like black mamba and viper (Foerster, 2008) have been reported as predator of guenons. But, predator encounter was rare in the open vegetation cover of the dry season. Lion and python were not observed during dry season. This shows that vegetation cover provide opportunity for predators to ambush and hunt prey including patas in the dense vegetation cover.

In addition to providing shelter for predators, dense and tall grass covers have obstructive effect on patas visual monitoring ability than protective function. Enstam and Isbell (2002) indicated that when patas encounter predators, they usually follow an escape strategy (like scanning and running) instead of concealing themselves in the ground vegetation cover. Vigilance behavior is a strategy that provides an active awareness of one's surroundings about predators or conspecific groups (Cowlishaw, 1998). According to Chapman (1985), the frequencies and duration of vigilance was positively correlated with the degree of anxiety of the animal. Thus, visual obstructive effects of dense and tall vegetation cover on patas' ability to sense dangers in its surroundings demands the animal to be more vigilant in the wet season. So, high vigilance rate in closed habitats might be explained by greater probability of predators to be concealed in the vegetation cover. Moreover, vegetation cover may also affect vigilance through its influence on visual communication within group members. In the case of visibility, obstructive effect of vegetation cover, frequent monitoring of group mates is expected to maintain cohesive group

members. Patas use visual information as a cue for controlling within social interactions (Jacobus and Loy, 1981).

In the dry season, except for scattered *Balanitus* trees, nonriverine trees shed their leaves/canopy cover and all above ground herbs were removed. Following removal of vegetation cover, visibility was much higher in the habitat during the dry season than during wet season. As a result of change in vegetation cover, patas monkeys can observe both predators and conspecific groups at farther distance in dry season. The less dense vegetation cover, rare predator encounter and better visibility in the dry season minimized the animals' perceived risk of predation and associated vigilance behavior. Patas, therefore, spent less time scanning bipedally in the dry season burned area or on the trees than in the wet season vegetation cover. This result supports earlier findings on the effects of reduced ground cover (Chapman, 1985; Jaffe and Isbell, 2009), and predation risk (Gaynor and Cords, 2012) on vigilance behavior. Chapman (1985) revealed a positive correlation between time spent in vigilance and density of vegetation in the green monkeys.

Basically, the effect of vegetation cover on primate predation risk or vigilance behavior is not always positive. Actually, the effect of vegetation cover on predation risk and antipredator behavior must be seen in two cases, which are in the ground cover and in the tall tree vegetation cover. Ground cover affects the visibility of both predators and prey. Prey species like small mammals that rely mainly on concealment to avoid being detected by predators often use ground vegetation covers as protective cover (Tchabovsky *et al.*, 2001). On the other hand, in arboreal primates that live in vegetation with tall trees and overlapped canopy cover, structures of the

habitat provide protection from terrestrial predation risk. Tall trees enable primates to increase their vertical distance from predators by climbing, or remaining in trees. Overlapping canopy covers also provide escaping routes and enable primates to move horizontally between trees without descending. Thus, in dense vegetation cover, and in habitats with tall trees, primates like vervet (Enstam and Isbell, 2002), colobus (Macintosh and Sicotte, 2009; Teichroeb and Sicotte, 2012), and chimpanzees (Kutsukake, 2006) feel low predation risk in the canopy; but when they descend to the ground they perceived high predation risk and increase their rate of vigilance. This study as in the case of earlier studies (Enstam and Isbell, 2002; Jaffe and Isbell, 2009) have confirmed patas monkeys prefer open habitats like nonriverine habitats than closed forest like riverine habitats with dense canopy cover. Thus, predation protection strategies observed in dense vegetation cover are not available to patas in the open habitat because trees with discontinuous canopy cover are ineffective at increasing horizontal distance from predators, especially those predators that can climb trees. Moreover, in contrast to solitary animals or small mammal group, patas are unable to hide from predators in the ground vegetation cover. Thus, the limitation in escaping ways due to lack of closed canopy cover and lack of ground cover to minimize predation risk might influence patas monkeys to be more vigilant during the wet season dense ground cover than the dry season bare ground cover as the survival strategy to increase their ability to detect predators before being detected by predators. This finding supports the notion that vigilance is the primary antipredator behavior of patas monkey (Enstam and Isbell, 2002; Enstam, 2007; Jaffe and Isbell, 2009). Increasing vigilance rate and escaping from predators as quickly as possible has been observed in patas monkeys inhabiting in open habitats.

