ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FEEDING ECOLOGY AND DIURNAL ACTIVITY PATTERN OF THE GREVY'S ZEBRA (*Equus grevyi*, Oustalet, 1882) IN SAMBURU COMMUNITY LANDS, KENYA

BY
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Thesis submitted to the School of Graduate Studies, Department of Biology, Science faculty of Addis Ababa University in the partial fulfillment for the requirements of Degree in Masters of Science, Dryland Biodiversity

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DEDICATION

This work is dedicated to my beloved mum Mrs. Munyiva Kivai, dad Mr. Kivai Mbindyo and my late grand mother Mrs. Ndendwa Munywoki. Their tender love and care has made me what I am and in them have learnt the essence of hard work. May the Almight God grant eternal peace and rest to the soul of my departed grandmother, and healthy and longer life to my beloved parents.

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ABSTRACT

The present study was carried out in Ngutuk Ongironi group ranch in Waso division and in Ngaroni and Barsilinga in Wamba division in Samburu district, Kenya during August to December 2005. The aims were to understand the diet, forage availability, sociality and diurnal activity pattern of Grevy's zebra at Samburu community grazing lands. Physical observation, step point method, clipping and weighing, focal animal sampling, scan sampling and direct count methods were employed to meet the study objectives. Inferential and descriptive statistics were applied in result analysis. Grevy's zebra foraged on 31 different plant species. *Indigofera spinosa* and *Indigofera circinella* were the most important food resources, which had seasonal mean frequency of occurrence of 92.5% and 62.0%, respectively, and contributed high percentages in the diet. Among the important species, *Sericocomopsis hildebrandtii* and *Cyperus rotundus* were the most preferred species during the dry and wet seasons with preference index of 6.8 and 4.0, respectively. Browsing was higher than grazing and green plant parts were preferred over both seasons. Barsilinga had the highest grass and herb diversity as well as the highest amount and best forage over the study period. August and December had the highest forage over the dry and wet seasons, respectively. Mean group size was highest in Barsilinga (5.03 ± 2.41) and Ngaroni (13. 66 ± 5.35) over the dry and wet seasons, respectively. Group composition was dominated by stallions in Ngutuk Ongironi and by mares in Ngaroni and Barsilinga during both dry and wet seasons, respectively. Territorial males dominated in Ngutuk Ongironi and mixed herds in Ngaroni and Barsilinga over the wet season while during the dry season the former dominated in Ngutuk Ongironi and Barsilinga while the latter in Ngaroni. Feeding, resting, walking and vigilance were the most important activities of the Grevy's zebra. Feeding was allocated more time than the rest of the activities during both seasons. Mares fed more than stallions and infants. The study concluded that Grevy's zebras are more of browsers than grazers and feed on diverse plant species. Feeding is the dominant activity, and mares feed more than stallions and infants. Group size, composition and types are highly influenced by spatial and temporal availability of forage. The study recommends provision of conservation education to the local people to enhance their coexistence with Grevy's zebras among others.

1.0 INTRODUCTION

1.1. Background and Problem Statement

Grevy's zebra *(Equus grevyi),* was distributed from Central Asia to South Africa once upon a time. However it is now confined to few areas of south and east Ethiopia and northern Kenya (Williams, 1998). In Ethiopia, the total number estimated in 1980 was 1,500 animals, but by 1995 only 500-600 individuals remained (Thouless, 1995). Most recent survey by Williams *et al.* (2003) indicated less than 150 individuals are remaining in Ethiopia. In Kenya, from 1977 to 1988, a tremendous down fall of about 69% was registered, from 13,718 to 4,276 individuals (Rowen and Ginsberg, 1993). Moreover, by 2000, the number had further declined to 2,571. Recent estimates are between 1,600 – 2,000 animals, thus suggesting a possible decline of up to 88% in Kenya over the past 27 years (Williams and Low, 2004). Consequently, the species is now placed under the IUCN Red data category and in Appendix 1 in CITES, implying it is endangered or threatened to extinction (IUCN, 2002; IUCN, 2006). Thus, there is a need for concerted conservation efforts to save the species from extinction.

The decline in the number of Grevy's zebra is continuing over the major areas of their range. The suggested explanations are habitat degradation, hunting, competition for critical resources from pastoral people and their livestock, tourism and drought (Muoria, 2004). Diseases could be another cause, especially anthrax which has caused a devastating effect on the population in the late 2005 and early 2006 (Low, 2006). Despite this fact, there is no formal conservation strategy for Grevy's zebra, either overall or within the range states of confirmed populations. Unfortunately, very little has been done to confirm the postulated causes, but instead attention has been biased towards population estimates and distribution. In addition, most researchers have concentrated on conservation areas yet these areas constitute 0.5% of the equid's range (Williams and Low, 2004). Only little is known on food as a key resource that could adversely dictate the reproduction, survivorship and distribution of Grevy's zebra in the wild, particularly in Samburu community grazing lands where currently a stable population of them remains (Nelson and Williams, 2003). Consequently, the current study was conducted to address this issue among others.

Research on forage availability has been carried out in Ngare Ndare and Buffalo springs, and similar work is in progress in Lewa Wildlife Conservancy (William, 1998; Rubeinstein, *et al*., 2004). Even though some work has been going on in Lewa Wildlife Conservancy, it is a private ranch with intensive management and a well protected area (IUCN, 2002). Despite the occurrence of Grevy's zebras in the conservancy, it does not reflect the true scenario of the community grazing lands and hence difficult to offer an effective model for conservation outside protected areas. In any case, it can offer a good area of investigation for comparative purposes of research done in other areas where Grevy's zebras occur.

Forage productivity and availability is tied with the range conditions, which is influenced by land fertility (Herlocker, 1992). Information on condition and trend is necessary to estimate current as well as the future potential of a given rangeland to sustain a given wildlife, livestock or human population (Pratt and Gwynne, 1977). Range condition is a dynamic phenomenon that influences forage productivity. Studies on forage availability are essential and could give an idea of the existing range conditions. Moreover, the whole spectrum of vegetation diversity and cover of a given area offers good knowledge of range conditions and forage production (Connel, 1975).

It is a common feature in savanna grasslands to find association of Grevy's zebras with other wild animals (Grier and Burk, 1992; Muoria *et al*., 2005), not mentioning livestock. This implies the existence of some level of interspecific competition. They also occur in variable groups utilizing same resource base, hence depicting intraspecific competition. These result in decreased recruitment of individuals in the population (Begon and Mortimer, 1986). However, species can coexist well if only they do not utilize common resources or if they exhibit resource partitioning.

Grevy's zebras show variability in their activity patterns, as influenced by environmental fluctuations in their habitat (Grier and Burk, 1992). Studies show that they spend 60-80% of their time searching for food (Nowark, 1991). Generally, the activity budget is

assumed to depend upon the resource availability. Although much work on behavior monitoring and activity patterns has been going on in Lewa Wildlife Conservancy (Rubeinstein *et al*., 2004), there is a need to understand the situation in the community lands.

1.2. Justification

Current research in Kenya reveals that the Grevy's zebra population has been steadily declining since the late 1970s despite enhanced protection (Williams, 1998; Rubeinstein, 1986; Muoria, 2004). Long gone are the times when 'thousands' of Grevy's zebras were seen each day at the spring in Laisamis (Stigand, 1913). Among the causes, immense pressure emanates from habitat degradation, directly impacting on forage production (Herlocker, 1992). Diseases which seemingly have received little attention might be contributing to the declining population as revealed in the recent anthrax outbreak in the study areas (Plate 1), which claimed death of several individuals (Low, 2006). Unless the root causes are fully understood and eliminated or controlled, the population of these animals will hardly stabilize.

Plate 1. Two stallions which had died of anthrax in Ngaroni area in December 2005.

Effective management of animal population largely relies on the understanding of the species interaction with its environment, which is well understood by quantifying its activity time budget (Bunnell and Gillingham, 1985). Moreover, time spent feeding by an

animal could be considered as a function of intrinsic energy demands and environmental constraints. Furthermore, knowledge on the dry matter intake and food value of the forage is essential in estimating the nutritional status of the population throughout the year and total amount of forage required for the population maintenance. This becomes a very crucial component in determining the carrying capacity of the area or habitat.

Food influences the animal's chance to survive and multiply by modifying its fecundity and longevity (Andrewartha and Birch, 1954; Lewis and Taylor, 1956). The breeding patterns, social organization, activity time budget and survivorship of Grevy's zebra largely are determined by food and water availability (Western, 1975; IUCN, 2002) which in turn is influenced by prevailing climatic conditions. The survival rate of the foals is also dependent on resource availability (Rubeinstein, 1986; IUCN/SSC Equid specialist group, 1992). Consequently, food availability needs to be comprehended for proper management and conservation strategies.

1.3 Literature review

1.3.1 Conservation status of Grevy's zebra

Grevy's zebra is one of the largest surviving wild equids. The species has its stripes set extremely close together (Plate 2) with stripes on the hindquarters remaining vertical until above the hind legs rather than being primarily horizontal as in other zebra species (Klingel, 1990). Currently, it is placed under the IUCN red list category and in Appendix 1 of the CITES listing, implying that the species is endangered and trade on its products is illegal (IUCN, 2003; IUCN, 2006). In 1970s', its highly demanded pelt contributed exorbitantly to the destruction of several regional populations (IEA, 1998). This coupled with human pressure on the wildlife habitats, effects of invasive alien species (Plate 3), harvesting and accidental mortality among other factors have contributed to its current conservation status (IUCN, 2006).

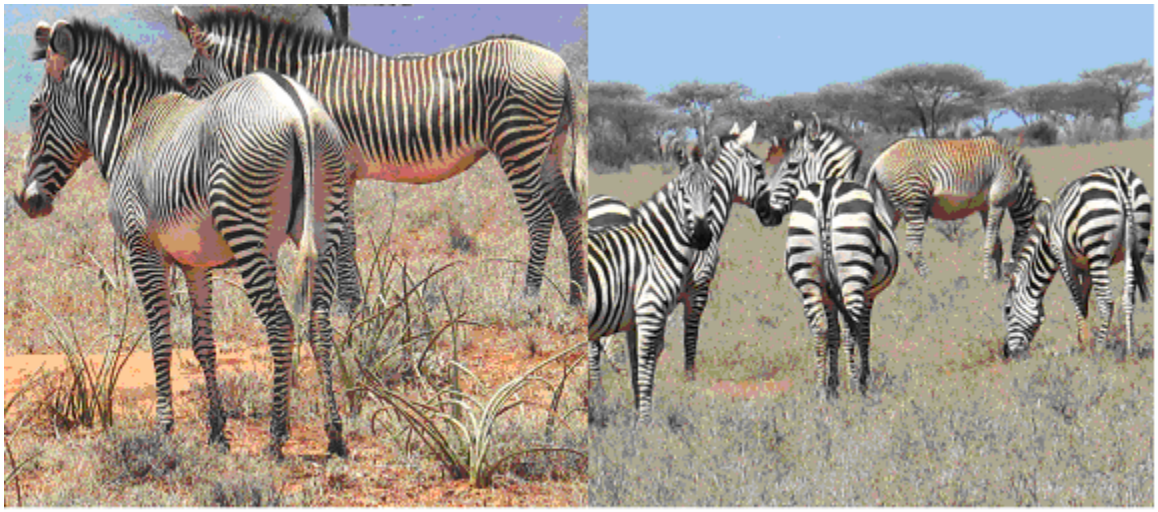

Plate 2. Grevy's zebras (a) and Plain zebras (b), showing the difference in the striping patterns.

Plate 3. Habitat degradation and invasion by *Sansevieria volkensii* and *Acacia lahai* in Barsilinga area.

1.3.2 Historical distribution

Historically, Grevy's zebra had a wide distribution in its natural range. Once, it spread from the Awash Valley, the Ogaden region, and north-east of Lake Turkana in Ethiopia, south into Kenya east of the Rift Valley and Lake Turkana, north of Mount Kenya and the Tana River, and east into western Somalia (IUCN, 2002). However, following a major decline in the 1970's and late 1980's, it occurred in the three isolated populations; in Kenya, north of the Tana River, Ethiopia, on the east side of Omo River to Lake Chewbahir and Somalia where it is now believed to be extinct as last sighting was in 1973 (Kingdon, 1979; Duncan 1992; IUCN, 2002). Eventually, in the dawn of the new millenium, Grevy's zebra occurred in few restricted ranges in Kenya, Ethiopia (Fig. 1) and possibly in Sudan. However, recent attempts of translocation of Grevy's zebra to Tsavo west and Meru National Parks have been made in Kenya though much is not known about the success of the population establishment in these areas (Nelson and Williams, 2003).

1.3.3 Population trends

Regarding the current population survey, Grevy's zebras in Kenya occur in high numbers in Samburu rangelands and Laikipia plateau, while in Ethiopia is in the northeast of Lake Turkana, the Alledeghi plains; the Yabello Sanctuary and around Lake Chewbahir (IUCN, 2003). Nevertheless, Grevy's zebra exists in much of its former range in Kenya mainly east of the Rift Valley and Lake Turkana, north of Mount Kenya and the Tana River, and east towards western Somalia. As mentioned in the introduction, the population has undergone a sharp decline over the past few decades. At present the population in Kenya is about 1600 - 2000 individuals while in Ethiopia it is less than 150 individuals (Nelson and Williams, 2003; Williams and Low, 2004).

1.3.4 Biology

Body length ranges from 250 to 300 cm and the shoulder height is 1.5 m. However, sexual dimorphism is quite pronounced in Grevy's zebra with males being larger than females. The mature male weighs on average 430 kg while mature female 385 kg.

Average life expectancy is 22 years in captivity and 18 years in the wild (Kingdon, 1979; Nowak, 1991). Females reach maturity at three years and males at six years.

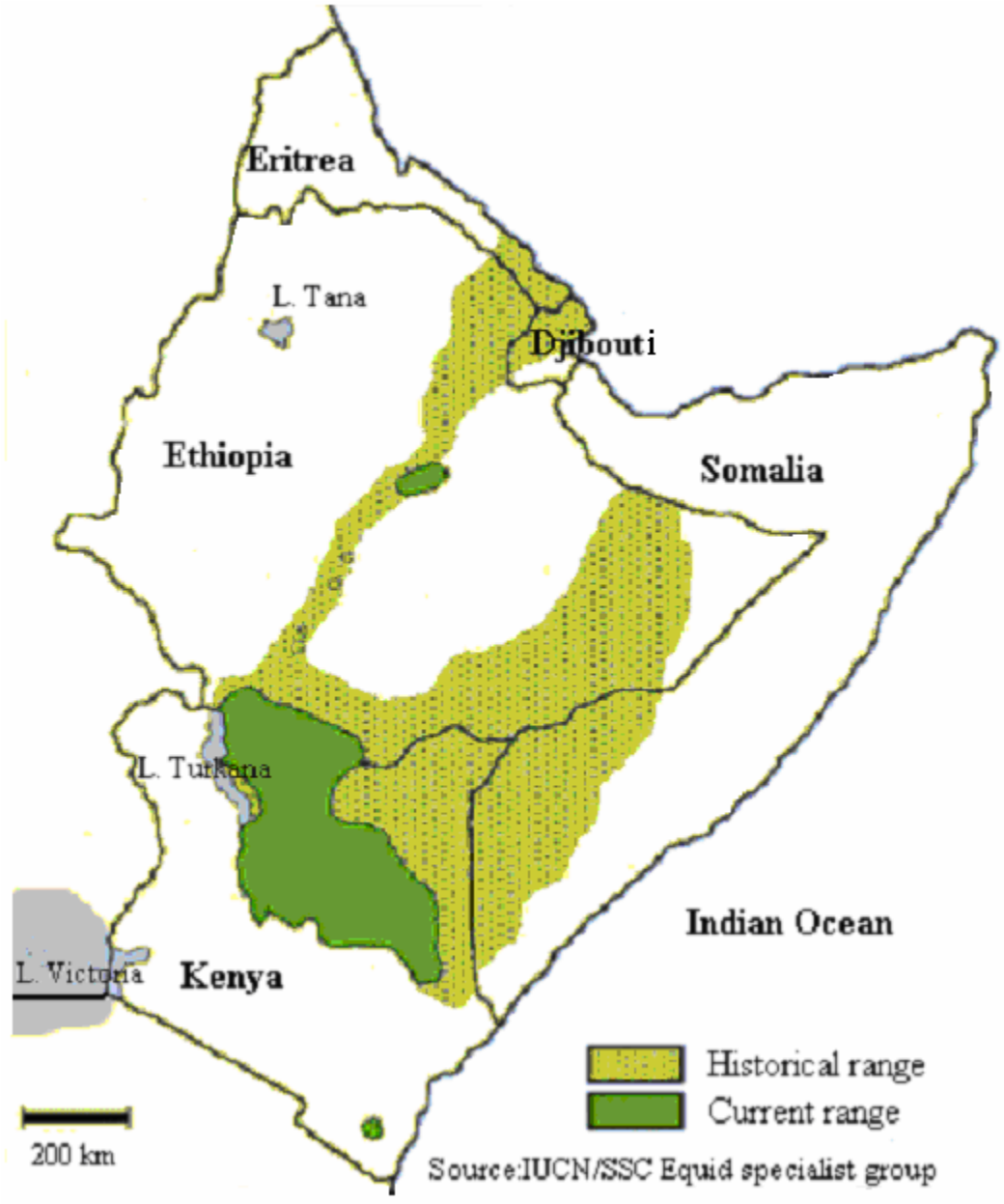

Figure 1. Map of historical and current distribution of Grevy's zebra**.**

Gestation period lasts from 390 to 400 days, with a single foal at a time with foaling interval of two years. Birth season is before the start of rains usually between August and September, but mating and foaling occurs all along the year. The foals start feeding few weeks after birth but generally weaned at the age 8 - 13 months (Olson and Dinerstein, 1998). Altogether, females return to localized birthing grounds, which seem traditional at the peak of foaling season.

1.3.5 Social organization and home range

Grevy's zebras exhibit some level of social organization. Unlike other equids, they are flexible in terms of social structures (Klingel, 1977; Ginsberg, 1989). They have open society in which mares with their foals and the males on established territories are the focal points. Unlike their relatives of Common or Plain zebras (*Equus burchellii*), adults do not have permanent bonds. Herds are fairly loose in form, and the only lasting association is between the mother and her foal (Klingel, 1974). Lactating females form nursing groups while the non-lactating females are very promiscuous with very weak bonds as influenced by male territories and abundance of food and water resources. Bachelor herds also do exist and may converge with other social groups to form mixed herds. Nonetheless, Grevy's zebras have very fluid bonds and their congregations are dictated by environmental conditions, such as drought (Williams, 1998).

Males are territorial maintaining large territories and associate with mares only when they enter their territory. In Wamba area, territories were established during the wet season due to irregular rainfall patterns in the area (Klingel, 1972). However, residential stallions maintained their territories while the non-resident and non-territorial stallions migrate and return during the wet periods. The most successful males win grassy territories close to water, which are major attractions, especially for lactating females (Williams, 1998). Aggression is not common except that the territorial males tend to assert their mating prerogatives. The territories extend up to 12 km^2, the largest among the ungulates (Kingdon, 1979). The residential stallion tolerates other stallions in his territory provided they do not interfere with his mating activity. Peak of territorial and mating behavior seems to be influenced by the local patterns of rainfall mainly occurring during the short

and reliable rains of July and August or later during October and November. Generally, the home range of both females and males can cover up to 10,000 km^2 (Duncan, 1992). Unlike most other equids, Grevy's zebras are very flexible in group formation.

