ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

POPULATION STATUS AND DIET OF STARCK'S HARE

(*Lepus starcki* Petter, 1963**)**

IN BALE MOUNTAINS NATIONAL PARK,

ETHIOPIA.

BY

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1. INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

1.1.1 Background of the study

The geographical location and physical features of Ethiopia have resulted in the diversification of wildlife (Yalden, 1983; Shibiru Tedla, 1995). Thus, Ethiopia possesses a unique and characteristic fauna with a high level of endemism (Yalden 1988; Hillman, 1993a, b).

In Ethiopia, 284 mammalian species have been recorded, of which 31(11%) are endemic (Hillman, 1993a; Leykun Abunie, 2000). A total of 861 bird species are also known to occur in the country, of which 16 are endemic (Hillman, 1993a; Yalden and Largen, 1992). However, due to human pressure on natural habitats and related factors, many of these wild animals are at present confined to the limited protected areas.

Ethiopia is distinguished from all other African countries by its large area of highlands. Over 80% of African highland areas above 3000 m altitude are located in Ethiopia (Yalden, 1983; Sillero-Zubiri, 1994). The Rift Valley separates the highlands and mountain areas of the country into Northwest and Southeast (Uhlig, 1988). Although the species diversity in these highlands is less than the lowland, there is a high number of endemic mammalian and avian species (Yalden and Largen, 1992; Kingdon, 1997; Stephens, 1997).

The Bale Mountains National Park (BMNP) is situated in the southeastern Ethiopia, along the eastern edge of the Rift Valley. It provides broad range of habitats from 1500 to 4377 m asl (Tullu Deemtu) (Hillman, 1986). BMNP was established in 1969 following the recommendation made in 1964/66 by Brown (Sillero-Zubiri, 1994). The Park was established primarily for the conservation of the Ethiopian wolf and Mountain nyala and also part of the largest tract of the afroalpine habitats in Africa (Hillman, 1993b; Befekadu Refera and Afework Bekele, 2004). It also conserves a major water catchments area important to both Ethiopia and Somalia (Hillman, 1988).

1.1.2 Statement of the problem and Justification

For effective research and management of wildlife species, a reliable estimate of population number and feeding habits of mammals are in the center of population biology and ecology (Putman, 1984; Matrai *et al*., 1998). Starck's hare (*Lepus starcki* Petter, 1963) is one of the

endemic mammals of Ethiopia (Yalden and Largen, 1992; Kingdon, 1997) and potentially a very important part of the ecosystem. Sillero-Zubiri (1994) made detailed study of the feeding ecology of the Ethiopian wolf in the BMNP. The diet of Ethiopian wolf in this area is primarily rodents followed by Starck's hare and other small ungulates. Morris and Malcolm (1977) and Malcolm (1997) stated Starck's hare as the important prey of the Ethiopian wolf. Although it is endemic to the country and an important part of the diet of the endangered and endemic Ethiopian wolf, detailed study about this endemic species is lacking. These points have led to the formulation of the objective of the present study.

The present study provides preliminary information on the current population status, diet and other related aspects of Starck's hare in BMNP. This information will form the base-line data relevant to further studies and conservation of the species. In addition, the study has critical value in the conservation of the Ethiopian wolf since this animal is part of the food chain.

1.2 Literature review

Although Starck's hares are common and widespread throughout the BMNP, no specific studies on the species have been carried out and literature available on the species is limited. However, limited information on the ecology, density, and taxonomy of the species in BMNP is referenced in Hillman (1986), Azzaroli-Puccetti (1987), Hoffman (1993), Sillero-Zubiri (1994), Azzaroli-Puccetti *et al.* (1996), Kingdon (1997) and Sillero-Zubiri and Macdonald (1997).

Lepus starcki ('Hillensa' in Afan Oromo, 'Tinchel' in Amharic, Starck's hare or Ethiopian highland hare in English) have a pale brown color (tawny) at their back, nape, chest and legs. The tail is white with black stripe. Ears have a prominent black tip. They have grooves on the front of the upper incisors that lack cement and large mesoptrygoid space in the palatal region of the skull (Yalden and Largen, 1992). The mean measurements of Starck's hare were: HB 42-60 cm, T 7-12 cm, W 2-3.5 kg (Kingdon, 1997).

1.2.1 Taxonomy and distribution

Starck's hare *(*Plate 1*)* is classified in the genus *Lepus,* Family Leporidae, Order Lagomorpha. The key characteristic of lagomorphs, to be classified in the separate order is the presence of the second incisor behind the first large upper incisor (Burton, 1984; Nowak, 1999).

The family Leporidae contains 11 genera and 60 species (Robinson and Matthee, 2005). The genus *Lepus* contains more than 29 species (Nowak, 1999; Vaughan *et al*. 1999). The important specific characteristics of hares occur in the morphology and anatomy of the teeth and skull. Thus, it is too difficult to identify the different species of hares looking at the physical appearance only, even in the hand (Young, 1975; Burton, 1984). Most hares in Africa are considered as *Lepus capensis* Linnaeus, 1758 (Robinson and Matthee, 2005). The taxonomy of the genus *Lepus* in Africa is very confusing and its classification is still debated (Wilson and Reeder, 1993; Robinson and Matthee, 2005). Although many hypotheses have been proposed to clarify the specific species of hares, taxonomists did not reach consensus.

In 1963, Petter originally described Starck's hare as a race of *L. capensis*, and an endemic mammal to Ethiopia (Yalden and Largen, 1992). However, Azzaroli-Puccetti (1987) argued that *L. starcki* should be regarded as an isolated southern race of European brown hare (*Lepus europaeus* Pallas, 1778). Because of its importance for hunting, the European brown hare was widely distributed to many countries outside its original range (Angerman, 1983; Nowak, 1999). However, initially *Lepus europaeus*, itself, was regarded as a race of *L. capensis*, but at present *L. capensis* and *L. europaeus* are grouped under different species (Yalden and Largen, 1992).

In Ethiopia, Azzaroli-Puccetti, (1987) identified five species of hares: *Lepus crawshayi* de Winton, 1899, *Lepus fagan*i Thomas, 1903, Lepus *habessinicus* Hemprich and Ehrenberg, 1832, *L. starcki* and *L. capensis*. Though *L. habessinicus* and *L. crawshayi* have been recognized as distinct species, Hoffman (1993) has included them in *L. capensis* and *Lepus victoriae* Thomas, 1893, respectively.

Kingdon (1997) grouped the African true hares under Cape hare (*L. capensis*), Scrub hare (*Lepus saxatils* F. Cuvier, 1823) and Starck's hare (*L. starcki*). In the above classification, unlike Hoffman (1993), *L. fagan*i and *L. victoriae* are grouped as sub-species of *L. saxatilis*.

Among the mammals, the genus *Lepus* is one of the most widespread species occurring in the Palaearctic and the Nearctic, including Ethiopia (Azzaroli-Puccetti *et a*l., 1996). Different species of hares have been distributed in different parts of Africa (Table 1).

Table 1. The different species of *Lepus* and their distribution in Africa.

Species	Distribution	Common name
Lepus capensis	The most wide spread	Cape hare
L. saxatilis	-Cape province -South Namibia	Scrub hare
L. starcki	Highlands of Ethiopia	Starck's hare (Ethiopian highland hare)

Source: Kingdon, 1997

Hares are confined to open and even dryland habitats. Unlike rabbits, they never excavate burrow (Kingdon, 1971). They mainly live in grass nests and sometimes shelter in caves and rocks (Kingdon, 1997). In Africa, the true hares are represented in open grass areas.

Starck's hares are mainly found in afroalpine parts of the BMNP including Tullu Deemtu but also seen at low density in heather moorland and forest as well as northern woodlands of the Park (Hillman, 1986). Yalden and Largen (1992) stated that Starck's hares are quite abundant on the moorlands of Bale Mountains. At the same time, they also occur on both sides of Rift Valley at altitude of 2140-4000 m asl in both grassland and afroalpine moorland. Sillero-Zubiri (1994) stated Starck's hares were particularly abundant on Sanetti Plateau and less in ericaceous heather and montane grassland. He also estimated the density 0.3, 0.2, 0.17, per ha at Sanetti Plateau, Tullu Deemtu and Web Valley, respectively.