Time spent in vigilance has been shown to be influenced by the social interaction of within group and between group members (Gaynor and Cords, 2012). In the conspecific vigilance model, it is found that vigilance is determined by social rank and low ranking individuals are more vigilant than high ranking individuals (Alberts, 1994). As the present study used instantaneous scan sampling on unidentified individuals, the effect of social interactions influence on the rate of vigilance, within group social interaction on vigilance behavior was not investigated here. However, intergroup encounter is not expected to affect rate of vigilance in patas. In the intergroup social monitoring of vigilance, it is predicted that the rate of vigilance increases in frequent intergroup encounters. In spite of the prediction made, rate of vigilance was low in more intergroup encounters during the dry season, particularly around water point, than in the wet season with low intergroup encounter. The lack of intergroup encounter effect on vigilance rate might be due to nonterritorial behavior of patas and less intergroup agonistic interactions. Most of the observed encounters between two groups of patas monkeys were not followed by agonistic interactions.

6.3. Ranging Behavior

Home range size of patas in this study seems to be smaller than what reported earlier. A maximum of 548 hectares was estimated as annual home range of the patas group. In Uganda, Hall (1965) reported 5200 hectares for a single group of patas. Laver and Kelly (2008) indicated that the home range estimation method has effect on the size of home range. The present study also resulted in different estimates of home range sizes in different home range estimation methods. Thus, due to the effect of the methods used and sample sizes, comparing home range size variation among studies is difficult. The result of the home range size of this study might not

be smaller than previous documents. Moreover, with regard to the effect of seasonal changes in the extent of home range, patas did not show statistically significant difference between wet season and dry seasons. Instead, patas followed shifting of home range sites in response to seasonal changes in the resource availability.

Similar to studies conducted on ranging behavior of other primates, ranging behavior of patas is basically determined by food resource availability and distribution (Chapman, 1988; Grueter *et al.*, 2008) as well as accessibility of drinking water (Scholz and Kappeler, 2004). Habitat heterogeneity including seasonality play important role in the ranging behavior as seasonality of resources affect patterns of feeding and ranging behavior. Seasonal changes cause variation in the availability of food and water resources across the home range of patas. In Alatish, strong seasonal variations have been observed in food and water availability. In the wet season, flood plains provide water and food resources, whereas these resources were dried due to high thermal effect during the dry season. Resources in the flood plains were unavailable during the dry season. As reported in feeding ecology of this study, different plant food resources were also limited in the dry season due to phenological changes.

In the wet season, within the home range of patas, preferred food and water resource were distributed patchily. In contrast, during the dry season, almost all parts of their home range are homogeneous in food availability, which was scarce in distribution. But, water was available only in the river bed of the Gelegu. In response to these dry season ecological changes, the patas monkeys shifted their ranging pattern following the location of water availability. The critical importance of water in the survival of patas monkeys is also reported by Isbell *et al.* (2013).

During the peak of the dry season, Hall (1965) and Struhsaker and Gartlan (1970) also reported that patas were using home range near water holes. Even though, frequent drinking was not reported in these two studies, preference of habitats near water points might reveal effect of water in their ranging behavior. However, in Alatish, perhaps due to high thermal effect during the dry season, patas were observed drinking daily in the peak dry season.

6.3.1. Home Range Utilization Pattern

The ranging pattern of patas is more even in the dry season than in the wet season. This ranging pattern is determined by the seasonal resource distribution in patas home range. The resource distributions were more heterogeneous in the wet season than in the dry season. As a result, during resource limited dry season, patas actively utilized all available local habitats within the home range. The small core area or frequently used area of the wet season home range compared to the dry season also showed that the resource distribution was more clumped in the wet season than in the dry season. In the wet season, patas spend more time near flood plain habitats that are temporarily richer in important fruit resources, and water sources. As a result of scattered food distribution pattern, the number of grid cells utilized was increased and grid utilization of patas monkeys were more evenly distributed across the home range in the dry season.

