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POPULATION ECOLOGY AND THREATS OF THE ROCK HYRAX (*PROCAVIA CAPENSIS*) IN BALE MOUNTAINS NATIONAL PARK, ETHIOPIA

GEBREMESKEL TEKLEHAIMANOT REDA

A THESIS SUBMITTED TO THE DEPARTMENT OF ZOOLOGICAL SCIENCES PRESENTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ZOOLOGY

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By

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

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ABSTRACT

Population Ecology and Threats of the Rock hyrax (*Procavia capensis*) in Bale Mountains National Park, Ethiopia

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A study on the distribution, population status, feeding ecology, habitat utilization and threats to the rock hyrax (*Procavia capensis* Pallas 1766) was carried out in the Bale Mountains National Park (BMNP), Ethiopia during August 2010 – February 2013. Distribution of the rock hyrax was assessed by questionnaire survey and field observations. Population status of the species was studied by stratified random sampling using point count method. Direct observations by scan sampling and rumen content analysis were used to study the feeding ecology of the rock hyrax. Data for habitat utilization of the species were collected using quadrat sampling of fresh faecal boli, animal sighting and time spent by the rock hyraxes in different habitats. Threats and population trend of the rock hyrax were studied by questionnaire surveys, interviews and field observations. Data were analyzed using one-way ANOVA, t-test and chi-square test. A total of 30,003 individual rock hyraxes were recorded with a mean population density of 664.5 and 529.9 individuals/km^2 during the wet and dry seasons, respectively in the nine sample counting sites. Adults comprised 70.5%, sub-adults comprised 8.3% and juveniles comprised 21.2% of the population. Male to female ratio was 1:1.4. Over 52% of the population constituted adult females and juveniles, showing reproductive potentiality and sustainability of the species. The mean colony range and mean colony size were 5–81.5 and 43, respectively. Rock hyraxes utilized more than 44 plant species as food. The species depends mainly on grasses, and increased browsing during the dry season. Habitat loss and fragmentation, wildfire and hunting by domestic dogs were the primary factors affecting the population status of the rock hyrax in BMNP. Awareness raising among the local people on conservation, benefit sharing of resources from the Park and conservation measures involving the local community are to be considered as priority measures in order to ensure sustainability of BMNP and the inhabiting rock hyraxes in the Park.

Key words: Afro-alpine habitat, conservation, distribution, habitat utilization, hyrax, population estimate, questionnaire surveys.

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DEDICATION

I dedicate this dissertation to my lovely children, Merkeb Gebremeskel and Yishak Gebremeskel.

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1. INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Ethiopia is located in the Horn of Africa stretching from 3^{o}N to 15^{o}N latitude and from 33^{o}E to 48^{o}E longitude with an area of 1,127,127 km^2. It is a country of diverse altitudinal, physiographic and biological features (EBI, 2014). During the Tertiary Period, the intrusion of lava resulted in the formation of the great height of Ethiopian plateau and the deposition of thick layer of basal (up to 3000 m deep) on the underlying marine cretaceous rocks (Yalden and Largen, 1992). The variation in the altitude of Ethiopia ranges from 110 m below sea level at Kobar Sink in the Afar depression to the highest peak at Ras Dejen (4,620 m asl) in the Simien Mountains (Yalden, 1983; Afework Bekele and Corti, 1997; IBC, 2008). It has very diverse climatic conditions varying from hot and dry desert in the lowland areas to cold and humid alpine habitats in the highlands. The Ethiopian highlands were formed during the Oligocene and Miocene geological periods, between 38 and 7 million years ago (Miehe and Miehe, 1994), before the formation of the Great Rift Valley that splits the highlands into two (Yalden and Largen, 1992). The highlands and mountain areas are divided into northwest and southeast by the Great Rift Valley as it traverses the country from north to south (Uhlig, 1988). The highland mountains are isolated from the rest of the East African highlands by broad lowlands. Almost 50% of the African highlands above 2000 m and 80% of the land above 3000 m asl occur in Ethiopia (Yalden, 1983). Ethiopia is often known as ‘the roof of Africa’ due to its altitudinal and mountainous characteristics (Nievergelt, 1981). The highlands of

Ethiopia comprise the major part of Conservation International's Eastern Afromontane hotspot (Brooks *et al.*, 2004). Past geological history; the large extent of highlands isolated from the rest of Africa and wide ranging climatic features have made Ethiopia the home of diverse endemic species of fauna and flora (Yalden and Largen, 1992; Hillman, 1993).

The flora of Ethiopia is very heterogeneous and diverse with an estimated number of 6,500 – 7,000 species of higher plants of which about 12% are endemic (Tewolde Berhan Gebre Egziabher, 1991). The country is also rich in its faunal diversity. There are over 320 species of mammals, 861 species of birds, 201 species of reptiles (over 87 snakes, 101 lizards and 13 species of tortoises and turtles), 63 species of amphibians, 200 species of fish and 1,225 arthropods (including 324 butterflies) in Ethiopia (USAID/Africa, 2008; IBC, 2009; Redeat Habteselassie, 2012; Afework Bekele and Yalden, 2013). Among these, 31 species of mammals, 18 species of birds, 10 species of reptiles, 25 species of amphibians, 7 species of arthropods and 40 species of fish are believed to be endemic to the country (Hillman, 1993; Jacobs and Schloeder, 2001; IBC, 2009; Afework Bekele and Yalden, 2013).

The isolated afro-alpine fragments of Ethiopia exhibit interesting patterns of floral and faunal distribution. However, as a result of extensive human pressure in the form of habitation and agriculture, a large variety of the mammals in Ethiopia are confined to a few uninhabited mountains and a few protected areas (Sillero-Zubiri, 1994; Evangelista, *et al*., 2007). The protected areas in the country include 21 national parks, two sanctuaries, three wildlife reserves, 20 controlled hunting areas, six open hunting areas, six community conservation areas and 58 national forest priority areas of which 37 are protected forests (IBC, 2012; Young, 2012). According to EWCA/SDPASE (2012), protected areas of Ethiopia constitute 14% of the area of the country.

The Bale Mountains is part of the eastern Afromontane hotspot of Ethiopia (Myers *et al*., 2000), which harbours diverse endemic plant and animal taxa. The mountains contain species that are Ethiopian endemics, but there are also species that are found only in the Bale Mountains ranges. These mountain ranges are among the most important conservation areas in the Ethiopian highlands that have also a very high international significance (IUCN, 2010). These mountains form the largest continuous area above 3000 m asl in Africa, supporting the most extensive Afro-alpine and sub-Afroalpine (Ericaceous) vegetation on the continent (Miehe and Miehe, 1994).

Mammals are structurally as well as functionally quite diverse groups of vertebrates with a global estimated number of 5416 species (Wilson and Reeder, 2005). The highest species richness of mammals is found in northern South America, especially in the Amazonian lowlands, the Andes, East Africa and Southeast Asia (Ceballos and Ehrlich, 2006). Over 1150 species of them are currently listed for Africa, but more mammalian species still await discovery (Kingdon, 1997).

Hyraxes are among mammalian groups thought to have originated from ungulates and are found only in Africa and the Middle East (Olds and Shoshani, 1982). Due to their superficial similarity, hyraxes were grouped earlier with rodents and then with rhinoceroses due to the similarity in their dentition. Their superficial similarity to rodents led Joseph Storr, in 1780, to mistakenly link them with guinea pigs of the genus *Cavia* under the Family Procaviidae Thomas, 1892, (meaning "before the guinea pigs") (Fischer, 1992). It was Thomas Huxley, who for the first time placed them in an Order of their own, Hyracoidea Huxley, 1869 (Kingdon, 2004). This Order consists of one extinct Family, Pliohyracidae and one extant Family, Procaviidae. The extant family comprises of three living genera; viz. *Procavia*, *Heterohyrax* and *Dendrohyrax* (Vaughan *et al*., 2000).