1.3.6 Habitat and diet

Grevy's zebra mainly inhabits semi-arid scrub and grasslands with a preference for grasslands growing on deep sand, hard-pans, and in areas where elephants and fire have degraded the dominant *Acacia-Commiphora* woodlands (Kingdon, 1979; Rubeinstein, 1986). Although very adapted to the arid environments, it is highly dependent on water and thrives well where there is permanent water (Williams, 1998). The males and non-lactating females can go for five days without water but the lactating females need water after every other day (Van Dierendonck, 1996). Principally, Grevy's zebra are said to be grazers, though browsing may comprise 30 per cent of their diet (Rowen and Ginsberg, 1993), but this mainly might depend on the area they inhabit as revealed by the current study.

1.3.7 Threats and reasons of population decline

The significant factors held responsible for the alarming decline of these animals are mainly hunting, habitat degradation and loss, competition for food and water resources from livestock and pastoralists, tourism and predation (IUCN, 2002). However, pouching is no longer a major problem in Kenya following the legal ban on hunting and trade in game trophies in 1976 and its entry in CITES list in Appendix 1 in 1979 (IUCN, 2002). Nevertheless, Grevy's zebras are hunted for meat by Borana, Somali and Turkana people in both Kenya and Ethiopia (Williams, 1998; IUCN, 2002). Moreover, unlike other ungulates, they are reluctant in fleeing away from predators as well as hunters rendering them more vulnerable (Kingdon, 1979). In addition, Grevy's zebra is used for medicinal purposes by some pastoral communities thus encouraging hunting (IUCN, 2002).

Protected areas form less than 0.5% of the Grevy's zebra range (Williams, 1998) implying the majority occur in community areas where there is no effective protection. Habitat degradation and subsequent loss of the Grevy's zebra in these areas is due to human activities (Packer, 1986; Villet and Woodiwiss, 1986; Williams, 1998; Oindo,

2002). Pastoralists are becoming more sedentary around permanent and seasonal water sources, leading to the exclusion of wildlife. Overgrazing, soil compaction and excessive soil erosion largely impair forage productivity (Bronner, 1990; Herlocker, 1992). Inappropriate distribution and introduction of non-native livestock species resulting into change in vegetation composition and communities worsen the situation (Herlocker, 1990).

Habitat degradation results in soil erosion and vegetation changes with annuals replacing the perennials, thus reducing food availability (Ginsberg, 1988; Herlocker, 1993). In addition, heavy utilization of the available forage by high livestock densities especially during the wet season amounts to the same. On the other hand, water points in the community areas are occupied by pastoralists and their livestock forcing Grevy's zebras to drink at night increasing their vulnerability to be preyed upon by the nocturnal big cats. This also engages them in long movements to get water jeopardizing the survival of the foals which is highly dependent on the distances made by the mothers in search of the fundamental resources (IUCN/SSC equid specialist group, 1992; Williams 1998).

However, drought is expected to favour Grevy's zebras as argued by IUCN (2002). This is because they can forage on inconsumable plant materials by the livestock in such periods. Nevertheless, competition with livestock deciphers to low survival of the foals in the pastoral areas (Rubeinstein, 1986). Despite the hardy nature of Grevy's zebras, competition with pastoralists and their livestock force them to migrate to other risk sites or vacate their ideal breeding areas (Olson and Dinerstein, 1998). Predation, though seen as a minor problem in the pastoral areas due to elimination of the big cats by the people, field observations indicate that many animals have a lot of scars (personal observation) especially at the rare parts suggesting predators have attempted to attack the animals.

1.3.8 Survival tactics in the wild

In several occasions, Grevy's zebras like other ungulates move or stay in herds despite their disintegration during the dry periods (Krebs, 1985b). This has been advantageous to this species as regards to their predator relationship. There is early detection of the predator as many eyes are keeping vigilant. On the other hand, their presence in large

numbers and acting together may deter the predator from attacking as it has been demonstrated by mobbing birds and troops of primates. On the same note, if the predator has to attack the group, it has to select a single individual. However, the animals flee in confusion, impairing the predator's concentration on the same animal and thereby reducing its chances of capture (FitzGibbon and Lazarus, 1995). Moreover, the Grevy's zebras camouflage well with the brown arid environments, also reducing the chance of being noticed by predators.

Alternatively, they try to avoid competition from livestock which occur in big numbers in their range by consuming plant parts and species not consumed by the livestock (Kingdon, 1979; Owen-Smith, 1979). Otherwise, they exhibit social habits which do not restrict their movement corresponding quite well with their need for bulk food resource. Therefore, dispersal during the harsh conditions is an elaborate coping mechanism in the dry land. As a result, the animals mainly congregate in refuge zones where they may find water and quality pastures during the dry season.

Although Grevy's zebras like other arid dwellers are tolerant to heterothermia, with prolonged period without water, they become susceptible to explosive heat rise, a potentially lethal condition which results from prolonged dehydration (Grenot, 1992). However, compared to other ungulates, they are quite tolerant and can go for almost five days without water (Rubeinstein, 1986). In addition, their ability to migrate to favorable environments especially near water points resolves such a problem (Western, 1975). Moreover, they drink during mid-day hours, especially in protected areas when visibility is high and predators are not active, thus reducing chances of predation (Kingdon, 1979).

1.3.9 Feeding ecology and behavior

Grevy's zebras illustrate a feeding system exhibited by other herbivores which depicts their interaction with the food supply. Where forage availability drops below threshold levels or water ceases to be available, all the Grevy's zebras migrate (Williams, 1998; Klingel, 1974). As elaborated by Krebs (1985a), ungulates in the Serengeti Plains which contain the highest concentration of mammals than elsewhere in the world, move in response to growth of grasses in a sequence. It has been shown that, grazers and browsers

actually do not select different kinds of species but instead different parts of the food plants (Krebs 1985a). Zebras eat mainly the grass stems and sheaths, Wildebeests eat the sheaths and the leaves and the Gazelles eat the grass leaves and the herbs, which have not been touched by other ungulates. Nonetheless, grass stems are very low in protein but high in lignin while grass leaves are very high in protein and low in lignin and thus provide more energy (Owen-Smith and Cooper, 1987). Moreover, the herb leaves contain more protein than the grass leaves and supply more energy (Krebs, 1985a).

However, in Grevy's zebra like other arid dwelling ungulates, food preferences is influenced by rainfall patterns, chemical components, shoot phenology and food availability (Noy-meir, 1973; Owen-Smith and Cooper, 1987; Watson and Owen-Smith, 2002). Moreover, according to the model of clever ungulates by Owen-Smith and Novellie (1982), an optimally foraging ungulate should widen its acceptance range with declining food availability. Consequently, Grevy's zebras have to diversify their food choice to cope with the unpredictable forage fluctuations in arid environments.

Nevertheless, Kingdon (1979) found that ***Pennisetum schimperi, Elusin jaegeri, Chrysopogon ancheri, Cenchrus ciliaris*** and ***Enteropogon macrostachys*** were some of the important grasses to Grevy's zebra diet during the dry season in Lewa downs which is a private ranch. Such grasses were very rare in Samburu area where the present study was conducted. This implies that food selection and preference in Grevy's zebras could be largely influenced by food availability within their habitat not even mentioning that they have to maintain high intake (Moehlman, 1974; Rubeinstein, 1981). This is supported by Muya and Oguge (2000) in their finding that benefits accrued from selectivity might be too expensive energetically to sustain where food resources are insufficient thus forcing the animal to utilize the most available species.

Grevy's zebras do not have specialized stomach containing bacteria and protozoa that break down the cellulose in the cell wall of the plants. According to Kingdon (1979), the speed of food passage through their digestive system is twice as fast as in average bovid. In addition, they take twice as much as ruminants on the same pasture to compensate their inferior food assimilation. Consequently, they survive by processing a much larger

volume of plant material through their gut than ruminants. Even so, like other ungulates, they experience seasonal variations in the food intake and preference which is influenced by quality of the available forage (Stanely-price, 1977). During the wet season when vegetation is actively growing, highly nutritious, low in fiber content and easily digested, the rate of passage through the digestive system increases (Blaxter, 1963; Mukinya, 1973; Mukinya, 1977; Stanely-price, 1977).

Grevy's zebras can not extract all the protein and energy from the food taken so they compensate this by volume. However, their large body size is advantageous over the other small sized ungulates with efficient digestive system as they require less energy and less protein per unit weight than smaller species (Krebs, 1985b). This increases their potential to survive in periods of food scarcity as they can tolerate low quality food. Although in the Samburu grazing lands they compete for food resources with numerous domestic animals, it might not be wholly disadvantageous as the herbivore's feeding activity improves the food supply available for a second species (Owen-Smith, 1985).

However, nutritional requirements in Grevy's zebra vary with the status of animals (Ginsberg, 1989) and like in other ungulates with sex (Bunnell and Gillingahm, 1985). For instance, lactating mares are actually left behind during dispersal once forage decreases to a given threshold which can not be tolerated by the non-lactating females and non-territorial males (Kingdon, 1979; Williams, 1998). On the other hand, in most ungulates, male tend to exhibit reduced selectivity during the breeding season as well as less time budget for feeding as they spend more time courting, social interaction and mating. Nevertheless, where breeding takes place throughout the year, differences in food selection between the sexes may not occur (Wronski, 2002).

1.4 Objectives

1.4.1 General objective

The objective of this study was to determine the feeding behavior and diurnal activity pattern of Grevy's zebras across a grazing continuum in pastoral lands under different land-use system.

1.4.2 Specific objectives

These were;

- To study the diet and feeding behavior of the Grevy's zebra in Ngutuk Ongironi Group Ranch, Barsalinga and Ngaroni community lands in Southern Samburu, Kenya.
- To estimate forage availability and variability in the three study areas during the dry and wet seasons.
- To determine Grevy's zebras herd size, group composition and type in the three areas.
- To determine Grevy's zebras diurnal activities at different time of the day and season.

1.4.3 Research Questions

What type of plant species contribute to the diet of Grevy's zebra at different times of the year and how much are they preferred? What is the available forage and does it differ in the three study areas and over time? How are the social groups and is there any variation with season in the three areas? What are the activities displayed by the Grevy's zebra, their budget and pattern at different time of the day and season?

2.0 METHODOLOGY

2.1. Description of the study area

2.1.1 Location, Size and Topography

The study area was in Wamba and Waso divisions, Samburu district of the Rift Valley Province of Kenya (Fig. 2). It is north of the Samburu National Reserve and west of Matthew Ranges, roughly 100 km northwest of Isiolo town. Approximately, it lies between 37°E - 38°E and 0° - 1°N, at an elevation of 1000 - 1350 m above sea level. The topography is generally flat to gentle undulating plains. The study area covers on average 841 km^2 with a total population of about 4,609 people according to the 1999 population census data.

2.1.2 Climate

Pratt and Gwynne (1971) described the study area as hot and dry. It is the driest part of Samburu district. Rainfall pattern is bimodal although poorly distributed and unreliable. Highest rainfall is recorded in April and the minimum in May among the wet months. Mean annual rainfall in the area is 375 mm. Temperatures are high with high seasonal and diurnal variability. They vary with altitude and generally ranges from 24°C (mean minimum) to 33°C (mean maximum). Evapotranspiration is also high.

2.1.3 Geology

The geology of the area is associated with the erosion of the Precambrian basement rocks, fluvial accumulation of sediments and soil deriving from recent volcanic activity (Touber, 1993). The soils are moderately to strongly weathered with a tendency to form strong sealing on the surface resulting to severe erosion. Dominating soils in the area are well drained, moderate to deep, dark reddish brown to dusky red, friable to firm, coarse sandy, and loam to sandy clay, cracking clay in some areas and rock outcrops. Rock types in the area include granite, gneiss, and quartz pegmatite among others. Major land features are Matthew ranges, Mount Nyiru, Sabache Mountain and Mount Ndoto.

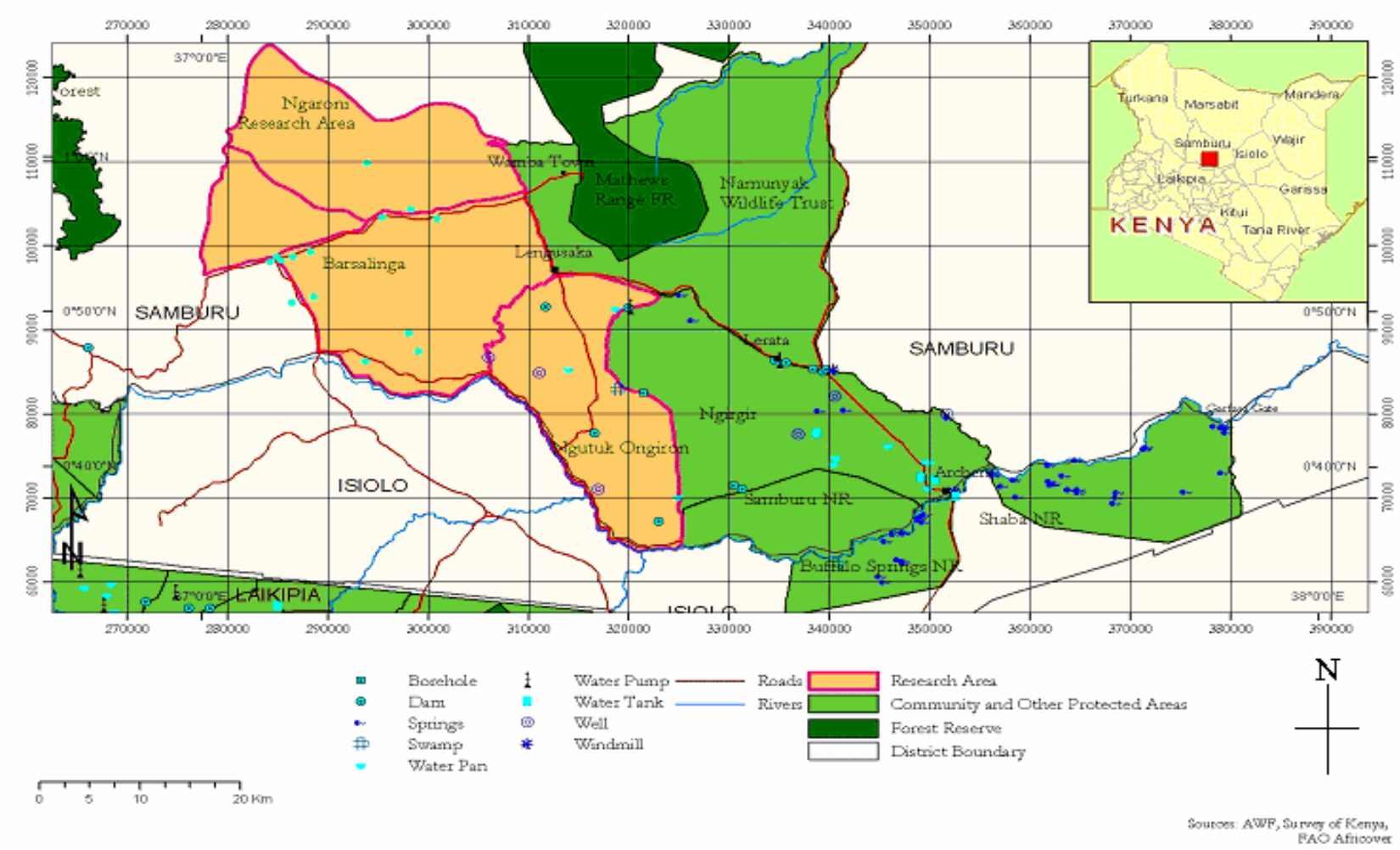

Figure 2. Map of the study area and its environs.

2.1.4 Vegetation

According to Pratt and Gwynne (1977), the physiognomic classification of the area realizes thirteen different vegetation categories. These are mainly; evergreen forests, evergreen bushland, evergreen to semi-deciduous bushland, evergreen shrubland, semi-deciduous shrubland, deciduous woodland, deciduous bushland, deciduous bush grassland, deciduous shrubland, deciduous shrub grassland, deciduous shrub annual grassland, dwarf shrubland and grassland. However, the major vegetation communities include *Oroptenium – Indigofera - Acacia tortilis* deciduous wooded grassland, *Tetrapogon – Aristida – Acacia tortilis - Acacia senegal* deciduous bush annual grassland, alluvial *Pennisetum sp* - S*etaria sp* grassland, *Acacia reficiens* dwarf shrubland and dry river bed riverine.

2.1.5 Water and Fauna

Water is not only a problem to wildlife but also to humans and livestock in Samburu. Water resources are limited and mostly seasonal. Ewaso Nyiro River is the only somewhat permanent source of water in the area. Earth dams and seasonal streams also occur throughout the area. Wildlife in the area is resident on open land where they share limited pastures with the livestock (Muoria *et al*., 2005). These include elephants, Grevy's zebras, Plain Zebras, Giraffes, Grant gazelles, Gerenuks, Dikdiks, Oryx, Bat eared fox, Wild dogs, Cheetahs, Pan cake tortoise, Shrews and Rodents.

2.2 Methods

2.2.1 Data Collection

The survey was carried out in the three areas; Ngaroni, Barsilinga in Wamba division and Ngutuk Ongironi group ranch in Waso division in Samburu district (Fig. 2). The criterion of area delimitation was accessibility, residence and abundance of the Grevy's zebras. This was determined after the reconnaissance survey which was carried out in July and early August 2005. Following the reconnaissance survey in the study area, 49 line transects were laid randomly for forage availability study, 18 transects in Ngaroni, 15 in Ngutuk Ongironi and 16 in Barsilinga. The transects were laid based on repeated

encounter of the Grevy's zebra in the area and differed in number depending on the size of the study area they utilized. Data on forage availability were collected once a month for two months during the dry (August and September) and wet season (November and December). Estimation of dry matter of the available forage was carried out by clipping forage in an area of 0.25 m^2 on 28 randomly selected transects in September and December.

Diet composition and food preference studies were based largely on physical observation sampling. The area was first surveyed to familiarize the researcher with the terrain and selection of ideal areas to carry out the observations. Data were collected twice during the dry and wet seasons. Through ground surveys, via off road driving, search for the animals in the area was carried out and their diurnal activity time budget studied once the focal animals were identified. Data on activities were recorded continuously for 15 minutes with sampling gap of 5 minutes, amounting to only three observation units every hour. This was done from 0600 h to 1800 h for five consecutive days at the beginning of each of the two dry and wet months. Moreover, data on herd size and group composition and type were recorded once a month during the study period lasting from August to December 2005. This was carried out early in the morning when the animals were active, between 0600 h and 1200 h.

2.2.2 Diet composition and feeding behaviour

This was carried out following the method adopted by Parker *et al*. (2003) in the study of diet of extralimital Giraffe. The same method has been successfully used in similar study by Stark (1986) for Savanna buffalo *Syncerus caffer*, Andanje and Ottichilo (1999) for Hirola *Beatragus hunteri,* and Watson and Smith (2002) for Eland. Mature animals were selected randomly and observed for five minutes while feeding (Altmann, 1974). Each observation unit was made for a different animal to maintain independence of the results. After five minutes, the animal was displaced and based on the last point where it was feeding, a 2 m square quadrat demarcated along the feeding track. On each feeding track at most five quadrats were laid at distance of 5 m. All the plant species present in these quadrats were identified and their total numbers recorded.