Overall range use of patas was not uniform. The group core area in the wet season was discontinuous, and usually closer to the flood plains. This discontinuous nature of the core cells is better explained by the dynamic nature of resource distribution across the home range. The study group shifts their home range preferences following flood plain food resource and water availability. As illustrated in Figure 10, range use was relatively more clumped in the wet season

than in the dry season. Particularly, in the late wet season to early dry season, patas track flood plains. Food resources like *I. aquatica* fruit, cotton flower buds and sorghum seeds were patchily available during the late wet season. As described in the feeding ecology of the present study, these food resources were the major food of patas next to gum. *Ipomia aquatica* was found in two large patches on the flood plains and cotton flower buds and sorghum seeds were also available patchily in cultivated lands around the Park buffer zone. However, these food resources were unavailable in the dry season due to seasonal changes. In addition, gum food resources available in tree patches were limited during the dry season. Thus, the alternative food resources in the dry season were root corms and tubers. The highly utilized grid cells in the dry season are frequently visited areas due to their proximity to the water point and perhaps burned areas preference for corm feeding strategy. During the dry season, patas prefer burned areas as this area helps them to forage corms, roots and tubers more easily than areas covered with dry tall grass. This dry season ranging pattern might reveal that water point or drinking site is the major determinant factor of patas ranging behavior than food distribution pattern.

6.3.2. Daily Journey Length

The result indicates that patas adjust their ranging length in response to seasonal changes. Daily ranging behavioral response to seasonal food resource availability depends on how much the travel time would need to increase to maintain the energy requirement of the animal (Isbell *et al.*, 1998b), how much foods differ in quality and spatial distribution (Chapman, 1988), and the general foraging strategy of the animal. As described in the activity time budget, this study found that patas increased travel time to meet their energy demands during food scarce dry season. In this energy maximizing strategy, patas are expected to increase their daily range length to meet their energy demands. But, if they were adapted to reduce energy expenditure in the resource

scarce dry season, patas would be expected to minimize their daily travel distance. Thus, long daily travel distance during the dry season might be due to the increase in travel time and energy maximizing foraging strategy of patas monkeys.

As stated above in range use pattern, patas monkeys visited more grid cells during the dry season than during the wet season. In the dry season, food patches were small in patch size, dispersed in distribution pattern and deplete in short time than in the wet season. Isbell *et al.* (1998b) showed that monkeys would be expected to travel long distance as food patches deplete. In relation to the increased number of grid cells visited, and more travel time among food patches, mean step length between grids will also be increased. Thus, patas monkeys were expected to travel long distance as the number of grid cells visited increased. In contrast, during the wet season, patas concentrated their activities around the flood plains for feeding and drinking. During this season, patas visited smaller number of grid cells and their travel distance was short. In addition, the distance of water point from the activity center in the home range determine daily range length (Scholz and Kappeler, 2004). In this regard, the activity center of patas in the wet season was closer . However, in the dry season, patas used water holes in the Gelegu river bed. As shown in the grid cell utilization distribution map, most grids were closer to the water source in the wet season, while in the dry season, the water hole was located at the periphery of the home range and patas were required to ytravel long distances between the water holes and the sleeping and/or feeding sites in the periphery.

6.4. Land Cover Changes and Conservation Threat

6.4.1. Conservation Threats on Landcover Changes

In the long time history of Alatish, fire has been recorded as the major threat of conserving flora and fauna. The survey conducted during the present study, in the northern part of the park from Bermil to Jabra, from Bermil to Amjale and from Amjale to Alga sites has revealed that habitats in the Park have been severely affected by fire. In the early dry season fire was most frequent along the Ethio-Sudan border. This probably reflects a high frequency of people travelling across the border. The Scouts during their patrol attested those fire events were anthropogenic effect of Fellata pastoralist nomads, who induced fire while they cross in to the Park.