The two species of hares in Ethiopia, *L. starcki* and *L. habessinicus* are adapted to quite different environments. *L. habessinicus* occurs at lower altitude and arid areas of eastern Ethiopia. However, *Lepus starcki* are confined to central highlands of the country (Fig. 1).

1.2.2 Ecology

As there is little information on the ecology of Starck's hare in BMNP, understanding the general ecology of hares is important for this study. Hares are herbivores and eat wide varieties of plants including grass, herbs, and barks of plants (Stanbury, 1972). However, they often show preference to certain species of vegetation (de Vos, 1964; Hamolka, 1987). These preferences vary greatly between regions and are dependent on the local plant communities (Hodges, 2000; Strevens and Rockford, 2002). The front teeth of hares continue to grow as long as the animal lives and are used to cut plants (Nowak, 1999; Vaughan *et al*., 1999). They have the dental formula 2/1 0/0 3/2 3/3 (Burton, 1984).

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Hares circulate food twice (as do rabbits) and produce two different types of faeces. One type is soft and rich in vitamins and re-eaten (eaten directly from the anus) while the other type is the hard dry dung pellets normally observed in their habitat (Burton, 1984; Nowak, 1999). Hillman (1986) and Kingdon (1997) mentioned the diets of Starck's hares on BMNP to feed upon the common moorland grasses such as *Agrostis, Eleusine, Festuca, Pennisetum and Poa.*

The reproduction of Starck's hare has not been yet studied. However, for the other species of African and European hares, the pattern of reproduction is well known. Kingdon (1997) stated that African hares have a continuous reproductive season in a year. There is no set breeding season in East Africa and gestation period is only six weeks. A female hare bears six litters a year normally with one or two young per litter (Dodds, 1965; Young, 1975; Vaughan *et al*., 1999). The young is born furred with eyes open and active compared to rabbits which are born naked and with their eyes closed (Burton, 1984; Nowak, 1999). The female hare spends little time taking care of her young (McCullough, 1989). The young are left in the forms (place where they stay during inactive time) and the mother only suckles them for a brief period of about five minutes every 24 hours (McFarland, 1985; Corbet and Hill, 1991; Vaughan *et al*., 1999). Yalden and Largen (1992) obtained two female Starck's hares shot on Sanetti Plateau in 1971; of which one was pregnant with one embryo.

Except during mating season, most species of hares are solitary (Flux, 1964; Cloudsley-Thompson, 1969; Kingdon, 1971; McFarland, 1985; Caughley and Sinclair, 1994). However, they usually live with others within the home range (Vaughan *et al*., 1999). The home range varies in size depending upon the type of habitat that includes forms, terrain, direction of light, and vegetation (McCullough, 1989; Estes, 1991).

To protect themselves from enemies they rely on camouflage, active sense organ (smell and sight) and speed. They can run at the speed of 70 km/hr (Kingdon, 1971). If they are chased, first, they run in straight line then they change to zigzag pattern. They take sand baths to keep their fur clean and groom themselves several times within a day.

The population of hares can be influenced by weather effects, food supply, predation, parasite and disease (Angerbjorn, 1983). They are the main food source of many animals, such as, Ethiopian wolves, foxes, mountain lions, wild cats, hawks and coyotes (Kingdon, 1971; Burton, 1984; Hillman, 1986; McCullough, 1989; Nowak, 1999; Vaughan *et al*., 1999).

1.2.3 Significance and Threats

Hares are important economically and aesthetically for humans (Burton, 1984; Nowak, 1999). They provide sport hunting, food and fur. Hares also form an important link in ecological food chains. Many predators rely on the abundance of hares for their diet. One example of this phenomenon is the linkage of Ethiopian wolf and Starck's hares in the Bale Mountains (Morris and Malcolm, 1977; Sillero-Zubirii, 1994; Sillero-Zubiri and Macdonald, 1997; Marino, 2003).

Human induced disturbance is the major threat in the BMNP (Hillman, 1986). In the higher parts of the Bale Mountains, there were very little settlements in the past. In 1984, permanent settlement in the Park was estimated at 2,500 (Hillman, 1986; Stephens, 1997; Marino, 2003). However, because of increased human pressure and expansion of agriculture on the lowland habitats of the Park, the human settlement has been increasing (Hillman, 1986; Gottelli and Sillero-Zubiri, 1990; Miehe and Miehe, 1994; Marino, 2002). The settlement areas are divided into permanent and nomadic (temporary). In addition to the settlements, for the purpose of utilizing mineral springs (Horas), large number of people enters the Park with their livestock and stay around the horas for about a month (Hillman, 1986; Kemp-McCarthy, 1990). This continued expansion leads to alteration of landscapes with irreversible loss of biodiversity.

Since the living condition during the rainy season is difficult on the afroalpine part of the park, the number of permanent settlements is relatively few (Miehe and Miehe, 1994). However, permanent settlements have been observed at the edge of southern side of Tullu Deemtu and around Sanetti area during the study period.

Bale is known for its cattle population. The most common large herbivores in the mountain massifs are domestic cattle (Stephens, 1997; Stephens *et al*., 2002). Hillman (1986) estimated the total number of livestock inside the Park to be 10,500. However, it has been increasing since the establishment of the Park. Sillero-Zubiri (1994) estimated the number of cattle in the Web Valley to be 43/km^2, counting 3,003 cattle in 70 km^2. In 1997, the number of livestock on Sanetti Plateau increased (Stephens, 1997). The number of livestock varied from season to season with the highest during late wet season in Web Valley. As all the livestock are herbivores and feed mainly on grasses, they compete with native herbivores of the afroalpine habitat, which may reduce the prey base of wolves.

1.2.4 Diet and density estimation techniques

Identification of diet of herbivores is more complex than carnivore diet (Putman, 1984). Thus a reliable method for measuring the species composition and proportion of food in the diet of herbivores is required (Fitzgerald and Waddington, 1979). Several methods have been used to identify hare diets including stomach content analysis, faecal analysis, direct observation, vegetation monitoring to find vegetation twigs (de Vos, 1984; Sinclair and Smith, 1984; Zimmer, 2004). Currently, DNA analysis method has been developed to enable identification of food plant species even from the residue of faeces (Matsuki, 2004). However, all the techniques have drawbacks (Fitzgerald and Waddington, 1979; Bart *et al*., 1998). Directly observing animals when they feed does not give accurate result, in habitats of high diversity of plant species, to species level (Wallamo *et al*., 1973). Stomach content analysis is not practical on live animal and the result may be unreliable in that some species of plants are easily digested and involves a portion of the meal (Westoby *et al*., 1976). Faecal analysis is potentially one of the best methods but identifying the plant fragments seen on the microscope is difficult (Fitzgerald and Waddington, 1979).

Density of hares can be estimated through faecal count, line transect (distance sampling method) and DNA analysis. Faecal pellet counts can be used to asses the numbers of hares present in the area. To use this technique the daily production of pellets per hare, the average decay rate and the number of pellets (all pellets) in the area should be known (Parkes, 1999).

Density estimation from the use of line transects is practical, efficient, and inexpensive for many population and it can give estimates of absolute hare density (Gates *et al*., 1968; Anderson *et al*., 1979; Buckland *et al*., 1993; Bart *et al*., 1998). The method assumes that, all animals on the transect (at the zero distance from the line) are counted and the visibility decreases with distance from the transect. This decline in visibility is measured empirically from data, and an estimate of density is calculated.

Through individual identification by using DNA of intestinal cells attached to faeces, it is possible to identify individual hares (Matsuki, 2004). This method is much more reliable compared with other methods, and based on faeces specimen number.