The earliest hyracoid was probably *Microhyrax lavocati* from the end of the Lower Eocene nearly 45–50 million years ago (Prothero, 1993). Fossil beds in the Fayum, Egypt, indicate that during the Oligocene (about 40 million years ago), hyraxes of all sizes lived throughout the planet earth. They were the most important grazing and browsing ungulates ranging in size from that of the contemporary hyraxes to that of a tapir or larger (Hoeck, 1978). Before the Miocene (about 25 million years ago), there were 11 genera of hyraxes, which were among the most successful herbivores in Africa. During the Miocene, at the time of the first radiation of bovids, competition with the bovids (African and Asian antelopes, bison, sheep, goats, and cattle) increased and hyraxes retreated to the more peripheral habitats with rocks and trees, habitats that were not invaded by bovids. Many of the hyraxes that could not find shelter or a specific niche died, and consequently, hyrax diversity was greatly reduced, and now only three genera remain (Hoeck, 2003). During the Meocene, hyraxes, elephants and sea cows (dugongs and manatees) had a common ancestor, whose population diverged in habitat utilization in order to survive the radiation. This divergence caused new species of animals (hyraxes, elephants, sea cows) to evolve, each of which utilizes a different habitat (Hoeck, 2003). Despite their smaller size and absence of visible tail and trunk, hyraxes are the closest relatives of elephants and manatees. Some morphological similarities such as digits with short rounded nails, lack of a clavicle (collar bone), testicondy (presence of a permanent abdominal testes) (Olds and Shoshani, 1982; Werdelin and Nilsonne, 1999), absence of a baculum (penis bone), position of teats in females (pectoral and ingunal), the serial arrangement of bones in the head of the astragalus (known as taxeopody), similarities in hemoglobin and eye lens proteins among the extant taxa revealed the relationship of hyraxes, elephants and sea cows (Rasmussen *et al*., 1990; Asher *et al*., 2003). Molecular studies have also shown that the three groups were derived from a common ancestor and were related each other (Milstrey, 1985; Shoshani, 1986; Springer *et al*., 1997; Gheerbrant *et al*., 2005). Based on these morphological and molecular evidences, many authorities placed the hyraxes in the superorder Paenungulata ("near ungulates") with Proboscidea (elephants) and Sirenians or sea cows (dugongs and manatee) (Springer *et al*., 1997; Pardini *et al.*, 2007) (Fig. 1). The large size of prehistoric hyraxes can also indicate the fact that modern hyraxes may be the closest terrestrial relatives of the elephant. Together with the elephant shrews, aardvark, tenrecs and golden moles, the Paenungulates make up the group called Afrotheria (literally meaning 'of African origin'), a mammalian group whose radiation is rooted in Africa (Kleinschmidt *et al*., 1986; Prinsloo, 1993; Prothero, 1993). Afrotheria are of African origin although some species have subsequently dispersed beyond Africa (e.g. Asian elephants and three species of sea cows) (Tabuce *et al*., 2008).

There is a large amount of data suggesting that all Afrotherian mammals descend from one common ancestor that diverged from other mammal species early in the evolutionary history making them more genetically dissimilar to other mammals across the world.

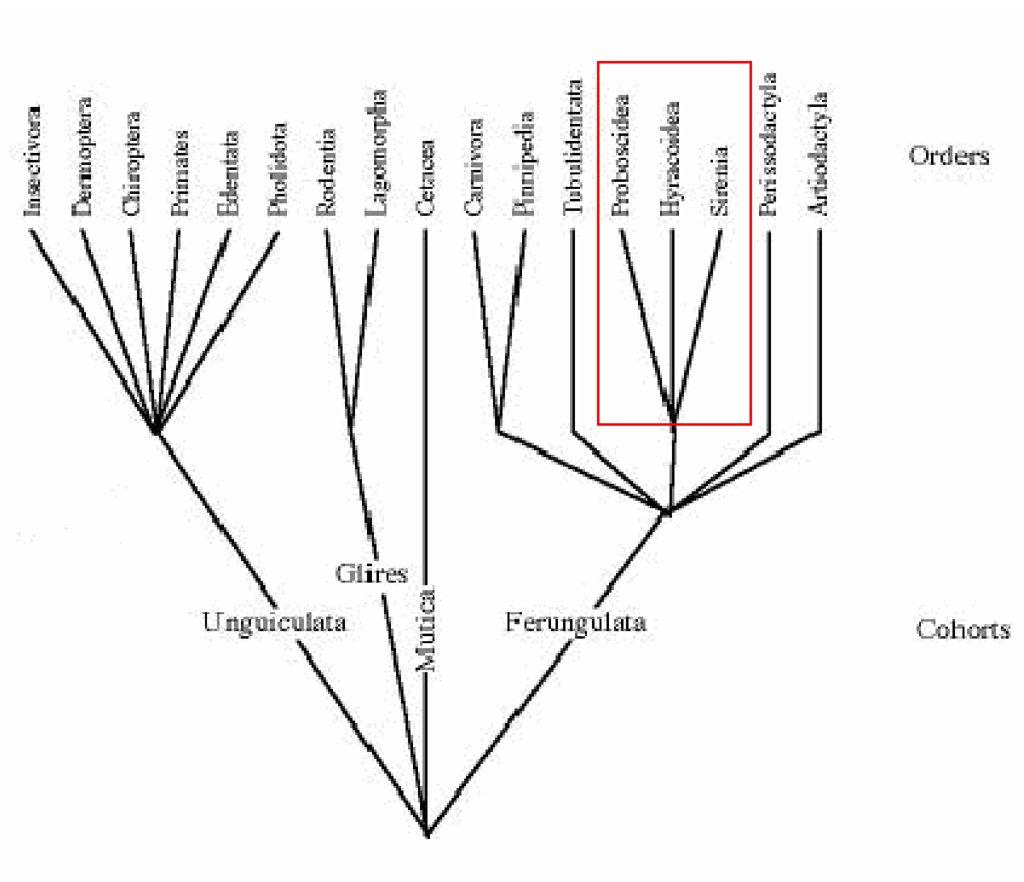


Figure 1. Phylogenetic relationship of Hyracodea with Proboscidea and Sirenia (after Simpson, 1945).

The descendants of the giant hyracoids evolved in different ways. Some became smaller, and gave rise to the modern Hyrax Family. Others appear to have taken to water (perhaps like the modern Capybara), and ultimately gave rise to the Elephant Family, and also the Sirenians (dugongs and manatees). Deoxyribonucleic acid (DNA) evidences support this hypothesis, and the small modern hyraxes share numerous features with elephants (Springer *et al.*, 1997) such as toenails, sense of hearing, sensitive pads on feet, small tusks, good memory, high brain functions compared to other similar mammals, and the shape of some of their bones. The classification of hyraxes was originally associated with elephants because early fossils of both lineages were similar. Recent investigations have also revealed that the antibodies, placenta, mammae and genitalia of hyraxes share features with those of odd-toed ungulates (Kingdon, 1997).

Procavia Storr, 1780 are strictly rock dwelling rock hyrax and considered to have evolved first in Africa before the Oligocene, some 40 million years ago (Walker, 1975). The genus is thought to retain the most primitive ungulate features while the *Dendrohyrax* probably evolved last from the same line as the intermediate *Heterohyrax* (Estes, 1991). *Heterohyrax* Gray, 1868 are rock dwelling and partially arboreal bush hyrax and *Dendrohyrax* Gray, 1868 are strictly arboreal (Kingdon, 2004; Skinner and Chimimba, 2005; Stuart and Stuart, 2007).

In Ethiopia, *Procavia* and *Heterohyrax* live in rock outcrops, piles of boulders and fractured cliff faces (Ashford *et al*., 1973). *Heterohyrax brucei* also live in hollow *Ficus* and *Acacia* trees in different parts of Ethiopia. The bush hyrax (*H. brucei*) is found in the South, East and northeast Africa, *H. antinae* in Hoggar Massif (Algeria) and *H. chapini* in the mouth of the River Zaire (Kingdon, 2004). *Dendrohyrax* species has not been described in Ethiopia as only little is known about it. The southern tree hyrax (*Dendrohyrax arboreus*) is found in Zaire, and East, Central and South Africa. The other species, the western tree hyrax (*D. dorsalis*), is found in the West and central Africa and the eastern tree hyrax (*D. validus*) is distributed in the eastern African mountains, islands and coasts (Kundaeli, 1976; Kingdon, 2004). *Procavia* and *Heterohyrax*, represented by *Procavia capensis* and *H. brucei,* respectively are present in BMNP (Hillman, 1993; Yalden *et al*., 1996).

1.2 Literature Review

Rock hyraxes, commonly known as rock dassies or rock rabbits are wooly, compact, weigh up to 4.3 kg (Olds and Shoshani, 1982; Kotler *et al.*, 1999; Wilson and Reeder, 2005) and superficially resemble guinea pigs for having rabbit-like appearance (Estes, 1991; Kingdon, 2004). They have agile movements in their rocky habitats suggesting their vernacular name, “rock rabbits”.

