ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

DISTRIBUTION, POPULATION STATUS AND DIURNAL ACTIVITY PATTERN OF BURCHELL'S ZEBRA (*Equus burchelli* , Gray, 1824) IN YABELLO WILDLIFE SANCTUARY, SOUTHERN ETHIOPIA

A Thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment for the requirements for the Degree of Master of Science in Biology (Dry land Biodiversity)

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June, 2010

APPROVAL SHEET OF THESIS
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Chairman Signature Date

DEDICATION

This work is dedicated to my mother W/ro Zewditu Terefe, whom I owe a lot and my late father Regassa Jetu and my brother Takala Regassa. May the Almighty God grant eternal peace and rest to the soul of my departed father and brother, and health and longer life to my mother.

ACKNOWLEDGEMENTS

I am deeply grateful to my advisor, Dr. Solomon Yirga, for his whole-hearted guidance and encouragement throughout this work. I am indebted to Oromiya Forest and Wildlife Agency, for allowing me to carry out my study in the Yabello Wildlife Sanctuary. I also thank Abaya Woreda Education Bureau for their sponsorship to pursue my study.

I wish to express my gratitude to the School of Graduate Studies, Addis Ababa University for providing funds for this research and the Department of Biology for facilitating my work. My thanks also go to the staff of Yabello Wildlife Sanctuary, particularly W/ro Zewditu Dandansa and Ato Aman Dadessa allowing me to use the Sanctuary facilities including a vehicle. I would like to thank all the staff members of Yabello Wildlife Sanctuary for their full-hearted cooperation, particularly Ato Okotu Dida, Ato Sora and Ato Abdullah Mohammed for their extensive assistance in the field work.

My special thanks to Alemu Ejeta and his wife for the valuable advice and support they have offered me during the field work. Moreover, I am highly indebted to my friend, Solomon Belete for providing me his Laptop to finish my thesis writing and to Tesfaye Bekele for his moral support and encouragement.

A special word of thanks to Borena people who were so kind and willing to supply me with information on the status and distribution of Burchell's zebra in Yabello Wildlife Sanctuary and also for their support, motivation, constant encouragement, advice, friendship and love.

Among many individuals who contributed to the study, I especially wish to extend my sincere appreciation to Dula Waqassa and Guyo for their full cooperation in capturing the study area picture. I would like to extend my thanks to my uncle, Ato Geleta Terefa and his family for supporting me in the field work, without them staying in that area was difficult. I also thank all those who assisted me in one way or the other towards the completion of this work. Finally, I am particularly grateful to my sisters Rawi Regassa, Konse Regassa, Melesu Regassa, Hulagersh Regassa and my brother Tolassa Regassa, for full cooperation and valuable guidance.

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ABSTRACT

A study on the distribution, population status, and diurnal activity pattern of Burchell's zebra (*Equus burchelli*, Gray, 1824) was carried out in the Yabello Wildlife Sanctuary, Southern Ethiopia during October, 2009 – March, 2010 including wet and dry seasons. Distance sampling line-transect counting method was used to estimate the population status of Burchell's zebra in the study area. The objectives of the study were to provide information on distribution, population status and diurnal activity pattern of Burchell's zebra in Yabello Wildlife Sanctuary. Data were analyzed using SPSS computer soft ware package and compared using one-way ANOVA, t-test, Tukey multiple comparison test and paired t-test to see differences in seasonal and hourly time budget. The sex ratio of adult male to adult female was 1.00:1.27. Group size changed seasonally. The mean average group size was 12.5. Burchell's zebras are mainly grazers. The group composition of the animal varied with season, forming large herds during the wet season and dispersing in to smaller groups during the dry season. The average herd sizes of one male harem and bachelor stallion herd's were 7.8 and 5.3, respectively. The sex structure of Burchell's zebras was adult male 34.5%, adult female 43.7% and young unknown sex 21.84%. Age composition of Burchell's zebra comprised 78.2% adult, 13.0% sub-adult, 5.3 % juvenile and 3.5% foal. The age ratio of adult to young was 1:0.25 and 1: 0.32 during dry and wet seasons respectively. There was no significant difference in the age ratio observed during wet and dry seasons ($P > 0.05$). On average, 78.2% of the total population was adults and only 21.8 % constituted young. The diurnal activity pattern of the animal follows the general pattern of ungulates in the Yabello Wildlife Sanctuary, characterized by morning and evening activity peaks with a period of rest in the middle of the day. Distribution and vegetation utilization of the animal showed a marked preference for open grassland habitat. However, there was a seasonal change in the preference of habitat. The main threats of Burchell's zebras in the study are livestock grazing, habitat destruction and disturbances, bush encroachment, poaching and termite mount. The study recommends an effective and realistic management policy to control illegal human settlement and farming activities in the sanctuary.

Keywords: Activity pattern, Burchell's zebra, distribution, habitat preference, population status, threat, Yabello Sanctuary.

1. INTRODUCTION

Burchell's zebra is a member of the family Equidae comprising large, single-hoofed ungulates that are built for speed and long-distance movements (Estes, 1997). The name zebra is derived from the Italian/Portuguese form of the name that was given to a group of species in the Democratic Republic of Congo (Skinner and Smithers, 1990; Furstenberg, 2002). Gray first described it scientifically in 1824, based on a skin obtained by Burchel in the Kuruman district of the Northern Cape, South Africa (Grubb, 1999). According to Groves and Bell (2004) zebras can be classified into three groups; Plains zebras (*Equus burchelli* or *Equus quagga*), Mountain zebras (*Equus zebra*) and Grevy's zebra (*Equus grevyi*). Burchell's zebras have six subspecies, Mountain zebras have two and Grevy's zebra has none.

Modern horses and zebras developed in North America and colonized Eurasia and Africa during the last 3 million years (Kingdon, 1997). At present, four of the six wild Equus species, including three zebra species, *E. burchelli* (Burchell's zebra*); E. zebra* (Mountain zebra); *E. grevyi* (Grevy's zebra) as well as the African wild ass *(E. africanus*), are confined to Africa (Estes, 1997; Furstenberg, 2002). Three of the four indigenous African equids are rare or restricted in distribution, while the Burchell's zebra rivals the horse as the most successful member of the family (Estes, 1997). At present, their distribution range is across the Somali-Masai arid zone through the southern savannah and marginally in the southwest arid zone, from southeastern Sudan to South Africa and Angola (Duncan, 1992b; Estes, 1997).

In Ethiopia, major populations of Burchell's zebra occur in Omo, Mago and Nechisar National Parks, as well as in Yabello Wildlife Sanctuary (Bolton, 1973; EWCO, 1995; Kirubel, 1985). Total population size of this species in the four protected areas was estimated to be around 2000 individuals (Duncan, 1992b). Since 1975, there was no effective protection in these parks, leading to heavy poaching (Graham *et al.*, 1996; Schloeder, 1996). Although Burchell's zebra is still by far the most abundant and widespread of all the African equids, several subspecies occur at low population levels and several are declining (Stuart and Stuart, 1997). Given the uncertain future of small, isolated populations of Burchell's zebra, some subspecies may well become vulnerable or endangered in the near future (Kingdon, 1997). While the cause of the decline of Burchell's zebra is not known, its incompatibility with modern agriculture and ranching

has led to its widespread extermination outside formally protected areas (Kingdon, 1997).

Burchell's zebra (*E. burchelli*) is considered to be one of Africa's most adaptable and successful grazers (Estes, 1991). Bennet and Hoffman (1999) and Fischhoff *et al*. (2007b) describe the social organization in equids as long-lasting non-territorial family groups with a stallion and one to a few mares with their foals, non permanent groups of bachelor or solitary males. Family groups can form unstable herds, which group of bachelor males also can join (Fischhoff *et al.*, 2007b). Burchell's zebra has a social system based on a family of 1 to 6 females led by a male. The home range of this species is 80-200km², with seasonal migration and daily change of locations to sleep, graze, roll in dust, rubbing against trees and drinking (Haltenorth and Diller, 1996).

Burchell's zebra utilizes a broad range of savanna habitats from treeless short grassland to tall grassland and open woodland (Estes, 1997; Stuart and Stuart, 1997; Kingdon, 1997). This species is equipped to deal with both early flush and long tough stems. It is often the pioneer that leads the way into taller, more wooded or wetter pastures and prepares it for the wildebeests, gazelle and other associated antelopes. Like other ungulates, it also frequents water bodies (Duncan, 1992a; Estes, 1997; Kingdon, 1997). Burchell's zebra is seldom found more than 10 to 12 km from water, and it moves daily between its preferred grazing and water supplies. Ecologically zebra is a pioneer in the grassland community where Wildebeest and Thomson gazelles follow once the zebras have broken down and opened up the dense stands of grassy stems by grazing and trampling. This activity makes the vegetation to be shorter and remove the older growth layer of lignified stems and seed heads to stimulate tender and nutritious new growth for selective grazers (Beekman and Prins, 1989). Thus, Burchell's zebra plays a great role in assisting the latter members of the succession within grazer community and enrich the variety and numbers of herbivores that could be sustained in the grassland ecosystem (Owaga ,1975).

Burchell's zebra is a diurnal species. Its activity patterns can vary depending on seasons, the animal's sex, age or reproductive state. According to Kamler *et al*. (2007) and Joubert (1972), there are many factors that can influence the activity pattern of an animal such as temperature, climate, biological cycles, light and darkness, feeding bouts, phases of the

moon, time of day/year, interactions and predation risks. The time Burchell's zebra have to spend on feeding every day can depend on different factors such as its requirements of nutrients and energy, the availability of digestible food and at what rate the food can be ingested (Beekman and Prins, 1989).

Burchell's zebra is the only equid which is still undoubtedly wide spread, and it is one of the most abundant ungulates in Africa (Cumming, 1982). The species is a useful model for the conservation and management of the other equids, some of which were as abundant and widespread in historical times. An understanding of the economic and ecological factors which contribute to maintaining the abundance and the genetic diversity of this species will help to improve the status of the other equids.

The knowledge of distribution of animals in relation to their environment is essential to effective game management and range utilization control. Since habitat destruction due to overgrazing could reduce the fertility and growth rate of animals (Laws and Parker, 1968), the knowledge of distribution of animals in the habitat is of crucial importance in population control and habitat management. The major physical factors affecting the distribution of animals in any habitat are the availability of water, effect of fire, topography, temperature variability and relative humidity (Odum, 1971). In areas where artificial permanent waters such as dams and bore holes have been established, the distribution of ungulates which require water for drinking and wallowing is directly influenced by the presence of water (Field, 1970). Thus, water becomes an important ecological factor affecting the distribution of animals in such areas.

Many studies on plains zebras in the East and South African ecosystems were done during the 1960's and 1970's. As medium-sized herbivores, plains zebras are also considered to be an important component of African mammal communities, and a good knowledge of their ecology and demography is therefore essential for the conservation and management of these equid populations. The ecology and behaviour of zebras are well-known because of previous studies that mainly dealt with their particular social system, and also allowed comparisons between different populations and zebra species from East to South Africa (Klingel, 1967; Smuts, 1976; Monfort and Monfort, 1978).

2. LITERATURE REVIEW

2.1 Burchell's zebra (*E. burchelli)*

2.1.1 Taxonomy

Burchell's zebra belongs to the Order Perissodactyla, Family Equidae, and Genus *Equus* (Kingdon, 1997). Among medium-sized mammals, the equid family stands out in the crowd of herbivore species. Equids belong to the order Perissodactyla, which includes three families (Rhinocerotidae, Equidae and Tapiridae). During the Eocene and Oligocene, the Equidae constituted a very diverse group, including 350 species. Today only eight species remain in the wild (Fig. 1), with five of them in Africa (Groves and Bell, 2004). They comprise four zebras (*E. grevyi, E. zebra, E. hartmannae* and *E. quagga*), one African wild ass (*E. africanus*), two Asiatic wild asses (*E. hemionus* and *E. kiang*), and one wild horse (*E. ferus przewalskii*).

Groves and Bell (2004) also recognized six subspecies of the Plains zebra *(E. quagga*), based on coat patterns, skull metrics, and the presence or absence of a mane and of the infundibulum on the lower incisors (intergrades are observed) from the northern to the southern limits of its distribution: *E. quagga borensis, E. quagga boehmi, E. quagga crawshayi, E. quagga chapmani, E. quagga burchellii, and E. quagga quagg*a (now extinct). These different subspecies are characterized by variations in their stripe pattern that tends to include more brownish stripes in the southern part of their range.

There was some taxonomic debate over the correct specific name for the plains zebra. It is now firmly established that the extinct *Quagga* is a subspecies of the Plains Zebra (Rau, 1978; George and Ryder, 1986; Leonard *et al*., 2005). The scientific name of the Plains Zebra has been changed from *E. burchellii* into *E. quagga*. A recent genetic study analyzed 17 Plains Zebra populations, representing five of the six subspecies (Lorenzen *et al*., 2008).

The study found very little differentiation among the populations. The five sampled Plains zebra subspecies, which included the extinct *Quagga*, could not be distinguished with the genetic markers used and no genetic structuring was found indicative of distinct taxonomic units. The molecular data represented a genetic cline and was differentiated along an east to south gradient in agreement with the progressive increase in body size

and reduction in stripes towards the south. This is consistent with the overlapping morphological parameters and geographical distribution of the subspecies reported in literature. Hence, the subspecies splits based on the morphological cline may be arbitrary, but are useful from a management perspective (Hack and Lorenzen, 2008).

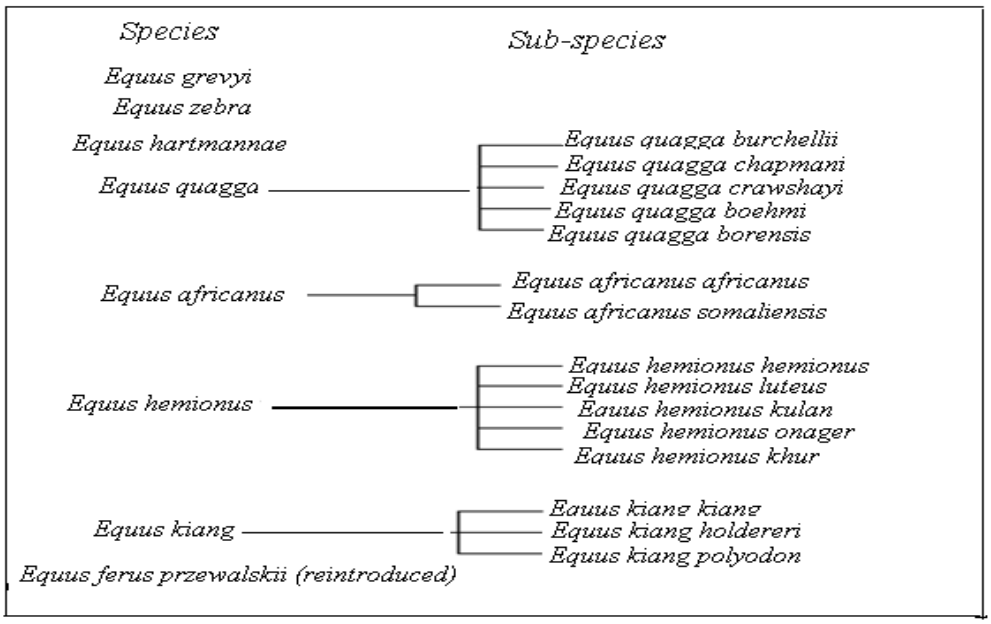

Figure 1. Taxonomy of wild Equidae (Groves, 1974; Groves and Bell, 2004).

A genetics-based taxonomy of the plains zebra has not been fully resolved and there is lack of consensus among traditional taxonomists for this species (Groves, 1974; Kingdon, 1979; Skinner and Smithers, 1990). Current plains zebra taxonomy divide the species' range into contiguous units, each home to a morphologically distinct subspecies. The most conspicuous morphological differences include body size and the width, intensity, and coverage of dark stripes on the adult pelage. Generally, the extent of stripe coverage decreases as one moves from north to south, although variation in stripe patterns within any particular population can be large and even include variants more characteristic of other subspecies (Kingdon, 1979).

Body size follows a similar north south cline, with *E. b. antiquorum* in the south averaging 28–40% larger than *E. b. grantii* in the north (Smuts, 1975). Small differences in teeth and cranial characters also separate some subspecies (Groves, 1974).

2.1.2. Description

Burchell’s zebras are easily recognizable, with their distinctive black and white stripes. The color is ochery or off-white, but never pure white. The shadow stripes are usually well marked, and the leg stripes are absent or poor, and almost never complete to hooves. The mane is well developed (Moehlman, 2002).

The patterns of their stripes differ from other species of zebras. Their stripes are wider and more horizontal towards the flanks and rear of the body. The stripes on the neck to the forelimbs are vertical and continue in the mane, which is short and sticks straight up. In most populations, the stripes extend to the belly where they meet. Stripes on the limbs are narrower and horizontal and continue until reaching the hooves. Facial stripes are ordered both horizontally and vertically creating beautiful patterns. Within the species, geographical variation in the pattern of stripes exists. In the southern regions, populations tend towards fewer stripes, with a disappearance on the rear, limbs and belly. They also have longer manes and tend to have stripes that are more buff and brown in color. Each individual's stripe pattern is unique and acts as an identifying characteristic similar to fingerprints in human beings (AWLF, 2008; Eltringham, 1979; Groves, 1974; Moehlman, 2002; Nowak, 1991).

Burchell's zebras (*E. burchelli)* of both sexes stand around 217 to 246 cm in length, with tail lengths of 47 to 56 cm. At the shoulder, their height is 110 to 145 cm. Males are slightly larger in size (320kg) than females (260kg) and usually have thicker necks as well (Plate 1). Both sexes have a black stripe running vertically between their hind legs; in males, it is narrow and wide in females. Females have one pair of mammae between their hind legs. Newborn foals weigh 32kg and have shaggy fur with brownish and buff stripes. The tail of Burchell’s zebra differs from other equids because they are short and end with a black tuff of hair (Estes, 1997; Holland, 2003).

Plate 1. Adult Burchell's zebra stallion (Photo: Author November, 2009).

2.1.3 Distribution

Burchell's zebra *(E. burchelli)* is the most widespread and abundant equid (Duncan, 1992a; Moelhman, 2002), with a current range covering eastern and southern African countries, from the southern Sudan in the north to Namibia in the west and South Africa in the south. The geographic range of Burchell's zebra spreads throughout southeastern Africa, with the highest population density in the Serengeti-Mara plains of Kenya and Tanzania. Their range reaches as far north as southern Ethiopia and Sudan, as far South west as Namibia, and as far south as the northern regions of South Africa. There are also populations in Uganda, Rwanda, Botswana, Zimbabwe, Zambia, Mozambique, and Malawi (Groves, 1974; Grubb, 1981; Moehlman, 2002).

At the beginning of the 19th century, and prior to the extensive European colonization of sub-Saharan Africa, Burchell's zebra ranged throughout most of the eastern, southern, and south-western regions of the continent. Although this species may have occurred as far north as Algeria at the beginning of the Neolithic period (Groves ,1974), by the 1800s none were found further north than southern Ethiopia and southern Sudan, east of the Nile River (Groves ,1974 ; Kingdon,1979).

Historical range included Kenya, Tanzania, and Sudan, with peripheral populations in Somalia, Uganda, Burundi, and Rwanda and continued south through Malawi, Mozambique, Zambia, Zimbabwe, northern and eastern Botswana, Swaziland, Lesotho, and South Africa as far south as the Orange River. They were also historically found in the south-eastern Democratic Republic of Congo (formerly Zaire), and extended westward and south through southern Angola and northern Namibia. This species is now extinct from countries such as Burundi, Lesotho and Angola. Currently the global population of Burchell's zebra resides only in Kenya, South Africa, Tanzania, Zambia, Zimbabwe and Ethiopia (Campbell and Borner,1995; Moehlman, 2002).

2.2 Ecology and behaviour

2.2.1 Ecology

The ecology and social behaviour of Burchell's zebras are well studied (Ginsberg & Rubenstein, 1990; Klingel, 1969; Rubenstein, 1986). Burchell's zebras are almost exclusively grazers, and are therefore mainly associated with open habitats like grasslands and savannah woodlands. In most African parks, Burchell's zebras coexist with grazing bovids of similar body size such as blue wildebeest (*Connochaetes taurinus*) and African buffalo (*Syncerus caffer*).

In contrast to the antelopes and other ruminants that comprise the main consumers of grass on the African savannas, Burchell's zebra utilize a hind-gut digestive system that allows them to process their food at relatively faster rate. Consequently, coarse vegetation of low nutritional value can sustain zebras as long as it is abundant, whereas similarly sized ruminants would starve on the same diet (Duncan, 1992b). This critical difference in digestive systems has at least three important implications.

First, by being able to exploit a greater range in fodder quality, plains zebra occupy a more extensive geographical range, a larger variety of habitats, and reach higher densities in some of the poorest grasslands than most other ruminants of equivalent size. Second, this ability to subsist on low quality forage, when combined with relatively large body size and its concomitant lowering of transport costs, enables Burchell's zebra to undergo large migrations to track changing resources. Thirdly, Burchell's zebra typically move into a grassland ahead of other grazers and, by removing the older growth layer of

lignified stems, sheaths, and seed heads, open it up to grazing by the more selective ruminants, such as wildebeest and Thompson's gazelle, which concentrate on the tender and nutritious new growth (Owaga, 1975). Thus, Burchell's zebra play a key role in initiating the pattern of succession within the grazer community, thereby enriching the variety and numbers of herbivores (Bell, 1971).

2.2.2 Habitat and home range

Burchell's zebra occupies the savannas of eastern and southern Africa through the Zambezian region to South Africa (Hack and Rubenstein, 1998). They prefer habitats with more annual rainfall as well as more accumulated vegetation than other equid species (Bauer *et al.*, 1994). This preference is most likely due to the large amounts of food the zebra requires. Burchell's zebras roam the open savannas of south and eastern Africa. They prefer the savannah ecosystem that range from open grasslands, open woodlands, and open scrub environments (Kingdon, 1997;, 2002). Occasionally, they may also inhabit taller grasslands, heavier woodland areas, and even hilly country and mountainous regions up to 4,400 meters in elevation. However, they avoid dense forests, deserts, and wetland areas (Eltringham, 1979; Grubb, 1981).

The home range of Burchell's zebras is dependent on necessary resources, mostly the availability of fresh water and grazing areas. Herds are non-territorial and occupy overlapping home ranges. Typically, groups occupy ranges of 300 to 400 sq. km in the wet season and 400 to 600 sq. km in the dry season. They travel up to 13 kilometers daily between resting areas in tall grasslands and grazing areas in short grassland areas. However, the necessity for fresh water and grazing lead to movements of 100 to 150 km seasonally. Their social spacing during migration is very similar to pure nomadism, with no spatial boundaries at all (Underwood, 1983; Estes, 1991).

2.2.3 Food and foraging

Burchell's Zebras are predominantly grazers but, will occasionally browse, eating primarily grasses, and focusing more on quantity rather than quality of food (Bauer *et al.*, 1994). They graze for up to sixteen hours a day due to the ineffective way digest food (Hack and Rubenstein, 1998). The grasses required by the zebra are abundant and evenly distributed which means lack of competition while foraging. Females also do not compete

while foraging because it reduces the amount of time spent grazing and thus, reduces their reproductive success. Zebra must go to a water source once a day, which is where aggressive encounters are more likely to occur (Rubenstein, 1993).