In livestock herding, fire has been used as a tool to control ectoparasite load, reptiles and large carnivore attacks as well as to clear tall grass cover for improving the quality of forage.. The fresh offshoots that may regenerate around seasonal wetlands and riverine habitats after burning in the dry season and the whole areas in the beginning of the rainy season would provide palatable and nutrient-rich fodder for herbivores. These strategies seem to be used by the neighboring nomads from Sudan, who intrude in to the Park with their livestock. As most of the fire incidents were observed in the Sudan border of Alatish Park and the Park scouts usually caught the Sudanese nomads inside Alatish, Sudanese nomads are responsible to burn the area during the dry season months to remove tall dry grasses and access for seasonal wetlands to support their livestock. Although controlled fire has positive effects in managed areas, uncontrolled fire with a potential to spread fast in the presence of dry fuel and wind result in the annual deforestation in the Park.

Fire has been also recorded as a threat in most western lowland areas in Ethiopia (Jensen and Friis 2001; Minassie Gashaw *et al*., 2002a,b; IBC, 2005; Sebsebe Demissew *et al*., 2005). Even in Alatish Park, controlling the activities of Sudanese nomads in the Park and uncontrolled fires induced by them has not been effective for setting long lasting solution of the conservation problems. Actually, the Park Scouts patrol to locate illegal activities inside the Park. When the Scouts got nomads, they chased nomads out of the park without taking legal actions. During the field study, the scouts in the study site were taken for operation of chasing the Sudanese nomads. As these nomads were armed, the scouts faced challenges for educating them and to peacefully solve the problem of conserving the area. According to the information obtained from the Park Staff the Quara District officials or EWCA also did not sufficiently enforce the practicality of cooperation on wildlife conservation agreement between the two countries for taking effective steps in ensuring conservation of the area.

As Minassie Gashaw *et al*. (2002a, b) reported severe removal of perennial grasses, shrubs and non-fire resistant trees in addition to the damage of viable and dormant seeds manifested the adverse effects of fire in western Ethiopia. Similarly, the changes in landcover in this study have revealed, vegetation cover of Alatish has been severely affected by fire. The deciduous woodland and bamboo woodland, which were more than 50% of the coverage of the Park in 1999, were reduced to about 20% in 2013. Alatish National Park Management Plan (2009) also noted that woodland ecosystem of the Park covers vast area of the vegetation and estimated about 50 to 60 % of the Park.

In contrast to the landcover changing trend of deciduous woodland vegetation, this study found that wooded grassland and *Acacia* woodland are highly increased in their coverage. Annual fire burn seems to cause removal of 5231.4 hectare woodland and expanding the wooded grassland by 5689.98 he ctare pe r ye ar. The riverine w oodland a nd w etlands, how ever, di d not s how significant changes in the extent. These overall patterns of landcover changes might be related to the variation in fire in tensity a mong the landcovers, f ire resistance n ature o f p lant t ypes and effect of fire on plant regeneration capacity (Minassie Gashaw *et al*., 2002a, b).

In deciduous woodlands, woody plants are not much dense; rather understory herbaceous plants and grasses as well as grass ground coverage range 30%–60%. According to Minassie Gashaw *et al*. (2002a), fire is r elatively m ore in tense in s ites with l arge gr ass bi omass. Thus, l arge herbaceous a nd gr ass f uel l oad de nsity i n the deciduous w oodland m ight a llow i ntense f ire burning t o occur a nnually a nd remove or m inimize t ree c overage. S uch c onditions can cau se reduction of woodland and increase in wooded grassland coverage in the Park.

On the other hand, reduction in woodland and increasing of wooded grassland coverage might be explained by fire resistance capacity of trees. As Minassie Gashaw *et al*. (2002a) have suggested trees w ith t hick b arks a nd w ide d iameter might re sist stronger f ire b etter th an s mall trees a nd trees with thin bark. According to these authors, moisture content and flammability of tree barks also d etermine f ire re sistance a bility o f tre e s pecies. T rees with d ry, s tring, f ibrous a nd ro ugh bark are prone to fire. Most trees in the woodland coverage of Alatish are small to moderate in size w ith r ough a nd s tring ba rks s uch a s *Terminalia* spp., *Combretum* spp., *Pterocarpus* and *Lannea* (ANPMP, 200 9). When fire a ppears, these w oodland pl ant s pecies bur n i mmediately

(Minassie Gashaw *et al*., 2002a). However, *Acacia seyal* with smooth barks, and *B. aegypthicus* with thick bark and large stem diameter may resist fire and protect their cambium. Expansion of *Acacia* woodland might also be related to this fire resistance capacity of Acacia. In addition to fire resistance of trees, Minassie Gashaw *et al*. (2002b) noted that significant proportion of large seeds of woody species such as *Combretum* spp. and *Entada africana* probably do not enter the soil, but stay in the litter and are exposed to fire. Alternatively, reduction in woody plant coverage may result from the effect of fire that precedes seed dispersal and cause low surface soil seed pool of some broadleaved herbs and woody species (Minassie Gashaw *et al*., 2002b).