Consumed species in the quadrat were examined based on fresh clippings and number of individuals consumed per species, parts clipped and phenology, bite height, consumed twigs and culms diameter and bite diameter were measured and recorded. The bite height and bite diameter were measured in centimeters (cm) using a meter ruler while the twigs and culms diameter in millimeters using a venier caliper. Consumed parts were classified as green leafy twigs, non leafy green twigs, brown leafy twigs, brown twigs, green leafy grass stems, non leafy green grass stems, brown leafy grass stems and tree pods and then their frequency of consumption was recorded. Moreover, the feeding track was examined between the quadrat and any consumed species not captured in the quadrats was recorded.

Bite size was estimated following Apio and Wronski (2005). The stem diameter at the point of browsing or grazing by the focal animal was measured using a venier caliper and related to the diameter of the unbitten portion. The biomass above the established diameter of browsing or grazing was clipped, dried in oven at 105°c and dry weight obtained was equated to the bite size. The study of bite, step, browsing and grazing rates adopted the method following Wronski (2002) in the study of Impala. Adult focal animals were chosen randomly. Three continuous observations, each one minute for bites and step rates, and two successive observations each five minutes for browsing and grazing levels were carried out for each focal animal at any sampling unit. Feeding at the ground level was categorized as grazing while feeding on leg to head level was termed as browsing (Wronski, 2002), only where the food item was not visible.

Drinking pattern as part of feeding behavior was recorded through focal observations at Sesia water hole and Ewaso Nyiro River over the dry season, and at Iltepes earth dam during the wet season. Observations were carried out form 0600 h to 1800 h, for five consecutive days in October and December. Moreover, feeding time budget and pattern as well as suckling of the foals was recorded in the detailed study of the activity patterns.

2.2.3 Estimation of forage availability

Step point and biomass estimation methods as outlined by Kent and Coker (1992), and Bonham (1989) were adopted. Along the 49 line transects established randomly during the reconnaissance survey, total cover, herb and grass cover as well as green and brown cover were estimated using step method. Sampling was done westwards at each transect and 25 points at a sampling gap of 4 meters were sampled. Each sampling point was established by lowering the pin perpendicularly to the ground. The plant species in contact with the pin were classified as either herb or grass. The number of green and brown leaves and stems besides seed heads touched were counted and the height of grass and herbs at each sampling point recorded. Where there was no plant touched, the grass or herb nearest to the pin in the sampling direction was recorded.

Estimation of available forage biomass was carried out by clipping the grasses and browse material in an area of $0.25m^2$ along 28 randomly selected transects. Clipping was done twice on each transect, at the starting and the last point of step point sampling. The grasses were clipped at the ground level while the shrubs and herbs only the browsable parts. Each species was clipped separately at a time and then dried in an oven at 105^oC. Afterwards, the dry weight in grams was taken using electronic spring balance. Finally, based on the mean dry weight of the clipped browse and grass in g/m^2, their availability was estimated and expressed in kilograms per hectare (kg/ha).

2.2.4 Group composition and size

Direct count and focal observation methods as adopted by Sutherland (2000) and Befakadu and Afework (2004) in the study of other animals were used. A slow moving vehicle was used to search for the Grevy's zebras in different habitats where accessibility was possible. Counts and detailed observations were made whenever the animals were encountered. The total number of individuals in a group was recorded. Animals were treated to be in the same group if the separation distance was less than 50 m (Lewis & Wilson 1979; Hillman & Hillman 1987; Befekadu & Afework, 2004). Sub-division into age structure and sex following Williams (1998) were also carried out to study group composition. The individuals in any group were categorized as stallions, mares, juvenile

males, juvenile females, infant males, infant females and unidentified where it was not possible to identify the individual for some reasons. Stallions referred to mature males, territorial or non-territorial and were identified based on their larger body size and expression of dominance. Mares were the mature reproducing females, lactating or non-lactating and were distinguished by nursing behaviour and body size. Juvenile males or females referred to sub-adults, medium sized and characterized by association with their mothers, absence of suckling and bright coloration. Infant males or females referred young ones, mainly recognized by their frequent suckling, more hairy with long mane extending beyond the neck region and high head to body ratio.

Herd types were categorized on the basis of the group composition and fell into one of the following types: territorial male, bachelor herd, mixed herd, lactating females, non-lactating females and miscellaneous groups. Territorial male was defined as any solitary stallion holding a territory. Bachelor herd referred to any association of two or more non-territorial stallions. Mixed herd was a group of adult, sub-adult and infants occurring together. Lactating females referred to a group of nursing mares occurring together or with juveniles. Non-lactating females were defined as group of females in their dry period occurring together and characterized by absence of foals. Miscellaneous groups referred to unusual groups encountered other than the above, for instance lone mares and lone infants among others.

2.2.5 Determining diurnal activity pattern

Methods used were focal animal sampling and scan sampling methods as applied by Martin and Bateson (1993) and Altmann (1974). Stratified random sampling was employed to select focal individuals. The stratification was based on age and sex category while random sampling was achieved through use of random numbers in selection of the focal animal. After selecting the focal individual, the striping pattern at the right thigh which is identical (Williams, 1998) was noted to ensure consistency in individual monitoring. Where focal animal was in a group, scanning was done and the dominant activity in the group at the start of the observation was recorded.

The activities monitored included, feeding, walking, resting, vigilance, mating, rolling, self grooming, mutual grooming, nursing, suckling, running, social interaction and others. However, feeding, walking, resting, and vigilant were the important activities and were the only categories defined here below. Feeding was referred to the entire process of food searching, location, biting and ingestion as characterized by slight movements with the head down and movements of mane. Walking was defined as the steady movement for more than four seconds with the head held horizontally. Vigilant was standing or walking with the neck held above the horizontal level, head high up with the ears oriented forward and eyes wide open. Resting referred to lying down in relaxing manner or standing still with head held horizontally and ears drooping. Others was referred to the rest of activities rather than the four defined above including the time the focal animal was out of sight. Observations lasted for 15 minutes at an interval of five minutes every hour from 0600h to 1800h. Where the animal went out of sight before 8 minutes were over and failed to reappear, the observation unit was cancelled. The observations were made in a way that in every hour, data were recorded for an adult male, adult female and an infant. The activities displayed and their duration were recorded continuously using a cumulative stop watch.

2.3 Data Analyses

Diet composition was analyzed by identifying the different species of vegetation consumed by Grevy's zebra, computing their relative frequency in the diet, preference indices and their relative abundance in the study area. The vegetation consumed were identified up to the species level mainly in National Museums of Kenya Herbarium. Species with mean seasonal frequency of occurrence of more than 20% were considered important in the availability while those with preference index of more than 1 were considered to be the preferred species. Relative frequency in the diet was obtained by dividing the number of quadrats in which the consumed species occurred by the total number of quadrats where diet observations were made as expressed in percentage. Species preference indices were computed following Parker ***et al***. (2003). That is,

$$\text{Preference index} = \frac{\text{Relative frequency in the diet (a)}}{\text{Relative frequency of the resource (b)}}$$

Whereby,

a - Frequency of occurrence of a given species in the diet

b - Relative dominance of the species in the area in which diet observations were made.

Relative frequency of occurrence was calculated by dividing the total number of individuals of a single species by the total number of individuals of all species observed in all the observation plots. Seasonal mean frequency of occurrence (M.O.F) was obtained by computing the average of species frequency of occurrence in both seasons.

Descriptive analysis of feeding time (for stallions, mares and infants), suckling pattern, feeding height, bite and step rate, browsing and grazing level were used to explain the feeding behaviour of Grevy's zebra. Amount of food intake per minute was estimated by multiplying the mean bite size by the number of bites per minute. This was multiplied by sixty to get the amount consumed per hour which was then multiplied by the total number of hours spent in feeding to get the daily amount of food intake. Forage availability data were analyzed by calculating and comparing species diversity in the three study areas using Shannon - Weaver Diversity Index as shown below then comparisons made among the areas.

$$H' = \sum_{i=1}^{s} pi \ln (pi)$$

Whereby; H' - Shannon-Weaver Diversity Index

Σ - Summation symbol

s - Number of species

pi - the proportion of individuals or the abundance of species i^{th} as a proportional of total cover in the sample

ln - Natural logarithm

Total percentage cover, herb cover, grass cover, green cover and brown cover were calculated to estimate the availability and quality of forage in the study area. Total cover was computed by dividing the number of points in which the pin was in contact with any

plant part by the total number of sampling points expressed in percentage. Herb, grass, green and brown cover were calculated by dividing the number of points in which the pin was in contact with equivalent plant parameter with the total number of sampling points. Dry matter estimation of forage was obtained by averaging the dry weight from all the clippings, then expressed in g/m^2 and subsequently in kg/ha. Comparisons were made for temporal and spatial change in forage, and the null hypothesis that, there was no difference in temporal and spatial changes in forage availability tested using Kruskal Wallis test while post hoc analysis using Dunn's multiple comparison tests. Data were first arcsine transformed before the analysis.

Data on activity time budget were analyzed by assessing time allocated for different activities at different hours of the day as well as different seasons. However, the preliminary assessment indicated that only feeding, walking, resting and vigilant were important for the Grevy's zebra and were analyzed independently while rest of the activities were lumped together as others. The mean time spent on each activity was obtained for the ten days of observation each season, and then multiplied by four to obtain the hourly time allocation. The proportion of time allocation in each hour was obtained by dividing the time spent in a single activity by total time spent in all activities and then was expressed in percentage. Differences in seasonal and hourly time budget among the stallion, mares and infants were tested using one way ANOVA followed by Tukey multiple comparison test, and paired t test. The data were arcsine transformed to ensure normality before the tests were run. Line graphs were plotted to show the activity peaks, patterns and for comparison purposes.

Group sizes were analyzed by computing the mean group size in each study area as well as season. Mann-Whitney U test was applied in testing the group size variations. Based on group composition, group types were defined, their frequencies observed and expressed in percentages. On the other hand, group compositions were analyzed by working out the proportions of different animal categories, and then expressed in percentages. Statistical tests for the differences in group composition and types were carried out using Chi-square analysis. For all statistical tests done alpha was set at 0.05.

3.0 RESULTS

3.1 Diet composition and feeding behaviour

3.1.1 Diet and seasonal preference

Grevy's zebras was observed to feed on 31 different plant species from 10 different families among the 67 species encountered along its feeding track (Appendix 1), during the period of study in Samburu community grazing lands (Table 1). Fifteen of the consumed species constituted grasses and sedges while sixteen comprised shrubs and herbs. *Indigofera spinosa* was the most abundant species in terms of Grevy's zebra food resource availability in Samburu grazing lands while *Aristida kenyesis* and *Digitaria velutina* were the least frequently encountered species. Among all the species consumed, 15 had more than 20% frequency of occurrence, implying that they were important in terms of consumption.

During the dry period, Grevy's zebra fed on 16 different species including *Acacia tortilis* pods as shown on Table 1. *Indigofera spinosa* and *Indigofera circinella* contributed the highest percentages in the diet (40.0% and 21.2%, respectively), though were not highly preferred. *Sporobolus pellucidus, Leptothrium senegalense, Justicia acaulis, Aristida kenyensis, Abutilon mauritianum* and *Chloris roxburghiana* contributed the least percentage in the diet (1.2% each). *I. spinosa* was the most abundant (95%) while *Abutilon mauritianum* and *Chloris roxburghiana* were the least abundant (3% each). *Panicum coloratum* had the highest preference index (38.5), but it was not important in availability as indicated by its relative abundance (5%).

Over the wet season, 23 different species were consumed (Table 1). *Indigofera spinosa, Pupalia lappaceae* and *Indigofera circinella* were the most abundant species (90%, 95% and 70%, respectively) and had the highest relative frequencies of occurrence in the diet (25.8%, 14.5% and 9.7%). *Cynodon dactylon* and *Digitaria velutina* were the least abundant (5% each) and were among the species which contributed the lowest

Table 1. Frequency of occurrence, relative dominance, relative frequency in the diet and preference indices of the plant species consumed by Grevy's zebra in Samburu community grazing lands during both dry and wet seasons ((-) - implied total absence, (0) - no information, M.F.O- seasonal mean frequency of occurrence).

Species	**Family**	**Frequency of occurrence**			**Relative dominance**		**Relative frequency in diet**		**Preference index**	
		Wet	Dry	M.F.O	Wet	Dry	Wet	Dry	Wet	Dry
Indigofera spinosa	Fabaceae	90	95	92.5	12.4	33.6	25.8	40.0	2.1	1.2
Pupalia lappaceae	Amaranthaceae	95	49	72.0	7.6	4.4	14.5	5.9	1.9	1.3
Indigofera circinella	Fabaceae	70	62	66.0	3.0	12.7	9.7	21.2	3.3	1.7
Barleria acanthoides	Acathaceae	55	51	53.0	1.2	2.4	1.6	7.1	1.3	2.9
Blepharis edulis	Acanthecea	60	43	51.5	7.6	-	1.6	-	0.2	-
Sporobolus pellucidus	Gramineae	50	49	49.5	3.8	4.9	3.2	1.2	0.8	0.2
Leptothrium senegalense	Gramineae	60	38	49.0	1.5	0.2	1.6	1.2	1.1	6.4
Sericocomopsis hildebrandtii	Amaranthaceae	30	22	26.0	0.6	0.9	1.6	5.9	2.8	6.8
Ipomea mombassana	Convolulaceae	50	-	25.0	3.2	-	3.2	-	1.0	-
Euphorbia acalyphoides	Euphobiaceae	45	5	25.0	1.1	-	1.6	-	1.5	-
Cyperus rotundus	Gramineae	45	-	22.5	2.0	-	8.1	-	4.0	-
Tetrapogon cenchriformis	Gramineae	-	41	20.5	-	2.9	-	2.4	-	0.8
Commelina echnosperma	Commelinaceae	40	-	20.0	1.4	-	3.2	-	2.3	-
Brachiaria leersiodes	Gramineae	40	-	20.0	5.7	-	1.6	-	0.3	-
Dactyloctenium aegypticum	Gramineae	40	-	20.0	2.9	-	1.6	-	0.6	-
Hibiscus macranthus	Malvaceae	-	32	16.0	-	1.6	-	2.4		1.5
Justicia acaulis	Acanthaceae	10	11	10.5	0.5	5.1	3.2	1.2	6.3	0.2
Ipomea paolii	Convolulaceae	20	-	10.0	1.0	-	3.2	-	3.1	-

Portulaca waightai	Portulaceae	15	3	9.0	0.6	-	1.6	-	2.6	-
Pavonia elegans	Malvaceae	10	8	9.0	0.1	-	1.6	-	14.7	-
Brachiaria xantholeuca	Gramineae	15	-	7.5	3.0	-	1.6	-	0.5	-
Panicum coloratum	Gramineae	-	11	5.5	-	0.1	-	4.7	-	38.5
Cyperus compressus	Gramineae	10	-	5.0	1.0	-	4.8	-	5.0	-
Boerhavia coccinea	Nyctaginaceae	10	-	5.0	0.1	-	1.6	-	14.7	-
Aristida kenyensis	Gramineae	-	8	4.0	-	1.5	-	1.2	-	0.8
Pennisetum mezianum	Gramineae	-	8	4.0	-	2.6		3.5	-	1.4
Digitaria velutina	Gramineae	5	3	4.0	0.1	-	1.6	-	14.5	-
Cynodon dactylon	Gramineae	5	-	2.5	0.3	-	1.6	-	5.5	-
Abutilon mauritianum	Malvaceae	-	3	1.5	-	0.1	-	1.2	-	9.6
Chloris roxburghiana	Gramineae	-	3	1.5	-	0.2	-	1.2	-	4.8
Acacia tortilis	Fabaceae	0	0	0	0	0	0	0	0	0

percentage in the diet (1.6% each). *Boerhavia coccinea, Vavonia elegans* and *D.velutina* demonstrated the highest preference (14.5 each) but were unimportant to Grevy's zebra in terms of availability and only accounted for 10%, 10% and 5% of species abundance, respectively.

Considering the only important species in availability, the three most important species in terms of Grevy's zebra food resource during the dry season as revealed by their relative frequency of occurrence were *Indigofera spinosa* (95%), *Indigofera circinella* (62%) and *Barleria acanthoides* (51%) (Table 1). The three species contributed the highest percentages in the diet (40.0%, 21.2% and 7.1%, respectively), even though they were not the most preferred. The most preferred species was *Sericocomopsis hildebrandtii,*

while the least was *Sporobolus pellucidus* with preference index of 6.8 and 0.2 respectively. On the other hand, the three important species recorded during the wet season were *Pupalia lappaceae* (95%), *Indigofera spinosa* (90%) and *Indigofera circinella* (70%) (Table 1). The three accounted for the highest percentages of Grevy's zebra diet during the wet season (14.5%, 25.8% and 9.7%, respectively). The most preferred species was *Cyperus rotundus*, while the least was *Blepharis edulis* with preference index of 4.0 and 0.2, respectively.

Shrubs, herbs, grasses and sedges formed the major component of the Grevy's zebra diet. Nevertheless, different parts were preferred at different seasons as shown in Figure 3. During the dry season, non-leafy or leafy green twigs of herbs and dwarf shrubs (Plate 4) were highly preferred constituting 40% of the food intake while the non-leafy brown culms of grasses were completely avoided. During the wet season green leafy twigs were highly preferred constituting 71% of the food intake. Except for the green leafy twigs, green leafy grass stems and green non-leafy twigs, all the other plant parts were avoided over the wet season.

Plate 4. Fresh clippings of *Indigofera spinosa* (left) and *Abutilon mauritianum* (right) by Grevy's zebra during the dry season.

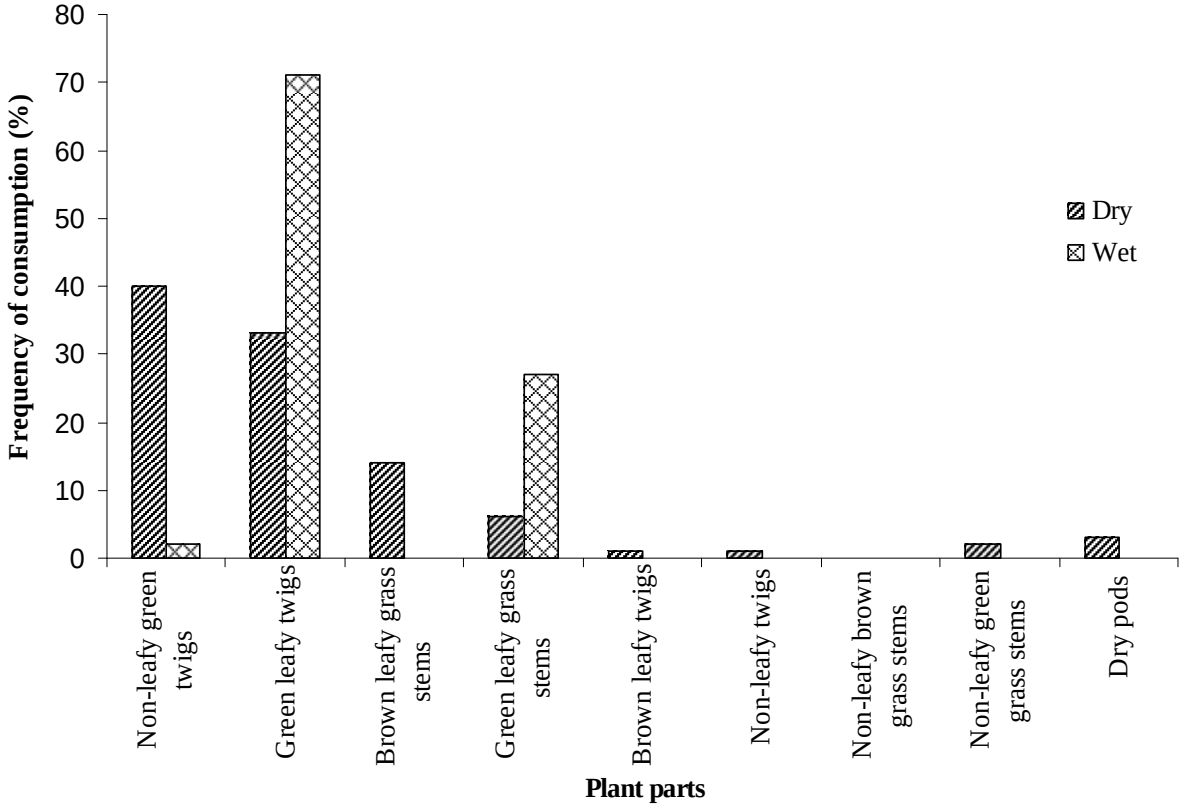

Figure 3. Plant parts preferred by Grevy's zebra and their percentage frequency of consumption during the dry and wet seasons in Samburu community grazing lands.