Burchell's zebra is non-ruminant, non-selective and roughage grazer, which feeds on both short young shoot and long flowering grasses (Arsenault and Owen-Smith, 2002; Bell, 1970; Owaga, 1975). They eat the coarsest part of the grass, which is relatively low in protein (Moss, 1982). Most of their diet (90%) comes from the stems and sheaths of short grasses, of which the especially favored ones are *Themeda triandra, Cynodon dactylon, Eragrustis superba,* and *Cenchrus ciliaris* (AWLF, 2008; Eltringham, 1979). As equids, zebras are hindgut-fermenters and use a different strategy to extract energy from their food resources compared to ruminants (Rubenstein, 1986). The wildebeest and the gazelle will often follow behind the zebra eating the shorter blades of grass and the new sprouts the zebras leave behind (Stevens, 1994). As other water-dependent species, they generally stay close to water sources (Bell, 1971; Estes, 1991; Skinner and Smithers, 1990).

2.2.4 Social organization

The social system of Burchell's zebra has been well studied (Klingel, 1967; Smuts, 1976; Monfort and Monfort, 1978). Burchell's zebras are highly social animals. Like the mountain zebra and horse, the basic unit in Burchell's zebra society is the 'harem', consisting of a single adult male, one to six adult females, and both sexes of offspring up to the age of 2 to 3 years (Klingel, 1969; Rubenstein, 1986). The social organization of the Burchell's zebra is divided into two groups: harem and bachelor. Bachelor groups average three males without a dominance hierarchy. The harem group is made up of unrelated individuals and averages seven members with strong personal bonds existing among members. The alpha male is the most dominant member then descending to the newest acquired female at the bottom of the hierarchy. Mutual grooming among members helps strengthen the bonds in the group (Moss, 1982).

The most dominant female, generally the oldest, leads the family to different areas to graze and obtain water (Ciszek, 1996). Males without a harem group live in bachelor herds or, although very infrequently in solitary (Klingel, 1969). The harem is the only group to have a dominance hierarchy, as there is no evidence of a dominance hierarchy

among stallions. Stallions will fight when one comes too close to the harem of another. The harem is a strong motivating factor in an aggressive encounter and a stallion will generally win a fight when his harem is in jeopardy (Schilder, 1988).

The zebras in a harem group recognize one another by voice, stripe pattern, and scent. The permanent harem society benefits Burchell's zebra because the male defends the females while they obtain the nutrients they require through grazing. The female zebra must travel a fair amount to acquire all the resources needed, making it more beneficial for a stallion to defend a group of females rather than a territory to attract females (Hack and Rubenstein, 1998).

The strong bonds between females are the central relationships within the harem. If the dominant stallion leaves or is killed, the harem will remain together for years waiting for another male to take over (Klingel, 1969). A dominance hierarchy is present in harems and employs a rank order of the dominant male, followed by the mares, and then the foals. The dominant female preserves the rank order by leading the group in single file movements, in which mares line up according to age correlated rank. Foal rank depends on mother's rank, they stand one place directly behind her in the line and the newest mare of a harem takes the lowest social rank and is placed at the end. The stallion pulls up the rear of the line taking a defensive role in case of predator attack (Fischhoff *et al.*, 2007a; Groves, 1974).

Foals leave the family group when they reach 1 to 4 years of age. Some males leave as early as 9 months old, joining bachelor groups. Bachelor groups may have up to 16 members, but are generally composed of only a few males. They are usually formed by young bachelors, but may also have older stallions no longer part of a family unit (Grubb, 1981; Nowak, 1991). Several harems come together to form large herds during their migratory journeys. Relationships between harems are relatively cordial and males have a ritual greeting. When they meet, males keep their ears standing up and sniff each others' bodies, especially their neck, nostrils, flanks, and tail. Females from other harems tend to be antagonistic towards each other (Anderson, 1992; Holland, 2003; Poole, 2006).

2.2.5 Communication and Perception

Six calls and two facial expressions are generally used in communication between individuals. Three of the calls are used as predator alert or threat calls, one is used to communicate injury, another is used in distress, and the last one is used in contact between individuals. Additionally, Burchell's zebras are able to visually recognize each other based on stripe patterns, which are unique to an individual zebra comparable to a fingerprint in humans. Stallions of different groups greet each other with their ears up. When they sense threat, especially in the form of combat, they will put their ears down. Greetings are also achieved through nose sniffing, rubbing, and genital smelling (AWLF, 2008; Groves, 1974).

2.2.6 Reproduction and Sexual behaviour

Burchell's zebra reproduce polygynously where by a single stallion may collect up to ten mares in a harem (Klingel, 1969; Rubenstein, 1986). In female defense polygyny, the females live in social groups that inhabit ranges too large for one male to control. Instead, males may follow the female groups and defend them. Adult stallions herd and protect their harems, which consist of 2-5 mares and his offspring (Estes, 1991). Adult female plains zebra *(E. burchelli)* live in fixed membership groups and associate with only one male. As a result, plains zebra mares mate with one male and are monandrous (Klingel, 1969).

The stallion defends the females in his harem and in turn these females mate only with that stallion. Polygyny is the preferred mating system of Burchell's zebra, because of the great distance the zebra must travel to obtain the large amount of food they require. If a stallion simply defends a territory there would not be enough food to support the females and their offspring. Due to the large distances the females must travel in combination with the large home range they occupy, the numbers of females that could come in contact with a male stationed in a territory could be very few. Thus, by defending a group of females, the male is guaranteed matings (Nowak, 1991; Pluhacek *et al*., 2006).

There is no a specific breeding season for Burchell's Zebra, although there is a peak during the rainy season (Stevens, 1994). Burchell's zebras can breed throughout the year. Most foals are born during the rainy season, which occurs from October to March in East

Africa. The peak number of births occurs during the month of January. When preparing to give birth, mares separate from the rest of the herd to hide from predators. While giving birth, foals and their mothers are extremely vulnerable to predation (Eltringham, 1979; Fischhoff *et al*., 2007a; Groves, 1974).

The female zebra can give birth to one foal per year from ages 3.5 to 18 years (Klingel, 1969). After a foal is born, there is a period called imprinting where the mother must chase off any other animal, including family members, to allow the foal to learn the stripe pattern, voice, and smell of its mother or else the foal will follow any moving object. This is an important occurrence, as females will not care for foals other than their own. Both the young males and females leave their natal herd. The male joins a bachelor group before forming his harem, while the female is kidnapped into a new harem (Stevens, 1994).

Young reach independence after 1 to 3 years, when they leave their natal group. After 16 to 22 months, foals reach sexual maturity, but neither males nor females will mate immediately. During this time, females have their first estrous and are “abducted” by outside males competing for them. Males will also leave the natal group at this time, when they roam with a bachelor group of males. If their mothers have another foal, they will leave earlier around the age of 1 year old, but most males leave by the age of 2 years. Young males in bachelor groups play and engage in mock fights, preparing for future fights when they begin searching for available mates and starting their own harems. When they reach 4 years, males are finally prepared to fight for mates and establish a harem. The inter- birth interval for Burchell's zebras is two years (Fischhoff *et al*., 2007a; Groves, 1974).

The estrus behavior in a young mare may be prevention against inbreeding as it attracts the attention of numerous stallions. The stance of a mare in her first estrus is very noticeable, which causes many males to take interest in her (Moss, 1982). The young mare stands with her legs slightly apart and her tail lifted straight up into the air. The mare's father will try to prevent her abduction, but is generally overwhelmed by several males at once (Klingel, 1969). She is eventually kidnapped from her natal harem by a stallion, but will change harems a couple of times before she becomes pregnant.

The harem in which she becomes pregnant becomes her permanent harem (Moss, 1982). Male foals often have a good relationship with their father and are not generally forced out of their natal harem, but leave on their own for a number of reasons. The possible reasons for a male leaving his natal herd includes: the foal's mother having a new foal, there are not any foals of the same age to play with, or a nearby bachelor group has foals of the right age to play with (Moss, 1982).

Mothers provide the primary care for their young, while the male is busy protecting and defending the harem. Foals weigh about 32 kg when born and are well developed at birth, able to follow the mother back to the herd within a couple of hours. Within 10 or 15 minutes the foal can stand on its own feet and within an hour it can walk around and even run. Foals start to eat grass when they are one week old. Weaning is around 7 to 11 months but females may lactate up to 16 months (Eltringham, 1979; Fischhoff *et al*., 2007b).

2.2.7 Lifespan/Longevity

In the wild, Burchell's zebras live an average of nine years. In captivity they can survive up to 40 years. Population growth and average longevity is most severely impacted by predation. Whereas other grazing herbivores such as gazelles and wildebeests are limited by the abundance of grass, Burchell's zebras are limited by the abundance of predators. Foals are especially vulnerable with 50% of juveniles annually dying due to predation. This high rate of juvenile mortality is also partly due to disease, death of mothers, low nutrition and drought (Anderson, 1992; Moehlman, 2002; Pluhacek, *et al*., 2006).

2.2.8 Predators

Medium-sized herbivores are generally the main prey species of lion, *Panthera leo,* and spotted hyena, *Crocuta crocuta* (Schaller, 1972; Kruuk, 1972). Lions are the major predators of Burchell's zebras, following the surprise attacks. However, the impact of predation can be considered as low due to the severe reduction of their densities as a result of poisoning lion by local people to protect live stock predation (Williams, 1998). In areas where density of lion (*Panthera leo*) is high, their impact on Burchell's zebra populations is profound. Hyenas, wild dogs, leopards, and cheetahs are their minor predators. Humans are becoming increasingly dangerous predators, as farmers view the zebras as competitors with livestock (Stevens, 1994). Leopard and cheetah are known

predators of the young and crocodiles predate upon adults as well (Rowen and Ginsberg, 1992).

2.2.9 Survival tactics in the wild

Group living is favored in the presence of concentrated predators. By living in a large herd, the chance of any one individual being eaten is greatly reduced (Rubenstein and Wrangham, 1986). Burchell's zebra often graze in large herds made up of many harem groups, which again, reduces the chance of any one individual being killed by a predator (Ciszek, 1996). In aggressive encounters the zebra will try to bite the legs of the opponent, neck wrestle, kick with legs, or bite the face and neck (Gomez-Garcia, 2000).

When threatened by predators, Burchell's zebras emit a high-pitched alarm call of the repeating two syllables "Kwa-hi". Mares protect their young foal, while stallions defend their harem with powerful kicks, pushes, and by biting at predators. During the night, at least one member of the harem remains awake hiding in tall grasses to guard and keep an eye open for nearby predators. Their black and white striped body patterns are also anti-predatory adaptations, providing camouflage during the night time and under dim light. By blending together to look like a gray mass from a distance, the black and white stripes also make it difficult for predators to single out individuals to attack within the herd, a form of disruptive coloration. Also, an individual's stripes make it difficult for predators to discern between the zebra's body and the surrounding vegetation (Ruxton, 2002; Lindblad, 1994).

Burchell's zebra utilize two selfish herds: that of their own harem and species, and that of a larger heterospecific aggregation while migrating. This second type of selfish herd includes wildebeests, gazelles, and other, animals. Traveling in such a large, diverse group means that they have more alarm calls to be aware of, and there are more animals available to vigilantly scan for predators. In addition, wildebeests are the preferred prey of lions, as compared to zebras, so it would benefit the zebras to mix herds with them (Scheel, 1993). When a member of the group is wounded, Burchell's zebras will surround the predator in a circle, biting and kicking until the predator succumbs or flees (Fischhoff *et al.*, 2007; Groves, 1974).

2.2.10 Ecosystem Roles

Burchell's zebras play an important role in the stability and dynamics of grazing communities where they live. They are an important portion of the east African ungulate fauna that make large-scale, 483 km migratory movements timed to the varying rainy season. They are the first to move in during grass succession, chomping down on old growth and stems, which keeps vegetation young and growing. This opens up grazing opportunities for blue wildebeests, gazelles, and topis, which are more picky about the vegetation they consume.

Zebra herds leave the grazing area during the dry season and in doing so trample the land and stimulate grass growth. This, along with their selection of grass stems, increases the quantity and quality of vegetation for following animal herds. The sheer number of Burchell's zebras gives them a fundamental role in grazing communities. Without zebras, the old vegetation would not be cut back and other grazing animals could not obtain the new growth and higher nutritional leaves they need to survive. Thus, Burchell's zebras are important in maintaining the immense diversity that exists in grazing communities (Eltringham, 1979; Moehlman, 2002; Nowak, 1991).

Burchell's zebras are hosts to several species of parasitic botflies. Botflies deposit eggs in the zebra’s skin, where the larvae mature until the pupa stage, when they leave the host body and continue development in the soil (Colwell *et al.*, 2005). They are nearly harmless to humans, except for their adverse effect on the livestock industry in Africa. As herbivores, they compete with livestock for water, grass and space. However, they also improve the health of grasslands through their use of tougher plant stems and grass (Moehlman, 2002).

Burchell's zebras are charismatic animals that attract many people to ecotourism. In certain countries in Africa, where other sources of income are unstable, ecotourism can provide a substantial contribution to the overall economy. Because of their distinctive stripes, zebras skins have been historically valuable and serve as an important commodity. Zebra meat provides food for local populations. Furthermore, as part of the native ungulate fauna of east Africa, they are critical in influencing vegetation dynamics, on which human, cattle and other domestics rely (Eltringham, 1979; Moehlman, 2002).

2.3 Threats and conservation status

Burchell's zebras are classified as Least Concern by IUCN (2008). Of all the wild equids, Burchell's zebras are the only species that are not severely threatened by extinction. The conservation status of the species shows low decline, although this species is already extinct in some countries (e.g. Burundi, Lesotho and probably Angola) where originally it was plentiful (Rubenstein and Hack, 2004). Habitat loss due to human activities and hunting (both illegal and legal) are the critical factors for its continual decline in major parts of its range.

Expanding settlements and agriculture are destroying their habitats and blocking their migratory routes. This caused the near extermination of Burchell's zebras from South Africa, Rwanda, and Angola (Rubenstein and Hack, 2004*)*. In areas where crop growth is difficult, Burchell's zebra populations compete for water and grass with domestic livestock. The presence of zebras near their livestock has led farmers and herders to hunting and fencing. The second primary threat Burchell's zebra face is from illegal hunting. Zebras are hunted for meat and for their skins. Zebra meat is eaten by local communities, so the hunting trade is locally and not internationally driven. Hunting tends to be a larger threat in the northern regions of the zebras' ranges, where political unrest is more common (Moehlman, 2002; Campbell and Borner, 1995).

Seventy-five percent of the Burchell's zebra population is in Tanzania and Kenya. Therefore, the global population is vulnerable to the stability of these countries. Civil unrest and political strife in these countries may have severe impacts on the long- term survival of them. Political instability corrodes the infrastructure of the park and wildlife reserve organizations needed to maintain ecotourism and conservation. Civil unrest also displaces people from their homes, spreading the range of their livestock into zebra territory and creating a greater demand for meat from the illegal trade (Moehlman, 2002; Poole, 2006). Duncan (1992a) suggests that in Namibia and Ethiopia, shooting to reduce competition with livestock, for profit, or both is a cause of declines in Burchell's zebra. In the present study area, the main threat of Burchell's zebra is loss of habitat and competition with people and livestock for space, water, and forage. Most wild mammals in developing countries are at risk due to a varity of factors in their natural habitats (Wilson *et al*., 1996). It is important for conservationists to have detailed information on impacts of ever expanding human populations in areas of rich wildlife populations.

3. OBJECTIVES

3.1 General objective

- The Objectives of the present study is to provide information on distribution, population status and diurnal activity pattern of Burchell's zebra in Yabello Wild life Sanctuary.

3.2 Specific objectives

The specific objectives of the present study are:

- To determine the current population size of Burchell's zebra in Yabello Wildlife Sanctuary.
- To examine the population structure of zebra in the Sanctuary.
- To describe diurnal activity patterns of Burchell's zebra at different time of the day and during wet and seasons.
- To determine Burchell's zebra herd size and group composition.
- To describe the distribution of Burchell's zebra in Yabello Wildlife Sanctuary.
- To provide information for the future conservation plan.

3.3 Research Questions

This study attempts to answer the following questions.

- What is the population status of Burchell's zebra in Yabello Wildlife Sanctuary and surrounding areas and how does it vary between seasons?
- What are the activities displayed by Burchell's zebra, their budget and pattern at different time of the day and season?
- Is there any variation in social groups of Burchell's zebra with season in the Sanctuary?
- How does herd size, group composition and types differ in different seasons ?
- What are the main patterns of movement of Burchell's zebra in relation to water, rainfall and plant productivity in space and time?

3.4 Significance of the study

Assessment of the current population status, distribution and diurnal activity pattern of Burchell's zebra is important for the management of the Sanctuary and will also provide some information on the existing knowledge gap on distribution of Burchell's zebras in Yabello Wildlife Sanctuary in particular and for protected areas of Ethiopia in general. More over, this study is expected to provide information on aspects of the ecology of Burchell's zebras in Ethiopia and gives base line information for further study on the species.

3.5 Beneficiaries of the research

- Yabello Wildlife Sanctuary is the immediate beneficiary of the research, to know local distribution and current population status of Burchell's zebra and the maintenance of the values and benefits obtained from the Sanctuary as well to meet the objectives for which it was established.
- Oromia Agricultural and Rural Development Bureau.
- Ethiopian Wildlife Conservation Authority to design sustainable way of natural resource conservation and management strategies in parks, so as to meet the objectives for which they were established.
- Other governmental and nongovernmental institutions that are concerned with wildlife conservation.

4. THE STUDY AREA

4.1 Location, Size and Topography

Yabello Wildlife Sanctuary is one of the protected areas and Wildlife Sanctuaries in southern Ethiopia. It is located in the Borena Zone of the Oromia Region, east of the town of Yabello. It was established in 1979 E.C. with an area of 2496 km^2 for conservation of endemic and other birds as well as mammals, which are found in the sanctuary. The Sanctuary lies between the meridian 4 ^{o} 37'- 5 ^{o} 12' N and 38^o 09'- 38 ^{o} 37' E (Fig. 2) and it has an approximate North-South distance of 65 km and 48 km East-West with an average altitude between 1800 to 2000m above sea level. The Sanctuary is 17 km away from the nearby town Yabello, 205 km far from the border town of Moyale, about 100 km from Konso and 565 km from Addis Ababa. The physical features of the Sanctuary is dominated by bush and range land.

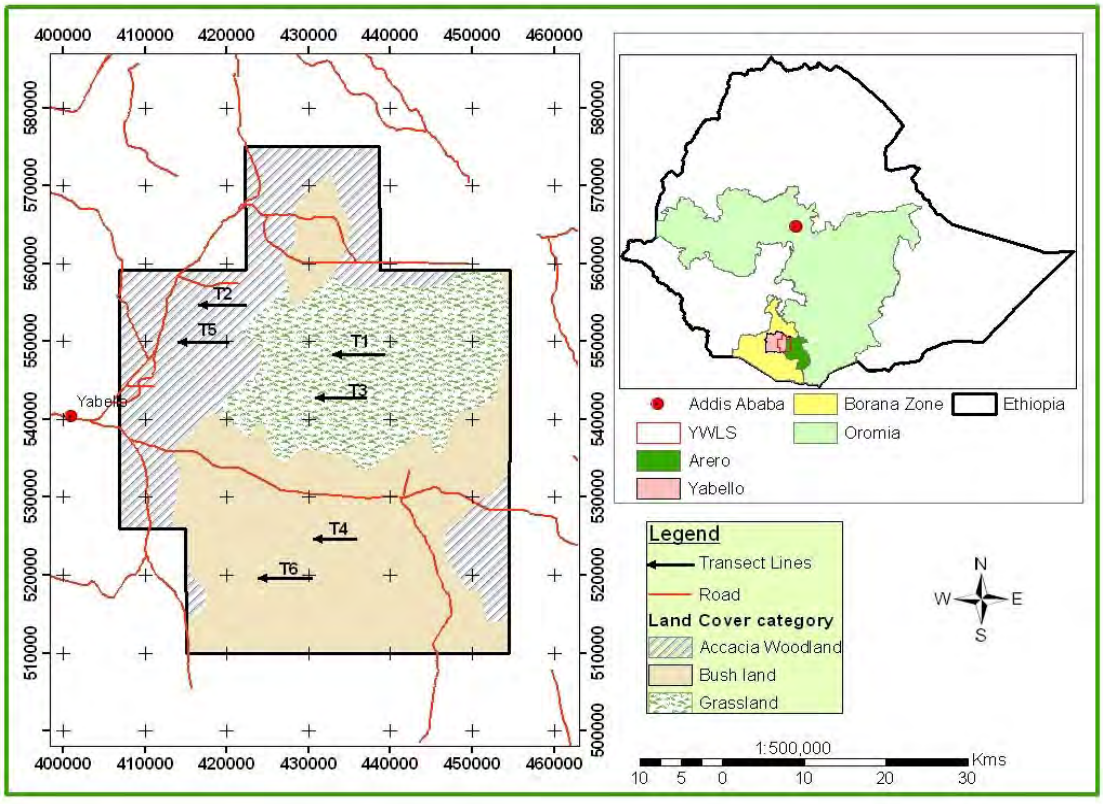

Figure 2. Map of Yabello Wildlife Sanctuary showing the transects (1-6). Inset: the map of Ethiopia showing the location of YWLS. YWLS = Yabello Wildlife Sanctuary.

4.2 Climate

Climate is one of the decisive factors affecting productivity mainly in arid and semi-arid ecosystems, such as Borana lowlands. Generally, the climate of Borana rangeland is typical of the equatorial regions of East Africa, but locally modified by altitude. The seasonal distribution of rainfall is almost entirely controlled by the annual north and south shifting of the Intertropical Convergence Zone that forms the northern boundary of the area of equatorial low pressure (Agrotec-C, 1974).

4.2.1 Rainfall

The rain fall regime in Borana dry lands is bimodal with two rainfall seasons. The main rainy season, known as the long rainy season is between March and May with the peak in April, and short rainy season is between September and November, with peak in October (Fig.4). Generally, rainfall decreases towards the southeast with increase in temperature and decrease in altitude. The major rainfall characteristics of the rangelands of Borana or low rainfall areas of East Africa in general are tremendous variability that occurs between years and localities (Agrotec-C, 1974). Such variability makes the rainfall arithmetical mean a very unsatisfactory way of expressing rainfall probabilities. The mean annual rain fall for the period 2000- 2009 was 612.36 mm. The peak mean monthly rainfall was in April (152.9mm) and October (127.6mm). The least mean monthly rainfall was in January (17.6mm).