2. OBJECTIVES OF THE STUDY

2.1 General objective

The over all objective of the present study is to determine the diet and current population status of Starck's hare in the afroalpine part of BMNP.

2.2 Specific objectives

These were:

- To estimate the density of Starck's hare in the afroalpine part of BMNP.
- To identify the diet of Starck's hare in Sanetti Plateau.
- To estimate the forage availability in the study area.
- To suggest measures for conservation of the species.

3. DESCRIPTION OF THE STUDY AREA

3.1 Location

The Bale Mountains National Park (BMNP) is located southeast of the Rift Valley about 400 km by road from Addis Ababa, between 6^0 29` and $7^0$ 10` North, and 39^0 28` and $39^0$ 58` East. It covers an area of 2200 km^2, with an altitudinal range from 1500 - 4377 m asl (Hillman, 1986).

The typical afroalpine habitats in BMNP, Sanetti Plateau (3800-4050 m), Web Valley (3450-3550 m) and Tullu Deemtu (4000-4377 m asl) formed the main study area (Fig. 2). Tullu Deemtu (at 4,377 m asl) is the highest mountains in southern Ethiopia and second in the country (Marino, 2003). The current study was located at the base of the mountain (4000 m asl).

3.2 Climate and soil

The climate of the Bale Mountains varies due to the great altitudinal gradient within the Park and the large extent of the mountain massif (Hillman, 1986). The Bale Mountains are subject to hot days and cold nights during the dry season, and a more temperate wet season from March to October (Stephens, 1997). Temperature shows altitudinal gradient within the Park

from -3 to 24^{0}C at low altitude, and from -15 to 26^{0}C at higher altitude during the dry season (Hillman and Hillman, 1987; Sillero-Zubri, 1994). The rainy season is warmer, compared to the dry season, and the temperature shows much less daily fluctuation. There is also a relatively narrower range in the diurnal temperature from 5 to 20^{0}C (Hillman, 1986).

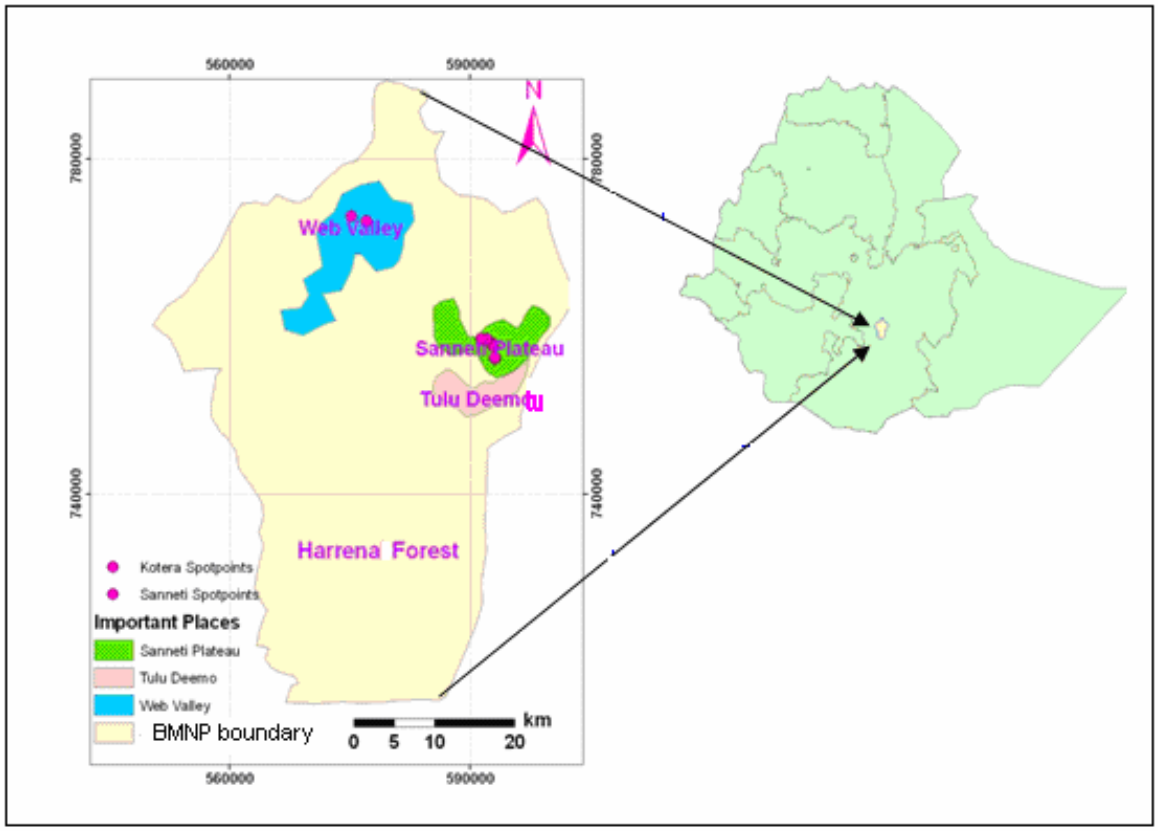


Figure 2. Location of the study area

In the Bale Mountains National Park, rains come from two different sources at various times of the wet season; the Equatorial Westerlies and the Indian Ocean Monsoon (Miehe and Miehe, 1994). The annual rainfall ranges from 1000 to1400 mm (Daniel Gamachu, 1977).

The Bale Mountains is characterized by eight months rainy season from March to October, followed by a four month dry season from November to February (Daniel Gamachu, 1977; Hillman, 1986; Sillero-Zubri, 1994). The annual rainfall increases with altitude until 3850 m asl, after which it begins to decrease again (Hillman, 1986; Sillero-Zubiri, 1994). The distribution of rainfall is not uniform during the wet season, showing two peaks from April to May and September to October. Storms of rain and hail sometimes give the mountain massif

the appearance of a snow field. Hail and snow can lie on the ground for one or two days (Sillero-Zubiri, 1994).

Mohr (1971) described that the Bale Massif consists of Tertiary Trappean lavas, which covered the Mesozoic Marine Sediments and the underlying Precambrian rock after the Eocene uplifting of the Ethiopian highlands. As the upper geological strata of the Bale Mountains are entirely volcanic, the soil is mainly derived from the basaltic and trachytic parent rock. It is fairly fertile silty loam of reddish brown to black color (Morton, 1976; Miehe and Miehe, 1994). The Bale Mountains show distinct signs of recent glaciations (Smeds, 1959; Morton, 1976; Hedberg, 1986).

3.3 Biodiversity

The Bale Mountains provide a broad range of habitats for large varieties of animal species, many of which are endemic (Mohammed Abdi, 1987; Lisanework Nigatu and Mesfin Tadesse, 1989; Yalden, 1988; Hillman, 1993a, b). Yalden and Largen (1984) underlined the importance of the Bale Mountains as a center of endemicity and reservoir of unknown genetic resources. More than 66 mammal species have been recorded, of which 17 species are endemic to the country, including the two endangered species, the Ethiopian wolf and Mountain nyala. Over 280 species of birds have been recorded (Yalden, 1988).

About 53% (9 of 17) endemic mammals of BMNP are rodent species (Hillman, 1986; Stephen, 1997). Of these, the giant mole rat (*Tachyoryctes macrocephalus*) has a particular importance as the main food item in the diet of the Ethiopian wolf (Sillero-Zubiri and Gottelli, 1995).

Yalden (1983), Hillman (1986), Minasie Gashaw (1990, 1991), Miehe and Miehe (1994), Sillero-Zubiri (1994), Minasie Gashaw and Masresha Fetene (1996), Nauke (2001) and Marino (2003) have carried out studies on different aspects of the vegetation in BMNP. The high rainfall in the Bale Mountains together with variation in altitude and topography resulted in diversity of the vegetation (Miehe and Miehe, 1994; Gotteli and Sillero-Zubiri, 1990). The BMNP contains the northern grassland, the northern woodland, heather moorland, afroalpine meadow and Harenna forest. Montane grasslands are represented by the northern Gaysay Valley while Harenna Forest is the woodlands and forest parts of the BMNP.