Taxonomy

Although there are some assessments made on the genus *Procavia*, its taxonomy is poorly understood (Yalden *et al*., 1986). Several authors have described four species under this genus: viz., Cape hyrax (*P. capensis*), Abyssinian hyrax (*P. habessinica*), Johnston’s hyrax (*P. johnstoni*), and western hyrax (*P. ruficeps*), while Bothma (1966) added a fifth species, the Kaokoveld hyrax (*P. welwitschii*), which had been treated as a form of *Heterohyrax*. But, Yalden *et al*. (1986) considers *habessinica* as a subspecies of *P. capensis*. Even though, *Procavia* is sometimes treated as a single species (Olds and Shoshani, 1982), usually they are divided into five species, most of which are divided into subspecies: namely, *P. habessinica*, *P. capensis*, *P. johnstoni*, *P. welwitschii* and *P. ruficeps* (Estes, 1991; Kingdon, 2004). Therefore, the monospecificity of the genus *Procavia* by Olds and Shoshani (1982) is debatable and further study on the genetics of the genus is required to resolve its taxonomy.

The subspecies, *Procavia capensis capillosa* Brauer 1917, found in the Bale Mountains is confined to high altitudes (2800–3500 m), and is isolated from the more northerly population by the Wabi Shebele River (Yalden *et a*l., 1986). They are distinguished from other *Procavia* and other hyracoids by their dental characters. The upper incisors are convergent and unique, and hence they closely resemble those of a rodent, while the lower incisors are parallel, not divergent as in other *Procavia*. Corbert (1979) and EWCP (2005) also documented the rock hyrax, *P. capensis capillosa* of BMNP as an endemic subspecies of the Bale Mountains, with considerably different fur and incisor teeth from other hyraxes of nearby areas. The rock hyrax, *P. capensis* is known since long, but it was Peter Simon Pallas, who described it in 1766 where he saw it for the first time in a tavern in Cape Town, where it was kept as a pet (Smithers, 1983).

Physical characteristics and physiology

Rock hyraxes are the smallest ungulates that are approximately the size of a large rabbit. They are compact bodied animals having short legs, small and round ears, cleft upper lip, a rudimentary tail and blunt hoofed digits (Olds and Shoshani, 1982; Kingdon, 2004) (Fig. 2). Their forefeet have four digits, which are plantigrade, while the hindfeet have only three digits, which are semiplantigrade (Fig. 3). All digits have flat, hoof-like nails, except for the second digit of the hind feet, which have long, curved claws used for grooming and scratching (Vaughan *et al*., 2000). Their feet have rubbery pads with numerous sweat glands, which help the animal maintain its grip when moving fast up steep rocky surfaces (Adelman, *et al*., 1975; Fischer, 1992; Nowak, 1999).

Figure 2. An adult male rock hyrax at Gaysay Valley, Bale Mountains National Park (Photo: Gebremeskel Teklehaimanot, 2012).

Species living in arid and warm zones have short fur, but those in alpine areas have thick, soft fur. Rock hyraxes have long vibrissae (tactile hairs) widely distributed over their bodies, probably for orientation in dark fissures and holes. They have a dorsal skin gland at the back surrounded by dark brown to black or creamy hairs that can be erected when the animal is excited. The glandular area has a tuft of short specialized fur known as osmetrichia. The gland secretes a clear, scented fluid that is considered to have a role in intraspecific communication signaling (Müller-Schwarze *et al*., 1977) and territorial marking. It is most clearly visible in dominant males while smaller in females and juveniles (Olds and Shoshani, 1982).

(a) (b)

Figure 3. Limbs of an adult male rock hyrax (a) Forefoot (plantigrade), (b) Hindfoot (semiplantigrade) (Photo: Gebremeskel Teklehaimanot, 2011).

There is a slight sexual dimorphism, with males being approximately 10% heavier than females (Klein and Cruz-Uribe, 1996). The average size of adult rock hyraxes varies greatly across Africa. It seems closely linked to average annual rainfall, which in turn affects the availability of food (Klein and Cruz-Uribe, 1996). The size increases in areas having up to a mean annual rainfall of 700 mm. Yom-Tov (1993) found size variations in the skull of rock hyraxes from different regions to be positively correlated with temperature. Their fur is thick and coat colour varies widely throughout their geographic ranges and strongly associates with the mean annual rainfall patterns (Bothma, 1966). It is dark brown in moist habitats and light gray in desert habitats. Testes are permanently abdominal and the uterus is duplex. Females have three pairs of teats, one pair pectoral and two pairs inguinal. The mouth is exceptionally large in order to facilitate quick eating. Rock hyraxes have a single pair of long, strong, continuously growing tusk-like upper incisors that are used mainly in defense, and their molars are similar to the cheek teeth of rhinoceroses. The two tusk-like upper incisors of males are larger, ridged or triangular in cross section, sharper and separated by about the width of a tooth (Fig. 4) (Fourie, 1983; Rifai *et al*., 2000) than those of females. The faces of these incisors are rounded in females. The two pairs of lower incisors are comb-like and used for grooming fur. There is a wide diastema between the incisors and the premolars. The permanent dental formula of an adult rock hyrax is I 1/2 C 0/0 P 4/4 M 3/3 with a total of 34 teeth (Barry and Shoshani, 2000).

Figure 4. Skull of an adult male rock hyrax showing its dentition (Source: retrieved from http://www.skullsite.co.uk/Hyrax/hyrax.htm, accessed on 17 January, 2010).

Males also have a larger larynx and larger guttural pouches, which help to amplify their territorial calls. Males also have blunter snouts and thinner bodies with thicker necks than females. The eyes are bulged and the pupil is shielded by a special membrane called umbraculum that shields the eye while a basking individual stares into the sun to detect aerial predators (Olds and Shoshani, 1982; Skinner and Chimimba, 2005).

Rock hyraxes have poor ability to regulate their body temperature. They maintain their body temperature by gregarious huddling, long periods of inactivity and basking. At air temperatures above 25^{o}C, body temperature is maintained by evaporative water loss from the nostrils, soles of the feet, panting, salivating and grooming. This allows them to exist in very dry areas and use food of relatively poor quality. The rock hyrax has incomplete thermoregulation, and is most active in the morning and evening, although their activity pattern varies substantially with the season and climate. They do not ruminate, but have complex gut with three partitions (unique to the hyraxes), viz., the fore-stomach, the paired caecum and colonic appendages that allow symbiotic bacteria to break down tough plant materials. They are able to digest fiber and extract nutrients as efficiently as that of the ruminants (Rübsamen *et al*., 1982). The gastrointestinal tract of hyraxes is unusual because of the presence of two appendices (Bjornhag *et al*., 1995) thought to be involved in water resorption (Hoeck, 1982). They also have efficient kidneys retaining water to live on minimal moisture intake and survive in arid environments (Louw *et al*., 1972). In addition, they have a high capacity for concentrating urea and electrolytes and excreting large amounts of undissolved calcium carbonate (Rübsamen *et al*., 1982). Rock hyraxes have low dietary nitrogen requirements, thus enabling them to survive periods of low dietary protein availability (Glick-Bauer and Dierenfeld, 1999).

Distribution and habitat

Before the Miocene, hyraxes of all sizes were common and widely distributed in different continents (Hoeck, 2003). Past distribution of *Procavia* extends from Africa to Europe, some parts of Asia, Russia and China (Dubrovo, 1978). At present, they are restricted to Africa and the Middle East and found throughout the sub-Saharan and north-eastern Africa, discontinuously distributed from Senegal and southern Mauritania through southern Algeria, Libya and Egypt (east of the River Nile) to the central and southern Africa (excluding the Congo Basin forest and Madagascar). Rock hyrax has the widest geographical and altitudinal distribution among the hyraxes (Macdonald, 1985; Stuart and Stuart, 2000). Beyond Africa, its distribution extends to the Middle East, particularly the Arabian Peninsula, mainly in the west, and to Lebanon, Jordan, Israel and Syria (Olds and Shoshani, 1982; Harrison and Bates, 1991; Kamal, 1996; IUCN, 2012) (Fig. 5). The occurrence, distribution and abundance of rock hyraxes depend upon a combination of several abiotic factors such as rainfall and the presence of suitable rocky outcrops and other hiding places, and biotic factors such as interspecific and intraspecific competition for food, predation and parasites (Skinner and Chimimba, 2005).