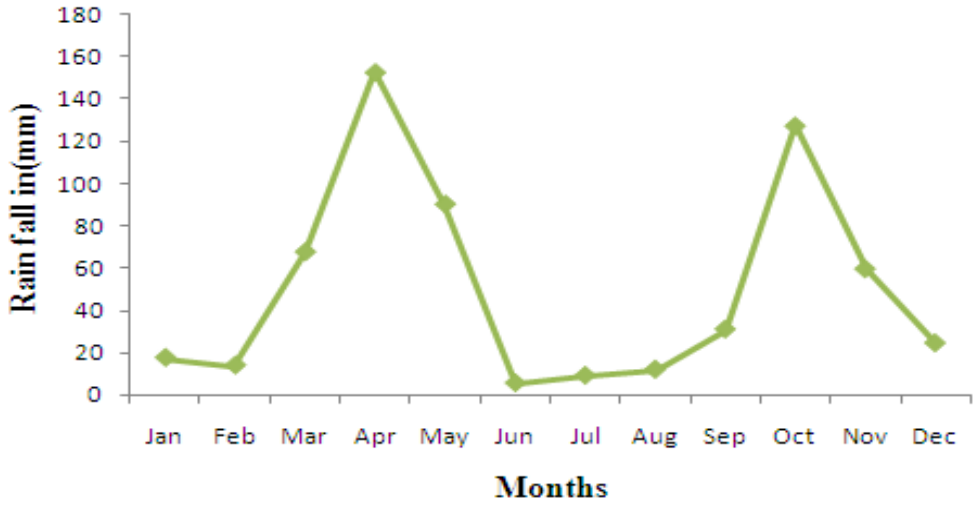

Figure 3. Mean monthly rainfall (mm) in the Yabello Wildlife Sanctuary during the years 2000-2009 (Source: NMAE, 2009).

4.1.2.2 Temperature

The hottest months were from January to February and temperature fluctuates between 27.9 to 28.9^{O}C. The weather remains pleasant between June-August. The mean annual maximum temperature was 28.9^{O}C. The mean annual minimum temperature was 12.2 ^{O}C.

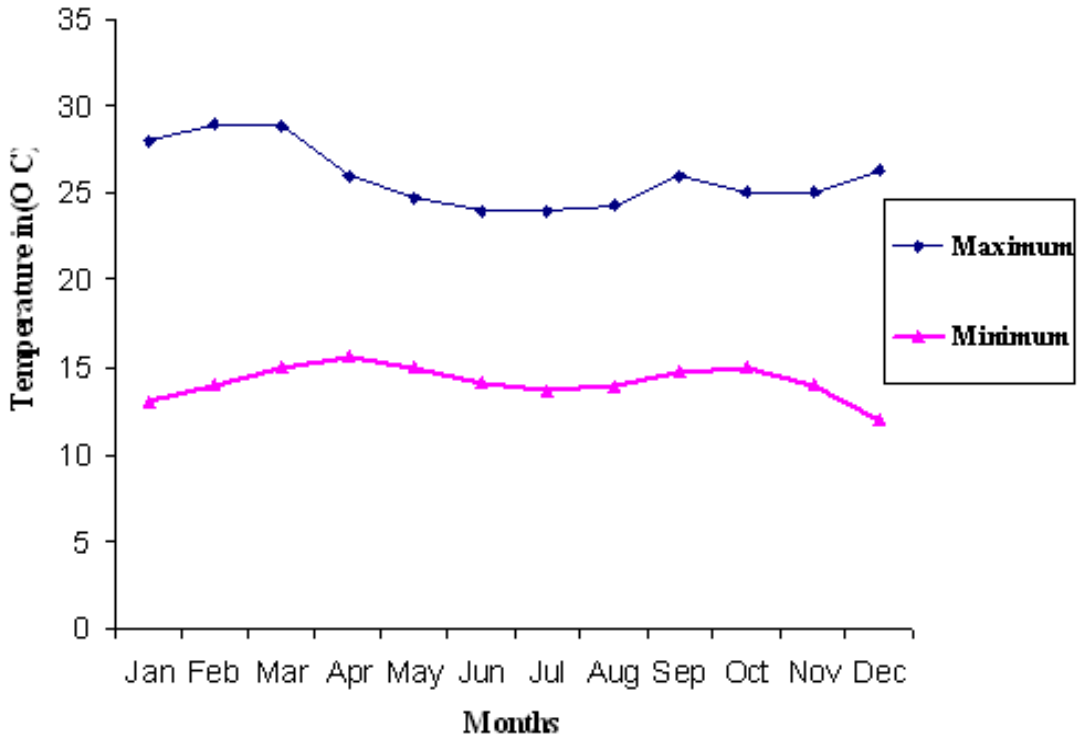

Figure 4 Average monthly minimum and maximum temperature in Yabello Wildlife Sanctuary during the years 2000-2009 (Source: NMAE, 2009).

4.1.3 Geology and Soils

Geologically the area is dominated by quaternary deposits (40%), basement complex formation at bottomlands (38%), volcanic (20%) and sedimentary deposits of 2% (Coppock, 1994). The soil is mainly red, ferruginous character in sloping areas and dark vertisols in the bottomland while the upland soils occurring elsewhere are well drained and usually have equitable proportion of sand (53%), clay (30%) and silts (17%) (Haugen, 1992). Vertisols are higher in organic matter and have clay content over 60% (Coppock, 1994). Compared with those on the red soils, black cotton communities are relatively decreased in species for some but not all groups in North Kenya. These types of

soils support most of the productive rangelands in East Africa (Young *et al*., 1997), and Coppock (1994) noted that the nutrient status is typical of tropical savanna. According to OBPED (2000), Yabello district is predominated by Chromic, Eutric and Luvisol soil types and they cover about 68% of the total area of district.

4.1.4 Vegetation

Borana lowland is mostly coverd with East African evergreen and semi-evergreen bushland and thickets along the high lying areas with relatively higher rainfall (Agrotec-C, 1974). The commonest habitat inside the Yabello Sanctuary is savanna woodland dominated by various species of thorny acacia (Appendix 1) (*Acacia tortilis, A. brevispica*, *A. horrida,* and *A. drepanolobium*) and *Commiphora,* and broad leaved *Terminalia* and *Combretum* (Borghesioand Giannetti, 2005). In addition, small patches of juniper (*Juniperus procera*) forest can also be found in high altitude just outside the boundaries of the sanctuary, although grazing and logging threaten its persistence (Borghesio *et al*., 2004).

In broad sense, *Combretum-Terminalia* (broad leaved decidious) woodland and *Acacia-Commiphora* (small leaved decidious) woodland are the two major vegetation types covering the Borana lowlands (Gemedo Dalle, 2004). The characteristic genera in the woodlands of Borana are of *Combretum* and *Terminalia*, whereas the bushlands and thickets, which covered the majority of Borana lowlands, are represented by species of the genera *Acacia* and *Commiphora*. Additionaly, species of the genera *Bosica, Maerua, Lanea, Balanites, Boswellia,* and *Aloe* are common **(**Coppock, 1994; Gemedo Dalle, 2004).

4.1.5 Human Population

Yabello has a population size of 61, 300 of which 49,768 rural (24,889 males) and 11,523 urban (5,763 male) dwellers. The district's population density was estimated to be 11 person per km^2 (CSA, 2007). The major town of the district is Yabello. Yabello, also spelled Yavello and Iavello, is located northwest of Moyale in the Borena Zone of the Oromia Region. An alternative name for this town is Obda**,** referring to a nearby mountain. The indigenous people of the study area are called Borana, the eldest branch of Oromo ethnic group in Ethiopia. They are mostly pastoralist (OBPED, 2000; Gemedo Dalle *et al.*, 2005).

4.1.6 Land tenure and landuse types

In Ethiopia, the government is the sole owner of the land. Farmers or landholders have only the right to use, which can be revoked at any time. Land use type in Borana can generally be categorized in to rangeland and farm lands. The dominant landuse is pastoralism by the Borana people, although settled agriculture (both commercial and subsistence) has increased in recent years (EWNHS, 2001, Borghesio and Giannetti, 2005). The basic source of income for Borana is livestock rearing and most of the land in the area is used as rangeland for their cattle. However, there is small scale agricultural practice whenever there is good rain. In most cases, non-timber forest product collection (NTFPs) and use in general and gum and gum resins, in particular is another dominant activity in the area, mainly during the drought season (Gemedo Dalle *et al*., 2005).

4.1.7 Fauna

There are some 38- 42 species of small and medium sized mammals. The sanctuary supports large concentration of Burchell's zebra and is one of the best places to see many other mammals. The Burchell's zebra is found in the sanctuary with Grant's gazelle and Gerenuk. It is one of the best places in Ethiopia to see Besia Oryx, Bohor reed buck, Bush pig, Hare, Guenther's dik-dik, Greater and Lesser kudu and Warthog. Carnivores including Lion, Leopard, Cheetah, African wild dog, Golden jackal, Serval cat, Side striped jackal, spotted hyena and Anubis Baboons are common (Appendix 2)

There are some 280 species of birds recorded from the Sanctuary (Appendix 3). These include two endemic birds of the sanctuary. The Ethiopian Bush-crow (*Zavattarions stresemanni*) (Plate 2) and White-tailed swallow (*Hirundo megaensis*) are the endemic birds of the sanctuary. The other endemic bird is the Prince Ruspoli's Tauraco (*Tauraco ruspolii*), which is found in Borena zone around Arero Junper forest (Bobela forest) to Dawa river. Ostrich is also found in and out of the sanctuary.

4.1.8 Water sources

In Yabello Woreda as a whole, there is a shortage of water both for human and cattle. The only water source of the area, especially around the Sanctuary, is rains. The rainwater, which is obtained during the rainy season, is accumulated in manmade ponds. This can be used for two years or more after the end of the rainy season. During the rest of the dry season, the local people and their livestock are subjected to go long distances to

get water. In general, water deficit is observed throughout the Woreda and specifically in and/or around the Sanctuary.

Plate 2. Ethiopian Bush-crow (*Zavattarions stresemanni)* in Yabello Wildlife Sanctuary (Photo: Author January, 2010).

5. MATERIALS AND METHODS

5.1. Data collection

Data collection was carried October, 2009-March, 2010. Reconnaissance observations were made before data collection to have deep information on accessibility, climate, vegetation cover, topography, infrastructure, fauna, distribution of Burchell's zebra and launching sampling plans. A research design was established depending on this initial observation. The actual data were collected by dividing the study period in to dry and wet seasons. Data collection was carried out from October to November, 2009 and March, 2010 to accommodate the wet season and from December, 2009 to February, 2010, to accommodate for the dry seasons with fragmented short term stay in the study area**.**

Seasonal differences in the population size, age categories and diurnal activity patterns of Burchell's zebra were compared. Separation of dry and wet seasons was based on the change of rainfall pattern and vegetation cover. Quantitative data were collected on the population size, age and sex categories, and habitat preference and vegetation utilization, distribution and activity patterns on the dry and wet seasons.

5.2 Population estimation

A Line-transect census method were employed to assess the current population status of Burchell's zebra as adopted by Ratti *et al*. (1983), Brennan and Block (1986) for different mammals and Yisehak Doku *et al*. (2007) for zebra. Line-transect sampling was designed based on six straight transect lines or a series of straight line segments (Anderson *et al*., 1979). Each of these transect-lines was 8km, long located randomly in the study area using Global positioning system (GPS). Among these, two were in the open grassland habitat, two were in the bush land and two were in the *Acacia* woodland.

Transects were placed by stratified random sampling approach in which transect placement was proportional to the area of this habitat type. Each adjacent transects were at least 1500m apart. All transects were roughly parallel to each other and their ends were not less than 1000m far from the habitat edge (Table 1). Silent detection method was practiced to minimize disturbances (Wilson *et al*., 1996). During transect walking, the observers recorded the start and end time, start and end GPS location, and GPS ID.

Whenever Burchell's zebras were encountered, the observer recorded the time, GPS location, group size, group spread, presence of other large mammal species in the vicinity, animal observer distance, transect-animal distance or perpendicular distance (PD) and habitat type where the group was feeding.

Censuses were conducted once per month on foot by the researcher and a well trained field assistant together with villagers who are familiar with the area. In the beginning of the study, the field assistant was trained to estimate animal - observer distance, and perpendicular distances. Surveys were conducted on transects starting from 06:00- 12:00 h in the morning and from 14:00 to 18:00 h in the afternoon at an average speed of 1 km/hr in the *Acacia* woodland and bushland or 2 km/hr in the grassland habitats.

The starting and ending GPS co-ordinates Census transects were predetermined and setup prior to starting the census. On census days, transects were walked from east to west (Figure 3). A GPS was used to walk along transects and the starting and ending co-ordinates were captured in to the GPS. Transects ran from east to west and walked as such to prevent the suns glare from distorting visibility. Starting and ending GPS co-ordinates with mean distances of each transect were recorded and are reflected in Table 1.

Table 1. Census transects for Yabello Wildlife Sanctuary with starting co-ordinates, ending co-ordinates and length of transects.

Transect	**Direction of traverse**	**Area size($km^{2)}$**	**Transect length (km)**	**Starting co-ordinate(x,y)**	**Ending co-ordinate (x,y)**
T1	East-west	12	8km	43576.2, 543462.2	435458.9 , 543624.6
T2	East- west	12	8km	435457.1, 543619.1	434981.5, 542867.8
T3	East- west	12	8km	437427, 543740.8	437656.2, 543724
T4	East- west	12	8km	434944.5, 542871.5	435841.6, 543850.9
T5	East-west	12	8km	435976.5, 543858.1	436571.5, 543842.9
T6	East-west	12	8km	432815.2, 525643.2	432118.5, 523665.1
Total		**72**	48	-	-

5.3 Population size and density

During the study, transects were covered systematically with a constant speed to maximize the probability of seeing all animals on the transect. A global positioning system (GPS) was used to follow straight-line by sighting of land markers on the line of travel as well as taking bearings to the objects relative to the transect line. Animals more than 300 m from the center line showed little reaction whereas animals within 300m showed variable responses, but were easily observed.

Perpendicular distance was measured accurately by using GPS. The study was designed and the data were analyzed to minimize the violation of the above assumptions and their effects. The censuses were conducted for both seasons (wet and dry) in order to achieve representative estimate. Any change in the population size between the dry and wet seasons was noted. The number of animals in the group, the sighting distance and perpendicular distance of the animal from the observer was recorded each time an animal or a group was spotted and the following estimation was made.

$$D = ns/2LW$$

Where

D = estimated density of animals (or animal groups)

n = number of animals (or animal groups) seen

s = mean group size

L = length of transect line(s)

W = mean perpendicular distance of animals (or groups) seen

The population size of Burchell's zebra was estimated by multiplying the population density (D) with total extent of habitat by the present study (A = 72 km^2), following the method of Buckland *et al*. (1993), Sutherland (1996) and Yisehak Doku *et al*. (2007).

$$N = D \times A$$

Where, N= Total Population Size

D= Population Density (individual per km^2)

A= Total extent of habitat by the present study (in km^2)

5.4 Age structure and Sex ratio

During the census of Burchell's zebra, detailed observations of the entire herd were collected (Appendix 4). This enabled to categorize them into their respective age groups.

Each of this individual in a group were identified and categorized in to its respective age and sex categories during counting. The categories used were adult male, adult female, sub adult, juvenile, and foal. To categorize the animals in to such groups, the works of Yisehak Doku (2003); Lewis and Wilson (1979); Bowyer (1984); Ndhlovu and Balakrishnan (1991); Bergerud (1971); Kingdon (1997) were followed. Identification of sex and age category were carried out in the filed by using body size such as the relative size, external genitalia and furry-hair as adopted by Klingel and Klingel (1966). Sex ratios for the herds were obtained from direct count of the animals using the methods of Woolf and Harder (1979); Melton (1983) and Mumin (1999).

Information on the approximate demographic composition and structure, such as age class and sex ratio, was used to predict the general trend of Burchell's zebra population whether it is declining, increasing or stable. Population trend of Burchell's zebra was also analyzed by comparing the present findings with the previous findings of different researchers conducted in Yabello Wildlife Sanctuary.

5.5 Group composition and size

Group composition and herd size were showed by using direct count and focal observation methods as used by Sutherland (2000) and Befekadu and Afework (2004) in the study of other animals. Repeated counting of the same herd or cluster was avoided using recognizable features such as cluster size, harem composition and distinct individuals with body deformities such as cut tail and ear (Wilson *et al.*, 1996). Thus, all herds were individually recognized. Following Lewis and Wilson (1979); Borkowski and Furubayshi (1998) for the study of different animals; individuals were considered as members of the same group if the distance between them was less than 50 m. Single animals are included within the term 'group' for the purposes of analysis (Arcese *et al*., 1995).

5.6 Diurnal activity pattern

Observations on diurnal activity pattern of Burchell's zebra were made using unaided eye and /or 8x30 binoculars (Appendix 5). Observation was facilitated by the animal's preference for short grass areas and by selecting strategic site on the hill, which enabled to observe even more than a group.

Focal animal sampling and scan sampling methods were used as adopted 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 numbers in selection of the focal animal. If focal animal is a group, scanning was done and the dominant activities in the group at the start of the observation were recorded. The activities recorded were feeding, walking, resting, standing, grooming and other activities. The latter included all activities that did not feature strongly in the general activity pattern such as playing, fighting, suckling and urinating. The diurnal activities were recorded in both dry and wet seasons in every 10 minutes in every hour during 06: 00 h to 18:00 h.

The activity of each individual zebra in each group under observation was recorded and ticked on the sheet at ten minutes intervals. When unique activity was observed, it was recorded on separate notebook. If the focal animals in the filed disappeared from view, the time intervals that the individual being observed out of sight was recorded. When the out of sight period was with longer duration than the duration of the common activities, it was deleted from the sample and duration of the sample period was deleted accordingly.

5.7 Distribution and Vegetation type utilization

5.7.1 Distribution

The location of each herd and individuals at each vegetation type was recorded. The method of Larson *et al*. (1978) and Norton-Griffiths (1978) was used to describe the dry and wet season distribution and the vegetation type utilization of the animal. By taking each group or individual sighting as scores with respect to habitat types and comparing their frequencies to the relative availability of vegetation type it was possible to detect the utilization of vegetation type and distribution of the zebra.

Intensive ground survey was carried out along the six transects in each of the monthly surveys in order to determine the distribution of Burchell's zebra. This was done in the morning 06:00-12:00 h and in the after noon hours 15:00h-18:00 h, three times per month in the wet season and the dry season.

5.7.2 Food preference

Food preference of the zebra was determined by a careful examination of the item consumed by the zebras as feeding sites (Martin, 1977). An animal was followed during active feeding time to observe the plant species that was consumed. For this, a focal animal was chosen and observed with the help of a binocular and/or naked eye depending on the distance of observation. After Burchell's zebra or group of Burchell's zebra have left the grazing site, the site was inspected and grasses consumed by them were recorded, freshly cut plants were carefully examined; samples were collected, and brought to a herbarium for identification.

5.7.3. Habitat preference

Habitat preference of Burchell's zebra was assessed via a combination of transect sampling in the three different habitat types and scan sampling on the selected study groups. During transect walking when Burchell's zebra was encountered, the habitat types were recorded on the basis of the dominant habitat of the area. In addition, the habitat types were recorded during scan sampling or activity time budget study, every 10 minutes.

5.8 Data Analyses

The data were analyzed using SPSS computer software program version 13. 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. Differences in seasonal and hourly time budget were tested using one way ANOVA, followed by Tukey multiple comparison test. Descriptive statistics was carried out to calculate frequencies, and to allow cross-tabulations.

A total of 20 days were used for the observation. Data from 20 days (dry and wet season) continuous contact provided 240 hours of quantified observation and 1,440 activity

records. Karl Pearson Correlation Coefficient test was used to see the interdependency of the major diurnal activity pattern of Burchell's zebras during their active hours of the day.

Group compositions were analyzed by working out the proportions of different animal categories, and then expressed in percentages. One way ANOVA was used to compare the wet and dry season population status of Burchell's zebra. Mann-Whitney U test was used to analyze data on differences between mean size of family harem and bachelor stallion herds. Further, the mean numbers of individuals during the wet and dry season were computed using independent sample t-test to see whether there is any significant difference in the population between the wet and dry season. Population estimation on each transect was compared using t-test ($p=0.05$). Animals counted under different seasonal conditions (dry and wet), sex and age category of the population were also compared using t-test for independent sample ($p=0.05$).

6. RESULTS

6.1. Population estimate

The results of transect counts for each month for both wet and dry seasons are given in Table 2 and Figure 5. Among 115 total herds of Burchell's zebra observed in Yabello Wildlife Sanctuary, 56 herds were counted during the wet season and 59 herds were observed during the dry season. A total of 396 individual zebras (obtained from 56 herds) were counted during the wet season and 524 individuals (obtained from 59 herds) during the dry season. Counts during dry season were significantly higher than counts during the wet season ($p< 0.05$). The highest and the lowest count were in January and November respectively. There was no significant variation ($p > 0.05$) on the counts of some transects between the two seasons, but there was significant different ($p < 0.05$) among the transects number one and three (Table 3).

Table 2. Number of herds (ni), mean heard size (si) and individual Burchell's zebra counted (xi) in each sampled transects during the wet and dry seasons.

Transect s	No. of burchell's zebra observed						Mean		
	Wet season			Dry season					
	ni	si	xi	ni	si	xi	ni	si	xi
T1	14	8.0	112	14	9.1	127	14.0	8.6	120
T2	7	6.5	46	13	9.3	121	10.0	7.9	83
T3	12	7.1	85	9	8.5	77	10.5	7.8	81
T4	13	7.2	94	3	8.1	24	8.0	7.7	59
T5	2	5.5	11	12	9.1	109	7.0	7.3	60
T6	8	6.0	48	8	8.2	66	8.0	7.1	57
Total	**56**	**40.3**	**396**	**59**	**52.3**	**524**	**58**	**46.4**	**460**

ni = mean number of herds (zebra clusters observed) per transect, si = heard size(mean number of individuals per cluster)per transect , xi = sum of individuals counted per transect. T1 = transect one, T2 = transect two, T3 = transect three, T4 =transect four, T5 = transect five and T6 = transect six.

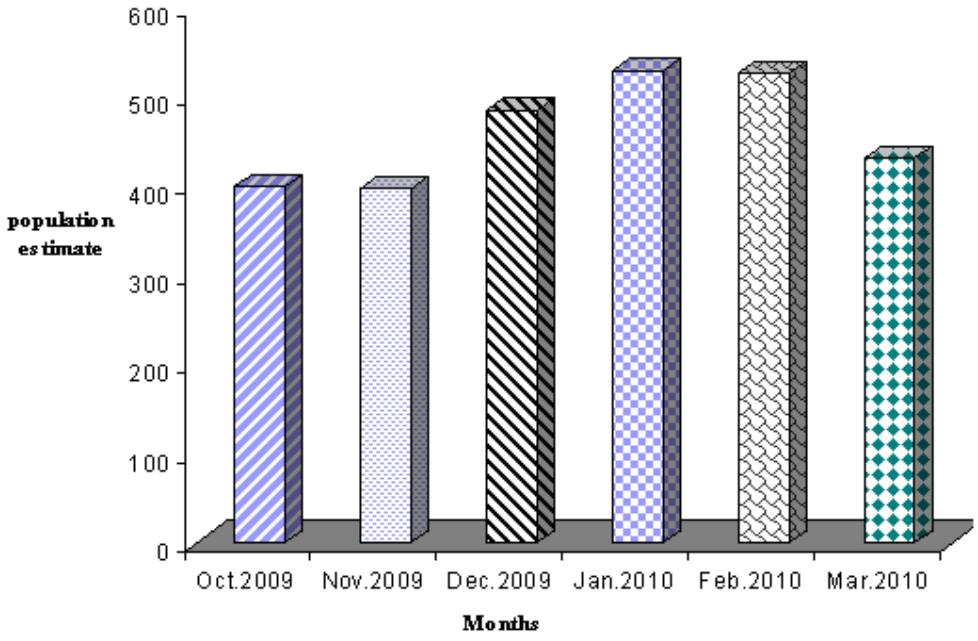

Figure 5. Monthly comparison of Burchell's zebra population estimate in Yabello Wildlife Sanctuary.