Ethiopia has the largest afroalpine habitat in Africa, of which most occur as part of the Bale Mountains (Yalden, 1983; Hedberg, 1986; Sillero-Zubiri, 1994). The afroalpine meadow covers 31.6% of the BMNP (Hillman, 1996). It is characterized by sparse, short vegetation adapted to low rainfall and heavy frosts. Due to the extreme climatic condition, the plant species diversity is low, and vegetation cover decreases at higher altitude (Sillero-Zubiri, 1994; Sillero-Zubiri *et al*., 1995; Minasie Gashaw and Masresha Fetene, 1996). The dominant vegetation in the afroalpine habitats are: *Artemisia*, *Kniphofia*, bushes of *Erica* and *Helichrysum citrispinium* (Marino, 2003).

The main representative of afroalpine habitat in BMNP and one of the present study areas, Sanetti Plateau, is dominated by short tussock grasses. However, the grass and herbaceous plants are dispersed and mosses cover large proportion of the ground (Marino, 2003). Tullu Deemtu was dominated by afroalpine *Helichrysum h*eath. However, Sanetti Plateau and Web Valley represent typical open grass afroalpine habitats (Sillero-Zubiri, 1994; Marino, 2003).

4. MATERIALS AND METHODS

4.1 Materials

Materials used during the study period includes: Global positioning system (GPS), binocular (both day and night vision), rangefinder, net, cameras, spring balance, dissecting kit, microscope, 70% ethanol, plastic bags, tape measure, stake flag, carnivore live trap, ruler and compass.

4.2 Methods

4.2.1 Preliminary study

Preliminary survey was conducted in the area during March-April, 2006. During this survey, all relevant information about distribution, activity (diurnal or nocturnal) and active feeding time of Starck's hare were assessed. In addition, climatic condition, topography and vegetation type and coverage of the afroalpine part of BMNP were observed. The night activities of Starck's hare were checked along the road using vehicle from Sanetti to Tullu Deemtu (12 km) and on foot on the other part of the study area. After this survey, Sanetti Plateau, Tullu Deemtu and Web Valley were selected for study area. The best time to study the species was identified to be at dusk and dawn when they were more active.

During the preliminary survey, Starck's hares were not observed in some part of afroalpine belt (*Ericaceou*s habitat and most *Helichrysum* heath). Hence, the total afroalpine grassland (Sanetti Plateau 133 km^2, Web Valley 120 km^2) and some part of *Helichrysum* heath (Tullu Deemtu 89 km^2) were taken as the major study area. This was based on previous BMNP habitat division (Hillman, 1986; Sillero-Zubiri, 1994).

4.2.2 Data collection and analysis

To estimate the density, line transects (distance sampling) method was used (Ruette *et al*., 2003; and Sutherland, 1996). A total of 10 transects were systematically located on 40 km^2 on each of the study area at the interval of 1 km. The length of each transect was 4 km. Transects were conducted on foot stopping and carefully observing at approximately 50 m interval. Each time, a hare was seen, was recorded as a sighting. However, in almost all cases more than one hare was visible and the group size was recorded. When hares were detected, the numbers of animal seen, the perpendicular distance, bearing, position and activity at the time were recorded (Appendix 1). The survey time was at dusk and dawn.

Data for vegetation availability was obtained from 44 sample sites using line intercept method (Floyd and Anderson, 1987; Sutherland, 1996; Cummings and Smith, 2001). Samples were systematically taken every 200 m interval from along transects randomly laid to different directions in the study area. Specimens were collected, pressed, dried and identified in the National Herbarium of Addis Ababa University.

In each sample site, coverage and frequency of individual plants were recorded and noted for each species on 15 m line intercept (Appendix 2).

To find the mean percentage coverage of each species (MPCSp),

$$MPCSp = \frac{TCSp}{L} \times 100$$

Where, TCSp = Total cover of the species

L= Length of line

To find the mean percentage vegetation coverage of the site (MPCS),

$$MPCS = \frac{TCS}{L} \times 100$$

Where, TCS = Total cover of the site

L = Length of line

To evaluate the richness of plant species in the study area,

$$RI = \frac{S - 1}{\ln(N)}$$ was used.

Where, RI = Richness Index

S = the number of species of the taxonomic group observed

N = total individual of them observed.

Diet analysis was carried out following the methods of Davison (1964), Putman (1984), Dingerkus and Montgomery (2001), Katona and Altbacker (2002), Clausnitzer (2003) and Reichlin *et al. (*2005).

To identify the types and proportion of plant species used by *L. starcki*, the combination of faecal and stomach content analysis and direct observation (on the field) was used. Fresh pellets of Starck's hare were collected from sites of different vegetation types during both seasons. In each season, two pellets were collected from 25 independent droppings at the minimum of 200 m interval. The samples were preserved in 70% ethanol and taken to the Department of Biology, Addis Ababa University, for further analysis. They were washed independently with distilled water to remove fine particles for proper identification and air dried. Two slides were prepared for each sample (mixing thoroughly) and observed under microscope to identify the diet (Appendix 3). All fragments found on the slides were identified as monocotyledon, dicotyledon, or unidentified. Relative occurrence was determined by dividing the number of microscopic views in which a given species occurred by the total number of views x 100 (Uresk, 1978; Katona and Altbacker 2002; Clausnitzer, 2003).

For stomach content analysis, different methods of trappings were used. Fresh Ethiopian wolf kills (n=2), live trapping by carnivore live traps (n=2), and netting (n=3). A total of seven hares were used to collect information on weight, measurements and parasite (if any) in addition to stomach content to compare with faecal analysis. The trapping took place in the morning and late afternoon to minimize the bias because of digestion. The stomach content analysis followed the procedure described for faecal analysis.

In addition to faecal and stomach content analysis, direct observation was used to identify different species of grasses eaten by Starck's hare. Different types of habitats, where usually hares feed were selected carefully for hide observation. Using 8 x 42 binocular, species of plant eaten were examined for 120 hrs. The plant species on the habitat were observed, before and after, to see the plant eaten by looking at the bite.

During the study period, in addition to the basic data for this study, all information observed about the ecology of the species was recorded, from personal observation and discussion with the local people.

For data analysis, Distance version Beta 4.1 and SPSS version 13.1 Software were used.

5. RESULTS

5.1 Density estimation

A total of 389 and 267 Starck's hares were recorded during wet and dry season, respectively. The difference was statistically significant ($X^2 = 22.69$, df =1, $P< 0.001$). The highest number was 185 during the wet season in Sanetti Plateau and the lowest number was 61 during the dry season in Web Valley (Table 2).

The mean density of Starck's hares in the study area was estimated to be 18.35 and 13.33 hares per km^2 during wet and dry seasons, respectively (Table 3). The highest density was obtained from Sanetti during the wet season (25.40/km^2) and the lowest at Web Valley during the dry season (8.51 km^2).

Starck's hares density during wet and dry season is given in Figure 3. During both seasons, large numbers of hares were recorded from Sanetti Plateau. On Sanetti Plateau, there was a significant difference in the Starck's hare counts among transects (X^2 =129.81 df= 9, $P< 0.05$). The highest number was 61 and 42 on transect 7 during the dry and wet seasons, respectively. The lowest was 5 on transect 5 and 2 on transect 3 during wet and dry seasons, respectively. Transect six, seven and eight crossed a rocky area with little wind. Hares were always abundant there (Fig. 4). However, there was no significant difference in the Starck's hare counts among transects in Web Valley and Tullu Deemtu ($P> 0.05$, fig. 5a, b).

Table 2. Number of sightings and Starck's hares recorded from each site during the two seasons.