Rock hyraxes occupy a wide range of habitats, from arid deserts to rainforest, and from sea level to the alpine zone of Mt. Kenya (3200 – 4300 m) (Young and Evans, 1993). As their name implies, they are typically associated with rocky outcrops, mountain cliffs or loose boulders that provide them shelter. Hyraxes living in rocky habitats avoid isolated holes that are large enough for predators to enter, and are exposed to wind (Sale, 1966b). They prefer to be in rocky outcrops found in savanna zones, semi-deserts and mountains (Estes, 1991).

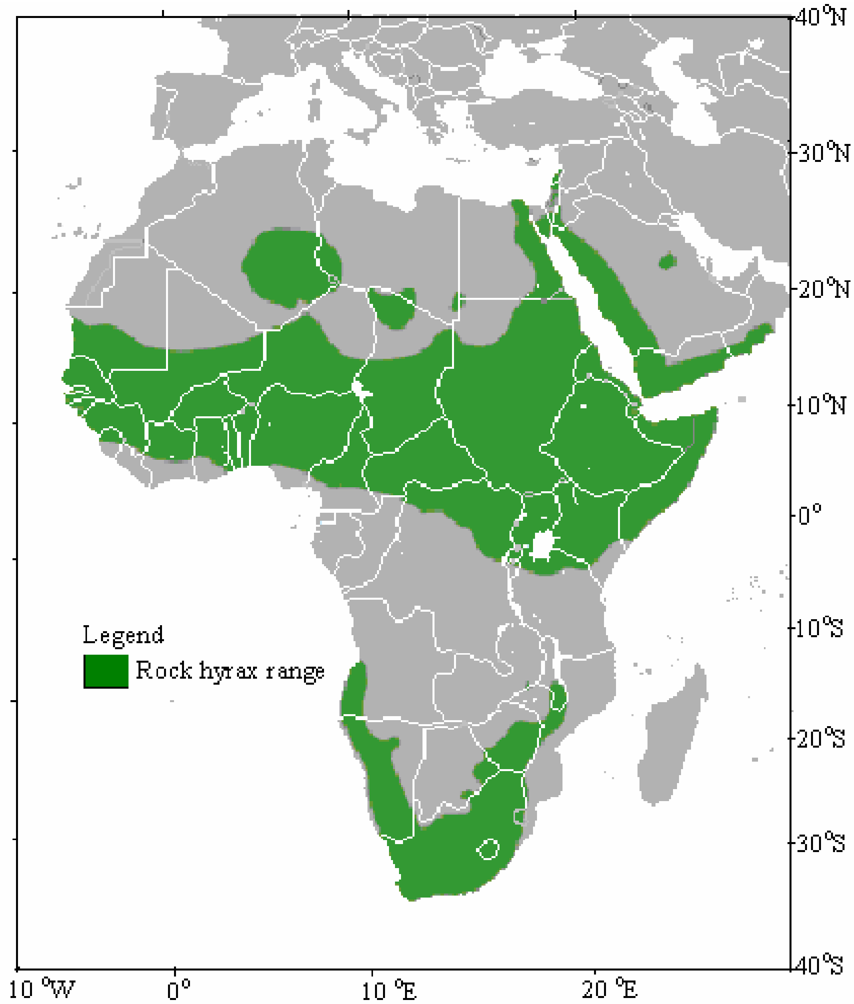


Figure 5. Distribution map of the rock hyrax (*Procavia capensis*) in Africa and the Middle East (Source: Adapted from IUCN Red List of Threatened Species, retrieved from http://www.iucnredlist.org/, accessed on 17 September, 2012).

Being slow moving and with few defenses against predators, rock hyraxes depend on rocky outcrops to escape from predators (Fairall *et al.*, 1983). Rocky outcrops also provide necessary shelter from extreme temperature and access to safe foraging areas and good vantage points (Davies, 1994).

The rock hyrax is the most arid-adapted hyrax species, and its range includes dry mountainous regions in the Namib, Sahara and Arab deserts (Bartholomew and Rainy, 1971; Estes, 1991). Although, it does not burrow, it also inhabits abandoned burrows, including those of aardvarks and meerkats.

Social behaviour and grouping

The rock hyrax is a social animal living in colonies that usually consist of a dominant, territorial male, several related adult females, commonly known as a harem, sub-adults and juveniles of both sexes (Hoeck *et al*., 1982; Fourie and Perrin, 1987a; Gerlach and Hoeck, 2001; Koren and Geffen, 2009). The species often occurs sympatrically with bush hyrax in some areas of its distribution, as in the Serengeti in Tanzania and Matobos in Zimbabwe (Barry and Mundy, 1998; Barry and Shoshani, 2000), sharing the same rock, and sleeping and sunning spots. This is considered as the most closely association between two species of animals than any other African mammals, except for some forest monkeys (Hoeck, 1975; Barry and Mundy, 1998; Estes, 1999; Barry and Mundy, 2002). The rock hyrax also shares same basking rock surfaces and foraging ground with Noki or dassie-rat (*Petromus typicus*) (Rathbun and Rathbun, 2005) and Agama lizards. They are diurnal, gregarious and live in colonies with as many as 10–80 individuals, depending on the home range size, size of the rock outcrop and abundance of other resources (Mendelssohn, 1965; Hoeck, 1982; Hoeck *et al*., 1982; Fourie and Perrin, 1989). They live in kopjes to avoid predation pressure (Olds and Shoshani, 1982). However, large colonies may be divided into small family groups.

Within a colony, there are four types of males; territorial males, peripheral males, early dispersing males and late dispersing males. A territorial male is the dominant male, which protects the harem of females as well as the kopje from peripheral males. Peripheral males are those which dispersed from other nearby kopjes. They are more solitary and sometimes take over a group when the dominant male is missing. Early dispersing males are juvenile that leave their natal kopje before they reach sexual maturity in order to establish themselves as a peripheral male at another kopje. On the other hand, late dispersing males leave their natal kopje after they have reached sexual maturity, at around 30 or more months of age (Hoeck *et al*., 1982). Within individual rock hyrax colonies, territorial males dominate other colony members and remain on alert for predators and conspecific rivals. Adult resident male hyraxes will remain with a group for only a few years before being expelled by other males. Male offsprings are forced to disperse at around 30 months of age, but usually forced to disperse earlier by 17 to 24 months (Hoeck *et al*., 1982), and they live on the periphery of colonies or in bachelor groups (Koren *et al*., 2008). Territorial males are relatively tolerant of their own male offsprings but very aggressive towards peripheral males, which may travel more than 2 km in search of undefended habitat. In most cases, there is no acceptable habitat nearby, young males are forced to defend sleeping holes on the periphery of the colony's territory. It has been suggested that a new colony might be formed from the dispersal of an adult male from the colony (Gerlach and Hoeck, 2001). When the territorial male dies or becomes weak, the top peripheral male replaces him (Hoeck, 1975; Hoeck, 1989; Estes, 1991). No similar social rankings exist between females (Fourie, 1983).

Colonies are typically composed of a territorial male that controls a harem of several related females and their offspring, but may consist of multiple families, each headed by an adult male. Sometimes peripheral males are found loosely associated with the colony (Fourie and Perrin, 1987a). Basically, rock hyrax colonies are female-bonded, and the members are usually related to each other (Fourie and Perrin, 1987a), but an adult, territorial male initiates the colonization in an area (Gerlach and Hoeck, 2001). The territorial male defends the kopje with chasing, biting, teeth gnashing and territorial calls in order to have exclusive access to the females. Females are usually phylopatric and may associate with each other indefinitely (Hoeck, 1982; Fourie, 1983). Female emigration is rare, but dispersing females have been accepted into other colonies after an initial period of hostility from resident females. There is no defined dominance hierarchy among females, but older individuals tend to be more dominant and vigilant than younger individuals (Olds and Shoshani, 1982; Estes, 1991).

Although rock hyraxes are basically endothermic, they have a difficult time maintaining their body temperature. They employ many of the same behavioral adaptations as reptiles to avoid extreme temperatures. In the mornings, they huddle together and bask in the sunlight to warm their body (Sale, 1970b). They prefer to warm their body on flat rocks that aid in the group basking process. If the day is exceptionally hot, rock hyraxes will retreat to their shelters to avoid the mid-day heat. At night, they return to their shelters for protection from predators, cold temperature and wind (Olds and Shoshani, 1982; Hoeck, 2003).