Table 3. Comparison of transect counts between dry and wet seasons using t-test.

Transects	t-value	p- value
T1	15.93	0.04
T2	2.23	0.269
T3	20.24	0.031
T4	1.68	0.341
T5	1.22	0.436
T6	6.33	0.1

T1 = transect one, T2 = transect two, T3 = transect three, T4 = transect four, T5 = transect five, T6 = transect six.

6.2 Population Trend

Although the methods used by the previous workers was different from the present study, the past and present trend of population of Burchell's zebra shows irregularity based on conservation effort made during the phase (Table 4). In the present study, the average of dry and wet seasons transect count at the study area was 1536 and 1224, respectively.

Table 4. Past and Present Population status of Burchell's zebra in Yabello Wildlife Sanctuary.

Year	Population size	Trend	Methods	Source
1990	1290+/-180	Stable/increasing	Aerial samples	Thouless,1995
19 95	2840	Stable	Aerial sample	Syvertsen, 1992
2009-2010	2760	Decreasing	Distance sampling	Present study

6.3 Population size and density

The population density of Burchell's zebra in Yabello Wildlife Sanctuary was 5.0 $\pm$ 2.4/ km^2 during dry season and 8 $\pm$ 2.1/km^2 during wet season. The average mean population density of Burchell's zebras in Yabello Wildlife Sanctuary was estimated to be 6.5 $\pm$ 2.3 individuals/km^2 during the study period. The population size of Burchell's zebras were estimated to be 4570 and 5732 individuals during dry and wet seasons, respectively, with 95% confidence interval of 4048 - 5067 and 5030 -5978 at 5 degree of freedom. The total population size estimate calculated from the mean population density estimate (D = 6.5 +2.2) was 5151 individuals with 95% confidence interval 4539 -5523 at 1 degree of freedom.

6.4 Age structure and sex ratio

The population structure and the proportion of various age –sex categories in the Yabello Wildlife Sanctuary was provided in Figure 6 and Figure 7 respectively. Out of a total number of 2760 individuals observed during the present study period, 951(34.5%) were adult male, 1205(43.7%) were adult females, 360(13.04%) were sub adult, 147(5.3%) were juvenile and 97(3.5%) were foals. The age ratio of adult to young was 1:0.25 and 1: 0.32 during dry and wet seasons, respectively (Table 6). There was no significant difference in the age ratio observed during both seasons ($P>0.05$). On average, 78.2% of the total population was adults and only 21.8 % was young.

Individual zebras encountered during the study period were grouped as adult male 541(56.9%) and 410(43.1%), adult females 691(57.3%) and 514(42.7%), and unknown sex 304(50.3%) and 300(49.7%) during dry and wet seasons, respectively (Table 5 and Fig 6). The adult male to adult female sex ratio was 1:1.27 and 1:1.25, adult to unknown sex ratio was 1:0.25 and 1: 0.32 during dry and wet seasons respectively. The age structure was also stable across periods (Figure 7) with no significant variation in the proportions of adult and sub-adult, yearlings and foals.

Table 5. Population structure of Burchell's zebra in Yabello Wildlife Sanctuary.

	No. of zebras		**Sex and age categories**					**Ratio**	
								Sex	**Age**
Month and year	**ni**	**xi**	**AM**	**AF**	**SA**	**Juv**	**Fo**	**AM:AF**	**Ad:Yg**
Oct. 2009	55	398	132	164	58	28	16	1:1.24	1: 0.34
Nov. 2009	58	396	128	160	61	29	18	1:1.25	1: 0.38
Dec. 2009	59	483	174	230	49	20	10	1:1.32	1:0.19
Jan. 2010	62	528	189	241	58	25	15	1:1.28	1:0.37
Feb. 2010	60	525	178	220	70	31	26	1:1.24	1:0.32
Mar. 2010	59	430	150	190	64	14	12	1:1.27	1:0.26
Average	**58**	**460**	**159**	**201**	**60**	**25**	**16**	**1:1.27**	**1:0.31**

ni = herds observed, xi = number of individuals , AM = adult male , AF = adult female , SA = sub adult ,Juv = Juvenile , Fo = foal , Ad = adult (AM+ AF), Yg = young (SA + Juv + Fo).

Table 6. Proportions of different age –sex categories of Burchell's zebra counted in dry and wet seasons.

Seasons	Sex and Age structure					Ratio	
	Sex		Age			Sex	Age
	AM	AF	SA	Juv	Fo	AM : AF	Ad:Yg
Dry	541	691	177	76	51	1:1.27	1:0.25
Wet	410	514	183	71	46	1:1.25	1 : 0.32
							1: 0.31
Average	**476**	**603**	**180**	**74**	**49**	**1.27**	

AM = adult male, AF = Adult female, SA = subadult, Juv = Juvenile, Fo = foal

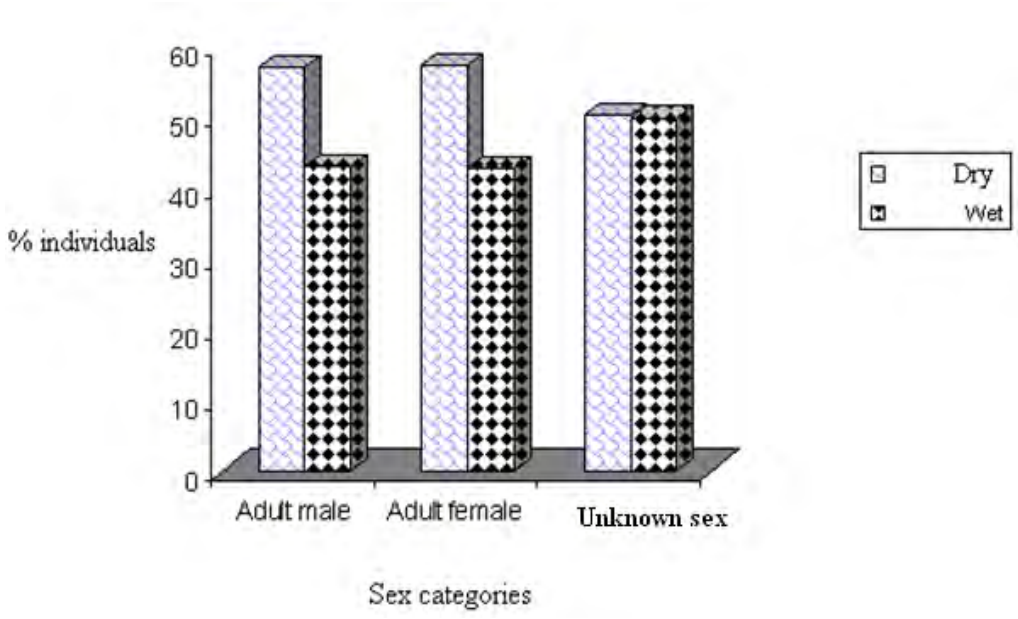

Figure 6. Percentages of sex categories of Burchell's zebras during the wet and dry seasons.

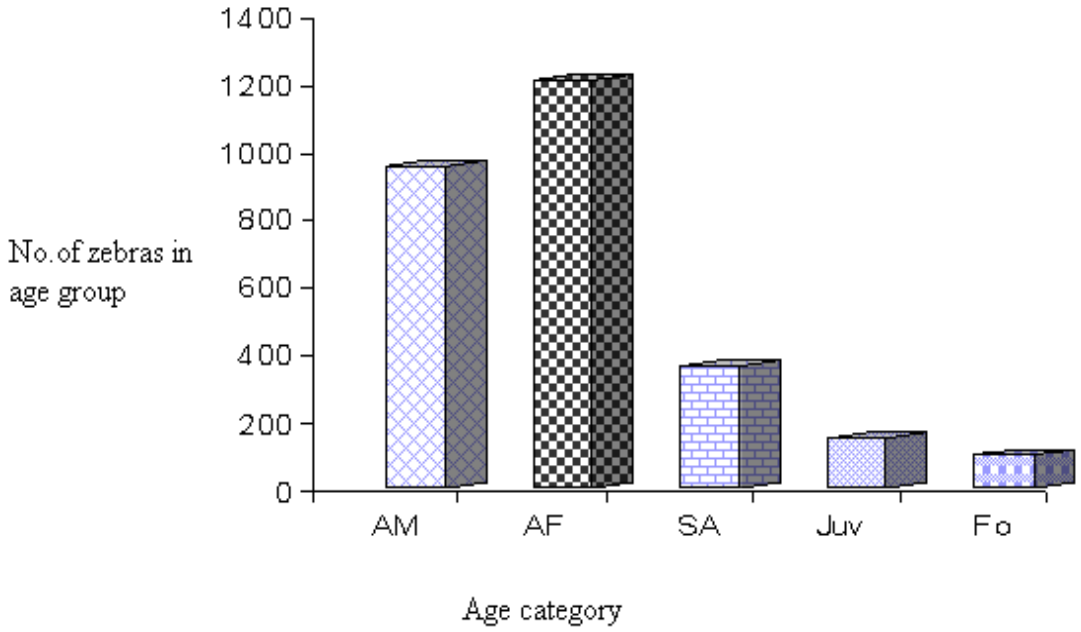

Figure 7. Number of Burchell's zebra in each age category.

6.5 Group size and composition

6.5.1 Group size

The average group size during wet and dry seasons is given in Table 7. The herds are composed of adult male, adult female, sub adults, juvenile and foal. Group sizes, composition and structure changed with the season.

There was a difference in grouping characteristics between groups containing juvenile and foals and those containing only stallions. Adults were consistently larger than young. Small groups containing 7 and 25 individuals were most common throughout the study period. The average number of wet season counts (1224) was grouped in 56 herds (groups) and the mean group size was 14.6. During dry season the total count was (1536) grouped in to 59 groups and the mean group size was 10.4. In October, November and March up to 44 animals congregated in large groups. In December, January and February, they split up in to smaller groups. The most frequently observed group size was 14 animals in wet season and 7 animals in dry season. A herd of below seven was rare in the study area. The group size differed within the wet and dry seasons. The highest range of group size as recorded during the wet season with the mean group size of 14.6. However, the total number of groups observed during the wet season was minimum. While during

the dry season the total number of zebra groups observed was highest, but the range of group size was smallest with mean group size of 10.4. Large group sizes of zebras were aggregated during the wet season, while during the dry season they split in smaller number of groups and distributed in a wider area during the wet season. Individual groups varied in size across the study area, with a modal group size of seven (Fig.8). There were significant differences in the group size across different sites ($p < 0.05$). The largest groups were observed in grassland and the smallest within woodland and bushland. Groupsise over the two seasons showed significant difference (Mann Whitney test, U' = 4890, P = 0.03).

Table 7. Group size of Burchell's zebra in the wet and dry seasons.

Season	Total number	Total groups	Rang of group size	Mean group size
Wet	1224	56	1- 44	14.6
Dry	1536	59	1- 14	10.4
Average	1380	57.5	28	12.5

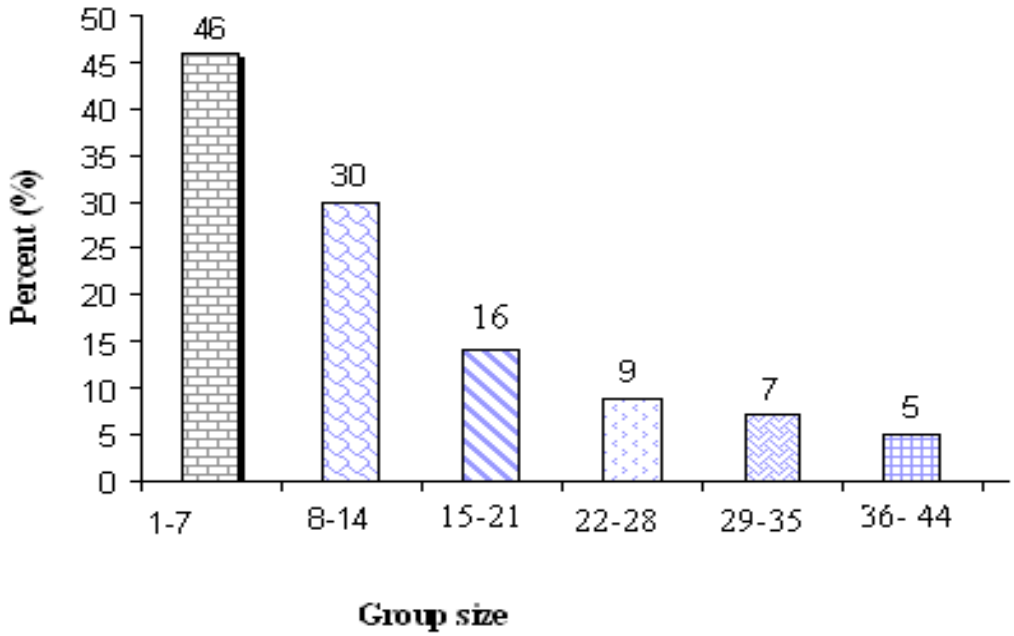

Figure 8. Percentage distribution of size of Burchell's zebra groups.

6.5.2 Group composition

There are two types of social groups in Burchell's zebras. One is family groups (stallion, mares and their foals) and the other is stallion groups (males only, including solitary males). The family stallion is the alpha–dominant within the group, foals have the rank of their dam, and rank-order is maintained in a single file movement, though the dominant female usually leads. Stallion-group adults are apparently of equal rank, but there is dominance hierarchy among the adolescents. With their first estrus, young females are abducted by males of other family-groups or stallion groups, the latter thus founding new family. In her first estrus, young female stands with legs apart and tail lifted in an estrus posture, which attracts up to 18 males. The family stallion is rarely able to keep her. Zebra social groups are non-territorial and have over lapping home ranges, but females are antagonistic towards those in other groups.

Out of 299 total observations, 67.2% were family herds and 32.8% were stallion herds. Adult male to adult female ratio of the family herd was 1.2: 4.7 and adults to young ratio were 2.9: 0.6. Family groups include one to six mares with the stallion and foals making up to 14 members. Mean family size was 7.8. Group composition was dominated by mares 60%, stallion 15%, and sub adults 15.7%, Juvenile 5.5% and foals 3.8 % (Table 8 and Fig 9). The proportions of stallions, mares, sub adults, juvenile and foals differed significantly.

Table 8. Group composition of Burchell's zebra in Yabello Wildlife Sanctuary**.**

Month& year	No. of herds		Herd size, mean		Sex and age category of family herd				
	Stallion	Family	Stallion	Family	**AM**	AF	SA	Juv	Fo
Oct. 2009	15	42	5.8	8.5	1.6	4.8	1.4	0.3	0.4
Nov. 2009	17	33	5.5	8.2	1	5.1	1.5	0.4	0.2
Dec. 2009	13	24	4	6.7	1.2	4	1	0.3	0.2
Jan. 2010	18	27	4.5	8.6	1.5	5.2	1.3	0.4	0.2
Feb. 2010	16	32	5.3	7.9	1.1	4.7	1	0.7	0.4
Mar. 2010	19	41	6.8	8	1.1	4.8	1.2	0.5	0.4
Average	16.3	33.5	5.3	7.8	1.2	4.7	1.2	0.4	0.3

AM = adult male, AF = adult female, SA = sub-adult, Juv =juvenile, Fo = foal

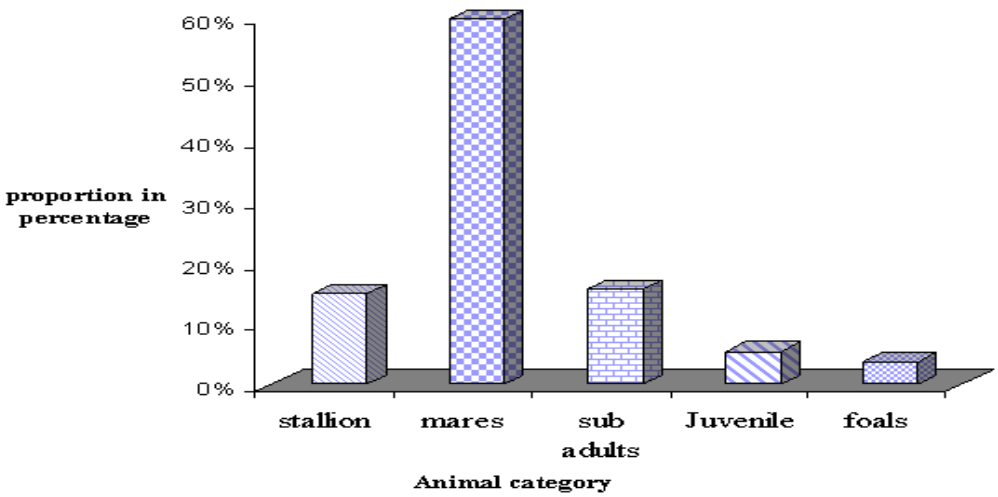

Figure 9. Group composition of Burchell's zebra in Yabello Wildlife Sanctuary.

6.6 Distribution and vegetation type utilization

6.6.1 Seasonal distribution

During dry season 59 groups of Burchell's zebra comprising 1536(57 %) individuals were recorded in Yabello Wildlife Sanctuary. While in wet season 56 groups comprising 1224 (43.3 %) individuals were recorded (Table 9, Fig. 10 and Fig. 11). This indicates that Burchell's zebra tend to converge in areas with strategic and scarce resources such as water and pasture in dry season while in wet season these resources are well distributed in the range, therefore zebra scatters over a large area reducing the chances of spotting them significantly.

Table 9. Seasonal distribution of Burchell's zebra in Yabello Wildlife Sanctuary.

Season	frequency	% frequency	No. of zebra	Percent (%)
Dry	59	51.3	1536	55.7
Wet	56	48.7	1224	44.3
Total	115	100	2760	100

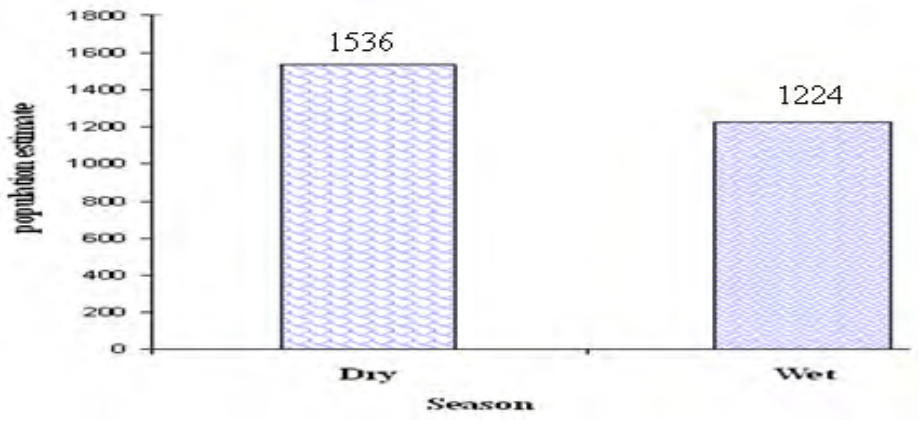

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Figure 10**.** Seasonal comparison of counted Burchell's zebra in Yabello Wildlife Sanctuary.

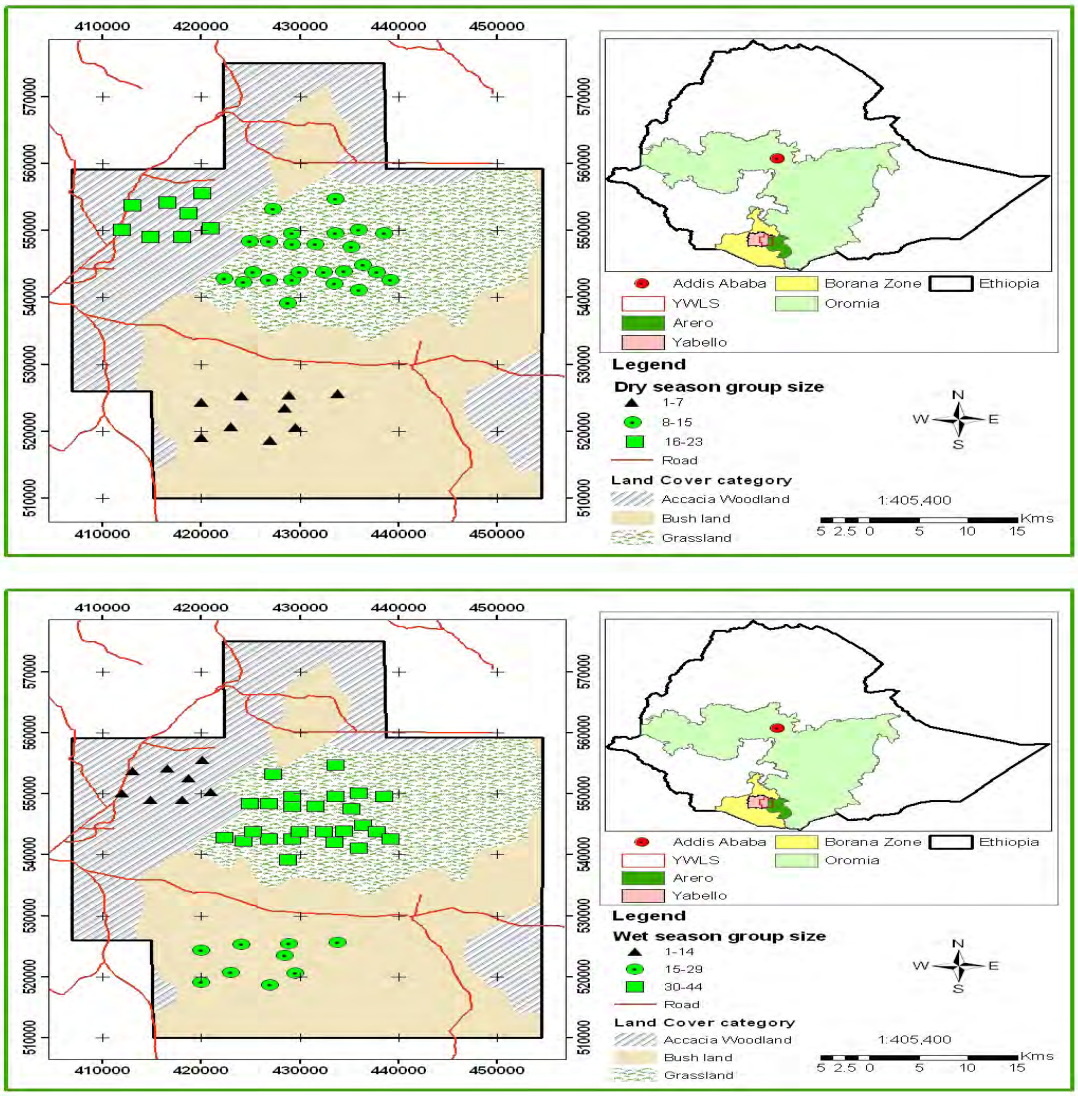


Figure 11. Distribution of Burchell's zebra during the wet and dry seasons in different vegetation types in Yabello Wildlife Sanctuary.