Study site	Season	Number of sighting	Number of individuals
Sanetti	Wet	59	185
	Dry	82	124
Tullu Deemtu	Wet	52	109
	Dry	49	82
Web Valley (Kotera)	Wet	70	95
	Dry	48	61
In total study area	Wet	181	389
	Dry	179	267

Table 3. Estimates of the density and abundance of Starck's hares for each site.

Study sites	Season	Density	95% Confidence interval (CI)	Abundance	95% CI
Sanetti	Wet	25.40	17.43-37.01	3400	2300-4900
	Dry	21.17	14.59-30.73	2800	1900-4100
Tullu Deemtu	Wet	16.11	10.71-24.23	1400	1000-2200
	Dry	10.31	7.05-15.10	900	600-1300
Web Valley (Kotera)	Wet	13.54	9.28-19.74	1600	1100-2400
	Dry	8.51	5.88-12.33	1000	700-1500
In total study area	Wet	18.35	12.47-26.99	6300	4300-9200
	Dry	13.33	9.17-19.39	4600	3100-6600

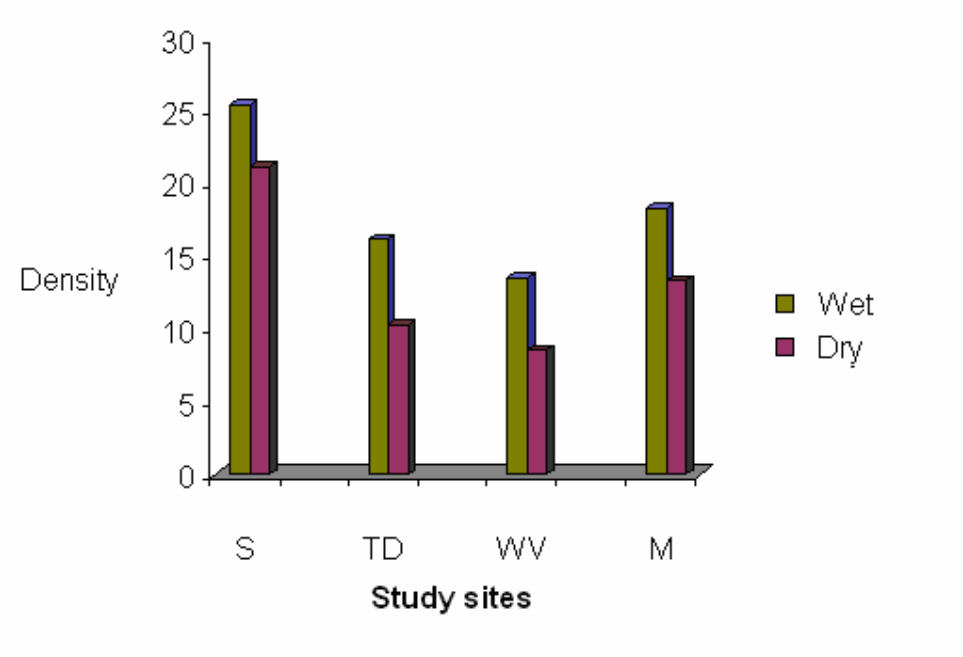


Figure 3. Density of Starck's hare in the study sites during wet and dry seasons.
(S= Sanetti, TD= Tullu Deemtu, WV= Web Valley, M= Mean).

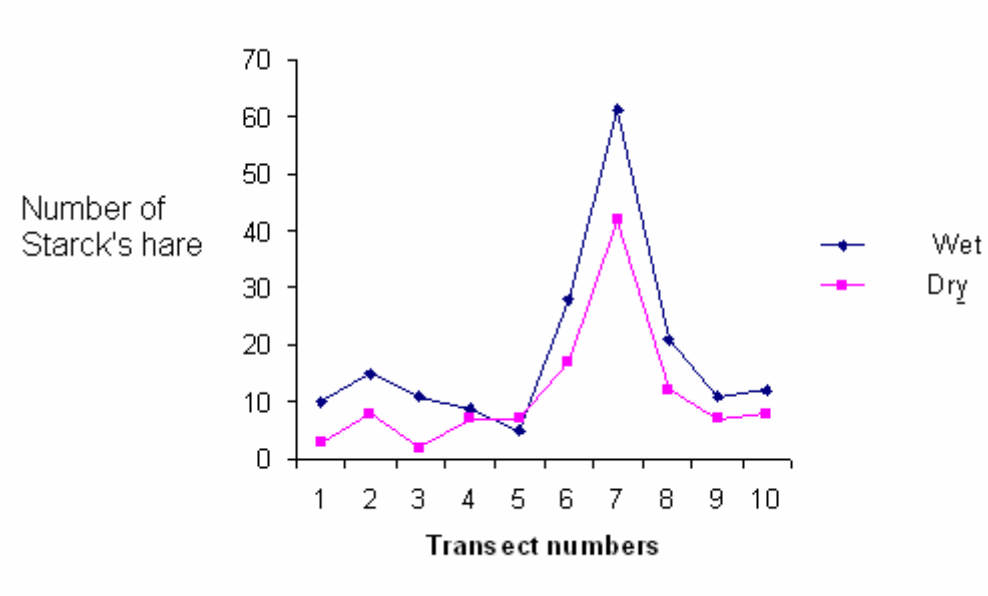
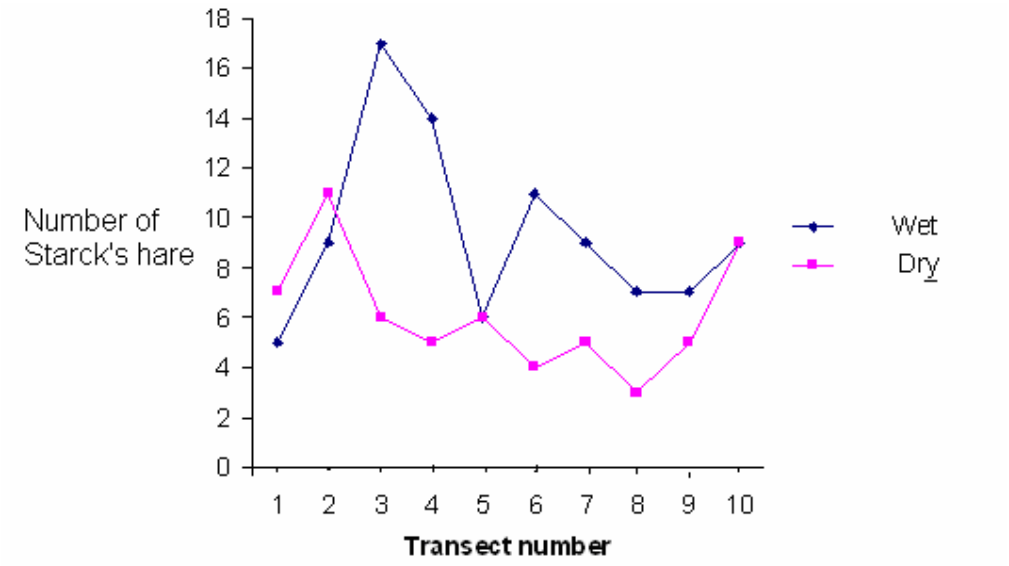
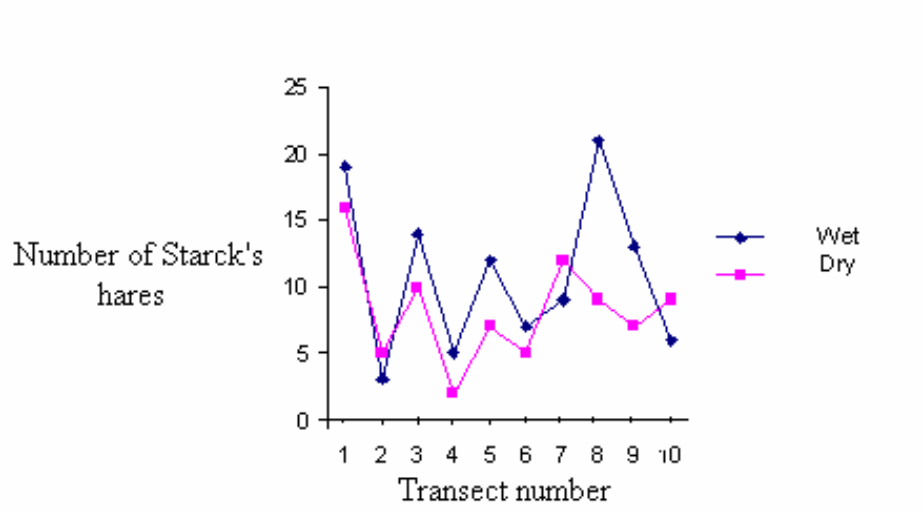


Figure 4. Number of Starck's hares recorded from each transect during wet and dry seasons in Sanetti Plateau.



a) Web Valley



b) Tullu Deemtu

Figure 5. Number of Starck's hares recorded from each transect during wet and dry seasons in Tullu Deemtu and Web Valley.