Unless the weather is very warm, rock hyraxes do not leave their shelter until morning when they typically spend an hour or so sunbathing (Bartholomew and Rainy, 1971). Their most striking behaviour is the use of sentries: one or more animals take up position on a vantage point and make alarm calls on the approach of predators. They often avoid the warmest part of the day by resting in shade. Rain is also avoided, and hyraxes may not leave their shelter at all during cold, rainy days. They are sometimes active during moonlit nights. Adult hyraxes spend 95% of their time resting (Sale, 1970b). Resting often involves heaping, which usually takes place inside their shelter as animals lay on top of one another. Evidences suggest that resting behavior is correlated with ambient temperature. As temperatures become increasingly warm, resting behavior changes from heaping to huddling to solitary resting (Olds and Shoshani, 1982; Estes, 1991). Rock hyraxes only graze for approximately 1–2 hours a day and use their large mouths to eat quickly.

The colony members defecate and urinate at communal latrine sites (Kingdon, 2001), resulting in the accumulation of ‘middens’ composed of a yellow-brown compact material known as hyraceum. In arid environments, hyraceum has a high preservation potential within the rock surfaces and crevices in which the animal inhabits and can form stratified deposits several centimeters thick (Carr *et al*., 2010) (Fig. 6).

(a) (b)

Figure 6. Communal latrine site of rock hyraxes: (a) Faeces, (b) Urine, at Keyrensa, Bale Mountains National Park (Photo: Gebremeskel Teklehaimanot, 2011).

Feeding behaviour and diet

Rock hyraxes are herbivores feeding almost on any plant that is available around their shelter (Hoeck, 1989; Kingdon, 1997). This species is a generalist herbivore, which feeds on a wide variety of plants, leaves, stems, fruits, barks and buds (Rifai *et al*., 2000), and even have a tolerance for eating highly poisonous plants, which other animals might not eat (Mendelssohn, 1965; Sale, 1965c; Fourie and Perrin, 1989). It is able to eat bark and twigs due to the design of its gut and its relationship with symbiotic bacteria, which allows to digest tough fibers (Rübsamen *et al.*, 1982). Occasionally, it also eats insects, eggs and lizards. The rock hyrax prefers to eat new shoots, fruits and berries. Its diet varies according to the season. Grass is a relatively coarse food item, and the rock hyrax, which changes between grazing and browsing (Hoeck, 1975) has hypsodont dentition (high crowns with relatively short roots) (Walker *et al*., 1978; Hoeck, 1989).

Rock hyraxes do not usually forage farther than 50–100 m from the rock outcrops they inhabit. They are unselective feeders, suggesting that their diet and associated faeces reflect contemporary local vegetation (Hoeck, 1975; Brown and Downs, 2005). However, Fourie (1983) documented that adult rock hyraxes have been known to move distances more than 500 m from their inhabiting rock outcrops, usually feeding as a group and with one or more individuals acting as sentinels from a prominent lookout position. Juveniles, however, never move more than 40 m from the den. Daily food consumption varies with body weight, and the moisture content of plants. When grazing, individuals maintain their spacing, and remain vigilant for potential predators (Olds and Shoshani, 1982; Hoeck, 1989). When leaving a kopje to forage, all animals leave in the same direction and as a single group, which may enhance the effectiveness of their sentinels (Hoeck, 1975; Davies, 1994). There are two daily peaks of feeding, one in the early morning and the other in the late afternoon (Lensing, 1983; Brown, 2003). Rock hyraxes feed rapidly, and individuals of the colony may spend only less than one hour per day feeding, which is relatively a short period for a herbivore.

Reproductive biology and behaviour

The territorial male mates with a harem of females. This system is evolved as rock hyrax females have to live together in order to survive high predation pressure (Fourie and Perrin, 1987a). Sexual maturity is attained within 16–17 months of age in both sexes (Olds and Shoshani, 1982; Nowak, 1999). Adult females become receptive once a year, and come into estrus during the breeding season, which peaks in April, although it differs from locality to locality (Nowak, 1999). Parturition occurs after a gestation period of 7–8 months, which is unusually long for a mammal of such small size. The number of young per female rock hyrax ranges from 2 to 4. Extended gestation in the rock hyrax is thought to reflect the fact that its ancestors were much larger in body size. Newborns are large and precocial, both eyes fully opened, a complete coat of hair, seen active immediately after birth, and can run within minutes (Hoeck, 1982; Hoeck *et al*., 1982; Fourine and Perrin, 1987b). The young are weaned at an age of three to five months. Rock hyraxes are polygynous and breed seasonally with births synchronized to occur during the rainy season (Koren and Geffen, 2009). Within a family group, all pregnant females give birth within a period of about three weeks.

The structure of the penis differs from the other hyrax genera, thus contributing to reproductive isolation where sympatry occurs with bush hyraxes (Olds and Shoshani, 1982; Estes, 1991). During the breeding season, there is a significant increase in territoriality, which is manifested by higher rates of calling and aggression in males; that correspond with an increase in testicle size. Testicles can become more than 20 times larger than their normal size during the breeding season. Outside of the breeding season, spermatogenesis does not occur. Females become increasingly aggressive as parturition approaches and temporarily form isolated nursing groups with other pregnant females. Males contribute a small proportion of caring for group pups by guarding (Koren, 2000), while females share daily parenting responsibilities. Play behavior of the young consists of nipping, biting, climbing, pushing, fighting, chasing and mounting (Sale, 1970b; Olds and Shoshani, 1982). Only little information is available on the average lifespan of the rock hyraxes; however, evidence suggests that they can live for up to 12 years in the wild (Olds and Shoshani 1982; Estes, 1991) and 14.8 years in captivity (Weigl, 2005).

Communication

Rock hyraxes have acute tactile, sight and auditory senses, although their near-vision is relatively poor. They have a variety of vocal calls. They are very noisy. Adults make use of at least 21 different vocal signals for communication. Male rock hyraxes produce long, complex songs, lasting up to several minutes (Koren *et al*., 2008; Koren and Geffen, 2009), which carry information on the characteristics and identity of the caller (Koren and Geffen, 2011). Rock hyrax vocalizations go a long way towards communicating the unique identity of the signaller. Each one has unique songs that communicate a variety of information such as age, social rank, hormone levels and size of the releaser (Koren and Geffen, 2011). Territorial calls in rock hyraxes repeat loudly and increase in volume and duration towards the end of the sequence before ending in a series of guttural noises. Adults also emit twittering or whinnying calls and striking alarm calls, which are made when a potential predator is identified. When threatened, they may growl or grind their molars. Infants make only five of the 21 sounds used by adults; three of these are vocal, including mewing calls given when they are lost or begging for food and two are non-vocal (Olds and Shoshani, 1982; Estes, 1991).

Rock hyraxes urinate and defecate on flat, or nearly flat rocky surfaces near the colony site. Crystallized calcium carbonate present in the excretion makes a white stain used in visual communication and these latrines also serve as scent where all members of the group share a common smell that scent their feet and fur used in olfactory communication (Kingdon, 1997; Chame, 2003). The dorsal gland and hair surrounding it are important for communication among conspecifics. This gland secretes a clear, scented fluid that is important for intraspecific olfactory communication and territorial marking. Fluid production from the dorsal gland increases with increased stimuli. In an aggressive context, fluid production is accompanied by a slight curling of the upper lip and piloerection of the neck hairs. Tactile hairs are found on the head and other parts of the body, for easy sensation during underground or within shelter movements, when eyes cannot function well (Barry and Shoshani, 2000). During territorial calls, males crouch and raise their head with their jaws slightly opening their mouth. They may also growl with gnashing teeth and give long-drawn piercing screams. Rock hyraxes show submission by presenting their hindquarters, backing away, closing their dorsal gland, and/or flattening their ears. Submissive behaviors are very important, as simple interactions such as approaching or directly staring at another adult might be seen as a threat, and their tusks can inflict fatal wounds. To avoid antagonizing other individuals, feeding or huddling individuals usually face away from each other (Olds and Shoshani, 1982; Estes, 1991).

Threats

Populations of rock hyraxes are regulated by predation, intra-specific competition, immigration, territorial fighting and dispersal (Hoeck, 1982). Rock hyraxes are subjected to threats of various avian and mammalian predators. Rock hyrax can act as a keystone species (Chiweshe, 2007) as they are a source of food of many predators such as the black eagle or Verreaux's eagle (*Aquila verreauxii*), which feeds almost exclusively (98% of its diet) on the rock hyrax, martial and tawny eagles, owls, leopards, lions, jackals, caracals, African wild dogs, spotted hyaena, African civets and several snake species such as the Egyptian cobras and puff adders (Gargett, 1990; Davies, 1994; Barry *et al*., 2002; Skinner and Chimimba, 2005; Druce *et al*., 2006; Chiweshe, 2007; Stuart and Stuart, 2007). Neonates are sometimes preyed upon by mongoose. Predators strongly influence the dynamics of hyrax populations (Palmer and Fairall, 1988). The threats also include human use for food and fur, periodic epidemics such as sarcoptic mange and localized depletion as a result of habitat loss (Hoeck, 1989; Stuart and Stuart, 1997; Chiweshe, 2005). External parasites such as ticks, lice, mites and fleas and internal parasites such as nematodes, cestodes and anthrax also play an important role in hyrax mortality (Macdonald, 1985).