3.1.2 Bite height, consumed twigs and grass stem diameter and bite surface area

As indicated in Table 2 below, mean diameter of twigs and grass stems consumed by the Grevy's zebra was 2.4 mm ± 0.1 with 8.4 mm and 0.4 mm as the maximum and minimum diameter observed. The maximum diameter was recorded for ***Sericocomopsis hildebrandtii*** and the minimum for the ***Aristida kenyensis***. The majority of the plant parts consumed by the Grevy's zebra ranged between 2 to 3 mm in diameter. The mean bite height was 9.24 ± 0.53 cm (n = 287 observations). Maximum bite height recorded was 55 cm for ***Pennisetum mezianum*** while the minimum bite height was 0.5 cm for ***Indigofera***

spinosa. Based on the same number of observations for bite height, mean bite surface area by the Grevy's zebra was 70.23 ± 14.31 cm^2. Maximum bite surface area was for *Barleria acanthoides* (1384.74 cm^2) while the minimum was for *Justicia acaulis* (3.14 cm^2) and *Indigofera spinosa* (3.14 cm^2).

Table 2. Mean diameter and standard error of twig and grass stems consumed by Grevy's zebras in Samburu community grazing lands.

Species consumed	**Mean Twigs/Culms diameter (mm)**	**Standard error (mm)**
Sericocomopsis hildebrandtii	5.3	0.8
Pennisetum mezianum	1.2	0.1
Panicum coloratum	1.0	0.1
Justicia acaulis	1.8	0.5
Indigofera spinosa	2.4	0.1
Indigofera circinella	2.6	0.2
Cynodon dactylon	1.1	0.1
Chloris roxburghiana	2.0	0.0
Barleria acanthoides	2.7	0.4
Aristida kenyensis	0.5	0.1
Abutilon mauritianum	1.9	0.1
Cyperus rotundus	1.4	0.2
Leptothrium senegalense	0.9	0.2

3.1.3 Bite size, rate and step rate

Based on the clipping, drying and measuring the dry weight of the plant species consumed by the Grevy's zebra the mean bite size was 3.04 ± 0.40 g. During the dry season, mean bite per minute was 7 ± 0.27 while during the wet season it was 9 ± 0.31. The mean step per minute was 10 ± 0.81 and 9 ± 0.74 during the dry and wet seasons, respectively.

3.1.4 Estimation of food intake

The daily food intake by an adult Grevy's zebra regardless of sex was estimated to be 11.82 ± 1.2 kg per day during the wet season and 8.43 ± 0.78 kg in the dry season (Table 3). Food intake per step for the two seasons was 3.04 ± 0.40 g and 2.13 ± 0.51 g, respectively. The dry matter food intake by an adult zebra showed an increase of 33% during the wet season.

Table 3. Estimation of daily food intake (expressed as dry matter content) of an adult Grevy's zebra during the wet and dry seasons in Samburu grazing lands.

Parameter	Season	
	Wet	**Dry**
Bites/Minute	9.00	7.00
Bites/step	1.00	0.70
Mean bite size(g) (± SE)	3.04 ± 0.40	3.04± 0.40
Food intake /minute (g) (± SE)	27.36 ± 2.79	21.28 ± 1.89
Food intake /step (g) (± SE)	3.04 ± 0.40	2.13 ± 0.51
Total feeding time/ day (h) (± SE)	7.20 ± 0.56	6.60 ± 0.60
Total food intake/ day (g) (± SE)	11819.52 ± 1205.28	8426.88 ± 748.44
Total food intake/ day (kg) (± SE)	11.82 ± 1.20	8.43 ± 0.78

Mares consumed on average 12.3 ± 1.26 kg and 8.81 ± 0.78 kg over the wet and dry seasons, respectively whereas stallions consumed 11.33 ± 1.16 kg and 8.04 ± 0.71 kg in wet and dry seasons, respectively (Table 4). However, food intake between the two sexes did not differ significantly ($p > 0.05$, Fishers exact test). Females showed 16% and males 17% increase in food intake during the wet season.

Table 4. Seasonal food intake between the mare (adult females) and the stallion (adult male) in Samburu pastoral lands.

Parameter (± SE)	Wet season		Dry season	
	Mare	**Stallion**	**Mare**	**Stallion**
Food intake per minute	27.36 ± 2.79	27.36 ± 2.79	21.28 ± 1.89	21.28 ± 1.89
Feeding time/day (g)	7.50 ± 0.58	6.90 ± 0.54	6.90 ± 0.70	6.30 ± 0.58
Daily food intake (g)	12312.00 ± 1256.00	11327.00 ± 1155.00	8809.90 ± 782.00	8043.00 ± 714.42
Daily food intake (kg)	12.3 ± 1.26	11.33 ± 1.16	8.81 ± 0.78	8.04 ± 0.71

3.1.5 Browsing and grazing levels

The proportion of browsing in Grevy's zebras was 61% and 80 % during the wet and dry seasons, respectively (n = 272 observation units of 5 minutes; Fig. 4). On the other hand, the level of grazing was 39% and 20% during the wet and dry seasons, respectively. Browsing decreased over the wet season when grazing increased.

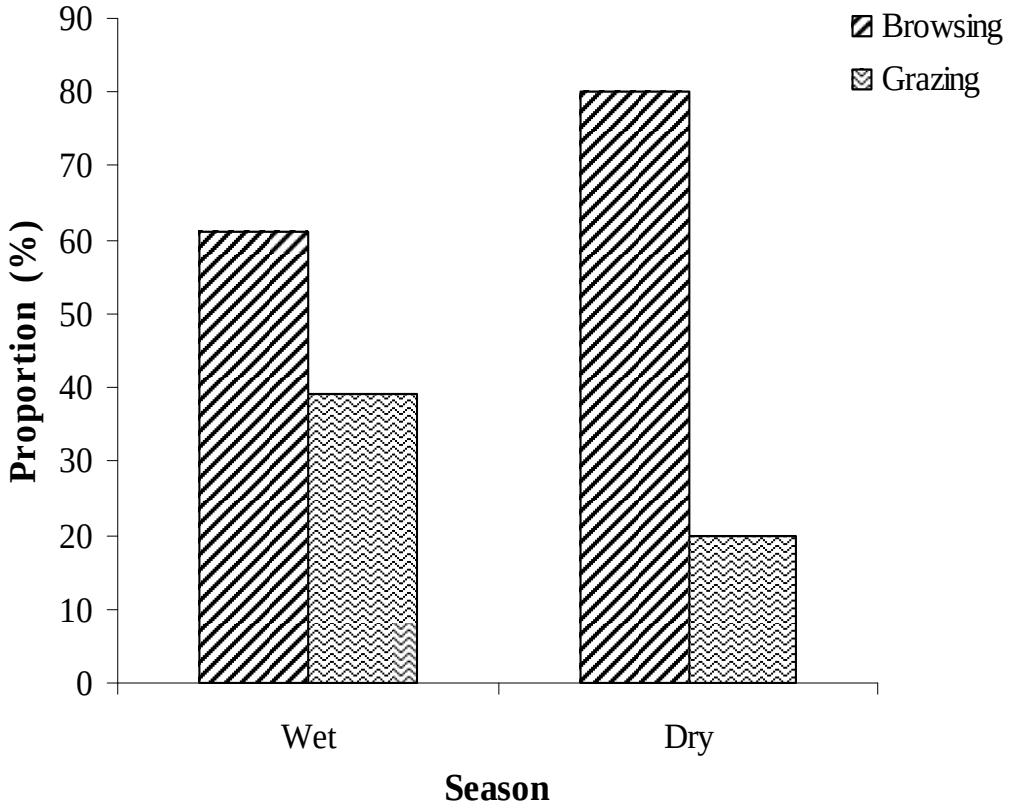

Figure 4. Seasonality in browsing and grazing level of an adult Grevy's zebra in Samburu grazing lands.

3.1.6 Feeding intensity

Mares fed more than stallions and foals during both seasons. Mean time spent in feeding per day was 7.5 ± 0.58 and 6.9 ± 0.70 hours for mares; 7.2 ± 0.54 and 6.3 ± 0.58 hours for stallions and 7.2 ± 0.60 and 5 ± 0.91 hours for foals during the wet and dry seasons, respectively. Nevertheless, there was no statistically significant difference in time allocated in feeding by the three animal categories in both seasons ($p > 0.05$).

3.1.7. Suckling pattern

Suckling was more frequent in the dry season than in the wet season throughout the day (Fig. 5). It showed two peaks in both seasons which coincided with resting periods. During the dry period the first peak was at 1000 h and the second at 1300 h, while in the wet season the first peak was at 0900 h and the second at 1300 h. In the early morning and late evening, suckling maintained low frequencies.

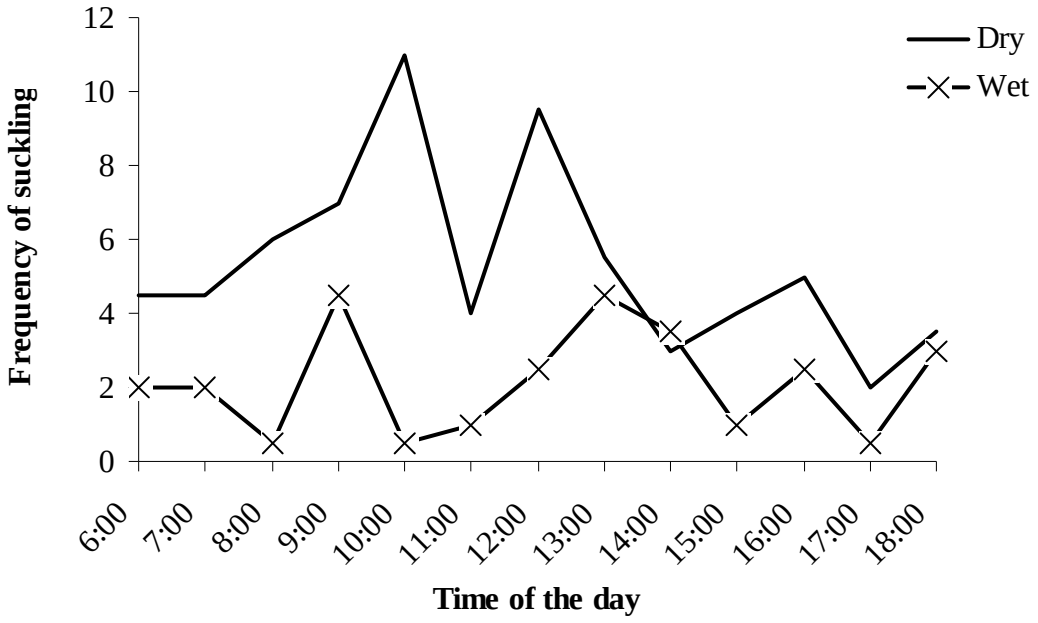

Figure 5**.** Seasonal suckling pattern of the foals in Samburu community lands during wet and dry seasons (obtained from frequency of suckling per 15 minutes observation units every hour from 0600 h to 1800 h).

3.1.8 Diurnal drinking pattern

Drinking took place early in the morning between 0600 h and 0900 h and late in the evening between 1700 h and 1800 h (Fig. 6). Between 0900 h and 1700 h drinking was avoided. This was the pattern observed during the dry season. There were no sightings for drinking during the day in the wet season. At both water points, groups observed drinking

water were mainly lactating female and territorial males. Lactating females formed more than 80% of the drinking observations.

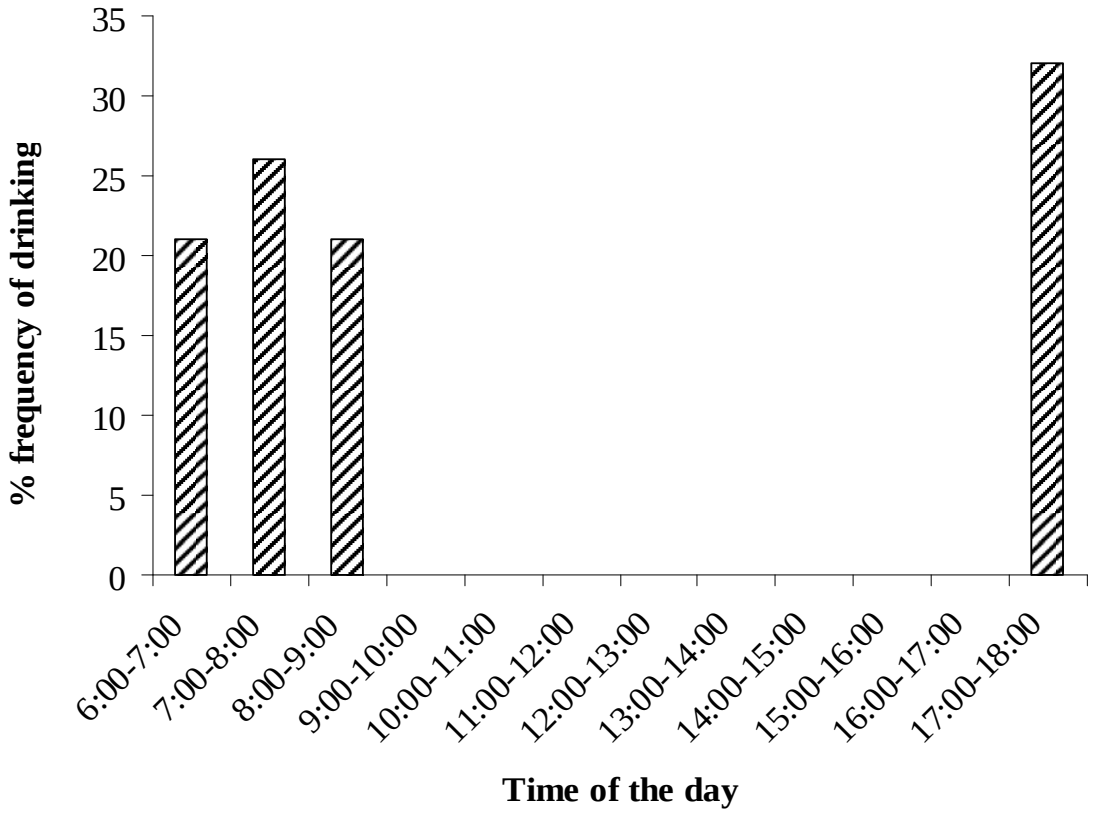

Figure 6. Drinking patterns of Grevy's zebra during the dry season in Samburu community areas, observations made at Ewaso Nyiro River and Sesia water point.

3.2 Forage availability

3.2.1 Herb and grass diversity variation

Herb and grass diversity was high during the wet season in Ngaroni (2.71 and 2.3, respectively) and Barsilinga (2.83 and 2.35, respectively) and high during the dry season in Ngutuk Ongironi (1.95 and 1.82, respectively), as shown in Figure 7. Both grass and herb diversity was highest in Barsilinga in both seasons (2.35 and 2.83, wet season; 2.15 and 2.58 dry season, respectively). Ngutuk Ongironi had the lowest species diversity index for both grasses and herbs among the three areas over the two seasons. Herb

diversity was higher than grass diversity over both seasons with exception of Ngutuk Ongironi. However, there was no statistical difference in species diversity in both grasses and herbs over the two seasons (paired t test, grass diversity; t = 0.3998, d.f. = 2, p = 0.728, herb diversity; t = 3.808, d.f. = 2, p = 0.0626).

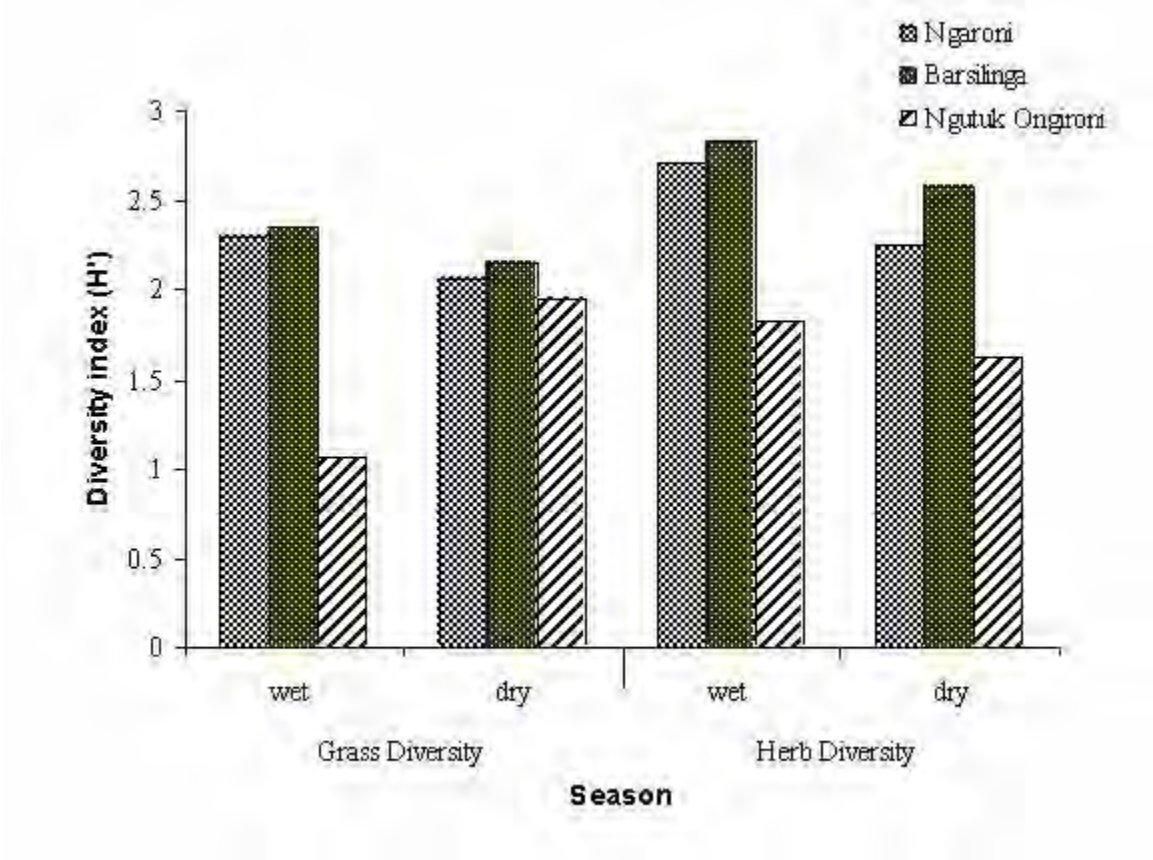

Figure 7. Herb and grass diversity in Ngaroni, Ngutuk Ongironi and Barsilinga, in August, September, November and December, 2005.