5.2 Forage availability

During the wet season, hares had most access to different species of herbs and grasses (Table 4). However, the proportion of plant species changed dramatically during the dry season. The major components of plant species in the study area were *Festuca spp., Alchemilla abyssinica, Helichrysum spp.* and *Trifolium spp.* Usually, Starck's hares use *Helichrysum spp.* as a shelter (Plate 2). During the dry season, the plants available for feeding were wetland plants. These include *Carex monostachya, Ranuculus oreophytus, Haplocarpha rueppelli and Trifolium*

acaule. Although *Festuca spp.* and *Alchemilla spp.* decreased in coverage during the dry season, their relative abundance was high. There was a significance difference (X^2 = 24.22 df = 2, P< 0.001) in species diversity within grass, herbs and shrubs in the study area. Herbs dominate all other species (Table 4). The percentage of plant cover is relatively high during the wet season (65.21%) and very low (< 30%) during the dry season (Fig. 6). However, species richness was the same in herbs and grasses during both seasons (Table 5).

Species	**Family**	**Coverage %**	
		Wet	**Dry**
Agrostis gracilifolia C.E. Hubbard	*Poaceae*	0.2	0.8
Alchemilla abyssinica Fress.	*Rosaceae*	11.8	4.2
A. haumanii Rothm.	*Rosaceae*	1.2	1.6
A. rothii Oliv.	*Rosaceae*	5.3	1.12
Anthemis tigreensis A. Rich	*Asteraceae*	0.72	0.53
Arabis alpina L.	*Brassicaceae*	0.21	0.11
Artemisia spoerri Engl.	*Asteraceae*	0.61	0.52
Carex monostachya A. Rich	*Poaceae*	0.3	0.43
Cynoglossum lanceolatum Forsk.	*Boraginaceae*	0.21	0.10
Dianthoseris schimperi A. Rich	*Asteraceae*	0.2	0.14
Erica philippia Complex	*Ericaceae*	0.42	0.41
Euryops prostratus Nordenstam	*Asteraceae*	0.37	00
Festuca spp.	*Poaceae*	15	6.33
Haplocarpha rueppelli P. Beauv.	*Asteraceae*	2.6	0.12
Hebenstretia dentate L.	*Scrophulariaceae*	0.2	0.17
Helichrysum citrispinum Del.	*Asteraceae*	2.6	00
H. gofense. Cuf	*Asteraceae*	8.8	5.25
H. splendidum Lees.	*Asteraceae*	5.9	1.22
Koeleria capensis Nees	*Poaceae*	0.51	0.31
Lobelia rhynchopetalum Hemsl.	*Campanulaceae*	0.2	0.23
Ranuculus oreophytus Del.	*Ranunculaceae*	0.23	0.81
Rumex abyssinicus Jacq.	*Polygonaceae*	0.3	0.63
Salvia nilotica Juss. Ex. Jacq	*Lamiaceae*	0.34	00
*Satureja simensis (*Benth.) Brif.	*Lamiaceae*	0.11	00
Senecio schultzii Hochst	*Asteraceae*	0.9	0.32
Thymus schimperi Ronniger	*Lamiaceae*	0.72	0.31
Trifolium acaule A. Rich	*Papilionaceae*	5.6	2.18

Table 4. Coverage of plant species identified from the study area using line intercept method from Sanetti Plateau.

Plate 2. Starck's hare form (shelter) from Sanetti Plateau

(By Tariku Mekonnen, June 2006)

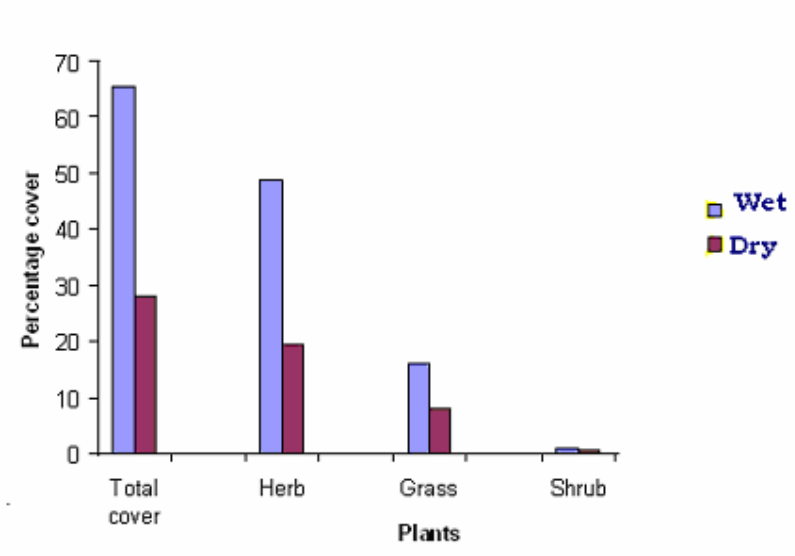


Figure 6. Coverage of plant species in the study area

Table 5. Species richness in the study area

Species	No. species		Richness index	
	Wet	Dry	Wet	Dry
Herb	21	17	0.657	0.706
Grass	4	4	1.443	1.443
Shrub	2	2	2.885	2.885

5.3 Food use

Diet composition between stomach content analysis and independent droppings (Tables 6 and 7) was not significantly different (wet season $X^2 = 0.048$, df = 1, $P > 0.05$ and dry season $X^2 = O.155$, df = 1, $P > 0.05$). Of the 27 plant species identified from the study area, Starck's hares entirely fed on monocotyledons (grasses) during the wet season. These were *Festuca spp*., *Koeleria capensis, Agrostis gracilifolia, and Carex monostachya*. During the dry season, dicotyledon plants were observed in the diet of Starck's hares, however, the proportion of monocotyledons was still high (Fig. 7).

Table 6. Relative frequency of occurrence of the plants identified from stomach content analysis (n= 4 and n=3) during wet and dry seasons, respectively.

Season	Stomach content sample	MN	DC	UN
Wet	1	91.67	-	8.33
	2	90.00	-	10.00
	3	100.00	-	-
	4	92.85	-	7.14
Dry	5	75.00	16.67	8.33
	6	87.50	12.50	-
	7	100.00	-	-

(MN= monocotyledon, DC= dicotyledon, UN= unidentified)

Table 7. Relative frequency of occurrence of the plants identified from independent droppings.