Procavia capensis avoid predators by staying alert and remaining close to cover while foraging. Individuals immediately respond to the alarm calls of territorial males and to the calls of other species such as bush hyraxes and some birds. Rock hyraxes also avoid predators by using burrows that are smaller in diameter than most predators in their habitat. They are also known to escape predation by pretending as dead and/or by frightening smaller predators by threatening in group (Olds and Shoshani, 1982; Estes, 1991).

Thus, there are no major threats to rock hyrax. However, they are hunted by local people and may have been extirpated in some localities. Several African tribes hunt, snare or trap hyraxes for their thick and soft fur and skin and also for food. The Hadza or Watindiga, a bushman tribe in Tanzania, hunt rock hyraxes for food (Smith *et al*., 2010). The rock hyrax is also hunted for food in some areas in Egypt (Nowak, 1999). In South Africa, people suspect that the hyraxes may compete with sheep for forage and hence are antagonistic towards them (Nowak, 1991). In countries like Ethiopia, Kenya and Israel, the rock hyrax is hated for being reservoir of cutaneuous leishmaniasis (Jacobson *et al.*, 2003; Wossenseged Lemma *et al*., 2009).

Conservation status

Hyrax populations are sensitive to habitat degradation and fragmentation caused by human activities. Although the rock hyrax is classified as a species of Least Concern in the IUCN's Red List of Threatened Species (IUCN, 2008), current population trend is unknown. However, their populations have declined due to disease, predation and territorial fighting (Hoeck *et al*., 1982). They are especially vulnerable to predation when they disperse, leading to a high, especially male juvenile, mortality (Hoeck, 1982). They occur in many protected areas across its range. Hence, the hyrax is listed as Least Concern in view of its wide distribution, presumed large population, its occurrence in a number of protected areas, and because it is unlikely to be declining fast enough to qualify for listing in a more threatened category (Barry *et al*., 2008).

1.3 Justification of the study

The rock hyrax is not well studied. Despite some studies on its feeding ecology (Hoeck, 1975), social organization (Hoeck *et al*., 1982) and behavioural ecology (Hoeck, 2003) in the Serengeti National Park (Tanzania); parturition and population dynamics (Barry and Mundy, 1998; Barry *et al*., 2002) in Matobo National Park (Zimbabwe); feeding and behavioural ecology (Sale, 1965a; 1965b;1966a; 1970b) in Kenya; population dynamics (Fourie, 1983) in Mountain Zebra National Park (South Africa) and social behaviour and communication (Koren *et al*., 2008; Koren and Geffen, 2009; 2011) in Ein Gedi Nature Reserve (Israel), little is known about the rock hyrax over its areas of distribution. The rock hyrax is one of the important prey of the Ethiopian wolf (*Canis simensis*) (Sillero-Zubirri and Gotelli, 1995) and raptors including Black eagle (*A. verreauxii*), Lammergyer (*Gypaetus barbatus*), Imperial eagle (*A. heliaca*) and Golden eagle (*A. chrysaetos*) found in BMNP (Anteneh Shimelis, 2008).

The rock hyrax has been a neglected species and there is no detailed study on the distribution and ecological aspects of the species in Ethiopia. Despite studies related to the population status and activity patterns in Dinsho area of the BMNP (Gebremeskel Teklehaimanot, 2004), cutaneous leishmaniasis (as hyraxes are reservoir hosts of the parasite, *Leishmania aethiopica* that causes the disease) (Wossenseged Lemma *et al*., 2009) and survey on some ecological aspects of the species in Tigray, Northern Ethiopia (Teklay Girmay *et al*., 2015), there is no published information on the population ecology of the species in Ethiopia to date. Data on the status and population trend of the species is unavailable. Hillman (1986) noted that measurements that enable accurate estimation of the population of rock hyrax are not made and there are probably thousands of them in BMNP.

There is no quantitative and qualitative data about the distribution, population status, feeding ecology, habitat utilization and threats of the rock hyrax in BMNP. Therefore, it is essential to examine the distribution pattern, ecology and types of threat of rock hyrax to establish priorities for long term conservation and management of the species. Valid methods for estimating the relative abundance of the rock hyrax populations are necessary to monitor their population conservation status and trends. It was in this context that the present research was initiated. Thus, the present study on the rock hyrax is the first of its kind in the BMNP to address issues related to the distribution, population status, feeding ecology, habitat association and major threats of rock hyrax. The present investigation is expected to provide information on the distribution and population ecology of the rock hyrax in the Park to fill the gap of knowledge in ecology of the rock hyrax in Ethiopia. Findings of this study are expected to be fundamental for further studies, understanding and conservation of the rock hyrax, which will also be crucial for the conservation and management of its predators; the endemic and critically endangered Ethiopian wolf and raptors found in the Park.

1.4 Objectives of the study

1.4.1 General objective

The general objective of this investigation was to assess the distribution, population status, feeding ecology and threats of the rock hyrax (*Procavia capensis*) in BMNP.

1.4.2 Specific objectives

- to assess the distribution pattern of rock hyrax in BMNP,
- to determine the population status and structure,
- to determine the colony size,
- to assess diet composition of rock hyrax in the study area, and
- to assess human impacts and other threats to the survival of the rock hyrax in BMNP.

1.5 Research questions

In order to conduct the study on the rock hyraxes in the study area, several questions were raised, which were answered using different methods. The following were the questions:

- What is the distribution pattern of rock hyraxes in BMNP?
- What is the population abundance and structure of rock hyraxes in the Park?

- Is the feeding pattern and diet composition of the species similar during the wet and dry seasons?
- What type (s) of habitat (s) do rock hyraxes utilize during wet and dry seasons?
- What are the major threats to the survival of the rock hyrax in BMNP?

2. THE STUDY AREA AND METHODS

2.1 Description of the study area

The Bale Mountains National Park is situated in southeastern Ethiopia in the Oromia National Regional State, along the eastern edge of the Great Rift Valley with an extent of approximately 2200 km^2 of mountains and forest (Hillman, 1986). The Park area lies within the geographical coordinates of 6º29'–7º10' N and 39º28'–39º57' E and covers the largest area above 3000 m asl in Africa (Hillman, 1986; Stephens *et al*., 2001). The Park's headquarter is located in Dinsho town, which is 400 km by road from Addis Ababa, the capital city of Ethiopia. The Park belongs to the Bale-Arsi massif, which forms the western section of the southeastern highlands. The local boundary of the Park lies within five Woredas (Districts): Adaba (west), Dinsho (north), Goba (northeast), Delo Menna (southeast) and Harenna Buluk (southwest). According to the Population Census Commission (2008), Dinsho town had approximately 3,000 residents. The Park was designated in 1974 primarily for the conservation of the endemic Mountain nyala (*Tragelaphus buxtoni*) and the Ethiopian wolf (*Canis simensis*) and also as part of the largest tract of the Afro-alpine habitats in Africa (Hillman, 1993; Befekadu Refera and Afework Bekele, 2004). This forms part of Conservation International's Eastern Afromontane hotspot (Brooks *et al.*, 2004). Today, BMNP is listed as one of the UNESCO 200 worldwide Bio-Regions (Umer *et al*., 2007) and represents a potential world heritage site. Despite this, the Park has never been formally gazetted or effectively managed to date.

There are broad altitudinal ranges in BMNP, ranging from 1,500 meters at the southern edge to 4,377 meters above sea level at the summit of Mount Tulu Dimtu in the central peaks (Yalden and Largen, 1992). Tulu Dimtu is the highest peak in southern Ethiopia and the second highest in Ethiopia (Marino, 2003). The area is characterized by high altitude plateaux and wide valleys bounded by volcanic plugs, lava flows and the precipitous Harenna escarpment to the South (Miehe and Miehe, 1994).