3.2.2 Spatial variations in forage availability.

In August 2005, total cover was highest in Ngutuk Ongironi (49 ± 4.55%), followed by Barsilinga (36 ± 5.20%) and lastly in Ngaroni (28 ± 2.18%). The difference was statistically significant (H = 12.002, p = 0.0025). Post Kruskal Wallis test, Dunn's multiple comparison test revealed that, Ngutuk had significantly higher total cover than the other two areas (p < 0.001). In September, Barsilinga had the highest total cover (47 ± 3.78%), followed by Ngutuk Ongironi (37 ± 3.88%) and then Ngaroni (24 ± 2.77%). The variations were significant (H = 15.405, p < 0.0001). Statistically, Barsilinga had higher

total cover than Ngaroni ($p < 0.0001$), but there was no significant difference in total cover between Barsilinga and Ngutuk Ongironi. In November, total cover was highest in Ngaroni (59 ± 3.50%), followed by Barsilinga (56 ± 3.80%) and finally in Ngutuk Ongironi (38 ± 2.67%). These differences were significant ($H = 19.067$, $p < 0.0001$). Ngutuk Ongironi had lower total cover compared to Ngaroni ($p < 0.0001$) and Barsilinga ($p < 0.01$), respectively. In December, total cover was highest in Ngaroni (77 ± 3.55%), followed by Barsilinga (65 ± 2.50%) and lowest in Ngutuk Ongironi (38 ± 2.67%). The differences were significant ($H = 33.093$, $p < 0.0001$). Ngaroni and Barsilinga had higher total cover than Ngutuk Ongironi ($p < 0.05$).

Herb cover varied significantly between the three areas in August, September and December ($H = 19.424$, $p < 0.0001$ in August; $H = 11.916$, $p = 0.0026$ in September and $H = 13.116$, $p = 0.0014$ in December, respectively) (Fig. 8). However, herb cover did not vary significantly between the three areas in November ($p > 0.05$). Grass cover differed significantly between the three areas in both November and December ($H = 20.845$, $p < 0.0001$ and $H = 23.292$, $p < 0.0001$, respectively) (Fig. 8). In both cases, Barsilinga and Ngaroni had significantly higher percent of grass cover than Ngutuk Ongironi ($p < 0.05$). However, there was no significant difference in percent grass cover between the three areas in August and September (Fig. 8).

The percent green cover differed significantly between study areas in all the four months ($H = 18.263$, $p < 0.0001$ in August; $H = 8.680$, $p = 0.01$ in September; $H = 30.273$, $p < 0.0001$ in November; and $H = 32.481$, $p < 0.0001$ in December) (Fig. 8). Ngutuk Ongironi and Barsilinga had significantly higher green cover in August and September, while in November and December Ngaroni and Barsilinga registered the highest. Although Ngutuk Ongironi recorded higher percent brown cover than the other areas in August, this difference was not statistically significant ($p > 0.05$). In September, November and December, the three areas differed significantly in brown cover ($H = 8.865$, $p = 0.0119$ in September; $H = 20.433$, $p < 0.0001$ in November and $H = 32.481$, $p = 0.0029$ in December (Fig. 8).

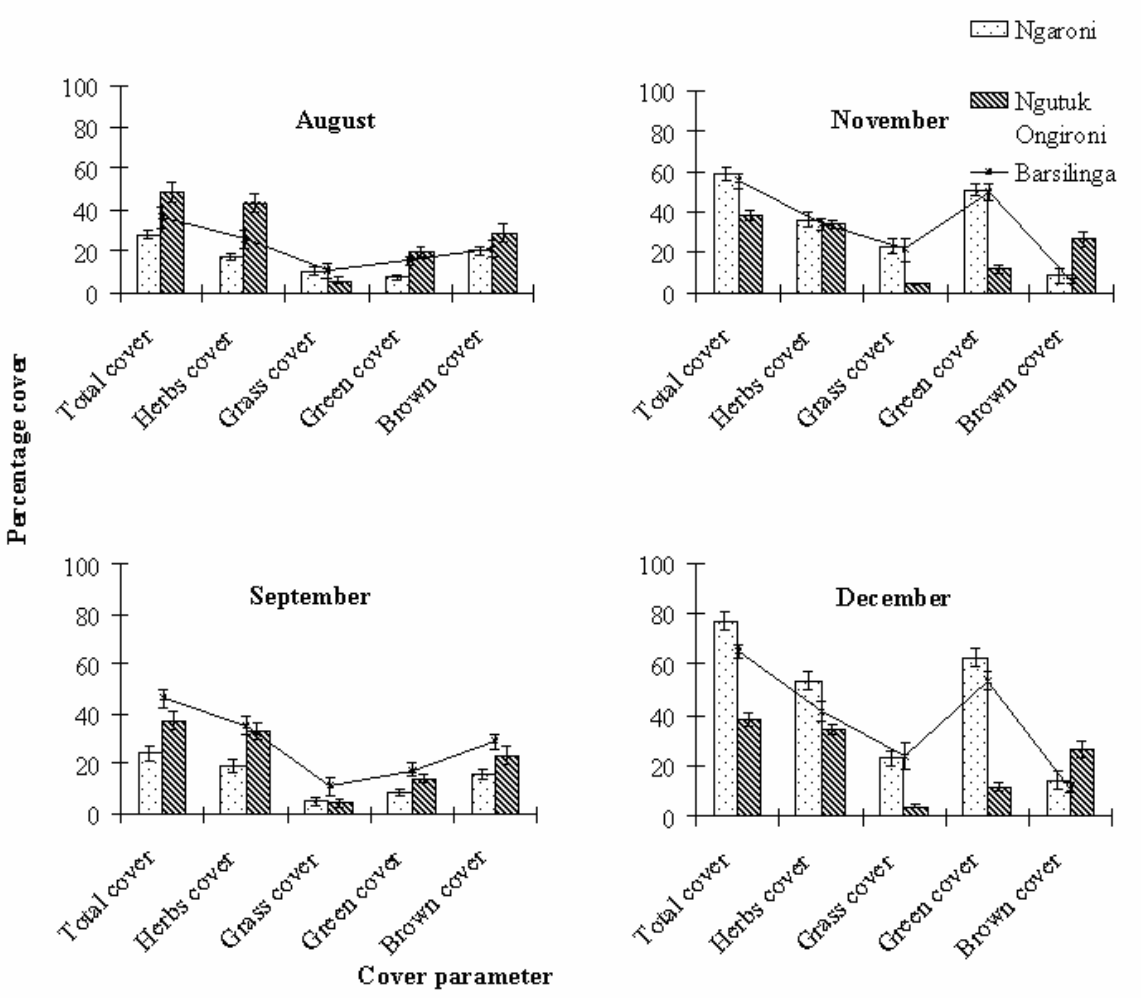

Figure 8. Spatial variation in forage availability (± standard error) in Ngaroni, Ngutuk Ongironi and Barsilinga areas in August, September, November and December, 2005.

3.2.3 Temporal variations in forage availability

Ngaroni

Total percentage cover was high in the month of December (77 ± 3.55%) and lowest in September (24 ± 2.77%). Over the four months, total cover variation was significant ($H = 55.265$, $p < 0.0001$). November and December had higher total cover than August and

September, but there were no significant differences between August and September as well as November December (Fig. 9). Herbs cover was at the peak in December (54 ± 3.32%) and lowest in August (17 ± 1.77%) demonstrating significant variation over the four months ($H = 43.110$, $p < 0.0001$). November and December had significantly higher amount of herb cover than August and September. Grass cover was highest in December (23 ± 2.99%) and November (23 ± 3.23%) and lowest in August (1 ± 0.03%). Statistically significant differences were evident across the four months ($H = 42.600$, $p < 0.0001$). Amount of grass cover was higher in December and November compared to August and September.

In Ngaroni area, green cover was highest in December (63 ± 3.43%) and lowest in August (7 ± 1.18%). Nevertheless, the four months differed significantly in green cover ($H = 55.177$, $p < 0.0001$). August and September registered lower green cover compared to December and November, but there were no significant difference between the former and the latter months. However, brown cover was highest in August (20 ± 2.02%) and lowest in November (8 ± 3.63%). Over the four months, significant differences were observed ($H = 25.912$, $p < 0.0001$).

Ngutuk Ongironi

Total cover was highest in August and lowest in September, recording 49 ± 4.55% and 37 ± 3.88%, respectively (Fig. 9). However, over the four months, total cover showed no significant difference ($p > 0.05$). Herb cover was maximum in August (34 ± 4.56%) and minimum in September (33 ± 3.28%). Alternatively, grass cover was at its peak in August (6 ± 1.60%), but remained constant at the lower level of 4% for the rest of the study period. However, both grass and herb cover showed insignificant differences across the four months ($p > 0.05$). Green cover varied significantly ($H = 11.353$, $p = 0.01$) between months, especially with August having significantly higher green cover than November and December. Brown cover was highest in August (29 ± 4.27%) and lowest

in September (23 ± 3.61%). Nevertheless, there was no significant difference in brown cover across the four months ($p > 0.05$).

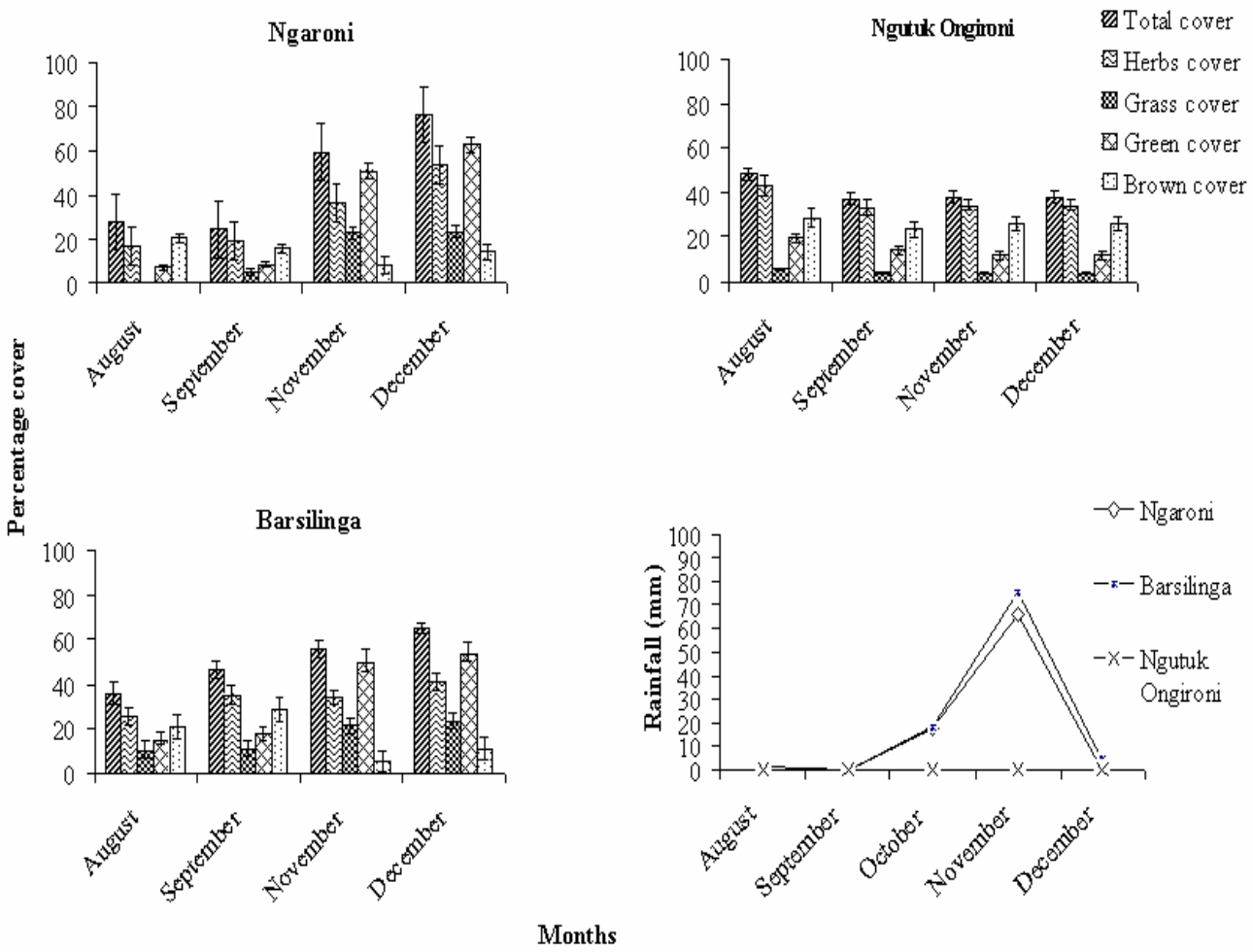

Figure 9. Temporal variation in forage availability (± standard error) in Ngaroni, Ngutuk Ongironi and Barsilinga areas and amount of rainfall received during the study period, August to December, 2005.

Barsilinga

Significant differences in total cover were observed across the four months (H = 20.878, p = 0.0001). December registered the highest total cover (65 ± 2.50%) while August the least (36 ± 5.20%) (Fig. 9). Herb cover was at its peak in December (41 ± 4.01%) while it was lowest in August (26 ± 4.06%). The increase in herb cover was significant between August and December (H = 9.084, p = 0.0282). Grass cover was high in December and low in August and September (11 ± 3.66% and 11 ± 3.62%, respectively) with December differing significantly from the two months (H = 10.527, p = 0.0146). Altogether, green cover was highest in December (54 ± 3.71%) and lowest in August (15 ± 2.08%). The differences were significant in the four months (H= 46.066, p < 0.0001). November and December had higher green cover than August and September. Moreover, the highest brown cover was recorded in September (29 ± 3.91%) and the lowest in November (6 ± 1.27%). The variation over the four months was significant (H= 29.613, p < 0.0001). November and December had the lowest brown cover.

3.2.4 Estimation of amount of food available for Grevy's zebra

During the dry season (September), the estimated amount of browse available (162.0 ± 22.0 kg/ha,) was more than the amount of grass (74.4 ± 20 kg/ha) (Fig. 10). However, the situation reversed over the wet period (December) when the amount of browse available (82.4 ± 11.2 kg/ha) was less than the amount of grass (112.4 ± 35.0 kg/ha).

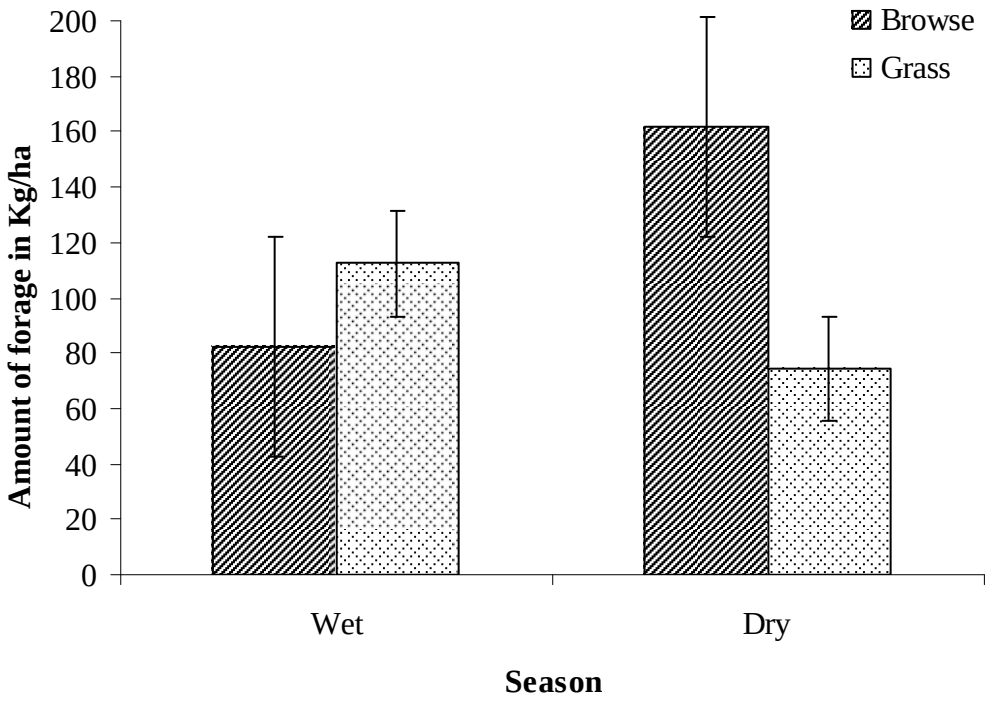

Figure 10. Dry matter estimation (± standard error) as a measure of available browse and grass in wet and dry seasons in Samburu community grazing lands.

3.3 Group size, composition and type

3.3.1 Group size

During the dry period the mean group size was highest in Barsilinga (5.03 ± 2.41) and was lowest in Ngaroni (1.93 ± 0.52) (Table 5). Ngutuk Ongironi had a mean group size of 3.22 ± 0.64). Over the wet season, Ngaroni had the highest mean group size (13.66 ± 5.35), followed by Barsilinga (3. 25 ± 0.75) and lastly Ngutuk Ongironi (1.9 ± 0.1). During the dry season, the maximum group size observed was 14 individuals in both Barsilinga and Ngutuk Ongironi areas while during the wet season it was 41 individuals in Ngaroni areas. The minimum group size was 1 individual in all the three areas. However, group size over the two seasons showed significant difference (Mann Whitney test, U' = 1279, p = 0.04).

Table 5. Seasonal group size variation in Samburu community lands observed in Ngutuk Ongironi, Ngaroni and Barsilinga between August and December (n = 95).

Season/Area	Group size estimate parameters		
	Mean group size (±SE)	**Max. Group size**	**Min. Group size**
Wet			
Ngutuk Ongironi (10)	1.9 ± 0.1	14	1
Ngaroni (20)	13.66 ± 5.35	41	1
Barsilinga (5)	3.25 ± 0.75	7	1
Dry			
Ngutuk Ongironi (31)	3.22 ±0.64	14	1
Ngaroni (12)	1.93 ± 0.52	5	1
Barsilinga (17)	5.03 ± 2.41	14	1

(Figures in brackets give the number of sightings)

3.3.2. Group composition

Group composition was dominated by stallions in Ngutuk Ongironi (35% and 38%) and by mares in Ngaroni (35% and 43%) and Barsilinga (42% and 47%) during both dry and wet seasons, respectively (Fig. 11). During the dry season, proportion of juvenile males and females was very low in Ngutuk Ongironi (2% and 4%, respectively) and Barsilinga (1% and 10%, respectively) with complete absence in Ngaroni. During the wet season, Ngaroni registered the highest proportions of juvenile male (15%) and female (8%) while Ngutuk Ongironi had no juveniles in its group composition. Proportion of infant males was highest in Ngutuk Ongironi and Ngaroni (17% each) during the dry season and in Ngaroni (11%) over the wet season. However, no infant males were recorded in Ngutuk Ongironi over the wet season. Proportion of infant females was high in Ngaroni (17%) and Ngutuk Ongironi (11%) over the dry and wet seasons, respectively. Over the dry season, Ngutuk Ongironi and Barsilinga showed complete representation of all the animal categories while during the wet season this was true only in Ngaroni.