6.6.2 Habitat preference and abundance

Out of the 56 groups of Burchell's zebra observed in wet season, 39 groups constituting 69.6 % were in grass land, six group constituting 10.7% were in woodland and 11 group constituting 19.7% were in bushland. In dry season out of 59 groups of Burchell's zebra observed 22 groups constituting 37.3% were in grassland, 30 group constituting 50.8% were in woodland and seven groups constituting 11.9 % were in bushland habitats. Burchell's zebra preferred open grassland habitats in wet season and woodland in dry season.

Burchell's zebra population was distributed in three vegetation types (Figure 12). Burchell's zebra showed high preference for open grassland habitats and observed primarily grazers. The distribution of the animal was varied according to the season.

Table (10) shows the number of Burchell's zebra seen in different vegetation types and expressed in percentage of the total number of animals seen during dry and wet seasons of the study period for the tallest and the oldest strands grass species which have the highest cell wall content in each vegetation community. The highest numbers of Burchell's zebra were observed in all vegetation types during the dry season than the wet season ($p<0.05$).

Table 10. The abundance of Burchell's zebra herd in different habitats during the wet and dry seasons

Habitats	**Numbers of Burchell's zebra observed**					
	Wet season		**dry season**		**Mean**	
	Ni	**xi**	**ni**	**xi**	**ni**	**xi**
Grassland	39	246	22	192	31	219
Woodland	6	55	30	262	18	158
Bush land	11	95	7	70	9	83

ni = number of group observed, xi = number of individuals

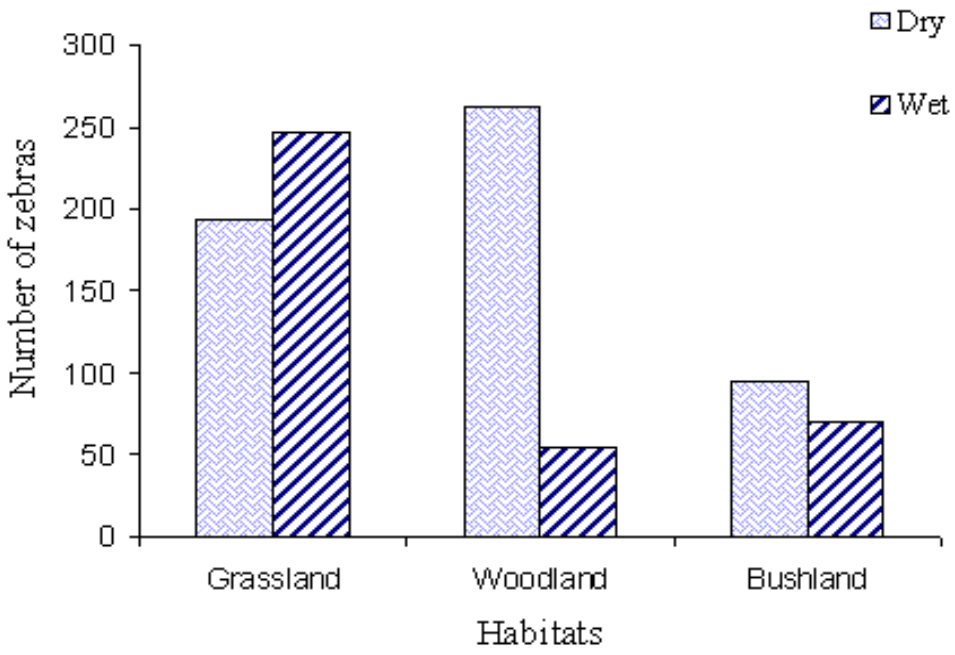


Figure 12. Abundance of Burchell's zebra during the wet and dry seasons in different habitats.

6.6.3 Food preference of Burchell's zebra

Table 11 shows the main grass species that Burchell's zebra consumed during dry and wet seasons. Burchell's zebra in Yabello Wildlife Sanctuary showed preference to certain grass species over other species ($p<0.05$).

During the study period, Burchell's zebra was never seen feeding on bushes and leaves. The grazing frequency was 27.5% on *Themeda triandra,* 20.4% on *Cynodon dactylon,* 13.5% on Setaria *verticillata,* 11.4% on *Ischaemum afrum,* 9 % on *Chryospongon aucheri, 5.3*% on *Elusine intermedia,* 5% on *Lintonia nutans,* 4.1% on *Aristida adoensis* and 3.8% on Cenchrus ciliaris. *T. triandra* and C. *dactylon* were the most preferred grass species accounting for 47.9% of the total frequency of grass intake, *S. verticillata, I. afrum and C. aucheri* were the medium preferred grass species accounting for 33.9 % of the total sighting frequency of grass in take and *E. intermedia, L. nutans, A. adoensis* and *C. ciliaris* were the least preferred grass species accounting only for 18.2 % of the total grass in take.

Table 11. Grass species consumed by Burchell's zebra during dry and wet seasons in Yabello Wildlife Sanctuary.

Scientific name	Vernacular name	% of frequency	In take
Aristida adoensis	Saatuu biilaa	4.10%	+
Cenchrus ciliaris	Mat guddeessa	3.80%	+
Cynodon dactylon	Sardo	20.40%	+++
Chryospogon aucheri	Alaloo	9%	++
Elusine intermedia	Coqorsa	5.30%	+
Ischaemum afrum	Guuree	11.40%	++
Lintonia nutans	Hiddo(luucolee)	5%	+
Setaria verticillata	Raaphuphaa	13.50%	++
Themeda triandra	Gaaguroo	27.50%	+++

High preference = +++, medium preference = ++, low preference = +

6.7 Diurnal activity patterns

Data on the various activity patterns recorded in the study period were grouped in to form six major activities, namely: grazing, standing, resting/lying in the open or in the shade, walking, grooming and other activities. The mean number of animals engaged in various activities for the whole days during the wet and dry seasons have been expressed as percentage as given in Table 12, 13 and Fig. 13, respectively.

Table 12. The mean numbers of animals (%) engaged in various activities during the wet season.

Time, h	Grazing	Standing	Walking	Resting	Grooming	Others
06 :00-7:00	52	15	22.9	2.9	4.3	2.9
07:00-8 :00	54.1	13.8	21.3	2.5	2.5	5.8
08 :00 –9:00	57.4	5.3	18.5	5.1	2.9	10.8
09 :00 -10:00	60	2.4	16	7.6	4.7	9.3
10 :00 -11:00	54	8.1	14	11.3	5.4	7.2
11 :00 –12:00	47.4	10.7	8.5	19.9	2.8	10.7
12 :00 –13:00	41.5	20.8	3.2	16.5	7.5	10.5
13 :00 –14 :00	43.2	17.1	3.2	14.5	7.8	14.2
14 :00 –15 :00	54.9	10.5	14.9	6.3	5.3	8.1
15 :00 –16:00	58.1	3.2	13.1	11.7	6	7.9
16 :00 -17:00	56.3	4.8	17.6	12.4	3.3	5.6
17:00 –18:00	57	4.9	18.4	6.3	7.6	5.8
Mean	**52.9**	**9.7**	**14.3**	**9.8**	**5**	**8.2**

Table 13. The mean numbers of animals (%) engaged in various activities during the dry season.

Time, h	Grazing	Standing	Walking	Resting	Grooming	Others
06:00-7:00	63.9	13.5	9	3.9	2.5	7.2
07:00-8:00	59.4	11.9	12.6	7.2	4.4	4.5
08:00-9:00	53.5	17	13.8	2.9	7.8	5
09:00-10:00	51.5	20.6	10.6	3.1	5	9.2
10:00 -11:00	58.5	12.5	7.2	5.7	5.3	10.8
11:00-12 :00	52	31.5	2.5	8.5	3	2.5
12:00-13: 00	49.3	30.8	3.6	10.2	2.6	3.5
13:00 -14:00	53.6	16.2	5.4	9.1	4.8	10.9
14: 00-15:00	61.8	13.7	9.8	6	2.3	6.4
15:00 –16:00	60.7	8.6	14.4	7.2	4.1	5
16:00 –17:00	64.9	6.8	10.6	2.5	3.2	12
17:00-18:00	62.6	5.4	13.9	6.7	5.2	6.2
Mean	57.6	15.7	9.5	6.1	4.2	6.9

6.7.1 Grazing

Grazing was the dominant activity of the zebra, although the time spent in grazing differed significantly between the seasons. Diurnal grazing behaviour was strongly biphasic, with animals showing strong avoidance of energy consuming activities such as grazing and walking during the hottest period of the day. Such activities increased in the early morning and late afternoon hour and correlated with lower ambient temperatures.

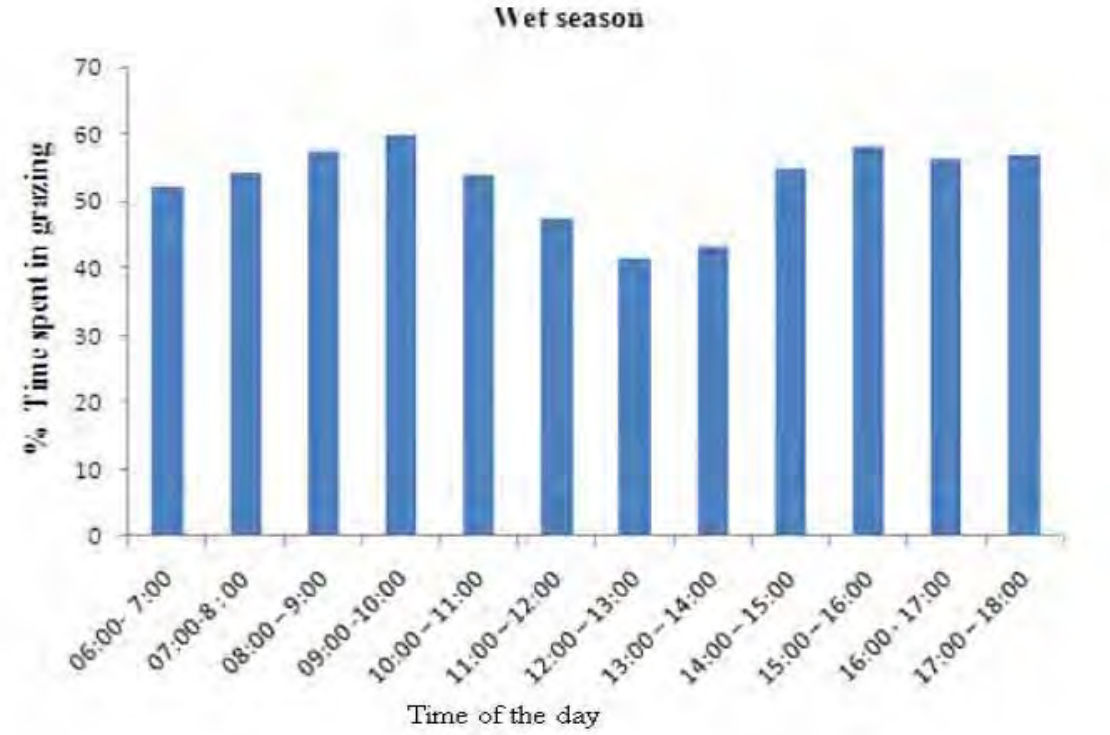
Energy conserving activities, such as resting and standing, showed a strong inverse correlation with grazing and walking.

There was an observed increase in the amount of time spent grazing during the 06:00-10:00h and 15:00-18:00h both in dry and wet seasons. Grazing activity remained at similar levels during the 06:00- 11:00 h and 14:00- 18:00h with a decrease observed during the 12:00-13:00h time period during dry seasons. During the wet season, the animals significantly allocated more time to grazing at 09:00h than 12:00h, 11:00 and 13:00h. In addition, time allocated for grazing at 09:00h was significantly higher than 8:00h, 15:00h, and 18:00h. There were two peaks in grazing during wet season, one between 06:00 - 100h and the other is 14:00- 18:00h. Over the dry season, grazing showed two peaks one is in the early morning between 06:00- 10:00h and the other is in the late afternoon between 14:00- 18:00h.

The differences in the time devoted for each activity during different hours of the day during dry and wet season were significantly different for grazing, standing, walking and resting ($p < 0.05$), but there was no significant difference between, grooming and others ($p > 0.05$) (Table 14). The time devoted to grazing during the dry season was significantly greater ($t = 13.183$, $p<0.05$) than the wet season. Multiple pair-wise comparisons using the Tukey test indicated that Burchell's zebras spent more time in grazing in dry season than in wet season, and more time grazing during the time period.

Table 14. Comparison of the activities between dry and wet seasons using ANOVA.

Activity	F-value	P-value
Grazing	13.183	0.000
Standing	2.218	0.000
Walking	14.227	0.00
Resting	23.346	0.003
Grooming	2.144	0.144
Others	0.185	0.667


Wet season
% Time spent in grazing
70
60
50
40
30
20
10
0
06:00- 7:00
07:00-8:00
08:00-9:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13:00-14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
Time of the day

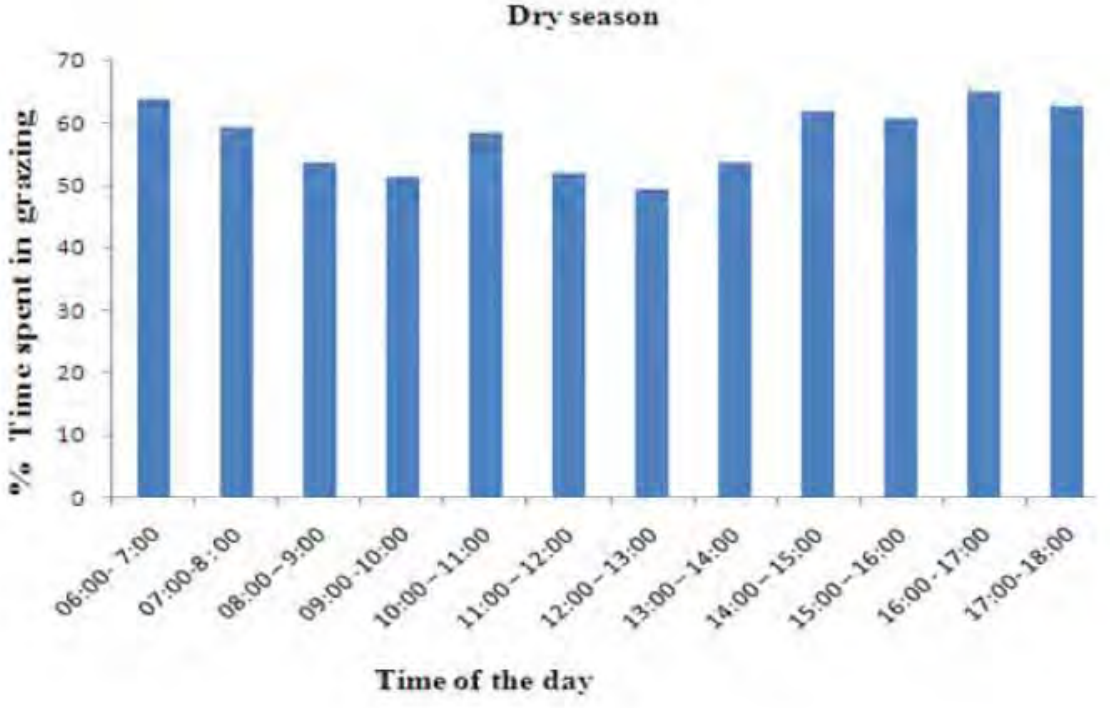

Dry season
% Time spent in grazing
70
60
50
40
30
20
10
0
06:00- 7:00
07:00-8:00
08:00-9:00
09:00-10:00
10:00-11:00
11:00-12:00
12:00-13:00
13:00-14:00
14:00-15:00
15:00-16:00
16:00-17:00
17:00-18:00
Time of the day

Figure 13. Grazing behaviour of Burchell's zebra, in percentage of observed time during the wet and dry seasons.

6.7.2 Walking

The animals walk for shorter distances and recommence grazing after 2- 6 minutes. The adult male, which is used as a guard often initiate the harem for walking when they were disturbed. Waking showed two peaks during the dry and wet seasons, respectively. Over the dry season, walking peaked in the early morning between 07:00- 9:00h and in the late afternoon 15:00–18:00h and during the wet season, it peaked early in the morning 06:00-10:00h and late afternoon at 14:00 -18:00h (Fig.14).

Walking was allocated relatively less time compared to grazing and standing in dry season, but more time was spent on walking during wet season next to grazing. The maximum time allocated to walking throughout the day during the wet season was 14% while over the dry season it was 9%. There was significant difference in time allocated to walking in both seasons ($p < 0.05$). Tukey multiple comparison test indicated that time allocation for walking was significantly lower at 12:00h and 13:00h compared to 14:00h and 15:00h.

The majority of the walking activity during the wet and dry seasons was during the cooler periods (06:00- 10:00h and 15:00- 18:00h of the day. The level of walking activity was at maximum during the 06:00- 10:00h and 15:00-18:00h time periods and decreased during the 11:00-14:00h time period.

The maximum time allocated for walking throughout the day among the Burchell's zebras during the wet season was 24 % (06:00h) while over the dry season it was 14 %(08:00 and 15:00h).

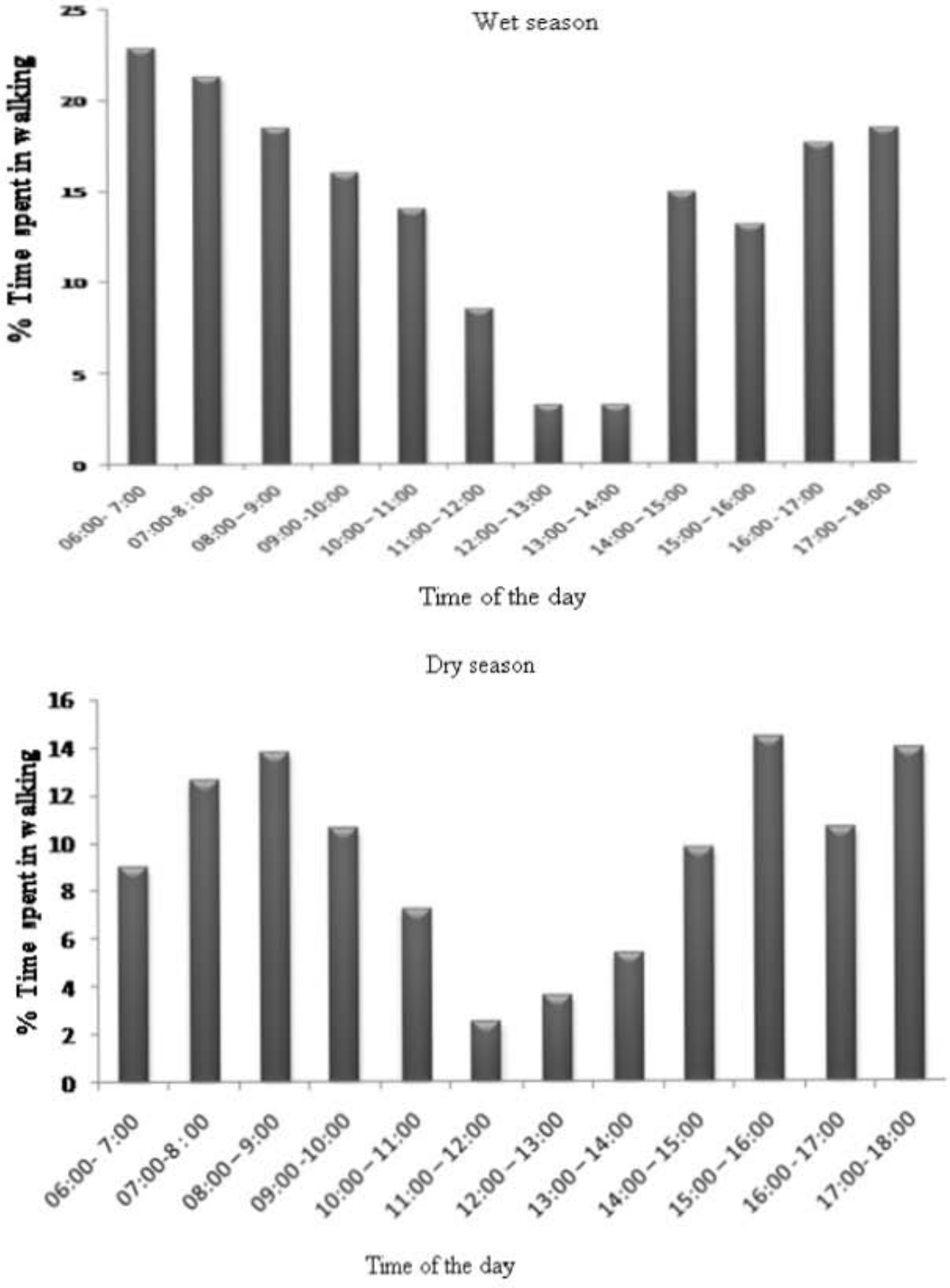


Figure 14. Walking behaviour of Burchell's zebra, in percentage of observed time during the wet and dry seasons.

6.7.3 Standing

In the study areas, when the Burchell's zebras were not grazing, they spend most of the time standing. Standing was the second frequent activity of Burchell's zebra next to grazing during the dry season, but the third frequent activity during the wet season next to grazing and walking. They were engaged in standing during the hottest part of the day during dry season (Fig 15). The time allocated to standing varies significantly with time of the day both in the wet and dry seasons ($p < 0.05$).