Unlike other ecosystems, the fire regime did not affect riverine woodland. This finding agrees with broadly defined Sudanian vegetation zone, where fire seems to affect nearly all vegetation types, except closed forest (Jensen and Friis 2001). Such fire effect is observed in western Ethiopia, from the border region with western Eritrea in the north to the Boma Plateau south west of the town of Maji in the south (Jensen and Friis 2001). Unaffected vegetation cover of the riverine woodland in Alatish might be related to fire resistance potential of trees due to their thick stem or large diameter and moist bark. Most riverine woodland is dominated by large sized trees like *Ficus sycomorus, Hyphaene thebaica, Acacia sieberiana, Stereospermum kunthianum,* and *Tamarindus indica*. In addition, within this woodland, understory grass and herb ground cover are weak and discontinuous. This poor grass and herb layer do not allow frequent and intense fire accident. The main ground layer grass cover includes *Bekeropsis uniseta, Eragrostis tremula* and *Sorghum sudanenis.* These grasses have capacity to regenerate immediately after fire due to residual moisture content of the soil. Thus, riverine woodland and wetland

ecosystems used as foraging area for wild animals and livestock during the dry season when green vegetation of other landcovers were rarely found.

Besides the major landcover changes between years, fire has also effect on seasonal landcover change. The non-woody vegetation cover of the woodland and wooded grassland ecosystem are often removed by fire and the clay and sandy soil remain bare in the long dry season. These two ecosystems are highly threatened by fire. Together with water shortage, removals of vegetation cover in the dry season make woodland and wooded grassland ecosystems unsuitable for wild animals.

6.4.2. Conservation Threats on Wildlife

The vegetation covers of protected areas are potential sites of wildlife shelter as well as ecosystem service in carbon sequestration. However, landcovers of the Alatish ecosystem experienced a dynamic phenomenon occurring within the interface between human activities and ecological restoration. Recurrent fire incidence caused by human activities altered Alatish like other western parts of Ethiopia. In western Ethiopia, uncontrolled fire threatened all forms of biodiversity including flora and fauna (Jensen and Friis 2001**;** Menassie Gashaw *et al*., 2002a, b; IBC, 2005; Sebsebe Demissew *et al*., 2005). The distribution of fires showed that western region of Ethiopia including Alatish was affected by fire in early 1990s (Jensen and Friis, 2001). Additional studies conducted latter (Heckel *et al*., 2007; Abraham Marye *et al*., 2008; Girma Mengesha and Afework Bekele, 2008; Tadesse Habtamu and Afework Bekele, 2008; Hailu Menale, 2011) have also noted the threat of fire in the Park. The present study also confirmed the existence fire as conservation threat in the area.

Frequent fire incidences affect all wildlife in western Ethiopia. Heckel *et al*. (2007) warn sustainability of wildlife in the northwestern region including Alatish. Due to the intensity of anthropogenic impact, major parts of the existing woodland and most of the wildlife in the Park will be lost in near future. In the view of habitat threat, the establishment of Alatish National Park in north-western Ethiopia was considered as great opportunity to conserve fauna and flora typical for the Sudan-Guinea biome.

Despite the opportunity of the Park in conserving wildlife, fire exacerbated removal of vegetation cover that serve both shelter and food sources for wild animals as well as maintaining moist conditions and moisture contents of the area. Especially in the dry season, fire has destroyed all understory vegetation coverage or herbaceous plants in wide areas of wildlife habitats and the ground remains bare in the long dry season except in the riverine woodland habitat. These devastating land-cover changes potentially affect biodiversity, climate change, and hydrology of natural ecosystem of the area. As a result of this, wildlife has been suffering to survive during dry season due to food and water scarcity as well as high temperature in the absence of shade (Plate 11). When the food supply was scarce, primates (anubis baboons and patas monkeys) were observed feeding on unusual foods like dried items that were not observed in the wet season or usual feeding behavior. Anubis was observed feeding dried stem pith of small woody shrub. Such unusual feeding was reported during drought years in southwestern Madagascar *Lemur catta,* which was feeding on dried leaves and desiccated seed pods (Gould *et al*. 1999).