The proportions of stallions, mares, juvenile males, juvenile females, infant males, infant females and unidentified individuals differed significantly from expected proportions within the three areas and over both seasons (Ngaroni, $\chi^2 = 36.09$, d.f. = 6, p = 0.0005; Barsilinga, $\chi^2 = 30.02$, d.f. = 6, p = 0.47; Ngutuk Ongironi, $\chi^2 = 45.45$, d.f. = 6, p = 0.0002). On the other hand, during both seasons, the proportions over the three areas varied significantly (dry season, $\chi^2 = 35.25$, d.f. = 12, p = 0.02; wet season, $\chi^2 = 103.63$, d.f. = 12, p < 0.0001).

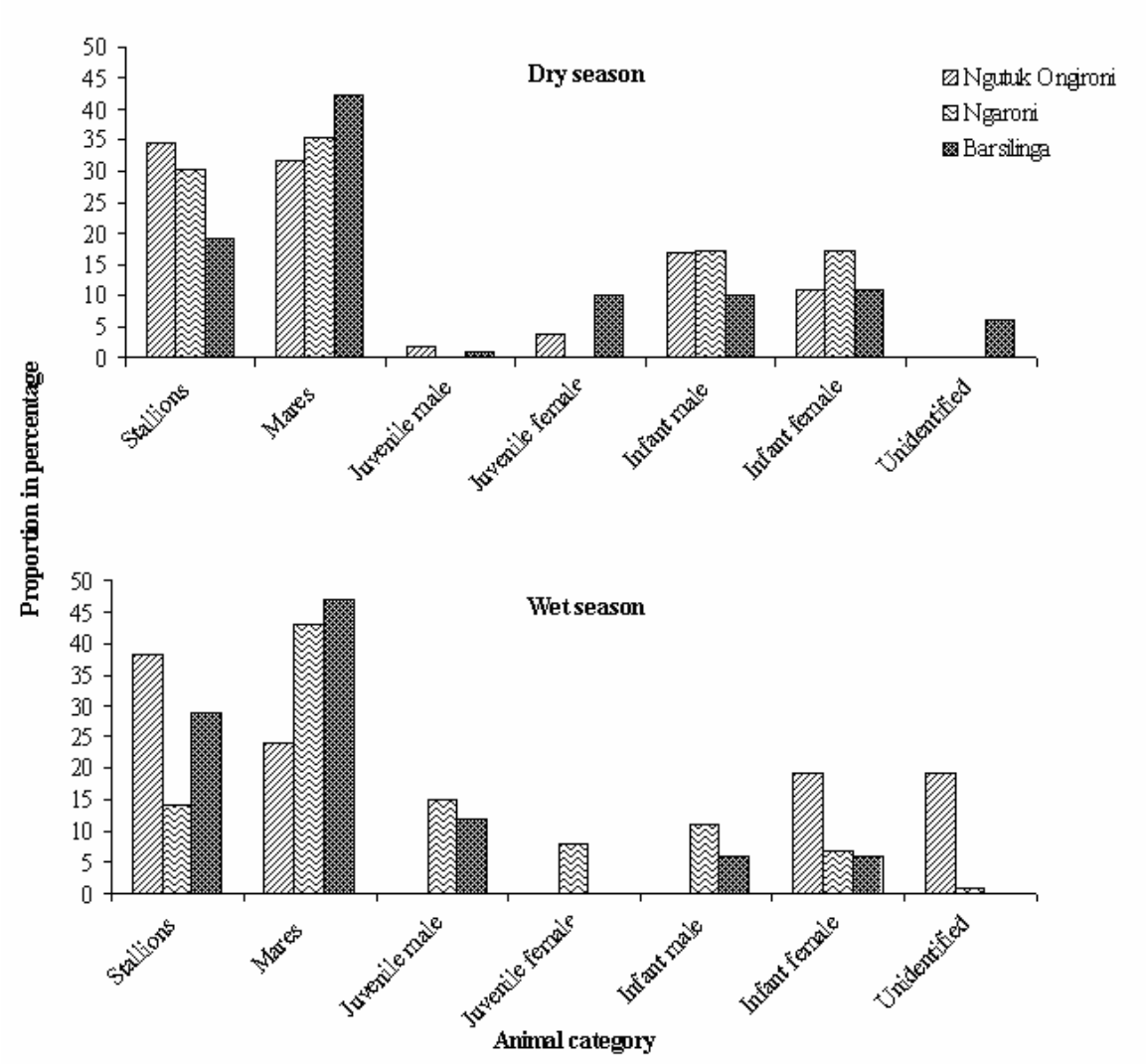

Figure 11. Group composition of Grevy's zebra in Ngutuk Ongironi, Ngaroni and Barsilinga areas during the wet and dry seasons.

3.3.3. Group types

Dominant group type in Ngutuk Ongironi over the wet season was territorial males (60%) while in Barsilinga and Ngaroni it was the mixed herds (60% and 75%, respectively). During the dry season territorial males formed the highest percentage in Ngutuk Ongironi (58%) and Barsilinga (53%) but mixed herds (Plate 5) predominated in Ngaroni (40%), Fig. 12. Bachelor herds were very rare and only encountered in Ngaroni over the wet season forming only 5% of the group types. Miscellaneous groups were only found in Ngutuk Ongironi and Barsilinga, and occurred in the former in both seasons. Groups of non-lactating females were hardly encountered in both seasons over the three areas. It was only territorial males and mixed herds which dominate the three areas in both seasons. During both seasons group types varied significantly over the study area (χ^2 = 21.56, d.f. = 5, p = 0.03).

Plate 5. A group of mixed herd zebras sighted in Ngaroni area during the wet season in December.

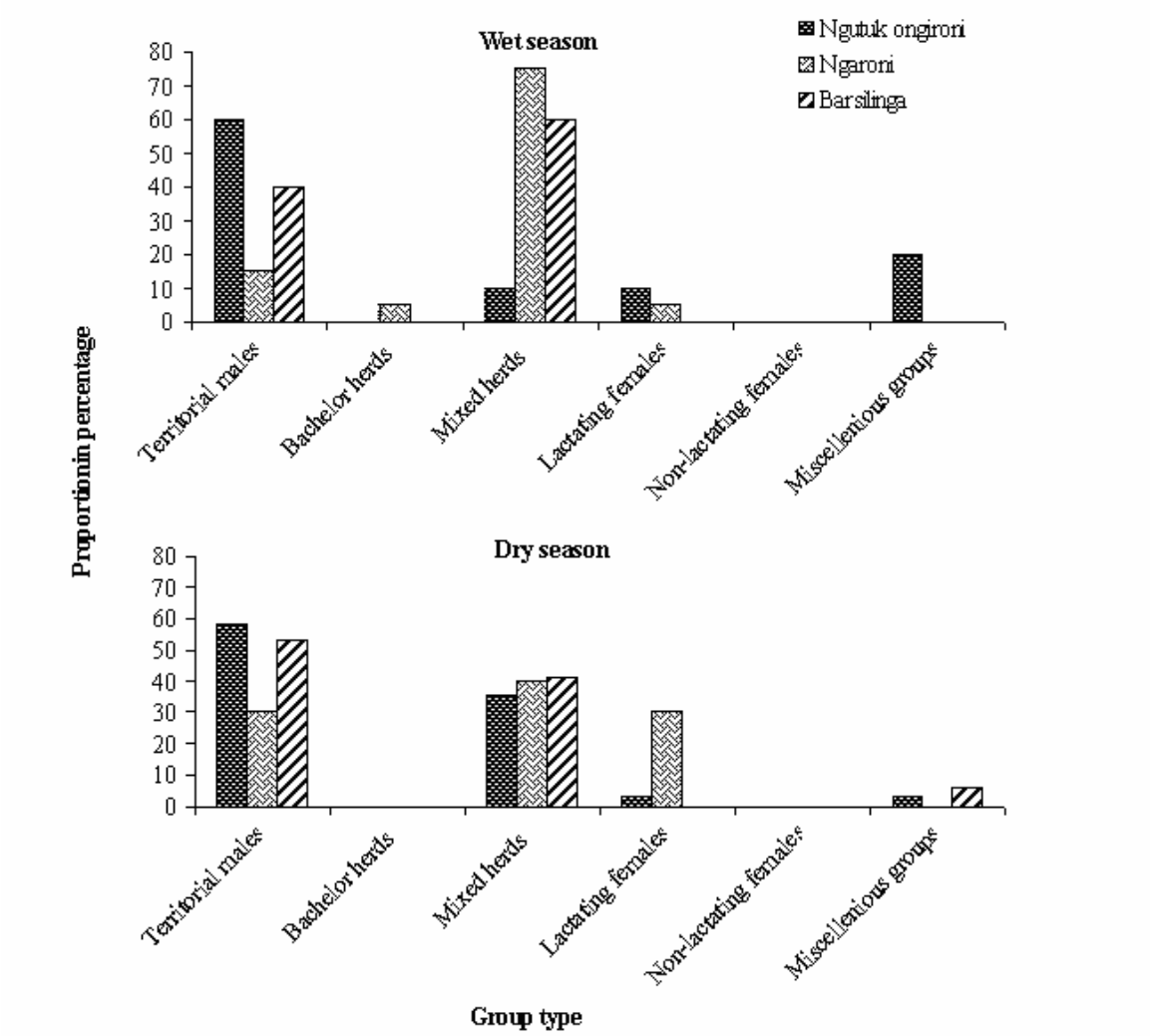

Figure 12. Grevy's zebra group types encountered in the three study areas and their variation over wet and dry seasons**.**

3.4 Diurnal Activity Pattern

Seasonal comparison of activity pattern

Feeding showed three peaks and two peaks during the dry and wet seasons, respectively. Over the wet period, feeding peaked in the early morning between 0600 and 0700 h and in the late afternoon between 1600 and 1800 h. During the dry period, it peaked early in the morning at 0600 h, at noon (1200 h) and late afternoon at 1800 h (Fig. 13). Hourly time budget among the animals differed significantly over both seasons (wet season: $F = 5.400$, d.f. = 38, $p = 0.0002$; Dry season: $F = 5.508$, d.f., = 38, $p = 0.0001$). Tukey multiple comparisons test showed significant differences between different hours of the day. During the wet season, the animals significantly allocated more time to feeding at 1600 h than at 0900 h, and at 1800 h than at 1300 h. In addition, time allocated for feeding at 1600 h was significantly higher than at 1200 h, and 1400 h. During the dry season, time allocated for feeding was low at 1000 h compared to 0600 h and 1800 h, but was significantly higher compared to 1700 h. Moreover, time devoted for feeding at 1800 h was significantly higher than at 0900 h, 1100 h, 1300 h and 1500 h. Feeding was significantly higher at 0600 h and 0700 h than at 1100 h and 1000 h, respectively.

Resting showed two peaks for both stallions and infants and a single peak for the mare during both seasons (dry season - at 1000 h (53%) and 1500 h (60%) for stallion, 1000 h (80%) and 1300 h (81%) for the infant and at 1000 h (61%) for mare; wet season - at 1100 h (55%) and 1300 h (56%) for the stallion, 0900 h (46%) and 1200 h (46%) for the infant and 1200 h (61%) for mare) (Fig. 14). Total time allocated to resting by the three animal classes in both seasons was not statistically significant ($p > 0.05$). However, hourly time budget for resting among the stallions, mares and infants varied significantly throughout the day during the wet season ($F = 7.428$, d.f. = 38, $p = 0.0001$) and in dry season ($F = 3.867$, d.f. = 38 $p = 0.0019$). Over the wet season, resting was significantly higher at 1100 h compared to 0600 h and 1800 h, 1300 h compared to 0600 h and 0700 h, and at 0900 h compared to 1700 h, respectively. Resting varied significantly, and was higher at 1100 h and 1200 h compared to 1700 h, 1600h and 1500 h, respectively. During

the dry season, resting was significantly higher at 1000 h than at 0600 h and 1700 h, but very significant compared to 1800 h.

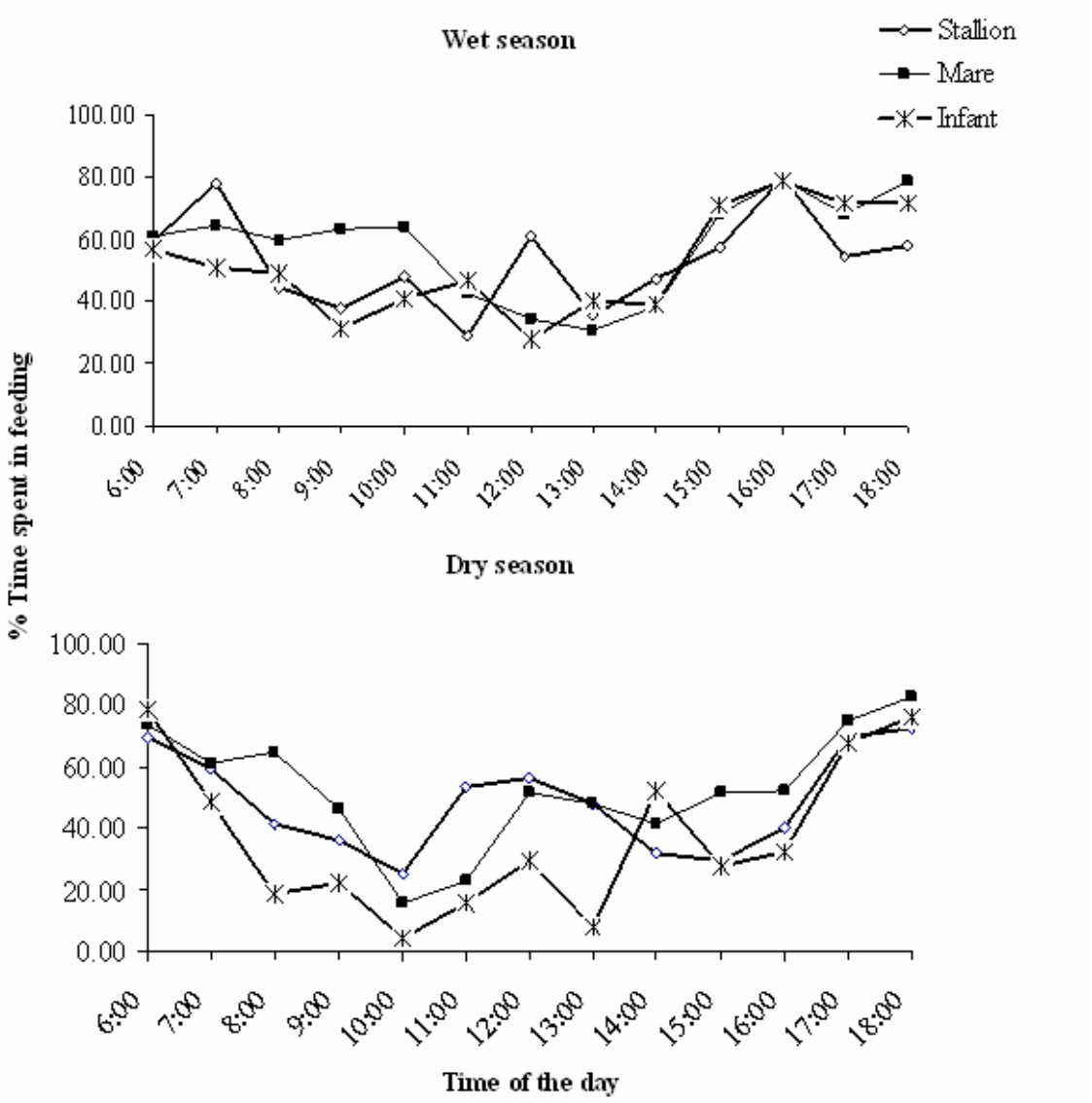

Figure 13. Hourly and seasonal pattern of feeding for the stallions, mares and infants zebras in Samburu community lands, Wamba area.

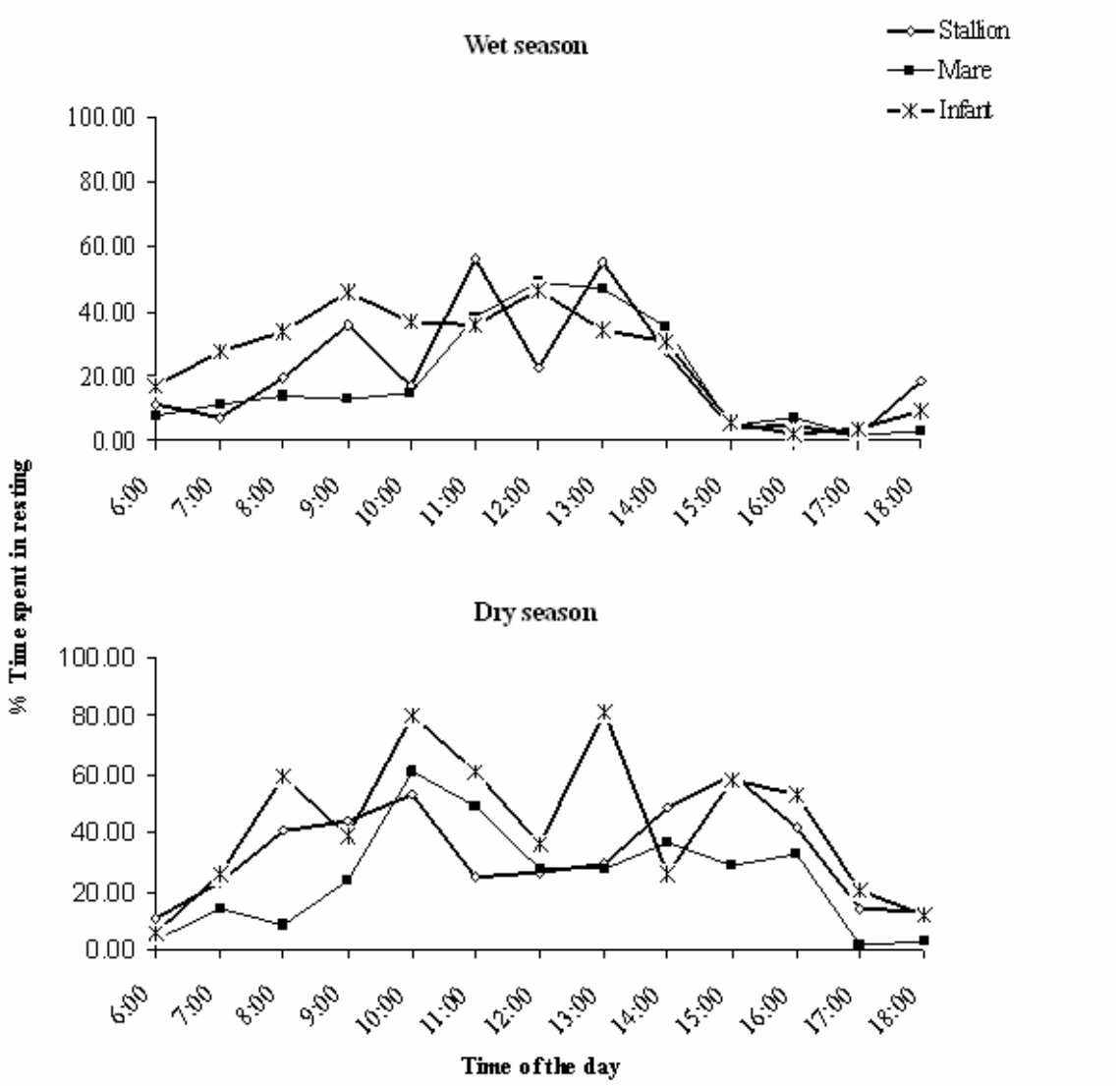

Figure 14. Hourly and seasonal pattern of resting among the stallion, mare and the infant zebras in Samburu community lands Wamba area.