Independent droppings	Wet			Dry		
	MN	DC	UN	MN	DC	UN
1	83.33	-	16.67	66.66	33.33	-
2	100.00	-	-	100.00	-	-
3	100.00	-	-	71.43	14.29	14.29
4	77.78	-	22.22	90.00	-	10.00
5	91.67	-	8.33	87.50	12.50	-
6	100.00	-	-	42.85	28.57	28.57
7	100.00	-	-	83.33	16.67	-
8	100.00	-	-	84.62	7.69	7.69
9	100.00	-	-	75.00	25.00	-
10	90.00	-	10.00	83.33	10.00	6.67
11	100.00	-	-	100.00	-	-
12	100.00	-	-	71.43	14.29	14.29
13	100.00	-	-	77.78	11.11	11.11
14	83.33	-	16.67	60.00	20.00	20.00
15	100.00	-	-	100.00	-	-
16	100.00	-	-	72.72	9.09	18.18
17	100.00	-	-	90.00	10.00	-
18	100.00	-	-	100.00	-	-
19	100.00	-	-	80.00	-	20.00
20	87.50	-	12.50	70.66	12.67	16.67
21	100.00	-	-	80.00	10.00	10.00
22	87.50	-	12.50	83.33	10.00	6.67
23	100.00	-	-	75.00	12.50	12.50
24	100.00	-	-	100.00	-	
25	100.00	-	-	100.00	-	-

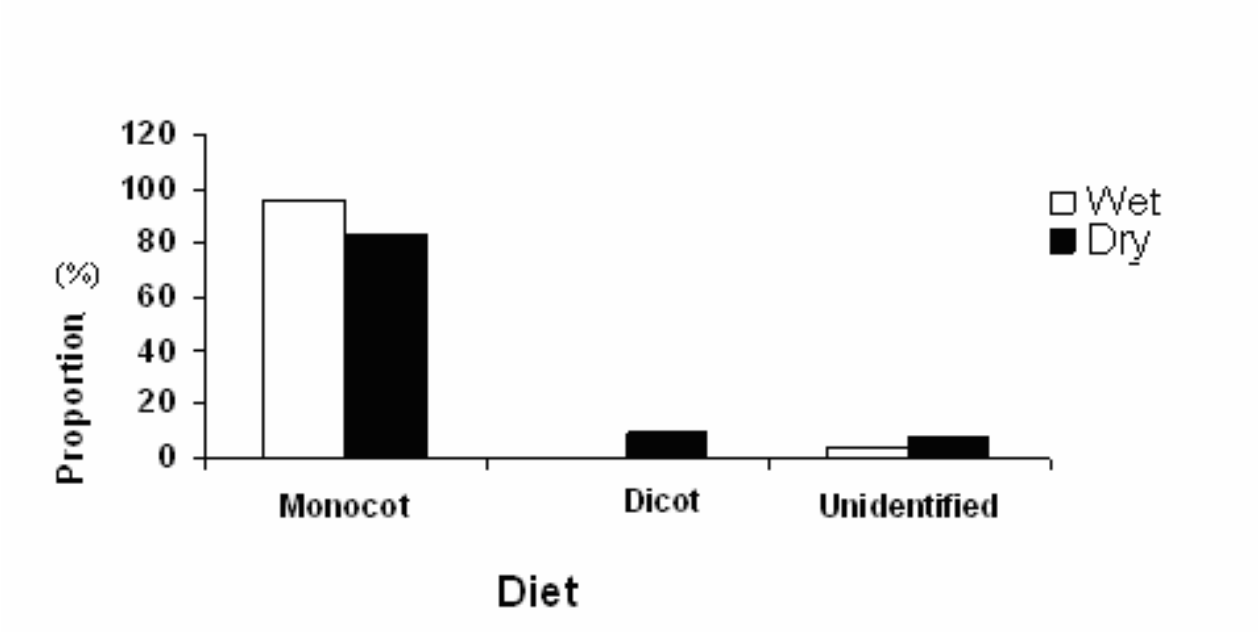


Figure 7. Proportion of food items in the diet of Starck's hare (from faecal analysis) during the two seasons.

Starck's hares were highly selective for monocot with limited use of dicots in the dry season (Table 8).

Table 8. Plant coverage and percentage dietary of starck's hare (faecal anlysis) in the study area.

	Monocot (%)		Dicot (%)	
	Plant coverage	Diet	Plant coverage	Diet
Wet	16.01	95.88	49.2	00
Dry	7.87	81.82	19.33	11.32

Starck's hares were almost restricted to rocky grassland with low wind areas. However, during the dry season when grasslands dried most Starck's hares were observed feeding in wetland habitats (Table 9).

Table 9. Number and percentage of Starck's hares recorded from different types of habitat and during different level of wind.

		Habitat type			Wind		
		Rocky grassland	Wetland	Others	Strong	Medium	Low
Wet	No. of individual	278	42	69	45	125	219
	%	71.47	10.80	17.74	11.66	32.13	56.30
Dry	No. of individual	95	112	60	54	71	142
	%	35.58	41.95	22.47	20.22	26.59	53.18

5.4 Body measurement

The measurements of adult Starck's hares captured during the study period were HB 45–58 cm, T 7.5-11 cm, and Wt 3-4 kg. One was pregnant with two embryos. However, three Starck's hares were observed with a single young in their form. There was no external parasite observed.

It is difficult to distinguish Starck's hares from the rocks of Sanetti Plateau (Plate 3). Thus, to protect themselves from predators they rely mostly on camouflage and speed. The main predators of Starck's hares in BMNP were Ethiopian wolves and some birds of prey. Ethiopian wolves hunt the Starck's hare in groups. However, a single wolf was observed chasing the species during the study period.

6. DISCUSSION

To estimate the density of hares using distance sampling, five assumptions are critical to achieve valid results. These are: animal directly on the line are seen with probability 1, animals are fixed at the initial sighting position (they do not move before being detected, and none are counted twice), the spatial distribution of animals is random with respect to the transect line, distance are measured accurately, and animals are correctly identified (Anderson

et al., 1979). In the present study, the main problem was Starck's hare move before being detected. However, the bias was minimized moving carefully during their feeding time.

IUCN (2006) grouped Starck's hares as least concern (Appendix 4). Compared to Sillero-Zubirii (1994) estimates (30, 20, and 17 per km^2 in Sanetti, Tullu Deemtu and Kotera, respectively) the present findings (23.29, 13.21 and 11.03 per km^2 in Sanetti, Tullu Deemtu and Web Valley, respectively) revealed that the density of Starck's hares declined in all study areas. However, a significant change was observed in Tullu Deemtu and Web Valley during dry season where overgrazing by livestock, human disturbance and predation was high. These factors have altered the population density of hares.

The large population count in Sanetti Plateau could be due to the availability of shelter, food (grasses), low predators, low disturbance by livestock and relatively limited settlements.

There was a significant difference in the counts of Starck's hare among the transects. This might be due to the difference in habitat type including food availability, cover and wind direction (Inglis, 1976; McCullough, 1989; Rogers and Gorman, 1995; Thulin, 2003). The highest numbers of hares were observed in rocky grassland habitat with scattered Erica (for shelter) and in the valley (to be protected from strong wind, cold and predators) (Plate 4).

A single Starck's hare lives in a form during their inactive period. However, they were observed in a group of two or more during feeding. This might be to protect themselves from predators looking in different directions while feeding.

During the present study, Starck's hares were not observed in tall and closed vegetation. This could be due to the disadvantage of such habitat in watching predators from a distance and less availability of grasses (Krebs *et al*., 2001).

During the dry season, the population of Starck's hares declined in all three sites. This might be due to scarcity of food and cover, which leads to predation and death (Flux, 1967; Angerbjorn, 1983).

Plate 4. Prefered habitat of Starck's hares from Sanetti Plateau.
(By Tariku Mekonnen, June 2006).

Total plant cover was high during the wet season compared to the dry season in the study area. This might be due to climatic variability that affects germination and growth of plants during the dry season. In this study, the most abundant plants species during both seasons were *Festuca spp., Alchemilla abyssinica, Helichrysum gofanse, H. citrispinum, H. splendidum* and *Trifolium acaule*. Other studies have also noted all these species, as a dominant group in the area (Minasie Gashaw and Masresha Fetene, 1996; Marino, 2003).