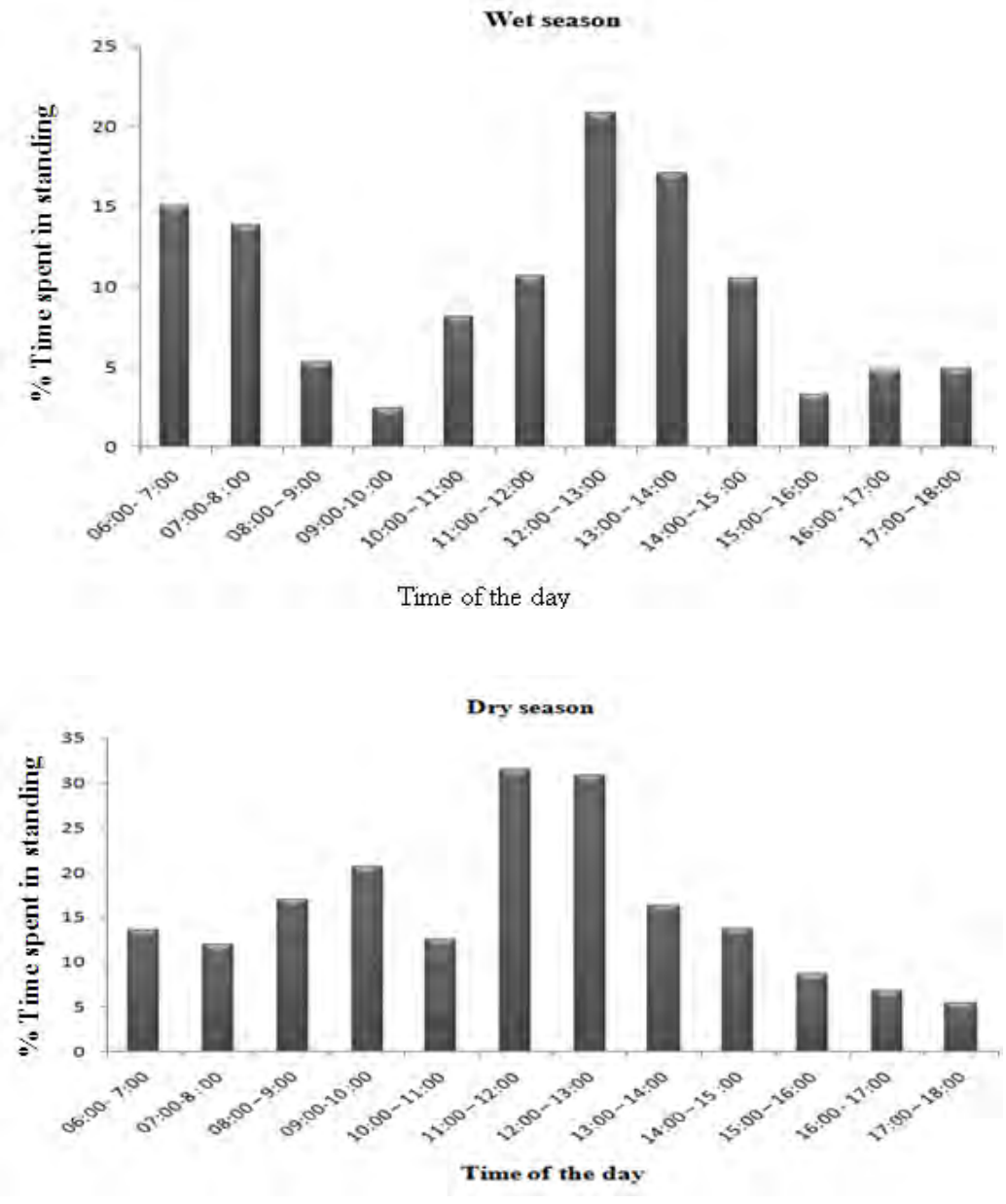


Figure 15. Standing behaviour of Burchell's zebra, in percentage of observed time during the wet and dry seasons.

6.7.4 Resting

Resting was frequent during the hottest part of the day and the zebras remained in the bush and *Acacia* woodland spending more than 30 minutes. Resting was increased in the middle of the day from12:00 -14:00h (Fig 16). Data shows that Burchell's zebra were engaged more in resting for an extended time in the wet season than in the dry season. In the study area adult zebras were never seen resting, but the young zebras spent more time in resting than adults.

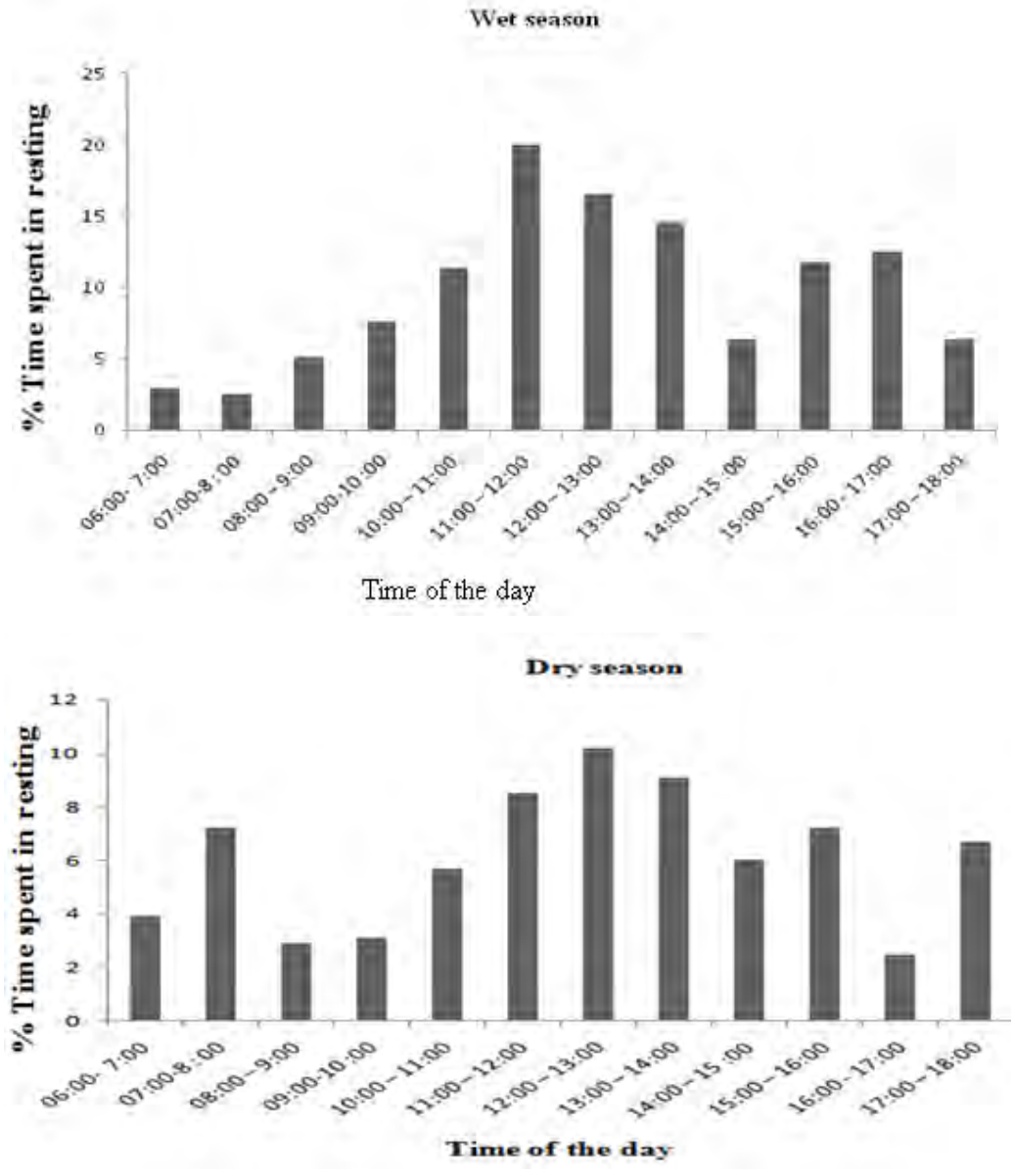


Figure 16. Resting behaviour of Burchell's zebra, in percentage of observed time during the wet and dry seasons.

6.7.5 Grooming

The time allocated to grooming did not vary significantly with time of the day either in the wet season or dry season (Fig 17). Grooming occurs between individuals, especially mares and their foals and stallions and their preferred mares. This is achieved when the grooming zebras stand side-by-side, head to tail and is effective in removing parasites. Grooming was allocated relatively less time compared to grazing, standing, walking, resting and others in both seasons. The maximum time allocated to grooming throughout the day in the dry season was 8 % (08: 00h) while over the wet season it was 7%, 8% and 6.5% at 12: 00h, 13:00h and 17:00h respectively. However, there was no significant difference in time allocated to grooming ($p > 0.05$) for both dry and wet seasons.

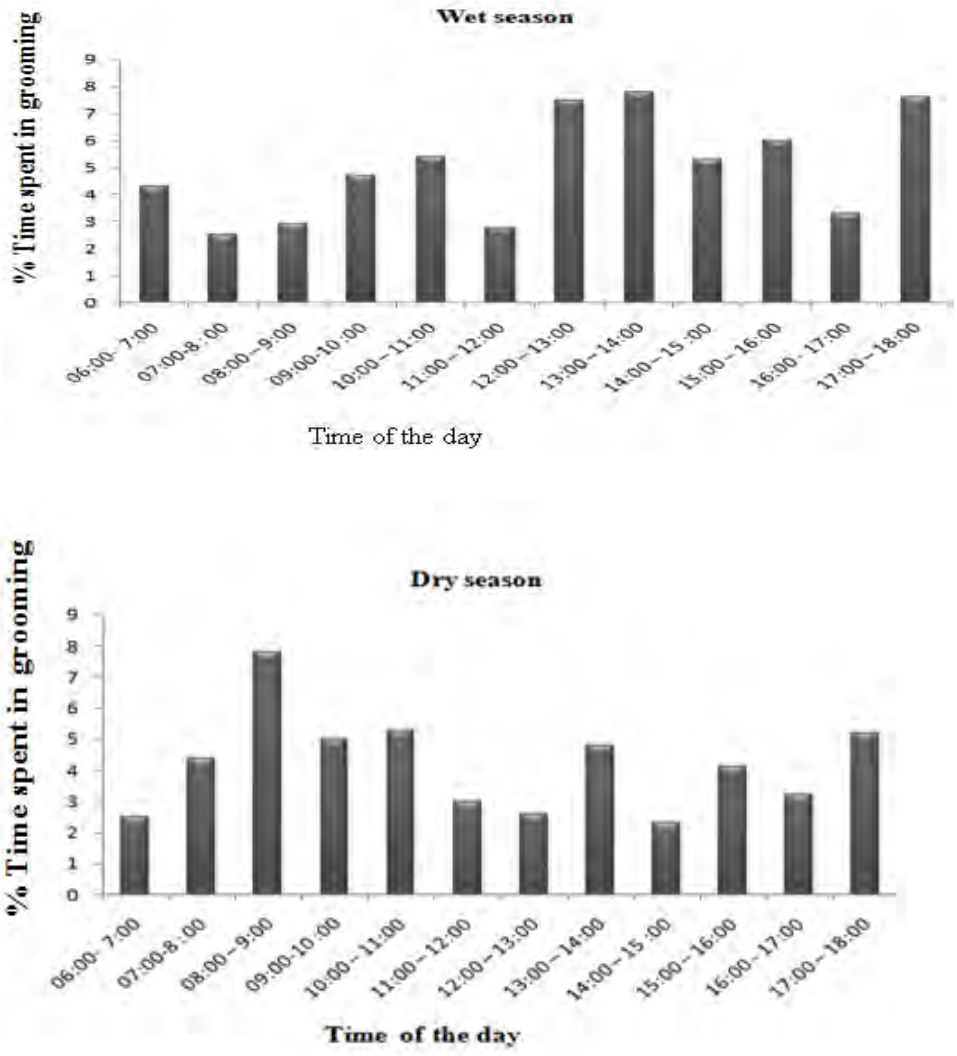


Figure 17. Grooming behaviour of Burchell's zebra, in percentage of observed time during the wet and dry seasons.

6.7.6 Other activities

During the wet and dry seasons, an increase in social activity was observed during the 12:00 -14:00h time period. This can probably be attributed to the aggregation of Burchell's zebra under available acacia woodland shades, thus allowing a greater opportunity for interaction. Levels of social activity were higher during the wet season throughout the time period with peaks in the mid day from 11:00-13:00h. Over the dry season social activities were allocated less time at 11:00 and 12:00h as compared to 07:00 and 08:00h, but more time was allocated at 09:00h, 10:00h, 13:00 and 16:00h respectively (Fig. 18). Other activities include urinating, drinking, suckling, fighting, sexual behaviour etc. other social activities were mainly observed during the warm resting periods between 11:00 to 13:00 hours.

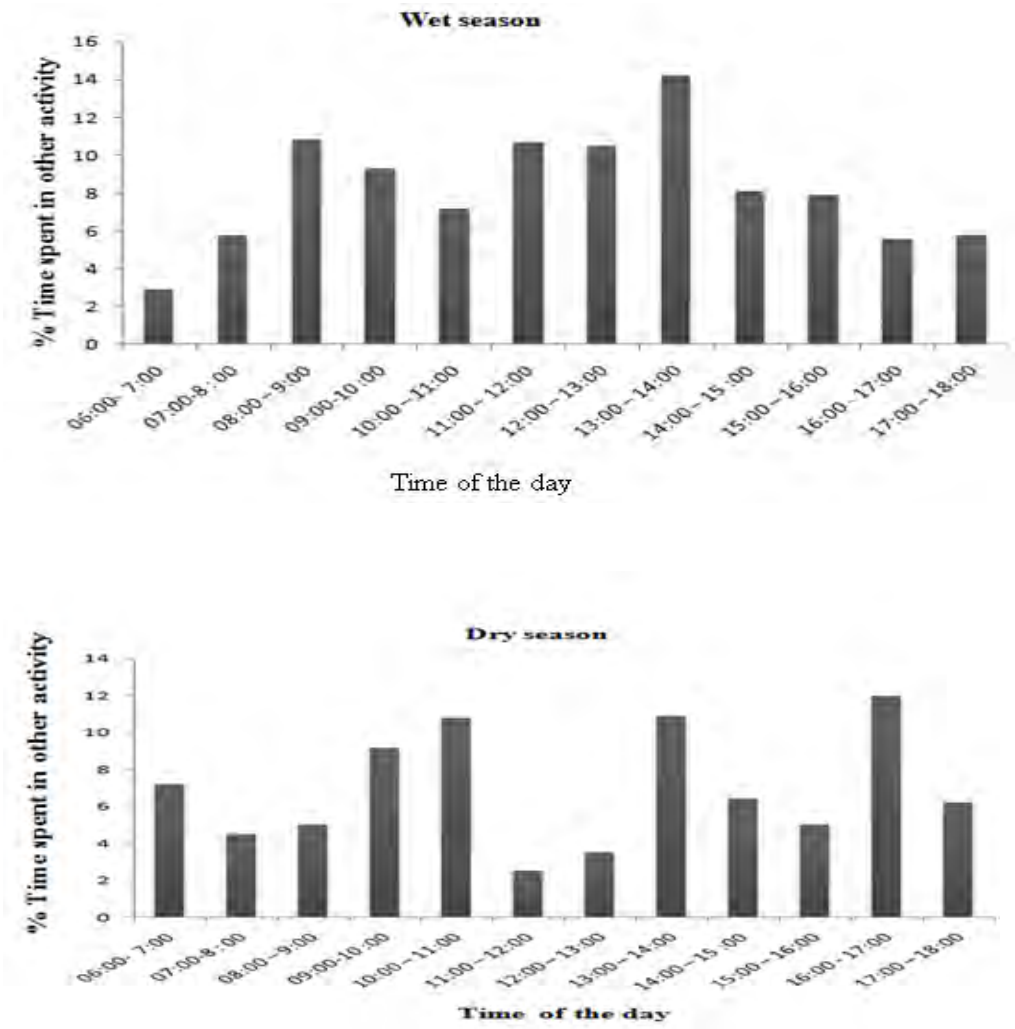


Figure 18. Others behaviour of Burchell's zebra, in percentage of observed time during the wet and dry seasons.

The average proportion of animals engaged in various activities for the whole day is expressed as follows: Burchell's zebras spent 58 % of their time grazing, 16 % standing, 10% walking, 6% resting, 4% grooming and 7% other activities (Fig 19) in the dry season, while in the wet season, 53% in grazing, 10% in standing, 14% in walking, 10% in resting, 5% in grooming and 8% in other activities. In the dry season grazing and standing were allocated significantly more time than other activities. Where as in the wet season, grazing and walking were allocated significantly more time than other activities. The difference in time allocation among six activity categories was statistically significant for grazing, standing, walking and resting ($F=67.512$, d.f. $=11$, $p<0.05$) during dry season and ($F= 47.532$, d.f. $=11$, $p<0.05$) during the wet season. The total time budget for each activity also showed significant difference for grazing, standing, walking and resting ($t= 69.265$, $p=0.001$, $t =19.058$, $p<0.004$, $t=22.572$, $p=0.03$, $t= 16.357$, $p< 0.002$) over the two seasons, respectively.

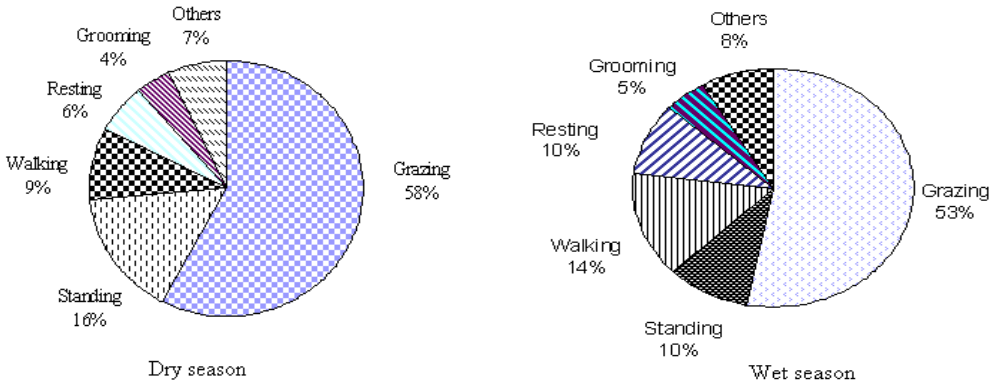


Figure 19. General activity time budget of Burchell's zebra during the wet and dry seasons**.**

The diurnal distribution of grazing behaviour of Burchell's zebra was biphasic, with increased grazing occurring during post-dawn and again pre-dusk. Fewer grazing activities were observed during the middle of the day, coinciding with increased ambient temperatures and an increase in resting, standing and other activities. The overall time budget of Burchell's zebras allocated to different activity patterns during different hours of the day showed significant difference in trends (Fig 20).

The variation in trends between the time allocated for grazing, walking, standing, resting, grooming and other activities of Burchell's zebra of different age and sex categories in the three periods of the day showed significant differences ($p<0.05$). The time allocated for different activities also showed significant differences ($t = 76.4$, $p=0.004$) during the wet and dry seasons. The pattern of diurnal grazing was inversely correlated with walking, standing, resting, grooming and others ($r = -0.178$, $p < 0.01$; $r = -0.631$, $p< 0.01$; $r = -0.472$, $p< 0.01$; $r = -0.210$, $p< 0.01$; $r = -0.428$, $p <0.01$) respectively, reaching a peak in the morning and afternoon periods during dry and wet seasons (Table 15).

The result of correlation analysis using Karl Pearson Correlation Coefficient showed statistically significant positive correlation between the pattern of diurnal resting and standing ($r = 0.29$, $p< 0.01$). The time allocated to walking activity was inversely correlated with standing, resting and grooming($r = -0.313$, $r = -0.370$, $r = -0.207$), respectively, during the wet and dry seasons. Standing activity also inversely correlated to grazing and walking ($r = -0.631$, $r = -0.313$), respectively. Furthermore, the time devoted to resting and grooming activities during different hours of the day were inversely correlated with grazing and walking ($r = -0.472$, $r = -0. 370$, $r = -0.210$, $r = -0. 207$), respectively. The diurnal activity budgets of other activities were inversely correlated with grazing ($r = -0. 428$).

Table 15. Karl Pearson correlation coefficient between six activity patterns of Burchell's zebra in different hours of the day in the wet and dry seasons.

Activities	Correlation value
Grazing	-.178(**)
Standing	0 .290(**)
Walking	-.313(**)
Resting	0 .290(**)
Grooming	-.210(**)
Other activity	0 .167

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

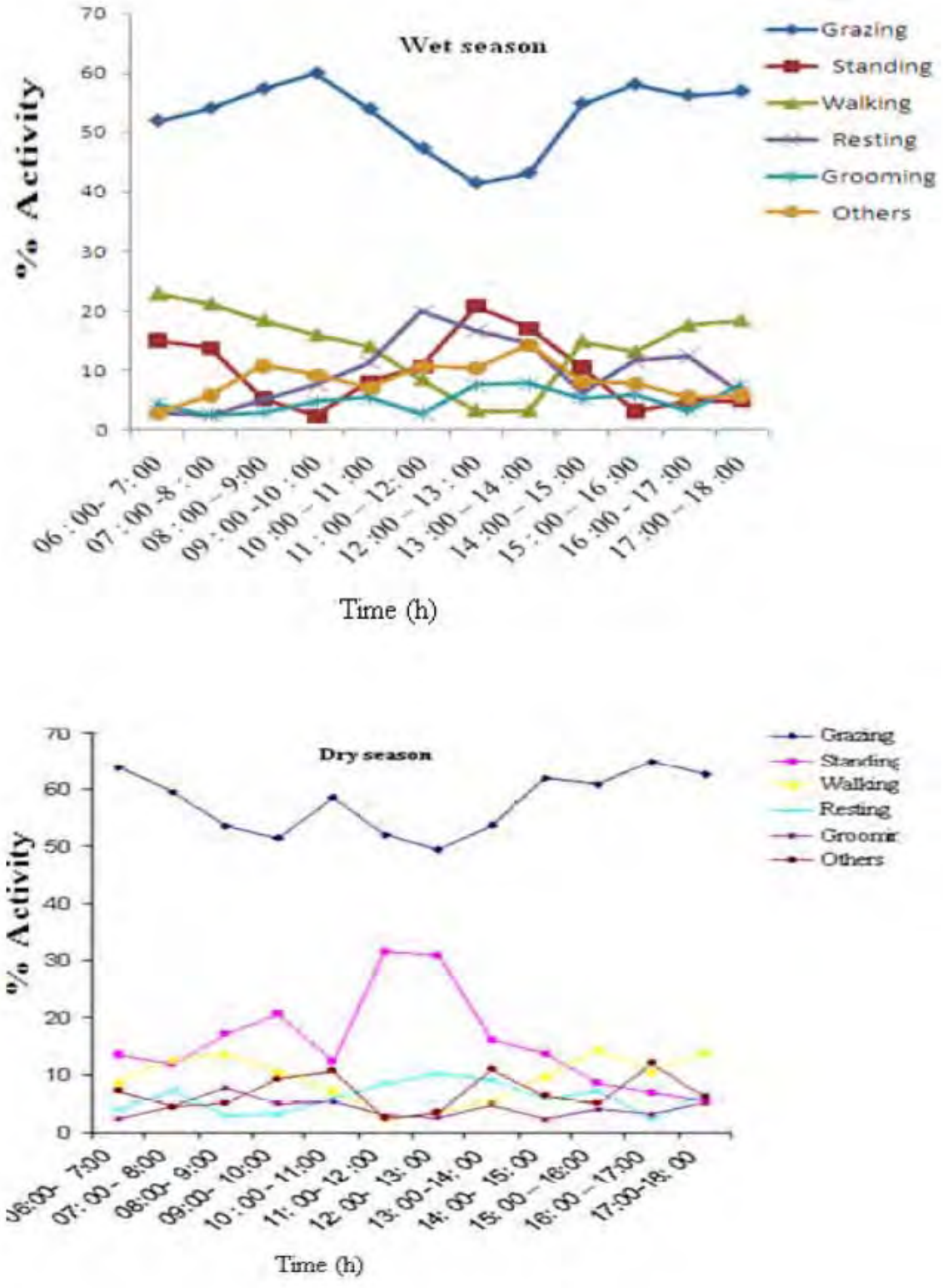


Figure 20. The interdependence of the six main activities of Burchell's zebra during different hours of the day in the wet and dry seasons.

6.8 Interspecies relationship

Burchell's zebra showed a tendency to associate with Grant's gazelle, Greater kudu, Gunther's dik-dik, Domestic cattle and goat that ranged in their habitats. The percentage frequency of such association was more with Grant's gazelle than other species (Fig. 21), but mammal species observed during the line transect count of Burchell's zebras in Yabello Wildlife Sanctuary are given in Appendix 3.