2.1.1 Geology and soil

It is believed that the Bale Mountains were formed from lava outpourings, which covered all underlying rock formations in the Miocene and Oligocene geological periods between 38 and 7 million years ago, and separated from the western Ethiopian highlands by the subsequent formation of the Great Rift Valley (Morton, 1976; Miehe and Miehe, 1994). Much of the original topography of the Oligocene lava outsprings has, therefore, been modified by over 20 million years of water, wind and ice erosion, to transform into the present landscape of BMNP (Hillman, 1986). The rocks of the volcanic outpourings are predominantly trachytes, but also include rhyolites, basalts and associated agglomerates and tuffs. The main Bale highlands consist of a vast lava plateau with at least six volcanic cones, each of more than 4,200 m high, which have been considerably flattened by repeated glaciations. Traces of former glaciers are common in the ericaceous and Afro-alpine belt. The mountains were locally glaciated, which shaped their recent geomorphology (Osmaston *et al*., 2005). The Bale Mountains show distinct signs of recent glaciations (Morton, 1976; Hedberg, 1986). As the crust of the Bale Mountains is of volcanic origin, the soils derived from the basaltic and trachitic parent rock are fairly fertile silty loams of reddish-brown to black (Morton, 1976; Miehe and Miehe, 1994). The profile from the upper Harenna escarpment has higher proportion of sand and gravel than clay minerals in the top soils. The top soil of the *Hagenia-Juniperus* forest has high proportion of organic carbon contents (Weinert and Mazurek, 1984 as cited in Miehe and Miehe, 1994). The eastern Sanetti Plateau possesses a high content of phosphorus (143 ppm) as a result of frequent fire in this area.

2.1.2 Climate

The Bale Mountains play a central role in the climate control of the region by attracting large amounts of orographic rainfall. Historically, the area has experienced a high degree of climate variability and related changes (Umer *et al.,* 2007). These past climatic changes have played a crucial role in shaping the present-day vegetation in the Bale Mountains.

Rains come from two different sources at various times of the wet season in the Bale Mountains National Park; the Equatorial Westerlies and the Indian Ocean Monsoon (Miehe and Miehe, 1994). Rainfall in the Park is characterized by one long rainy season from March to October followed by four months of dry season from November to February (Daniel Gemechu, 1977). The wet season rainfall pattern is slightly bimodal, with heavy rainfall from July to October with the highest peak in August, and the short rainy season from March to June, with the peak in April (Fig. 7). The mean annual rainfall differs with altitude, with lower altitudes receiving 600–1000 mm of annual rainfall and higher altitudes receiving up to 1200 mm (Hillman, 1986; Williams, 2002). Precipitation around the BMNP Headquarters area (Dinsho) averages 1,219 mm annually (Biruktayet Assefa *et al.*, 2010), and has a bimodal distribution pattern with the "short rains" locally called "belg" occurring from March to May and the "long rains" locally called "kiremt" occurring from August to October. Temperature shows altitudinal gradient within the Park from –3 to 24 ^{o}C at low altitudes, and from –15 to 26 ^{o}C at higher altitudes during the dry season (Sillero-Zubiri, 1994).

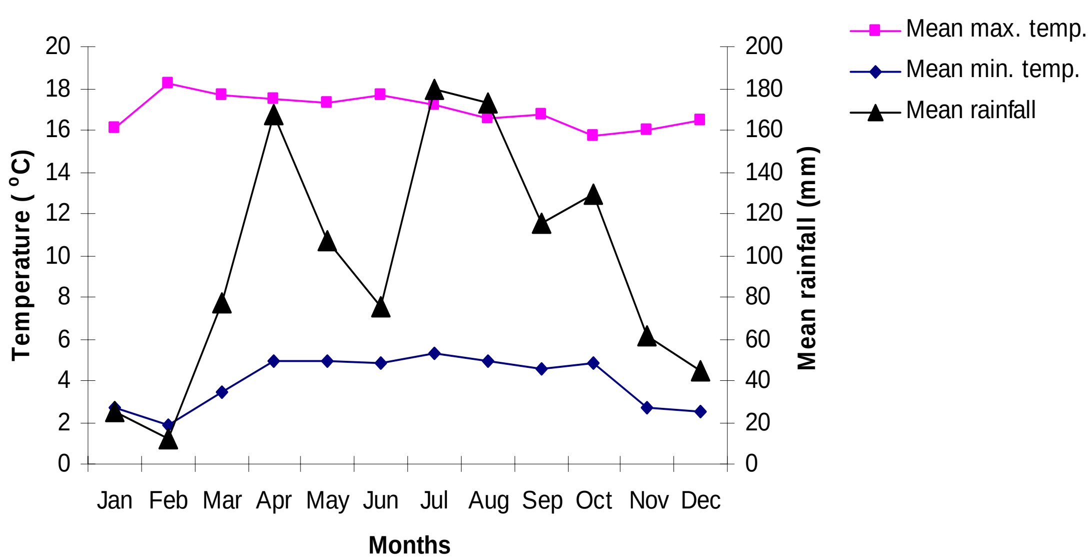


Figure 7. Mean monthly maximum and minimum temperature (^{o}C) and mean monthly rainfall (mm) of Dinsho Station, based on data between 1994 and 2012 (Source: National Meteorological Agency).

Temperatures vary widely throughout BMNP. On the plateau, daytime temperatures are usually around 10°C with strong winds; in the Gaysay Valley, average daytime temperature is around 20°C, and in the Harenna Forest, it is around 25°C. However, weather changes frequently and sometimes drastically. In elevations over 3,000 m, night frosts are common. Relative humidity recorded was 17% and 100% during the dry and wet periods, respectively (Hillman, 1986).

2.1.3 Hydrology

The Bale Mountains are conservation sites for major water catchments (Hillman, 1993; Sillerio-Zubiri, 1994) and are sources of about 40 small and large rivers contributing to five major rivers (the Web, Wabi Shebelle, Welmel, Dumal and Genale) that mainly flow to the lowlands of the eastern part of Ethiopia and the neighbouring Somalia (BMNP GMP, 2007). The Afro-alpine wetlands and the Harenna forest hold the water, releasing it year round to the arid and semi-arid areas of the southeastern and the southern Ethiopia, including the Ogaden and Somali agricultural belts. There is around 600–1,000 mm rainfall annually in the lower altitude areas and 1,000–1,400 mm in areas of higher altitudes. An estimated 12 million people from southeast Ethiopia, Kenya and Somalia are dependent on the water from the Bale massifs. Furthermore, two rivers originating from Bale, the Wabe Shebelle and Yadot, have hydroelectric schemes. The dam on the Yadot River supplies electricity to Delo Mena, while the dam on the Wabe Shebelle provides electricity to the Bale area.

Additionally, there are numerous natural mineral water springs, locally called “horas”, which provide an essential source of minerals for livestock. The mineral springs within the Park are valued for their high mineral content (sodium, potassium, magnesium, zinc and calcium), and local pastoralists believe that in order to maintain good health and milk production, their livestock must be given “hora” water (personal communication).

2.1.4 Vegetation

Due to the high rainfall coupled with variation in altitude and topography, the Bale Mountains are endowed with diverse vegetation (Miehe and Miehe, 1994; Gotteli and Sillero-Zubiri, 1990). The vegetation is largely of the Afro-alpine and sub-alpine types. The flora of the alpine zone is equally notable with about 163 highland endemics, 27 of which are restricted to Bale Mountains itself, including *Alchemilla haumannii* (Birdlife International, 2006) and *Euryops prostratus* (Williams *et al.*, 2004). There are 1321 flowering plants in BMNP of which more than 163 (12%) are endemic to Ethiopia, and 23 (14%) endemic to BMNP (Anteneh Belayneh *et al*., 2013). The mountains also host a number of unique plants such as Lobelias (e.g., *Lobelia rhynchopetalum, L. scebelii* and *L. giberroa*) and Senecio species (e.g., *Senecio nanus, S. fresenii, S. inornatus, S. ochrocarpus*, *S. ragazzi*, *S. schultzii*, *S. subsessilis* and *S. unionis*). Besides, the endemic plant populations of Bale Mountains are important reservoirs of genetic diversity (Uhlig, 1990; NBSAP, 2005). The area is also regarded as one of the most important area for genetic stock protection of wild forest coffee (*Coffea arabica*) and various medicinal plants in Ethiopia.