Walking was allocated relatively less time compared to feeding and resting in both seasons. Maximum time allocated to walking throughout the day among the Grevy's zebras during the wet season was 24% (1000 h) while over the dry season it was 19% (0600 h). However, there was no significant difference in time allocated to walking ($p > 0.05$) for the three categories of Grevy's zebra (Fig. 15). During the dry season hourly time budget significantly varied among the animal categories ($F = 2.517$, d.f. = 38, $p =$

0.0237). Tukey multiple comparison test indicated that time allocation for walking was significantly lower at 1800 h compared to 1200 h and 0600 h, respectively.

The time allocated to vigilance did not vary significantly with time of the day either in the wet season or dry season (Fig. 16). On the other hand, stallions and mares were significantly more vigilant than infants ($p < 0.05$).

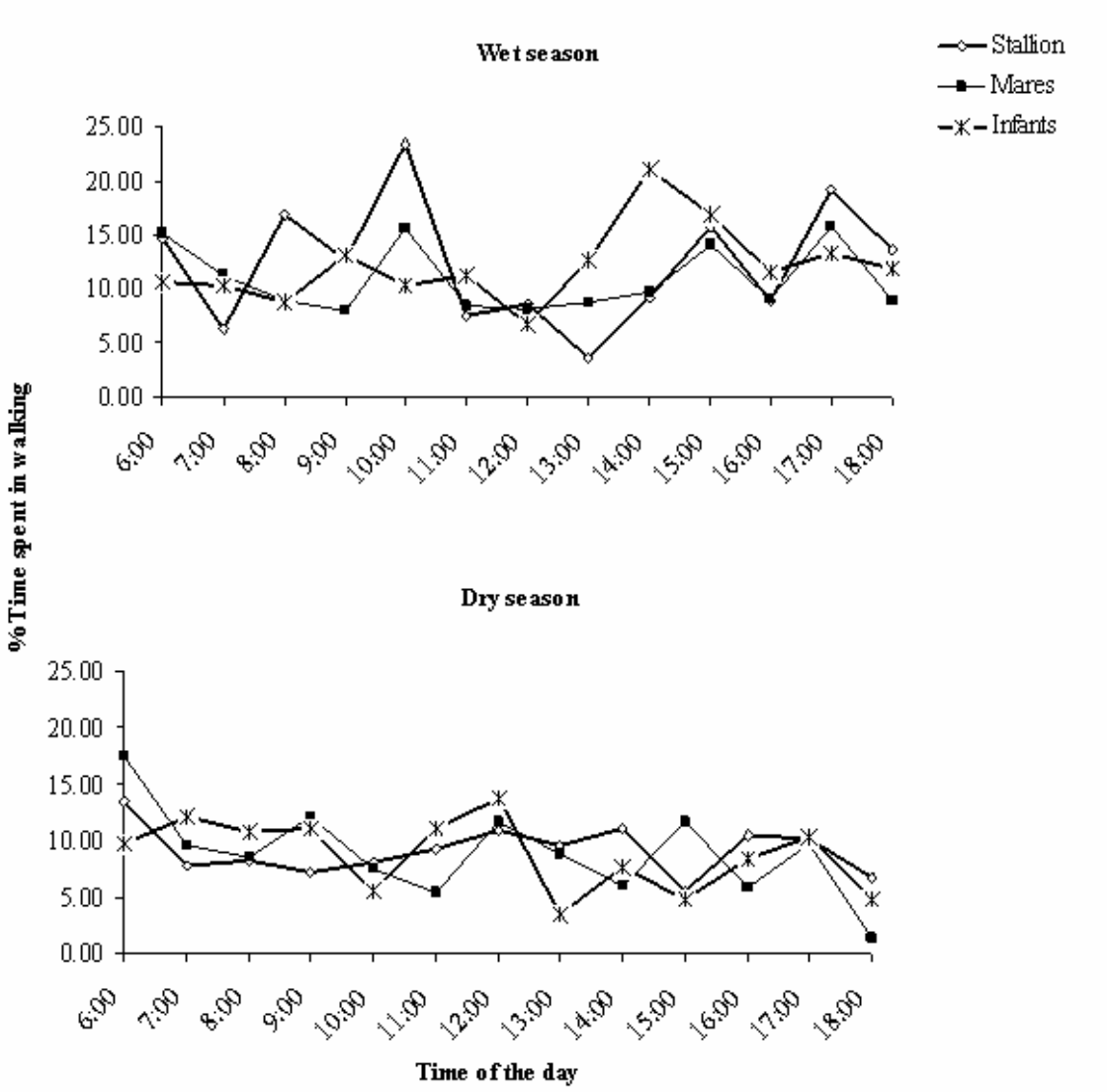

Figure 15. Hourly and seasonal pattern of walking among the stallion, mare and the infant zebras in Samburu community lands, Wamba area.

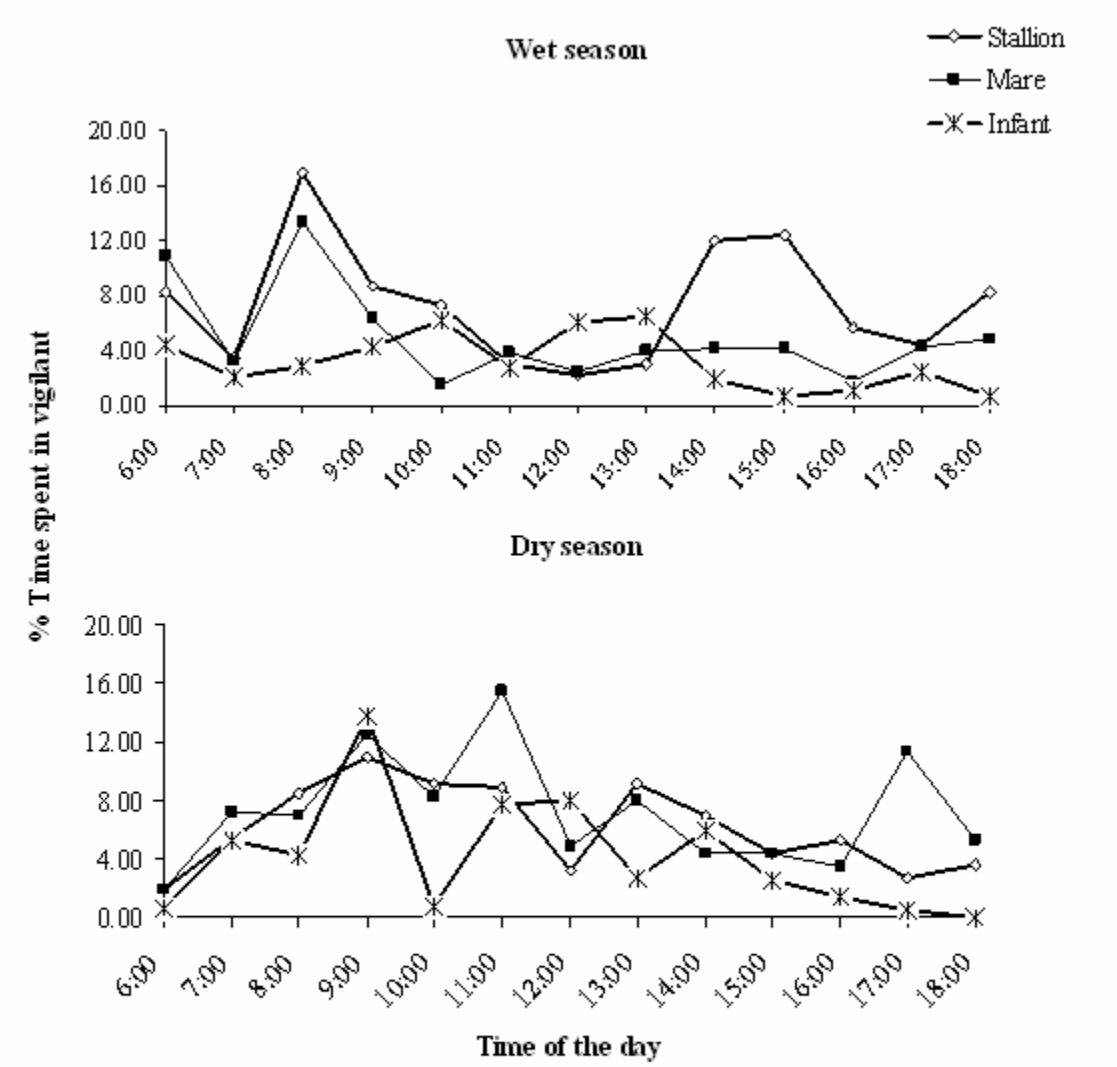

Figure 16. Hourly and seasonal pattern of vigilance among the stallion, mare and the infant zebras in Samburu community lands, Wamba area.

Time allocation to other activities was less than 20% throughout the day during the wet season and less than 14% during the dry season (Fig. 17). Hourly time budget was not significantly different in both seasons ($p > 0.05$). However, the three categories of Grevy's zebra differed significantly in their total time budget for other activities in dry season ($F = 9.596$, d.f. = 38, $p = 0.0005$). The stallions were less engaged in other activities than the infants and mares.

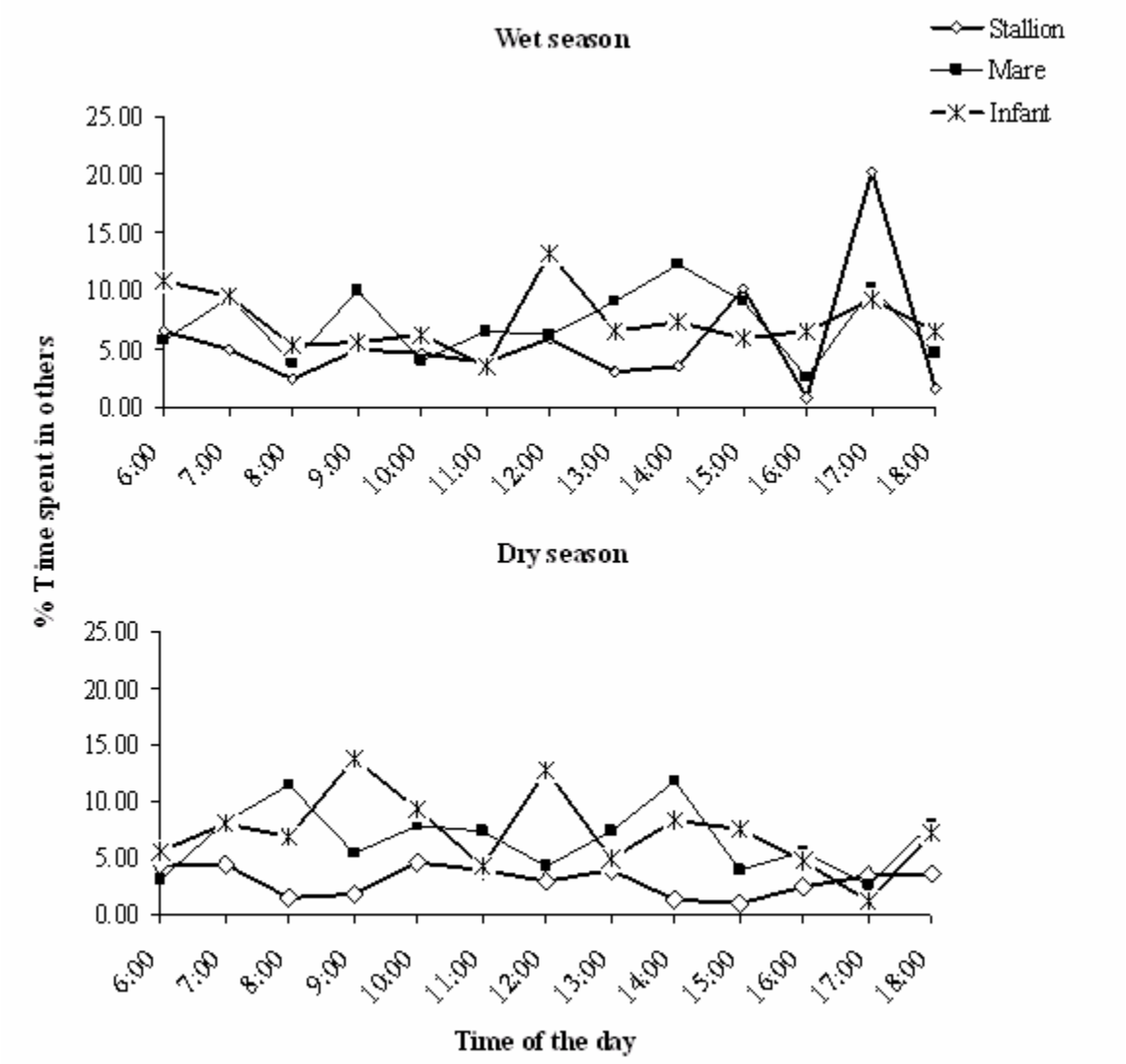

Figure 17. Hourly and seasonal pattern of other activities by stallion, mare and the infant zebras in Samburu community lands, Wamba area.

Regardless of the animal category, on daily basis Grevy's zebras spent 54% of their time feeding, 12% in walking, 22% in resting, 5% in vigilant and 7% in other activities over the wet season, while over the dry season, 46% in feeding, 9% in walking, 33% in resting and 6% in both vigilant and other activities (Fig. 18). The difference in time allocation among the five activity categories was statistically significant ($F = 61.188$, d.f. = 64, $p < 0.001$ during the wet season and $F = 34.702$, d.f. = 64, $p < 0.001$ during the dry season). Over both seasons, feeding and resting were allocated significantly more time than other activities. Comparing total time budget for each activity in the two seasons, there was no significant difference ($p > 0.05$) in feeding, walking, vigilant and other activities. However, resting varied significantly over the two season ($t = 2.326$, $p = 0.0383$).

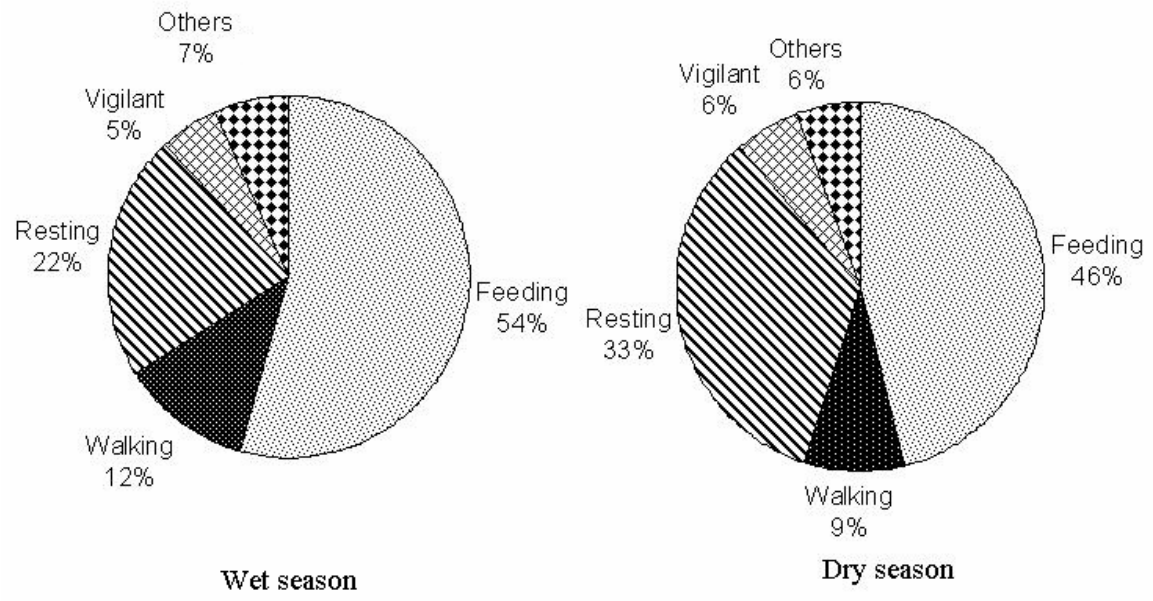

Figure 18. General activity time budget of Grevy's zebra during wet and dry seasons, obtained by pooling together data for time allocation for all the three animal categories.

4.0 DISCUSSION

Grevy's zebra foraged on 31 different species from 10 families. Consumption of such diverse species was as a result of reduced food selection to ensure high food intake to compensate the poor digestion efficiency (Kingdon, 1979). However, there were seasonal foraging differences with more different species being consumed during the wet season (Table 1), thus supporting the clever ungulate model of food selection (Owen-Smith and Novellie, 1982). Moreover, food resource preference also showed variation between the two seasons as indicated by the preference indices (Table 1). The trend was probably due to varying phenological conditions and fiber content among the food resource species complying with anti-feedant model of food selection (Van soest, 1982; Cooper and Owen-Smith, 1985; McNaughton, 1988).

The most abundant species during both seasons especially *Indigofera spinosa, Indigofera circinella*, *Pupalia lappaceae* and *Barleria acnthoides* contributed the highest percentage in the diet even though not very much preferred. They were readily available hence the reason for their high frequency in the diet (Owen-Smith, 1985). *Cyperus rotundus* (sedge) and *Sericocomopsis hildebrandtii* were highly preferred during the wet and dry seasons, respectively. The implication for high preference of *Cyperus rotundus* could be due to succulence and low fiber content favouring digestibility while for *Serricocomopsis hildebrandtii* was due to high leaf ratio over the wet season and retention of green leaves over the dry season (Blaxter, 1963; Mukinya, 1973, Watson and Owen-Smith, 2002). The observed differences in preference for different species over the two seasons could have been a function of chemical component, morphology and availability (Van soest, 1982; Owen-Smith & Cooper, 1987; Watson and Owen-Smith, 2002).

Green and succulent parts were the most preferred compared to other parts consumed over both seasons (Plate 4). However, non-leafy dry twigs and grass stems were avoided as much as possible. This was because green parts are more nutritious with high moisture content and easily digested because of low fiber content as opposed to the dry parts (Woie, 1984). Nevertheless, quality and quantity of forage need to be balanced to meet

body energy and nutritional requirements; hence the consumption of the non-green plant parts mainly over the dry season (Woie, 1986).