The percentage of sighting of Burchell's zebras herd counted alone are 70 (60.8%) of the total observation. They were seen in association with Grant's gazelle 25 (21.7%), Greater kudu 3 (4.3%), Domestic cattle 8 (7.2%), Gerenuk 5 (4.3%) and Gunther's dik-dik 2 (1.7%) of observations.

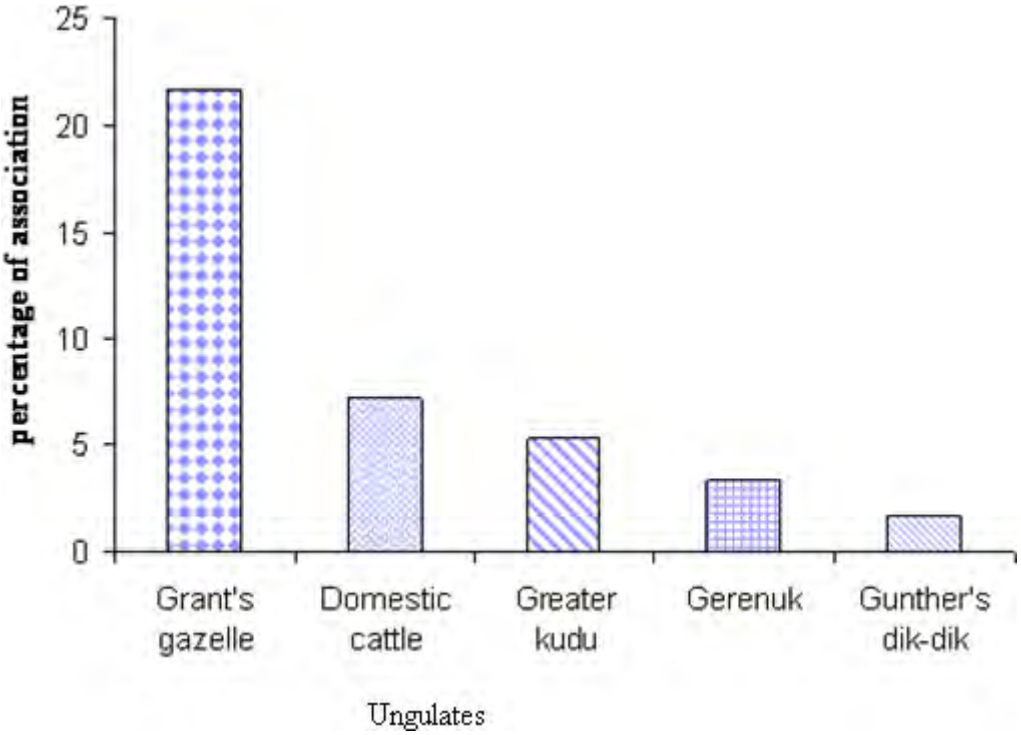


Figure 21. Association of Burchell's with other ungulates in Yabello Wildlife Sanctuary.

6.9 Human Settlement and Livestock grazing

6.9.1 Livestock abundance

The increasing number of livestock around the sanctuary was one of the important factors affecting the status and distribution of Burchell's zebra in the study area. The dominant herbivores over the whole study area are cattle, goats, sheep, donkeys and camel (Fig 22). Thousands of livestock competes directly for food with Burchell's zebra and other wildlife in the Sanctuary. Livestock distribution throughout the Sanctuary increased especially during the wet and late dry seasons, when the grasses were at grazable size. A total of 10,163 domestic animals were recorded grazing in Yabello Wildlife Sanctuary along the transect lines. Cattle were the highest followed by goats with 7110 and 2113 individuals, respectively. Overgrazing increases competition for pastures especially during dry seasons. Ubiquitous presence of thousands of livestock competes on the same area with Burchell's zebra for food especially at Government cattle ranch in the Yabello Wildlife Sanctuary. The present study identified 37 villages and settlements within the present range of Burchell's zebras in the Yabello Wildlife Sanctuary (Figure 23).

Table 16. Total Livestock species recorded in Yabello Wildlife Sanctuary.

Species	Total
Cattle	7110
Goats	2113
Sheep	280
Camel	621
Donkey	39
Total	**10,163**

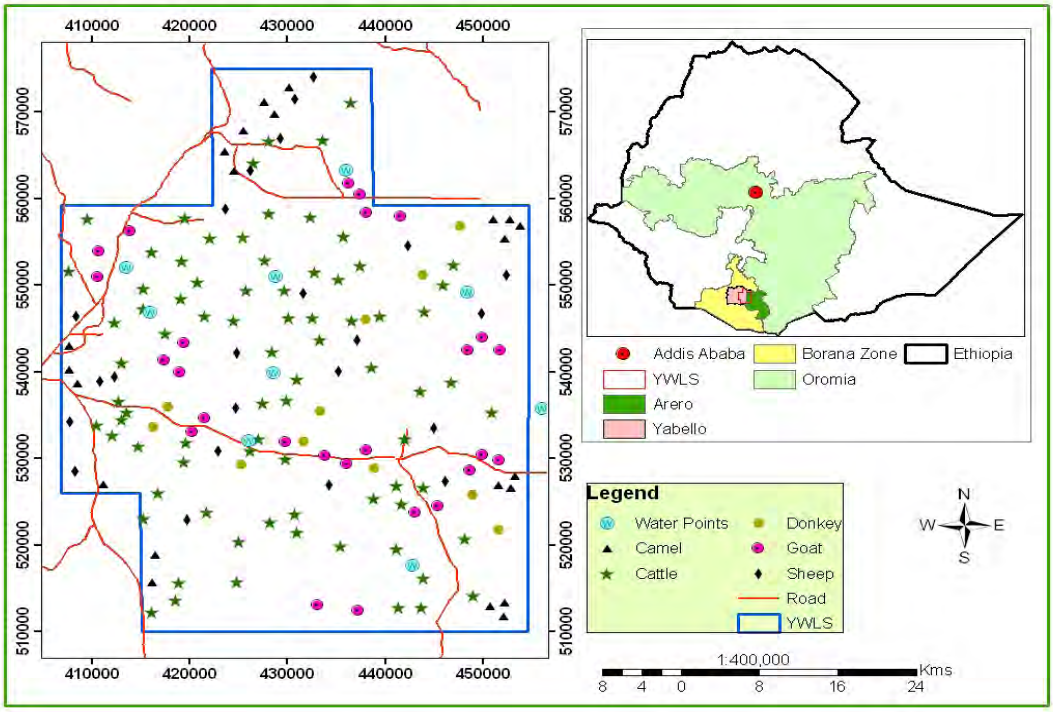


Figure 22. Livestock distribution in Yabello Wildlife Sanctuary.

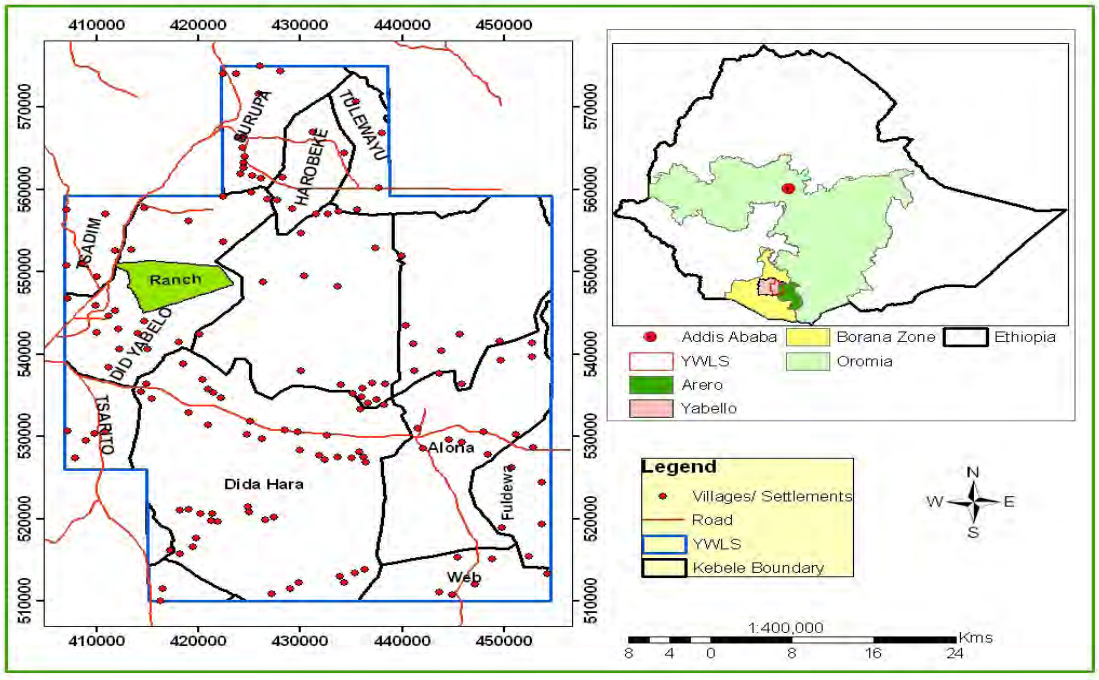


Figure 23. Human settlements in Yabello Wildlife Sanctuary.

7. DISCUSSION

7.1 Population status and distribution

In order to manage the population of Burchell's zebra properly and to take conservation measures accordingly, estimating their population in the study area is important. Separation of the study period in to dry and wet seasons was important in order to observe the influence of the different seasons on the vegetation cover and hence, the distribution of animals. More zebras were counted during the dry seasons. This is because the dry season coincides with fawning. Even though, breeding in the Burchell's zebra is not seasonal and foals may be born at any time of the year, there does, however, a breeding peak from December to January, and 85% of the foals are usually born from October to March (Skinner and Smithers, 1990; Furstenberg, 2002).

A population build up could be expected in the wet season, but this was not well confirmed by the result of the present study. There was no significant difference ($p > 0.05$) on the counts of some transects between the two seasons. Line- transect counts of Burchell's zebra among transects one and three were significantly different ($p < 0.05$). This could be due to a number of ecological factors. The relative abundance of animals is naturally associated with preference towards a given habitat. This depends on what the habitat provides in terms of food, breeding site, protection from predators, overheating and cold and free space.

However, the tolerance for these needs is different among different groups of organisms. Small mammals for example, give priority to cover than food. Usually they avoid predators by hiding or else, if spotted there is little chance to escape. Large mammals, on the other hand, emphasize the importance of food in their habitat. Most of them run to avoid predators rather than hide. They can use any standing tree or some behavioral strategies to avoid sun during the very hot hours of the day. Differences in the counts of zebras in the six transects have most likely

resulted in the tendency of Burchell's zebras to seek for habitat with a good supply of nourishment.

The present study is in agreement with what was reported by van Eeden (2006) that Burchell's zebras are abundant in open grassland habitat. The highest number of Burchell's zebra was 112 and 85 in transect 1 and 3, respectively and 94 and 48 in transect 4 and 6, respectively and the lowest number was recorded in transect 2 and 5 which was 46 and 11, respectively. The highest count recorded in transect 1 and 3 was in accordance with the preference of the open grassland habitat. The vegetation map of the study area (Figure 3) shows that transect 1 and 3 are mostly covered with open grassland and transect 4 and 6 were covered with bushland. Burchell's zebra preferred open grassland mostly and bushland in medium and least in woodland in wet seasons. In contrast, they prefer woodland more in dry season, because of hot sun they shift their habitat into woodland in order to protect from the sun.

7.2 Age categories

The knowledge of sex ratio and age distribution of individual mammals is vital for evaluating the viability of a species because these variables reflect the structure and the dynamics of population (Wilson *et al*., 1996). Sex and age structure of a population at any given point of time is also an indicatior of the status of the population (Woolf and Harder, 1979). The result of the present study showed more than 50% of the population is composed of females. The high population of females and fairly high proportion of young indicate a healthy, increasing zebra population in the study area, similar to the study carried out by Yisehak Doku *et al.* (2007) in Nechisar National park. An increase of the young numbers recorded during the dry season observations suggest that birth is in the beginning of the dry season. The present study is in agreement with the findings of the previous studies on plains zebra was that family groups (or harems) are stable in the adult age class.

7.3 Group size and sex ratio

There are two main hypotheses regarding the herding behaviour of the ungulates. The first suggests that when in herds the animals can prevent or avoid the predation better than when alone (Hamilton, 1971; Giest, 1974; Eisenburg, 1981). This could be done by a variety of methods including improved predator detection, active group defense and predator confusion. The other hypothesis links the animal social organization with the distribution and availability of its food supply (Jarman, 1974).

Larger species can afford to be less selective, and can therefore live in larger groups (Mishra, 1982). In species, which exhibit flexible social system, it is suggested that they will form large groups when there is abundance of high quality forage but will be forced into smaller groups when food supply is less abundant and dispersed in distribution.

The pattern of group size in the different habitat types in both seasons was entirely different. Despite the highly significant difference indicated for groups in the open grassland compared to those dense and intermediate habitats, very little differences could be detected when adults, sub-adults and yearlings were observed. Group size varies in relation to different external conditions. Data on grouping patterns of herbivores may be indicative of the effects of a changing environment (Leuthold and Leuthlod, 1975), reproductive behavior (Jarman and Jarman, 1973) and environmental disturbance resulting from heavy grazing, fire and other factors. Significant difference in group size was found in all three habitat types and such differences persisted when group size were dispersing into the most important categories; mares, stallion and mixed groups. Ungulate species living in open habitats generally form larger groups than those in bushland or forest (Jarman, 1974).

The density of food resources alone may explain the occurrence of small groups of ungulates in woodland habitats because of limited vegetation on the forest floor, which is too sparse for a large feeding group (Owen- Smith, 1982). In open fields or

grasslands, food resources are more abundant and sufficient to support large feeding groups of ungulates (Hirth, 1977). In the study area, water is also a limiting factor for the distribution of group sizes of Burchell's zebras as they can not survive the dry season without water.

7.4 Food preference

The herbivore diet is influenced by several factors including anatomical and physiological characteristic of animals, community structure of plants and its structure and chemical constituents (Owen-smith, 1982). Preference for a given habitat type is largely determined by the available vegetation within the area, providing food, water, minerals, shelter from climatic extremes and cover from predators (Jarman and Sinclair, 1979). Food resources however, not only vary between different habitat types, but also show marked seasonal variation within a given habitat, in response to changes in rainfall patterns (Sinclair, 1975).

Habitat requirements of Burchell's zebras were closely associated with the availability of water and edible grasses. Lamprey (1963) estimated that 92.5 % of the food of zebra was grass. 5.4 % was herb and 2 % was shrub. Vesey- Fitzgerald (1965) noted that Sporobolus species and Vossia species are preferred grasses of Burchell's zebra in the Rungwa Valley, Tanzania. Even though, Burchell's zebra is known to feed on all grasses in the area, evidence from the stomach contents shows that the major food item comprises the dominant fire grass, *Themed triandra* (Casebeer and Koss, 1970).

Yisehak Doku *et al.* (2007) reported that grass comprises all the diet of plains zebra (now renamed as Burchell's zebra) in Nechisar National park. Bell (1971) concluded that the zebra can maintain eating a diet which contains too low level of protein to support a ruminant. The zebra has been seen to select not only the most fibrous part of the plant, but also the tallest (i.e., the oldest) strands (Bell, 1969), which have the highest cell wall content (Bell, 1971). So the zebra is apparently surviving on a diet containing less soluble nutrients and more fiber than is the wildebeest (Janis, 1976).

Equidae obtain about 30-70% of their total digestible energy from microbial fermentation of cellulose and hemicellulose in cecum and large colon (Janis, 1976; Hintz *et al*., 1978; Duncan, *et a*l., 1990). In the present study, the diet of Burchell's zebra comprises grass species in both dry and wet seasons in Yabello Wildlife Sanctuary.

7.5 Diurnal activity pattern

There was significant differences in the amount of hours devoted to different activities (t =76.4=, p< 0.05). Burchell's zebra spent more than 50% of their day time grazing and standing. Similar observations were reported by Grogan, 1978 and Gakahu, 1984 and for other herbivores by Spinage (1968), Lewis and Wilson (1979), and Birhanu Gebre (2000). Their activity follows the general pattern of ungulates in the Yabello Wildlife Sanctuary. The general daily pattern of Burchell's zebra was characterized by morning and late afternoon activity with a period of rest in the middle of the day.

Burchell's zebra was active in grazing from 06:00h –10:00 hr. After 15:00 h, the grazing activity rises steadily and approaching 70% by 18:00h during dry season and 65% during wet season. Around the middle of the day, Burch ell's zebras remain standing or resting/lying down about 35% and 25% in dry and wetseasons, respectively, under the shade of *Acacia* woodland to escape the intense heat of the day.

Grazing activity was minimum during the wet season. Decrease in grazing time with increase food availability during the wet season has been observed. The difference in the distribution of time budgets of the wet and dry season may lead to the conclusion that temperature and food availability seem to be the determinant factors governing the activities of Burchell's zebra. Seasonal variations in daily activities were perhaps related to temperature, rainfall and ground plant biomass in reedbuck (Roberts and Dunbar, 1991). The distribution of day time activity for Burchell's zebras in Yabello Wildlife Sanctuary with increased activities of grazing and walking concentrated in

the early morning and late afternoon and a major resting/lying period during the middle of the day is similar to that observed elsewhere (Joubert, 1972; Sandra, 2009; Beekman and Prins, 1989; Gakahu, 1984; Grogan, 1978).

As a single species may show different behavioural patterns in different environmental conditions (Delany and Happold, 1979), effective management of species depends on the knowledge of the way in which it interacts with its specific environment (Leuthold, 1977). One of the most useful methods of describing this interaction is to quantify the basic activity patterns, which exist for any species at a given time and place during the different seasons (Jarman and Jarman, 1973; Leuthold and Luthold, 1978; Norton, 1981). Annual cycles in ungulate activity are influenced by forage quality and quantity, digestive system constraints and energy conservation needs (Jarman and Jarman, 1973; Owen-Smith, 1982; Leuthold, 1977).

Survivorship of animals depends on the time allocation to behaviors governing either the animal's probability of avoiding predators or its energy acquisition rate (Caraco, 1979). Feeding constitutes the major component of all activities in natural population (Rozin, 1976). Brey (1974) and Panksepp (1974) have described both physical and physiological control of daily and seasonal feeding. Activity profiles indicate the time budgeting of animals and suggest species utilize resources in relation to its environment. Majority of wild ungulates are with many phases of daily activity rhythm in which feeding bouts are interspersed with other activities.

The present study in Yabello Wildlife Sanctuary indicates that Burchell's zebra spent most of its time for grazing as evident from the activity time budget. Standing and walking were other major components of activity of the zebra. Grazing peak was in the morning from 06:00 to 10: 00 hours and after noon from 14:00- 18:00 hours. Activity patterns of animals are determined by numerous factors. A biotic environmental factor such as light and temperature may influence optimum daily and seasonal activity patterns (Nielsen, 1983; Patterson *et al*., 1999).

Body mass, human disturbance, social behaviour, predator avoidance, prey acquisition and competition also may affect activity in different forms (Rocowitz, 1997). Hence, important time when animals are active may be important for understanding their ecological niche and hence to develop conservation plans for imperiled species (Hwang and Garshelis, 2007). The common trend in the diurnal activity patterns of Burchell's zebra at Yabello Wildlife Sanctuary was generally rested more in the middle of the day, and grazes more in the morning and afternoon.

Grass eating ruminants digest their food more efficiently with an increasing proportion of fibre in their diets than do non-ruminant herbivores, but they are restricted to diets with a poor protein concentration of between 7 and 8%; large non-ruminant herbivores can utilize lower quality diets (van Soest, 1982). Hind-gut fomenters can compensate for lower digestion efficiency by increasing food intake resulting in retention times approximately half as long as in ruminants of the same size, so that the energy and nutrient assimilation obtained by hind –gut fermenters on low- quality diets is higher than that obtained by ruminants Bell (1971). It is thought that hindgut fermenters have a selective advantage when food quality is a limiting factor, whereas ruminants perform better when the quantity of food is limited (Janis, 1976). Burchell's zebra in Yabello Wildlife Sanctuary fit this scheme very well, as they increase their grazing time to compensate for reduced food quality in the dry season.

Burchell's zebra is a water dependent, non-selective roughage grazer (van Soest, 1982). Comparison of the present study results for day time grazing with those of other studies suggest that day time grazing is similar to the 65% found by Klingel (1967). Other studies on Burchell's zebra also report approximately 65% of the time grazing over 24 hours (Grogan, 1978); Gakahu, 1984). Zebra spend most of the day time grazing, but this pattern is not constant throughout the year. They have an after noon resting period when food conditions are good, but they use this time grazing when food is less abundant.

The availability of pasture and atmosphere seem to be the strongest ecological determinants in the seasonal variation of the basic type. The activity patterns of ungulates may also be influenced by sex and age of the animals (Jarman and Jarman, 1973). Beekman and Prins (1989) reported that mammalian herbivores spent much of their time on feeding. Grazing equidae spend up to 18 hours of their time per day to graze (Houpt *et al*., 1986; Pratt *et al*., 1986). Three studies on Plains zebra shows that they devote around 60-70% of their time (out of a 24h period) to grazing (Grogan, 1978; Gakahu, 1984; Beekman and Prins, 1989).

In periods when food is scarce, for example in the dry season, the flexibility to regulate its time budget can be a help to maintain intake requirements (Beekman and Prins, 1989). Bell (1971) concluded that the zebra can maintain eating a diet which contains too low level of protein to support a ruminant. The zebra has been seen to select not only the most fibrous part of the plant, but also the tallest (i.e., the oldest) strands (Bell, 1969), which have the highest cell wall content (Bell, 1971). So zebra is apparently surviving on a diet containing less soluble nutrients and more fiber than is the wildebeest (Janis, 1976).

Equidae obtain about 30-70% of their total digestible energy from microbial fermentation of cellulose and hemi celluloses in the cecum and large colon (Duncan, *et al*., 1990; Janis, 1976). To meet energy demands, they have to consume food for 60% of their time under best conditions and 80% under poor conditions (Bell, 1971; Tyler, 1972). Gwynne and Bell (1968) studied that the zebras have adapted their grazing by eating only the high-fiber and low protein of the grass. This gives them a lot of habitat in the savanna to graze on and also leaves the more nutritious parts for the wildebeests. Non-ruminants, such as zebras, have a low coefficient of dry matter digestibility reaching about 42- 45% (Abaturov, 1995).

The time devoted to grazing was peaked during the dry season and gradually decreased during the wet season. The increased in grazing time with decreasing food availability in the dry season has been reported for several African grazers (Owen-

Smith, 1982). In the present study, the annual mean proportion of time spent grazing by Burchell's zebras at Yabello Wildlife Sanctuary was estimated to be 55.5%. Burchell's zebras were standing most in the mid day; this may be due to the hot temperature. Standing was least in the afternoon, probably due to the higher need of grazing.