Pellets of Starck's hares were available on Sanetti Plateau at all months. They can be easily differentiated from sheep's and goats' pellets by its color and it is relatively less digested (Plate 5). To trap hares, using net was the preferred method in this study. Starck's hares were observed during the daytime with the highest number early in the morning and late afternoon. This supports the suggestion of Hillman (1986) that Starck's hares are diurnal on Sanetti. The activity of Starck's hares was mainly based on weather condition rather than day and night.

Thus, direct observation can be used to see the species of plants eaten in a very sparse habitat of Sanetti Plateau (Flux, 1964). However, several studies have shown that most species of hares are strictly nocturnal (Hamolka, 1987; Kingdon, 1997; Nowak, 1999).

Starck's hares have a preference for grasses as these occurred at high frequencies in all independent droppings. Supporting this, Hewson and Hing (1990) concluded that hares spent a large part of their time grazing on wild grassland, indicating a preference for grasses. During the dry season, they fed on diverse plant species than during wet season, even though there was relatively high plant species diversity during the wet season. This might be because of low availability of preferred food (grasses). The plants consumed during the dry season were based on the availability in the area (wetland plants). However, certain species such as *Alchemilla spp.* were never, eaten although abundant.

From all the grass species identified from the study area, Starck's hares fed frequently on *Festuca* species. This was the most available and soft grass species (Owen-Smith, 1994; Hodges, 2000; Flux, 1967). Soft and green parts of the plants were the most preferred compared to other parts during the study period during both seasons. Most literature implies that hares are generalized herbivores, with a diet consisting primarily of grasses and shrubs, but also barks, fruits, seeds, leaves, and buds based on the habitat types (de Vos, 1964; Burton, 1984; Hamolka, 1987; Rao *et al.*, 2002). However, in the present study hares were observed feeding only on grasses with little herbs.

The pattern of Starck's hares habitat use observed was consistent with other studies in East Africa (Kingdon, 1997). There was a significant association between the occurrence of hares and habitat types.

7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

The present survey provides information on population status and diet of Starck's hare in the afroalpine part of BMNP. It is expected that the information gathered will help for further detailed studies on different aspects of the species.

The densities of Starck's hares were estimated to be 25.40, 16.11, and 13.54 per km^2 during wet season and 21.17, 10.31, and 8.51 during the dry season in Sanetti, Tullu Deemtu and Web Valley, respectively. Discussion with the local people and the present study showed that the population of Starck's hares has been decreasing from time to time. However, to reach at a conclusion continuous census is required from different parts of the Park. Even though, the largest number of Starck's hares occurred in afroalpine part of the Park, they are also observed in the lowland area including Dinsho.

Although dicot plants were the most abundant plants in the study area, Starck's hares were restricted to monocot plants. This revealed that these herbivores are selective in their food habits. The low preference ratio for herbs and the observed abundance of grasses in the faeces confirms that Starck's hares are primarily grazers rather than browsers. However, different factors influence their grazing behavior during the dry season. These are distance from their shelter sites, less moisture content and less availability of the grass.

Although Starck's hares occurred in all the study sites, their distribution was not homogenous. They were recorded more frequently in rocky grassland and wetland habitats during the wet and dry seasons, respectively. Starck's hares move relatively longer distance away from their form for feeding during the dry season, hence they are more exposed to predators (Ethiopian wolf and some birds of prey) during the dry season than the wet season.

7.2 Recommendations

Based on the result of the present survey and previous studies, the following recommendations are suggested:

- Starck's hares are found only in a very restrictive range of the country (Ethiopia), which is one of the criteria to be 'a rare animal', and are decreasing in number. Hence, a long-term study on the population status and distribution in the central highland of the country is necessary to better understand this species and to suggest effective conservation and management measures.

- Little is known about the reproduction, home range and social behavior of Starck's hares. Hence, researchers need to be encouraged to study the different ecological parameters of the animal.

- During the dry season, all herbivores (domestic and wild) gather on a very small portion of the total area (wetland habitat) to compete for the very scarce food (Plate 6). This is a big threat for Starck's hares as well as other native herbivores of the area. Thus, special attention should be given to minimize domestic herbivores during the dry season.

- Although Starck's hares are solitary, they are observed in huge herds in certain places. The local people called such places '*Gaba Hillensa'* that means 'the market of hares'. During the study period, 69 hares were counted from such area. Hence, special attention should be given for such areas to minimize disturbance by livestock and humans

- The current assessment and several previous studies have indicated that the afroalpine habitats of Bale BMNP have changed dramatically due to settlement and livestock. In line with this, the population of several species of wild animals including Starck's hare has been declining. Taking this into account, protection strategies should be developed by wildlife conservationists.

- More emphasis should be given to resettle the people outside the Park. Hence, the community, governmental and non governmental organization should cooperate and work hand in hand.

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APPENDICES

Appendix 1. Distance sampling field data sheet

Transect No. ---------- Date---------- Page------of-------

	UTMX	UTMY	TIME
Start			
End			

Rangefinder---------- Observer---------- Bearing

UTMX	UTMY	Bearing	Distance (m)	Species	Group size	Habitat	Weather % cloud	Wind None(0), low(1), Medium (2), strong (3)

Appendix 2. Line intercept: vegetation field data sheet

Line No.----------

Line length---------- Vegetation type----------

Date---------- Page------of----------

Observer----------

	UTMX	UTMY	TIME
Start			
End			

No	Species	Coverage		
		Start	End	End - Start

Appendix 3. Diet analysis data sheet

Independent droppings	Slides								Total			
	1				2							
	Mono	Dic.	Seed	Unid.	Mono	Dic	Seed	Unid.	Mono	Dic	Seed	Unid

Mono = moncot, Dic = dicot, Unid = unidentified

Appendix 4. *Lepus* Red List

IUCN Red List of threatened Species (2006)

Scientific Name		**Common Name**	**Category**
1	*Lepus alleni*	ANTELOPE JACKRABBIT	Least Concern
2	Lepus americanus	SNOWSHOE HARE	Least Concern
3	*Lepus arcticus*	ARCTIC HARE	Least Concern
4	*Lepus brachyurus*	JAPANESE HARE	Least Concern
5	*Lepus californicus*	BLACK-TAILED JACKRABBIT	Least Concern
6	*Lepus callotis*	WHITE-SIDED JACKRABBIT	Lower Risk: Near Threatened
7	*Lepus capensis*	CAPE HARE	Least Concern
8	*Lepus castroviejoi*	BROOM HARE	Vulnerable
9	*Lepus comus*	YUNNAN HARE	Least Concern
10	*Lepus coreanus*	KOREAN HARE	Least Concern
11	*Lepus europaeus*	BROWN HARE, EUROPEAN HARE	Least Concern
12	*Lepus fagani*	ETHIOPIAN HARE	Data Deficient
13	*Lepus flavigularis*	,TEHUANTEPEC JACK RABBIT,	Endangered
14	*Lepus habessinicus*	ABYSSINIAN HARE	Least Concern
15	*Lepus hainanus*	HAINAN HARE	Vulnerable
16	*Lepus insularis*	BLACK JACKRABBIT	Lower Risk: Near Threatened
17	*Lepus mandshuricus*	MANCHURIAN HARE	Least Concern
18	*Lepus microtis*	AFRICAN SAVANNA HARE	Least Concern
19	*Lepus nigricollis*	INDIAN HARE	Least Concern
20	*Lepus oiostolus*	WOOLLY HARE	Least Concern
21	*Lepus othus*	ALASKAN HARE	Least Concern
22	*Lepus peguensis*	BURMESE HARE	Least Concern
23	*Lepus saxatilis*	SCRUB HARE	Least Concern
24	*Lepus sinensis*	CHINESE HARE	Least Concern
25	***Lepus starcki***	**ETHIOPIAN HIGHLAND HARE**	**Least Concern**
26	*Lepus timidus*	ARCTIC HARE, MOUNTAIN HARE	Least Concern
27	*Lepus townsendii*	WHITE-TAILED JACKRABBIT	Least Concern
28	*Lepus yarkandensis*	YARKLAND HARE	Lower Risk: Near Threatened