Mean browsing or grazing height was 9.24 cm implying that, Grevy's zebras were ground feeders. On the other hand, mares intensively nursed their young ones during the dry season than the wet season, usually during the resting hours. The reason for this might have been due to high water requirements, since infants are left at kindergartens while the mothers go to drink (Williams, 1998). At the same time, it was the period when the mares were not actively feeding. High temperatures during the dry period also could have contributed to the same. In both seasons, browsing dominated, contributing 80% and 61% in both dry and wet seasons, compared to grazing, 20% and 39%, respectively. Consequently, Grevy's zebras were more of browsers than grazers as opposed to the findings of Rowen and Ginsberg (1993), that they are principally grazers. The observation could be supported by the fact that, in Samburu community lands herbs dominated the grasses in diversity and cover. This implied that the area was ideal for browser rather than grazers.

On average, an adult Grevy's zebra was estimated to consume 11.82 and 8.43 kg per day during wet and dry seasons, respectively. Therefore, food intake increased over the wet season. Mares consumed more than the stallions over both seasons. This was because females have high energy requirements than males (Bunnell and Gillingahm, 1985). Likewise, increased food intake during the wet season was a matter of increase in food availability, quality and reduced patchiness. The findings were in line with those of Mnene and Stuth (1986) who found that, where forage is limiting animals can consume 50-60% less than where forage is abundant. Moreover, high feeding intensity over the wet season compared to dry season was due to improved food quality. This facilitates high rate of digestion and passage of food through the guts (Stanley-price, 1977) hence high food demand.

Drinking occurred very early in the morning and very late in the afternoon during the dry season (Fig. 6). This conformed to the pattern observed by Williams (1998) and Rowen (1992), in Barsilinga and Laikipia areas. This was due to monopolization of the water points during the day by pastoralists and their livestock, forcing the Grevy's zebras to drink at such a time or at night. However, the observed drinking pattern increased their predation risk as it coincided with time when visibility was impaired and active period of predators (Caro and FitzGibbon, 1992). Over the wet period, Grevy's were hardly observed taking water from the water points simply because of reduced water requirements due to low temperatures, green pastures and presence of water in natural water pans or dishes where they could utilize the water unnoticed.

Species diversity was high in wet season than the dry season except in Ngutuk Ongironi, (Fig. 7). The presence of rains during the wet season resulted to sprouting of annual species enriching the diversity in both grasses and herbs in Ngaroni and Barsilinga. This was in line with findings of Oindo (2002) that, interannual variability in vegetation takes place as a result of climatic variability affecting germination and growth. Ngutuk Ongironi hardly received rainfall hence the low diversity index. Among the three areas, Barsilinga had the highest diversity of grasses and herbs. The reason being, it was less degraded and presence of dense bush discouraged heavy utilization by livestock compared to other areas.

Total cover as a measure of forage availability was high in August over the dry season and in December during the wet season as shown in Fig. 8. This supports the findings of Williams (1998) that, forage is abundant in early stage of the dry season and late in the wet season. However, the above observation did not hold true for Ngutuk Ongironi as it failed to rain over the wet season. In overall, Barsilinga had the highest total cover and green cover compared to the other areas over the study period. This implied that it had the highest amount and the best quality of forage. The differences in forage availability among the three areas were attributed to different levels of livestock grazing pressure (Plate 6), rainfall and range degradation (Connel, 1975; Herlocker, 1992). Grazing amounts to high intensity of defoliation and thus reduces plant vigor and cover (Woie,

1986; Owen-Smith, 1994). Barsilinga was characterized by more glades of *Pennisetum* grasslands with high grass biomass, closed habitat hindering intense grazing by livestock and experienced some precipitation over the dry season unlike the other areas. All these contributed to its potential to have the highest amount and good quality forage.

Plate 6. Food competition between livestock and Grevy's zebras in Ngaroni area.

Browse contributed the high proportion of the available forage during the dry season than the wet season while the reverse was true for grasses. This was due to fast growth of annual grasses during the wet months and heavy utilization of the browse material as their quality improved with shoot growth. Season highly influences the available browse and graze, and there is high consumption of browse in wet season (Mnene and Stuth, 1986). In addition, as it got drier or grazing pressure intensified forage progressively became limiting in the three study areas.

Ngaroni showed the highest mean group size during the wet period despite the fact that it demonstrated the least mean group size over the dry season (Table 5). On the other hand, Barsilinga had the highest mean group size over the dry season. Similar observations were made by Muoria *et al*. (2004). In the other areas, mean group size showed a declining trend during the dry season. The differences in group size in the study areas

were as a result of aggregation and spatial distribution in forage and water resources. Over the wet season, due to the effect of rainfall, quality and amount of forage as well as water availability improved especially in Ngaroni and Barsilinga were it had rained. Consequently, the animals aggregated to large groups mainly in Ngaroni where it was open and with high amount of green cover as opposed to Barsilinga. These observations were consistence with those of Klingel (1974) and Williams (1998) in similar studies in Ngare ndare, Wamba and Buffalo springs. Alternatively, Ngaroni could be a traditional breeding zone as it was the same time when the majority of the animals were observed to have foals and others at their late pregnancy.

Decline in mean group size in Barsilinga was as a result of predator avoidance as the area was bushy and the animals migrated to open areas (Geist and Walther, 1974; Fryxell, 1991). Low mean group size in Ngutuk Ongironi was a consequence of paucity in food and water resources, as the area hardly received rains in the entire study period, triggering the animal dispersal. The findings conformed to those of Klingel (1972) and Kingdon (1979) that Grevy's zebras are quite nomadic as dictated by local rainfall patterns but there are resident populations which remain behind during migration. However, highest group size was 41 individuals contrary to Kingdon (1979) and Muoria *et al*. (2004), who found that Grevy's zebras form groups of over 200 individuals. The observation in the current study was attributed lack of sufficient rains and associated low food availability. This might have triggered dispersal to avoid the costs of intraspecific competition in food resource.

During both seasons, group composition in Ngutuk Ongironi favoured the stallions while in Ngaroni and Barsilinga the mares as opposed to other age categories (Fig. 11). Limited forage in Ngutuk Ongironi had forced majority of the Grevy's zebras to migrate only leaving the residential territorial males, which could withstand the conditions hence the high number of stallions (Kingdon, 1979). Barsilinga and Ngaroni were better in forage availability and offered good refuge zones in both season hence the high number of mares. Moreover over both seasons proportion of juveniles was very low compared to that of adults and infants in the three areas. This implied that there was low survival rate

or recruitment of the infants to juvenile stage. The reason to this could have been high mortality rate of infants as a result of diseases, poor nutrition, predation and long distances traveled by the mothers in search of food and water resources (Ginsberg, 1989; Williams, 1998; IUCN, 2002). However, the differences in proportions of different animal categories among the three areas were also as a result of prevailing environmental conditions and territoriality (Howard, 1986).

The present study revealed that territorial males and mixed herds were common group types over both seasons in the study areas. Nonetheless, mixed herds declined in Ngutuk Ongironi while increased in Barsilinga and Ngaroni areas over the wet season. However, decrease in territorial males in Barsilinga and Ngaroni and the increase in Ngutuk Ongironi could be explained by attachment to their territories, spacing out and remaining behind during migration (Klingel, 1974; Kingdon, 1979; Williams, 1998). On the other hand, lactating females formed nursing groups and stuck to male territories with sufficient fundamental resources during the dry period (Williams, 1998). In addition, during the wet season, rains in Ngaroni and Barsilinga areas increased forage availability resulting in aggregation of the Grevy's zebras in large mixed groups (Rodgers, 1977; Kingdon, 1979; Hobbs and swifts, 1988; Ginsberg, 1989) masking other group types. These explain the dominance of the mixed herds, as well as the decline in mixed herds in Ngutuk Ongironi and territorial males in Barsilinga over the wet season.

Bachelor herds, non-lactating females and miscellaneous groups were uncommon over the two seasons. During the dry season, dispersal or establishment of territories by the bachelor herds was responsible for this while over the wet season it was as a result of aggregation. This supported findings of Klingel (1977) that, non-lactating females and non-territorial males are the first to migrate leaving behind territorial males and lactating mares when forage availability fall below certain thresholds.

Grevy's zebras devoted more time in feeding than in any other activities over both wet and dry seasons. Rubeinstein ***et al***. (2004) obtained similar results in behavioral study of Grevy's and Plains zebras in Lewa Wildlife Conservancy. Additionally, Grier and Burk

(1992) concluded that, feeding is the most important activity for all organisms in which they devote most of their time. Moreover, allocation of more time to feeding in Grevy's zebra was attributed to their inefficient digestive system which calls for high food intake rates (Foose, 1982; Crawley, 1983; Owen-Smith, 1992). Even though feeding never ceased completely throughout the day, it showed three peaks during the dry period and two peaks during the wet season (Fig. 13) among the three animal classes. The peaks were in the early morning and late afternoon in both seasons, with additional peak at noon over the dry season. These findings mirrored the work of Twine (2002) that zebras maintained a high feeding activity throughout the day including the hottest period of the day mainly between 1200 and 1400 h demonstrating their high heat tolerance. High feeding in the early morning and late afternoon was as a result of low temperatures and limited disturbance by livestock, creating conducive feeding atmosphere.

Resting was the second important activity and was allocated more time during the dry season than the wet season among the three animal categories (Fig. 14). However, infants rested more than mares and stallions, and even devoted more time in resting than feeding during the dry season. More resting by the infants was attributed to energy constraints due to high movements in search of food and water by their mothers, low tolerance to heat stress and absence of weaning. These observations concurred with those of Schmidt-Nielsen (1964) and Rowen (1992) that infants were energetically constraint by long movements by their mother in search of food and there is need for equilibrium in body temperature in arid environments. Over both seasons, mares delayed in resting and had a single peak, unlike the stallions and the infants which showed two resting peaks. This implied continued feeding to cater for their high nutritional and energy requirements because of lactation. Moreover, resting period was prolonged over the dry season than in wet season in all the three categories. This was because of high diurnal temperatures characteristic of the dry period, hence the animals had to shelter to counter the problem of heat stress and water loss through sweating (Blevosky and Slade, 1986; Stark 1986).

Walking was significantly low at 1800 h than the rest of the day during both seasons. This was attributed to the predation risk associated with feeding at night which triggered

intense feeding at 1800 h and reduced movements. Similar findings were obtained by Stark (1986) in his study of Savanna buffalo. To add on, low walking at such time could have been due to reduced disturbance by livestock and herders, since it was the time they retired to their homes. Nonetheless, vigilance was high in the dry season than in wet season and mares as well as stallions were more vigilant than the infants. Decline in vigilance over the wet season was as result of aggregation holding true the findings of Kingdon (1979), which revealed that with increased aggregation in Grevy's zebra vigilance decreases. High vigilance by the stallion and mares was attributed to territory guarding and mothering character, respectively. Moreover, mares and infants were more involved in other activities than the stallions. The observation implied that at times the mother highly influences the behaviour of the infant, and additional activities like suckling and nursing hardly found in stallions accounted for the difference.

5.0 CONCLUSIONS

Grevy's zebras in Samburu community grazing lands are more of browsers than grazers. Based on the forage availability, herbs dominate the grasses cover making the area more ideal for browsers than grazers.

Grevy's zebras feed on diverse plant species and exhibit seasonal variation in food preferences, largely influenced by availability and quality of the food resource. During the wet season, they feed on more plant species than in dry season and prefer green plant parts over both seasons.

Indigofera spinosa, *Indigofera circinella, Sericocomopsis hildebrandtii* and *Cyperus rotundus* are very important species for the survival of the animals in the community grazing lands. *Indigofera spinosa* and *Indigofera circinella* contributes the highest percentage of their diet while *Sericocomposis hildebrandtii* and *Cyperus rotundus* are the most preferred species during the wet and dry seasons, respectively.

Food intake rate as well as feeding time among the Grevy's zebra is influenced by food resource patchiness and increases during the wet season. Mares tend to feed more than the stallions and infants. In addition, Grevy's zebras drink early in the morning later in the afternoon and at night when the water points are not actively utilized by pastoralists.

Daily total time budget for mares, stallions and infants does not differ significantly for different activities, but hourly time budget does within and among the animal categories during wet and dry seasons. However, feeding and resting are the major activities which claim a lot of time regardless to season. Feeding among Grevy's zebra never ceases completely throughout the day and it is intense early in the morning and late afternoon over both seasons.

Resting is high and prolonged during the dry season than in wet season. Nonetheless it is at the peak at the mid-day hours in both seasons, but over the dry season, peak resting is realized as early as 1000 h. Infants rest more than the stallions and mares and mostly by

lying down rather than standing unlike the adults and juveniles. Vigilance is high during resting with mares and stallions more vigilant than the infants. Moreover, vigilance is maximized by resting while facing in different directions.

In Barsilinga, Ngaroni and Ngutuk Ongironi, herbs dominate grasses in cover and diversity. However, Barsilinga has the highest and best forage than Ngaroni and Ngutuk Ongironi, but forage increases over the wet season depending on rainfall and utilization by livestock. The range condition of the study area is deteriorating as indicated by presence of invasive species (Plate 3) and severe erosion (Plate 7).

In Samburu community grazing lands, Grevy's zebras group sizes, composition and types are highly influenced by spatial and temporal availability of forage. However, mixed herds and territorial males are common group types over both seasons. Nonetheless, mixed herds dominate the wet season and mask the other group types.

6.0 RECOMMENDATIONS

- Grevy's zebra share common food resources with livestock in pastoral community in Wamba area, both the Grevy's zebra conservationists and the community need to formulate grazing systems which will allow a balance in forage availability and utilization. This should in particular involve the elders who have the prime decision on forage use among the community in order to facilitate the formulation and implementation of the grazing system.

- As evidenced from the field observations (Plates 3 & 7), the area is becoming bare mostly because of overgrazing; hence steps in arresting the land degradation need to be taken. Proper stocking rate, reseeding programmes and other soil erosion control measures need to be considered to halt the severe soil erosion and gulley formation.

Plate 5. Gulley erosion as an indicator of habitat degradation in Ngaroni area in September 2005

- Water is scarce and poorly distributed, especially over the dry period, as such the concerned authorities should think of providing water resources throughout the year. Moreover, formulation of water use rules in line with Grevy's zebra water requirement and associated risk of drinking at night is necessary.

- Herders need to be educated on how they can coexist well with Grevy's in their community grazing fields. For instance, some of the Grevy's zebras encountered had their ears chopped off or notched by herders, which may interfere with the social behavior of the animal hence affecting other aspects of survival. At the same time, herders at times disturb these animals while herding as they view them negatively as potential competitors for forage with their livestock. Therefore, conservation education program involving all the stakeholders is necessary.

- The habitat in the three areas seems to be rapidly changing, as indicated by invader species (*Acacia lahai*, *Prosopis juniflora*, *Aristida sp*. *Solanum sp*. among others) and bush encroachment, not mentioning the suppression of grasses by woody species, continuous monitoring of forage availability is highly recommended. More research needs to be carried out on dispersal patterns as well as identifying the refuge zones of Grevy's zebra during the dry season which actually will enhance their monitoring and conservation. Such areas are critical habitats and require special attention to protect them from further degradation.

- Altogether, diseases impact on the Grevy's zebra survival in Samburu community grazing lands has not received special attention, as revealed in the recent anthrax outbreak. Therefore, more research on common diseases and their epidemiology need to be explored and control measures put in place.

- As Wamba area lies in the arid zones where climatic conditions are quite dynamic, long term studies in activity time budget and patterns need to be considered to give a diverse knowledge on how environmental change impact on the above parameters.

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8.0 APPENDIX

Appendix 1. Plants species encountered along the Grevy's zebra feeding tracks in both wet and dry season, indicating a choice for selection as food resource (N-implies not encountered, Y – encountered).

Species	Season encountered		Life form
	Wet	Dry	
1. *Amaranthus sparganiocephalus*	Y	N	Annual
2. *Aristida kenyesis*	Y	Y	Annual
3. *Barleria acanthoides*	Y	Y	Perennial
4. *Becium filamentosum*	Y	N	Perennial
5. *Blepharis edulis*	Y	Y	Perennial
6. *Boerhavia coccinea*	Y	N	Annual
7. *Brachiaria leersiodes*	Y	N	Annual
8. *Brachiaria xantholeuca*	Y	N	Annual
9. *Sida ovata*	Y	N	Perennial
10. *Cleome hirta*	Y	N	Annual
11. *Commelina africana*	Y	N	Annual
12. *Commelina echnosperma*	Y	N	Annual
13. *Commicarpus helenae*	Y	N	Annual
14. *Cucumis dipsaceus*	Y	N	Annual
15. *Cynodon dactylon*	Y	N	Perennial
16. *Cyperus compressus*	Y	Y	Annual
17. *Cyperus niveus*	Y	N	Annual
18. *Cyperus rotundus*	Y	N	Annual
19. *Dactyloctenium aegypticum*	Y	N	Annual
20. *Digitaria velutina*	Y	Y	Annual
21. *Eragrostis tenuifolia*	Y	Y	Annual
22. *Euphorbia acalyphoides*	Y	Y	Perennial
23. *Geigeria acaulis*	Y	Y	Perennial
24. *Hibiscus macranthus*	Y	Y	Perennial
25. *Indigofera circinella*	Y	Y	Perennial
26. *Ingigofera spinosa*	Y	Y	Perennial
27. *Ipomea mombassana*	Y	N	Annual
28. *Ipomea paolii*	Y	N	Annual
29. *Ipomea spathulata*	Y	Y	Perennial
30. *Justicia acaulis*	Y	Y	Annual
31. *Kyllinga flava*	Y	N	Annual
32. *Leptothrium senegalense*	Y	Y	Perennial
33. *Lippia somalensis*	Y	N	Perennial
34. *Lippiia caviodola*	Y	Y	Perennial
35. *Oroptenium capense*	Y	Y	Perennial

36. Pentanisia ouranogyne	Y	N	Annual
37. Polygala sphenoptera	Y	N	Annual
38. Portulaca waightai	Y	Y	Annual
39. Ruellia patula	Y	N	Annual
40. Sericocomopsis hildebrandtii	Y	Y	Perennial
41. Solanum coagulans	Y	Y	Perennial
42. Solanum incanum	Y	Y	Perennial
43. Acanthospermum hispidum	Y	N	Annual
44. Sporobolus pellucidus	Y	Y	Perennial
45. Tephrosia polyphylla	Y	Y	Perennial
46. Tetrapogon cenchriformis	Y	Y	Annual
47. Tragus berteronianus	Y	N	Annual
48. Tribulus terrestris	Y	Y	Annual
49. Pavonia elegans	Y	Y	Perennial
50. Abutilon mauritianum	N	Y	Perennial
51. Aristida adscensionsis	N	Y	Annual
52. Asparagus africana	N	Y	Perennial
53. Aspilia mossambicensis	N	Y	Perennial
54. Chloris ruxburghiana	N	Y	Perennial
55. Digitaria xantholeuca	N	Y	Annual
56. Eragrostis cilianensis	N	Y	Annual
57. Melhania velutina	N	Y	Perennial
58. Panicum coloratum	N	Y	Perennial
59. Pennisetum mezianum	N	Y	Perennial
60. Pupalia lappaceae	N	Y	Annual
61. Rynchosia minima	N	Y	Annual
62. Sansevieria volkensii	N	Y	Perennial
63. Seddra bagshawei	N	Y	Perennial
64. Heliotropium somalense	Y	Y	Perennial
65. Talinum portulacifolium	N	Y	Annual
66. Pavonia patens	N	Y	Perennial
67. Acacia tortilis (pods)	N	Y	Perennial