7.6 Threats of Burchell's zebra population in the Yabello Sanctuary

7.6.1 Habitat destruction and disturbance

Most of loss of habitat types and species composition occurred mainly due to livestock grazing, which led to disappearance of high forage species and encroachment of shrubs and trees. Cutting of trees for the sake of fuel wood and for timber production has been a common practice in and/or around the sanctuary. Deforestation is increasing from time to time, leading to permanent destruction of the habitat. Local people cut trees (e.g.*Acacia* spp., *Terminalia glaucescens, Albizia schimperiana*) for construction purpose.

The major components of habitat destruction and disturbance in the study area were settlement in and around the Sanctuary (Plate 3), tree cutting was mainly associated with new settlement, which resulted in deterioration of the remaining vegetation cover of the area. This minimizes the feeding ground, nesting and mating site of the wild animals. As a result, the vegetation structure has changed dramatically, grass cover has declined and the density of woody shrubs has increased alarmingly.

There were also many other problems observed. For instance, intensive exploitation of the woodlands for construction and fuel wood purpose due to the increased human population. Charcoal making is also becoming very common in the area.

Plate 3. Settlements in the boundary of the Sanctuary (Photo: Author December, 2009).

7.6. 2 Livestock abundance

Livestock is the most commonly observed animal in the Sanctuary. The increased number of livestock around the sanctuary was one of the important factors affecting the status and distribution of Burchell's zebra in Yabello Wildlife Sanctuary. The dominant herbivores over the whole study area are cattle, goats, sheep, donkeys and camels (Figure 25). Thousands of livestock competes directly for food with Burchell's zebras and other wildlife in the Sanctuary (Plate 5). Livestock distribution throughout the Sanctuary increased especially during the wet and late dry seasons, when the grasses were at grazable size. During the wet season, the number of livestock counted inside the Sanctuary was 6110 and during the dry season, these were only 4053 (Plate 4). Zebra populations were also challenged at water points by human and live stock (plate 6).

Plate 4. Livestock grazing in the Yabello Wildlife Sanctuary (Photo: Author October, 2009).

Plate 5. Competition for food between Burchell's zebras and livestock in Yabello Wildlife Sanctuary (Photo: Author October, 2009).

Plate 6. Challenges of Burchell's zebra at water point in the Yabello Wildlife Sanctuary (Photo: Author February, 2010).

7.6.3 Hunting

The Sanctuary has only six permanent game scouts to protect the 2496 km^2 Sanctuary areas (Table 17). Poaching of Burchell's zebras and other wildlife species are common in Yabello Wildlife Sanctuary. The small number of game scouts may be one of the causes of ineffectiveness to protect the animal from illegal hunters. In addition to this, the staff members of the Sanctuary live about 17 km away from the Sanctuary in Yabello town. At the same time, the concerned officials are also reluctant to enforce the law.

Table 17. Yabello Wildlife Sanctuary staff members.

Item	Number	Year
Park warden	1	2009
Ecologist	1	”
Scouts	6	’’
Expert	1	’’
Secretary	1	’’
Total	**10**	

Source: Yabello Wildlife Sanctuary Office Report (2009).

7.6.4 Bush encroachment

In the Borana rangelands of southern Ethiopia, a progressive increase in bush encroachment and loss of grass cover (Coppock, 1994) is associated with changes in patterns of livestock grazing (Bille *et al*., 1983). Heavy livestock grazing in turn has reduced the herbaceous vegetation cover (Coppock, 1993). Several native *Acacia* species among which *A. drepannolobium, A. oerfota*, *A. mellifera* and many others were observed to be an emerging rampant species replacing some of the valuable species at Yabello Wildlife Sanctuary. Due to its rapid expansion, *A. drepannolobium* was the most serious problem in the area.

It had been observed during the field survey that this species had formed a pure stand replacing all other species that used to grow in the area. According to the local communities, such a serious bush encroachment happened in Borana because of the

official ban of rangeland burning since 1970s. The ban on fire in the 1970s might also have facilitated the expansion of bush encroachment (Coppock, 1993).

In order to sustain the productivity of the woodland as a whole and grass species in particular, appropriate resource management measures must be taken. These probably demand for the re-utilization of controlled fire as a management tool, and selective clearing of invasive species. Above all, strengthening of the traditional resource management system is very crucial. The open palatable grasslands have been changed to unpalatable grassland and dominated by various species of *Acacia* (Plate 7). The expansion of large number of acacia seedlings in grassland habitat in many parts of the sanctuary increased bush encroachment.

Plate 7. *Acacia drepannolobium* encroachment in the Yabello Wildlife Sanctuary (Photo: Author February, 2010).

7.6.5 Damage due to Termites

Termite was also found to be another emerging issue in most of the study areas and it needs attention before it become out of control (Plate 8). During the survey, several termite mounds were observed here and there in the woodlands. Termites mainly interfere with regeneration and even kill mature trees of the preferred species. Hence, this also needs management measure before it comes out of control.

Plate 8. Damage of termites bound in the Sanctuary (Photo: Author January, 2009).

8. CONCLUSION

One of the objectives of this study has been to see the distribution, population status and diurnal activity pattern of Burchell's zebra in Yabello Wildlife Sanctuary. It is apparent that changes in habitat quality, overgrazing, habitat degradation and competition with domestic livestock are the main human induced factors for the decline of the species. Yabello wildlife Sanctuary is under high pressure of being used as grazing lands by pastoralists. Livestock are grazing in the area extensively. Pastoralists move their cattle from one locality to the other in response to the change in environmental factors. However, this tradition has been changed to a kind of sedentary with the increase in human population and livestock, resulting in habitat changes due to overgrazing. Water source inside the boundary of the Sanctuary has attracted many pastoralists to settle around these conservation areas. This has, partly contributed to the reduction of important wildlife species in the Sanctuary. Monitoring this habitats using ecologically acceptable measures and avoiding bush encroachment is essential.

Different approaches are being forwarded regarding the means of conserving natural resources. Conservationists accept the principle that indigenous people have the right to use, own and control their traditional territories (Mackinnon *et al*., 1986). However, this idea is difficult when it comes to implementation with the current human pressure (Spinage, 1998).

Ecologists are arguing that all people constitute a threat to nature due to dual problems of population increase and the adoption of new technologies. These factors can be generalized as: the rapid increase in human population and the need for additional land to increase production for sustainability of the family, improved technologies to bring a serious threat for wild animals such as the use of guns, wire snares, gin traps, insecticidal poisons, scattering of in destructive litter, plastic and metals that are ecologically incompatible with conservation of nature, use of modern veterinary medicines to increase stock numbers have also contributed to over grazing and degradation of the ecosystem, the desire of monetary wealth inspired people to misuse resources. The above problems are prevalent in the study area. Effective management of zebras and other wildlife resources in the Sanctuary can be realized only if the current pressure in the conservation area is controlled and when the pastoralists are provided

with legal rights to use the resource at a limited level that are compatible with the ecology of the area and participate them in its conservation and management.

The trends in the population status of zebra population in Yabello Wildlife Sanctuary have showed decreased compared to earlier study of Syvertsen (1992) and Thouless (1995). The population structure and group composition of Burchell's zebras were adult female biased. The high percentages of females and fairly high young population showed that Burchell's zebra's population has a potential to increase.

Grazing was the dominant activity of zebras in the study region; although the proportion of time spent grazing differed significantly between the sexes and seasons. Diurnal grazing behavior was strongly biphasic, with animals showing strong avoidance of energy consuming activities such as grazing and walking during the hottest period of the day. Such activities increased in the early morning and late afternoon and correlated with lower ambient temperatures.

Marked differences were observed between the diurnal activity budgets of Burchell's zebra in different seasons and hours of the day. Grazing occupied most of the time and, together with walking, resting and standing, accounted for at least 90% of all diurnal activities.

The transect data confirm the general statement of earlier authors that Burchell's zebra inhabit open grassland and lightly wooded areas and tend to avoid dense woodland and thickets. The diurnal activity of Burchell's zebras depends on variation in climatic condition. Seasonal changes affect the timing of grazing and resting (lying down) activities.

9 RECOMMENDATIONS

- ☞ The population status of Burchell's zebra has declined in Yabello Wildlife Sanctuary, mainly due to adverse human activities and livestock abundance. To alleviate such threats, immediate conservation measures should be taken for sustainable survival of Burchell's zebra and other wildlife in the Sanctuary.
- ☞ It is important to integrate the use of full indigenous knowledge and modern conservation systems to develop a deeper understanding of the species and their ecosystems.
- ☞ The sharing of benefits with the communities living inside and adjacent to the Sanctuary will help to reduce conflicts between wildlife managers and local communities. There should be close link between the Sanctuary authority and the local communities living around. Local communities should have a role of in designing, planning, implementation and evaluation of the wildlife conservation program.

- ☞ The number of tourist visitors to the Yabello Wildlife Sanctuary is surprisingly low. So, the posting of standard road-signs, production of brochures and maps, should publicize it. Sign posts should be placed using flagship species, such as the Burchell's zebra, Oryx, Endemic birds etc. in the vicinity of the Sanctuary on the main road in every few kilometers to invite and attract the tourists.

- ☞ Open grass land habitats constitute the major preference of Burchell's zebras. It is important to improve both the quality and the quantity of forage availability within the Sanctuary. Measures of controlling the invasion of the plains by bush encroachment should be undertaken through controlled burning and selective ploughing of the natural grasslands within the Sanctuary. Both the burning and ploughing programs should be controlled and monitored by the Sanctuary authorities. The vested interests and experience of pastoral communities are crucial for the implementation of such vegetation management program.

- ☞ There should be an effective and realistic management policy for the Yabello Wildlife Sanctuary, to control illegal human settlement and farming activities. It should therefore, aim at reconciling the interests of conservation and local pastoral communities. Effective laws and regulations of the Sanctuary policy should be practiced. Sanctuary wardens and scouts should get full responsibility to protect the Sanctuary. Effective control of illegal, destructive and human hunting and enforcement of laws prohibiting hunting should be practiced.

- ☞ It is quite important to up-grade the skills of game-scouts of the Sanctuary to make them knowledgeable in matters of wildlife conservation and enforcement of all the legal measures. The Sanctuary management staff should have good facilities with the appropriate manpower, equipment and budget.
- ☞ The boundary of the Sanctuary should be clearly demarcated and well known by the local communities, the governmental officials and the Oromia forest and Wildlife enterprise.

- ☞ Habitat restoration is perhaps the only appropriate conservation strategy that may solve the rapid decline and eventual extinction of some species like Oryx and African wild dog in the Sanctuary. Cattle, sheep, goats and camels are found in large numbers and at high densities in the area. They are estimated in tenths of thousands of individual livestock. Live stocks do not feed strategically as do by other wild herbivores; hence resource of a given area will be eaten until it is totally exhausted. This may damage the vegetation cover and degrade the habitat qualities that are required by burchell's zebra and other herbivores. Plant species, such as A. *drepannolobium* are spreading in to open grassland rapidly. This may have a serious impact for the future unless measures are undertaken to control its expansion as it is unpalatable.
- ☞ The cattle ranch that was established inside the boundary of the Sanctuary should be transferred to other place which is appropriate to livestock ranching immediately without further disrupting the habitat of zebra population and other Wildlife species.

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11. APPENDICES

Appendix 1. The list of plant species that include scientific name, local name, family and growth habit of all woody species encountered at Yabello Wildlife Sanctuary.

Scientific name	Vernacular name	Family	Habit
Acacia bussei Harms ex S. jostedt	Hallo	Fabaceae	Tree
Acacia oerfota (Forssk.) Schweinf	Waanga	Fabaceae	Shrub
Acacia seyal Del.	Waacuu diimaa	Fabaceae	Tree
Acacia Senegal (L.) willd.	Sephansa diimaa	Fabaceae	Tree/shrub
Acacia mellifer (Vahl.) Benth	Saphansa gurraacha	Fabaceae	Tree/shrub
Acacia oerfota(Forssk.) Schweinf	Waanga	Fabaceae	Shrub
Acacia totrtilis (Forssk.)Hayne	Dhadacha	Fabaceae	Shrub
Balanites aegyptica (L.) Del.	Badana Lu'oo	alanitaceae	Tree/shrub
Boswellia neglecta S. Moore	Dakkara	Burseraceae	Tree/shrub
Bosciamossambicensi Klotzsch	Qalqalcha	Cpparidaceae	Tree
Commiphorakua (R.Br.Ex. Royle) Vollesen	Callaanqaa	Burseraceae	Tree/shrub
Commiphora baluensis Engle.	Agarsuu	Burseraceae	Tree
Commiphora africana (A. Rich.)	Hammesa dhiiroo	Burseraceae	Tree/shrub
Commiphora boranesis	Rigaa qeeroo	Burseraceae	Tree/shrub
Commiphora habessinica (Berg)	Hoomacho	Burseraceae	Tree/shrub
Commiphora confuse Vollesen	Siltaachoo	urseraceae	Tree

*Commiphora schimperi (*Berg.)Egngl.	Hammesa qayyoo	Burseraceae	Tree/shrub
Lanea rivae (Chiov.) Sacleux	Handaraka	Anacardiacea e	Tree
Dichrostachyuscinerea(L.)wightet Arm.	Jirimee	Fabaceae	Tree/shrub
Grewia bicolor Juss	Harooressa	Tiliaceae	Shrub
Grewia tenax (Forssk.) fiori	Saarkama	Tiliaceae	Shrub
Sterculia stenocarpa H. Winkler	Qarari	Sterculiacea	Tree

Appendix 2. List of some Mammals species recorded in Yabello Wildlife Sanctuary**.**

Common name	**Scientific name**	**Local name**
African wild dog	*Lycaon pictus*	Yeyyii
Anubis baboon	*Papio anubis*	Jaldeessa
Oryx	*Biesa oryx*	Saalaa
Bohor reed buck	*Rudunca rudunca*	Siqee/Goda
Burchell's zebra	*Equus burchelli*	Harree diidoo
Bush pig	*Potamochoerus porcus*	Boyyee
Cheetah	*Acinonyx jubatus*	Abboshamane
Common warthog	*Phacochoerus aethiopicus*	Goljaa
Gerenuk	*Litocranius walleri*	Guguuftoo
Golden jackal	*Canis aureus*	Sardiida/Jedalla
Grant's gazelle	*Gazella granti*	Hiddii
Greater kudu	*Tragelaphus strepsiceros*	Gadamsa Guddaa
Guenther's dik-dik	*Madoqua guentheri*	Tarrii
Hare	*Lepus sp.*	Illeensa
Leopard	*Panthera pardus*	Qeeransa
Lesser kudu,	*Tragelaphus imberbis*	Gadamsa xiqqaa
Lion	*Panthera leo*	Leenca
Serval cat	*Felis serval*	Daraafessa
Side striped jackal	*Canis adustus*	Sardiida sarara cinaa
Spotted hyena	*Crocuta crocuta*	Warabessa

Appendix 3. List of some bird species recorded from Yabello Wildlife Sanctuary.

Species	Season	Year	Criteria
Abyssinian Scimitarbill (*Rhinopomastus minor*)	resident	1996	A3
African Grey Flycatcher (*Bradornis microrhynchus*)	resident	1996	A3
Ashy Cisticola(*Cisticola cinereolus*)	resident	1996	A3
Banded Warbler (*Sylvia boehmi*)	resident	1996	A3
Bare-eyed Thrush (*Turdus tephronotus*)	resident	1996	A3
Black-billedWoodhoopoe(*Phoeniculus somaliensis*)	resident	1996	A3
Black-capped Social-weaver(*Pseudonigrita cabanisi*)	resident	1996	A3
Black-throatedBarbet(*Tricholaema melanocephala*)	resident	1996	A3
Boran Cisticola(*Cisticola bodessa*)	resident	1996	A3
Collared Lark (*Mirafra collaris*)	resident	1996	A3
D'Arnaud's Barbet (*Trachyphonus darnaudii*)	resident	1996	A3
Donaldson-Smith's Nightjar (*Caprimulgus donaldsoni*)	resident	1996	A3
EasternChanting-goshawk(*Melierax poliopterus*)	resident	1996	A3
EasternYellow-billedHornbill(*Tockus flavirostris*)	resident	1996	A3
* Ethiopian Bush-crow(*Zavattariornis stresemanni*)	resident	1996	A1, A2,A3
Ethiopian Grosbeak-canary (*Serinus donaldsoni*)	resident	1996	A3
Golden-breasted Starling(*Cosmopsarus regius*)	resident	1996	A3
Grey Wren-warbler(*Camaroptera simplex*)	resident	1996	A3
Grey-headed Silverbill (*Lonchura griseicapilla*)	resident	1996	A3
Hemprich's Hornbill (*Tockus hemprichii*)	resident	1996	A3
Hunter's Sunbird (*Nectarinia hunteri*)	resident	1996	A3
Kenya Violet-backed Sunbird (*Anthreptes orientalis*)	resident	1996	A3
Little Brown Bustard(*Eupodotis humilis*)	resident	1996	A3
Magpie Starling (*Speculipastor bicolor*)	resident	1996	A3
Masked Lark(*Spizocorys personata*)	resident	1996	A3
Mouse-coloured Penduline-tit (*Anthoscopus musculus*)	resident	1996	A3
Pale Prinia(*Prinia somalica*)	resident	1996	A3
Pink-breasted Lark(*Mirafra poecilosterna*)	resident	1996	A3

Pringle's Puffback (*Dryoscopus pringlii*)	resident	1996	A3
Purple Grenadier(*Uraeginthus ianthinogaster*)	resident	1996	A3
Pygmy Batis(*Batis perkeo*)	resident	1996	A3
Red-and-yellowBarbet(*Trachyphonus erythrocephalus*)	resident	1996	A3
Red-bellied Parrot (*Poicephalus rufiventris*)	resident	1996	A3
Red-rumped Waxbill (*Estrilda charmosyna*)	resident	1996	A3
Rosy-patchedBush-shrike(*Rhodophoneus cruentus*)	resident	1996	A3
Rueppell's Weaver (*Ploceus galbula*)	resident	1996	A3
Rufous Chatterer (*Turdoides rubiginosa*)	resident	1996	A3
Rufous Short-toed Lark(*Calandrella somalica*)	resident	1996	A3
Scaly Chatterer (*Turdoides aylmeri*)	resident	1996	A3
Shelley's Starling (*Lamprotornis shelleyi*)	resident	1996	A3
Short-tailed Lark(*Pseudalaemon fremantlii*)	resident	1996	A3
Somali Fiscal(*Lanius somalicus*)	resident	1996	A3
Somali Golden-breasted Bunting(*Emberiza poliopleura*)	resident	1996	A3
Somali Sparrow(*Passer castanopterus*)	resident	1996	A3
Somali Tit (*Parus thruppi*)	resident	1996	A3
Speke's Weaver (*Ploceus spekei*)	resident	1996	A3
Star-spotted Nightjar (*Caprimulgus stellatus*)	resident	1996	A3
Steel-blue Whydah (*Vidua hypocherina*)	resident	1996	A3
Straw-tailed Whydah (*Vidua fischeri*)	resident	1996	A3
Taita Fiscal(*Lanius dorsalis*)	resident	1996	A3
Three-streaked Tchagra (*Tchagra jamesi*)	resident	1996	A3
Tiny Cisticola(*Cisticola nanus*)	resident	1996	A3
Von der Decken's Hornbill (*Tockus deckeni*)	resident	1996	A3
Vulturine Guineafowl (*Acryllium vulturinum*)	resident	1996	A3
White-bellied Canary (*Serinus dorsostriatus*)	resident	1996	A3
White-bellied Go-away-bird (*Corythaixoides leucogaster*)	resident	1996	A3
White-breasted White-eye(*Zosterops abyssinicus*)	resident	1996	A3
White-crowned Starling (*Spreo albicapillus*)	resident	1996	A3
White-headed Buffalo-weaver (*Dinemellia dinemelli*)	resident	1996	A3

White-rumped Babbler(*Turdoides leucopygia*)	resident	1996	A3
* White-tailed Swallow (*Hirundo megaensis*)	resident	1996	A1, A2,A3
Yellow-neckedSpurfowl(*Francolinus leucoscepus*)	resident	1996	A3
Yellow-vented Eremomela (*Eremomela flavicrissalis*)	resident	1996	A3

Source: Birdlife International (2009) with some modification.

Astrics(*) indicates the endemic birds to Yabello Wildlife Sanctuary.

A1 = Species of global conservation concern

A2 = Assemblage of restricted range species

A3 = Assemblage of Biome- restricted species

Appendix 4. Data collection sheet (Population census form) for Line- transects.

Place_____ Date_____

Transect number_____ Start time_____ End time_____

Name of data collector_____ Target species_____

Transect direction_____ Transect length_____ Season_____

Observation	Date	Species	No. seen	Sex		Age					Habitat	Remarks
				M	F	AM	AF	SA	JV	Foal		

AM= adult male AM= adult female. SA= sub –adult. JU= Juvenile, Foal

*Grassland, Woodland, Bush land

Appendix 5. Diurnal activity pattern recording sheet for Burchell's zebra.

Place_____ Date_____

Month of season_____

Transect number_____

Name of data collector_____target species_____

Time	No.of observation	Grazing	Walking	Resting	Grooming	Standing	Others	Remarks

Appendix 6. The list of grass species that include scientific name, Vernacular name and family name recorded from Yabello Wildlife Sanctuary.

Scientific name	**Vernacular name**	F**amily**
Aristida adoensis Hochst.	Saatuu biilaa	poaceae
Aristida kenyensis Henr.	Biilaal	’’
*Bothriochloainsculpta(*A.Rich.) A.Camus	Luucolee	’’
Cenchrus ciliaris(L.)	Mat guddeessa	’’
Chrysopogon Auheri(Boiss.) Stapf.	Alaloo	’’
Cynodon dactylon(L.) Pers.	Sardoo	’’
*Dactyloctenium Aegyptium(*L.*)*	Ardaa	’’
Eleusine jaegeri Pilg.	Coqqorsa	’’
Elusine intermedia (Chiov.) S.M. phillips	Coqorsa	”
Eragrostispapposa(Roem.&Schult.) Stued.	Samphee/samphilee	’’
Ischaemum afrum (J.f.Gmel.)	Guuree	’’
Leptothrium senegarense(Kunth) Claylon	Biilaa diidaa	’’
Lintonia nutans Stapf	Hiddoo(Luucolee)	’’
Lintonia nutans Stapf.	Ardaa	‘’
Loudetia flavida (Stapf) C.E. Hubb.	Seericha gaaraa	’’
Pennisetum mezianum	Ogoondichoo	’’
Pennisetum mezianum Leeke	Ogoondhichoo	’’
Sporobolus pyramidalis .Beauv P.	Seerricha	”
Themea triandra Forssk.	Gaaguroo/Marra-saalaa	”

Declaration

This is to certify that this thesis entitled “Distribution, population status and diurnal activity pattern of Burchell’s zebra (*Equus burchellii*, Gray, 1824) in Yabello Wildlife Sanctuary, Southern Ethiopia.” Submitted to the School of Graduate Studies, Department of Biology, Science faculty of Addis Ababa University in partial fulfillment for the requirements of degree of M. Sc., in Dry land biodiversity, done by Reta Regassa Jetu, ID.No.GSR/ 0733/01 is an authentic work carried out by him under my guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief. All the sources of materials used have been duly acknowledged.

Reta Regassa Jetu	_____	_____
Name of Student	Signature	Date

Dr.Solomon Yirga (D.Sc)	_____	_____
Name of advisor	**Signature**	**Date**