Plate 13. Ecological stress in wildlife during the dry season. Left: Baboon eating dry stem in fire burned area. Right: Patas monkeys sheltered themselves from solar radiation and hot temperature at the base of *Balanitus* tree stem when most tree canopies were removed by fire and seasonal effect.

In some cases, fire may also directly affect insects, nests of birds, slow moving wild animals like reptiles and small mammals. Removal of vegetation covers may also affect smaller wild animals such as reptiles and rodents to be easily hunted by predator eagles (Plate 12). In the area, there are different eagle species like Lizard Buzzard, Long-crested Eagle, Dark Chanting-Goshawk, Grasshopper Buzzard, Gray Kestrel, Black-shouldered Kite, and Snake-eagle.

Studies also reported decline in diversity and abundance of rodents (Ivlev *et al*., 2011) or complete disappearance of large mammals (Heckel *et al*., 2007; Girma Mengesha and Afework Bekele, 2008) in northwestern region of Ethiopia. Despite Tadesse Habtatmu and Afework Bekele (2008) reported diverse rodent species, after few years Ivlev *et al*. (2011) reported that the species diversity of rodents was extremely poor. The ANPMP (2009) stated that there were

about 37 mammalian species in the area, but out of them eight have been observed at least before 15 years of the report. Disappearance of some large mammals might have been resulted due to environmental changes aggravated by fire besides natural seasonal stresses of resources in the region. Girma Mengesha and Afework Bekele (2008) noted that large mammals like Tora hartebeest and Roan antelopes were common in the region before 1980's drought period. According to Hailu Minale (2011), Fellatta and other tribes who settled inside and around the Sudan Dinder National Park during the drought period are responsible for ecological disturbances and wildlife threats in Alatish National Park of Ethiopia. During the dry season pastoralist nomads from Sudan migrated to Alatish on yearly basis and settle temporarily inside Alatish. Their activity inside the park including fire and forage competition of their livestock with wild animals highly threatened survival of wild animals and sustainability of the Park in general.

Plate 14. Lizard species threatened by predator; its neck and head are injured.

Livelihoods of the indigenous societies in the area are largely based on hunting and fishing (Abraham Marye *et al*., 2008). However, threats of hunting appear to be largely subsistence and have been minimized with increased management efforts through developing community education and participation.

CHAPTER 7 CONCLUSION AND RECOMMENDATION

This study conducted in Northwest Ethiopia is the first morphological and behavioral study in the northeast biogeographic range of the Patas monkey, *Erythrocebus patas.* Most studies of *E. p. pyrrhonotus* have been conducted in Kenya, Uganda and Cameroon. The current study in Ethiopia found some distinct morphological and behavioral features compared to the four subspecies described earlier. Morphologically, adult males do not have white spot on their nose, which is one character of *E. p. pyrrhonotus*. In addition, as reported in our preliminary study (Solomon Yirga *et al*., 2010) in Benishangul, which is southern adjoin of Alatish, the adult male fur is black on its shoulder to arm. This black fur is also observed on the adult male patas in Alatish. Adult female patas observed in Benishangul and Alatish have a distinctive white frontal band. Moreover, patas monkey in Alatish seem to be distinct in their feeding behavior. Their feeding behavior is highly seasonal with significant proportion of plant fruits in the late wet season dietand ground food sources such as corms and tubers food items during the dry season. In the previous studies corm was not reported as major food item in patas monkeys. Thus, based on morphological features and feeding behavior differences, the study suggest that patas monkey in West Ethiopia is distinct enough from *E. p. pyrrhonotus* to warrant as new and discrete subspecies.

The habitats of patas monkey in the western lowlands of Ethiopia are highly seasonal. The seasonal environmental changes influence food and water resource availability, predation risk and ectoparasite infestation in the area. Food and water were extremely scarce during the late day season. All water sources including rivers dried out in their flowing courses. In the wet season, the tall grass ground cover provides shelter for ground predators like serval, and cause thick

infestation. In the peak dry season, high temperature is also another ecological stress for the survival of patas in Alatish. Overall seasonality of the environment determines their behavior. Patas monkeys are adapted to this seasonality in the habitats by adjusting their behavior in feeding strategy, activity time budget and ranging patterns. In their feeding behavior, patas monkey respond to seasonal food resource availability changes by shifting their feeding to the available food resource. Dietary switching and widening alternative food sources are their major feeding behavioral responses to seasonal food resource availability. Patas widen their food option and take more nutrients when food resources are available. This might help them as energy reserve mechanism to survive during the food scarce dry season. Moreover, patas monkeys are flexible in their activity time budget tt o cope with seasonal environmental conditions. They seasonally change activity time budgets of different behavior according to their survival value to cope with the trend of ecological factors. Resting and moving activity were critical during the extreme high temperature and food scarce dry season. In the dry season, the needs for resting and moving activities were compromised by reduction in social time and vigilance. On the contrary, at time of high predation and ectoparasite risk in the wet season, patas spent significant proportion of time on grooming and vigilance.

Patas monkeys also respond to seasonal environmental changes in resource availability and distribution by seasonally shifting their ranging behavior. When food and resources were available and distributed in large patches like flood plains, patas concentrated their range utilization in small part of their home range or core area. In the wet season, due to clumped home range utilization, the daily range length and home range sizes were short and small, respectively. In contrast, during the dry season, both water and food resources were scarce. Most of the above

ground food resources were abandoned, and alternative food resources were dispersed and unpredictably distributed food sources in the ground. During this time, patas monkey utilize their home range evenly. As a result of this range utilization pattern, daily range lengths were long and their home range size was large compared to wet season. Patas monkeys do not prefer riverine habitat. During the wet season, patas never visited riverine habitat. They used flood plains as source of water and concentrated their feeding activity closer to it. However, in the dry season, when all flood plains were dried, patas monkeys left the flood plains. In this season, they used river courses as source of water, but other than drinking site, patas monkeys did not stay in the riverine habitats as feeding site.

During the dry season, except some rockyriver beds the river flow was completely dried. This implies that water shortage was a threat to the survival of patas in the semi-arid environment of Alatish. In addition to seasonal ecological stress, fire induced by illegal nomads and honey collectors caused habitat loss and degradation. This human interference intensifies the aridity of the habitat during dry season. Nomads also encroach on seasonal wetlands or flood plains and potential water points for their cattle grazing and water source. Patas faced competition with cattle for water access and food resources. Thus, extreme seasonality of the environment and human impact are the major conservation challenge for wildlife conservation including patas in Alatish National Park.

The overall vegetation covers also show changing in the reduction of woody vegetation cover and expansion of open habitat or wooded grassland. As reported in the earlier study, this study found that most of the conservation threats in the Park were caused by nomad intruders from

Sudan. The reported problem in habitat alteration at the time of establishment of Alatish as National park still exists.

Therefore, base on this study findings the following recommendations were made:

1. Morphological features of patas monkeys in Benishangul-Gumuz and Alatish National Park revealed that patas monkeys found in Ethiopia are distinct from *E. p. pyrrhonotus*. However, to conclude taxonomic status of all patas population found in Ethiopia is distinct, additional studies should be conducted in patas population found in Gambella and Southwest parts of Ethiopia.
2. Behavioral characterization of patas monkeys in this study is limited on one site, Alatish National Park. So, to widen our understanding about their behavior further study on different habitat should be conducted.
3. In this study, patas monkeys were described based on their morphology and Behavior. Thus, to develop complete description of their taxonomic status, molecular analysis should be carried out.
4. Even though the establishment of the Park is considered as conservation initiative, the study found that the habitats of Alatish National Park and wildlife dwelling in the Park are still threatened by human impacts. Thus, to control illegal human activities that severely affect biological resource potentials of the Park, continuous monitoring and boundary park collaboration with the Dinder National Park of Sudan are needed. Unless immediate handling measures on the fire and nomads' impact on the park can be taken, observations of this study and earlier studies revealed nature conservation potentials of the Park will be lost in un-reversible extent.

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