There are five vegetation zones in the BMNP. These are: the northern grasslands, northern woodlands, the heath (ericaceous) moorlands, the treeless Afro-alpine habitat, and the southern Harenna Forest (Hillman, 1986; Miehe and Miehe, 1994; EWNHS, 1996). Due to the wide range of habitats, each vegetation zone has its own characteristic flora and fauna. The distribution of the vegetation in the Park is correlated with altitudes that vary based on climatic conditions (Hedderg and Edward, 1989; Miehe and Miehe, 1994).

2.1.5 Fauna

The major mammalian species in the northern woodlands and grasslands include the endemic Mountain Nyala, Bohr reedbuck, the endemic Menelik`s bushbuck, grey duiker, warthog, olive baboon, black and white colobus monkey, golden jackal, spotted hyaena and serval cats (Stephens, 1997). At higher altitudes of rocky habitats, klipspringer and rock hyrax occur. The central Sanetti Plateau supports the endemic mammals: the Ethiopian wolf (*Canis simensis),* giant mole rat (*Tachyoryctes macrocephalus*), Starck's hare *(Lepus starcki*) and other densely populated rodent species such as *Tachyoryctes splendens, Lophuromys melanonyx* and *Praomys albipes*. Bushpig, giant forest hog, warthog, olive baboon, black and white colobus monkey, lion and Menelik's bushbuck also occur in the largely unexplored southern Harenna forest. The recently described Bale Monkey (*Chlorocebus djamdjamensis*), endemic to the area, is also found in the Harenna forest and also Hagereselam Region (Southern Nations, Nationalities and Peoples' Region, Sidamo) (Addisu Mekonnen *et al*., 2010). Sixty seven mammal species are known to occur in the Bale Mountains of which 20 species are endemic to the country and six are known only from the Bale highlands (Hillman, 1993; Stephens *et al*., 2001; Afework Bekele and Yalden, 2013). Some of them are Ethiopian wolf (*C. simensis*), Mountain nyala (*Tragelaphus buxtoni*), Strack's hare (*Lepus starcki*), Giant molerat (*T. macrocephalus*) and Bale monkey (*C. djamdjamensis*).

Due to the high diversity and density of rodents, BMNP is also very important for many rare large eagles, vultures and other raptors. The mountains harbour diverse endemic and range-restricted avian species, and are an important site for both resident and migratory birds (Lavrenchenko, 2000; Birdlife International, 2006). Bale Mountains range is also the only known breeding site for a number of Eurasian avian species, such as the golden eagle, the ruddy shell duck and choughs.

There are also two reptiles endemic to the BMNP, namely Bale Mountains two-horned chameleon (*Chamaeleo balebicornutus*) and Bale Mountains heather chameleon (*Chamaeleo harennae*) and 12 endemic amphibians of which four are endemic to the Park, namely Osgood's Ethiopian toad (*Spinophrynoides osgoodi*), Ethiopian short-headed frog (*Balebreviceps hillmani*), Bale grassland frog (*Ptychadena harenna*) and Bale mountain frog (*Ericabatrachus baleensis*) (EWCA, 2013). The Park also harbours many species of fish in its rivers and streams.

2.1.6 Human settlement and land-use patterns

The Bale Mountains area was largely uninhabited prior to the establishment of BMNP (Stephens *et al*., 2001). However, since its establishment in 1969, human settlement and cultivation inside the Park has been increasing. During 1974–1991 periods, due to the investments in mechanized state farms in the lowlands, little room was left for pastoralists except at higher altitudes. Since then, the BMNP area has been under increasing pressure from an ever-growing human population. The estimated human population in the Park in 1984 was 2500 people (Hillman, 1986), mainly the pastoralists. During the change of government in 1991, firearms became readily available, and as a result, direct killing of wildlife and resettlement of previously cleared areas became common, resulting in considerable destruction of habitats (Shibru Tedla, 1995; Stephens *et al*., 2001). Reports show that settlement has increased markedly in the recent past. In 2008, the number of inhabitants was estimated at over 40,000, a 16-fold increase in 20 years (BMNP GMP, 2007), increasing pressure on the natural resources of the area and depleting natural habitats of wildlife. Settlement appears to have increased in all areas of the Park, including remote and inhospitable areas of the Afro-alpine and Harenna forest.

Currently, existing settlements are growing and new settlements are appearing in previously unsettled and environmentally sensitive areas. The settlers use the Park areas for permanent and temporary settlements and farming activities. Besides, they use this area as a source of timber and fuel wood, charcoal production, honey gathering and temporary use of the area for cattle rearing and grazing and the “horas” for drinking their livestock (Hillman, 1986; personal observation). Livestock kept around the “horas” for several days severely affect the habitats. The Ericaceous heathlands are used as important source of firewood and building materials. Most of the settlers are pastoralists, and they burn *Erica* during the dry season (Marino, 2003). The BMNP is exposed to severe human-induced threats from expanding settlements, agricultural and livestock grazing (Miehe and Miehe, 1994; Stephens *et al*., 2001; Williams *et al.*, 2004).

2.2 Methods

In the present study, different methods were used to collect data on the distribution, population status, feeding ecology and threats to the rock hyrax in BMNP. The major methods used were sample population census, trapping, field observation, scan sampling, questionnaire surveys, interview and informal discussions.

2.2.1 Duration of the study

The present research was conducted from August, 2010 to February, 2013. August – October, 2010 and August – October, 2012 (wet season) and December, 2010 –February, 2011 and December, 2012 – February, 2013 (dry season).

2.2.2 Data collection

A reconnaissance survey was conducted in August 2010 to collect basic information on topographic features, accessibility, distribution and habitat of the rock hyrax, climatic conditions, vegetation type and extent of the study area and to identify suitable sampling sites in BMNP. Data were collected by direct observations, trapping and semi-structured questionnaire, interviews and informal discussions.

2.2.2.1 Distribution

Data on the spatial distribution patterns of the rock hyrax in BMNP were collected by intensive field observations during the study period. Additional data were collected by conducting questionnaire survey using informal interviews with the Park Ecologists, Scouts, Field Assistants, local community and herders as adopted by Iwanaga and Ferrari (2002). All reported sightings of the hyrax in the Park were recorded. Actual sightings during field observations (Rifai *et al.*, 2000; Shrestha *et al*., 2005) and indirect evidences like the rock hyrax call, presence of fresh pellets and a whitish crystalline hyracium on rocky surfaces around their shelters were also used to determine the distribution of the species (Stuart and Stuart, 1994; Milner and Harris, 1999; Isbell and Chism, 2007; Topp-Jørgensen *et al*., 2008; Gebrecherkos Woldegeorgis and Tilaye Wube, 2012). Rock hyrax core areas and shelter sites were identified by observing the emergence of hyraxes in the morning and afternoon and presence of fresh dung piles and hyracium stains on rocky faces around their shelter in some sites, following the methods of Chame (2003), Druce *et al*. (2006), Sutherland (2006) and Andreas *et al*. (2008). Location of the rock hyrax distribution sites were recorded using a Global Positioning System (GPS) and used for specifying the distribution sites of the rock hyraxes in the Park. In order to compare and evaluate the effect of season on the rock hyrax distribution, distribution patterns of the rock hyrax were studied both during the wet and dry seasons.

2.2.2.2 Population census

Based on the information obtained from the reconnaissance survey and on the distribution of rock hyraxes, nine sample sites were randomly stratified from the already identified hyrax potential habitats to conduct population census (Fig. 8). These sites were Gaysay Valley (Site 1), Adelay Ridge (Site 2), Web Valley (Site 3), Meraro (Site 6), Morebawa (Site 7), Keyrensa (Site 8), Worgona Valley (Site 10), Garba Guracha (Site 13) and Harenna Escarpment (Site 19).

Gaysay Valley (37N 0584844, UTM 0787167): This site is located at the northern tip of the Park at an altitude of about 3050 m asl., which is characterized by open grassland and a gorge guarded by small cliffs on both sides, a cave and rock piles through which River Danka flows. The rock piles harbour two rock hyrax colonies. Common wild animals found in the area are mountain nyala, Bohr reedbucks, common warthog, serval cat, common jackal and spotted hyaena. The dominant grasses in the area include the genera *Festuca*, *Andropogon*, *Carex*, *Bromus* and *Poa*. There are also scattered *Juniperus procera* trees, shrubs like *A. afra*, *H. splendidum*, *Phytolacca dodecandra*, *D. peninn-ervium*, *H. revolutum*, *E. dumalis* and *Inula confertiflora* and scattered herbs of *F. communis* and *K. foliosa*. As the site is situated at the periphery of the Park, livestock grazing, construction of settlements and fence and human disturbance are common around this area.

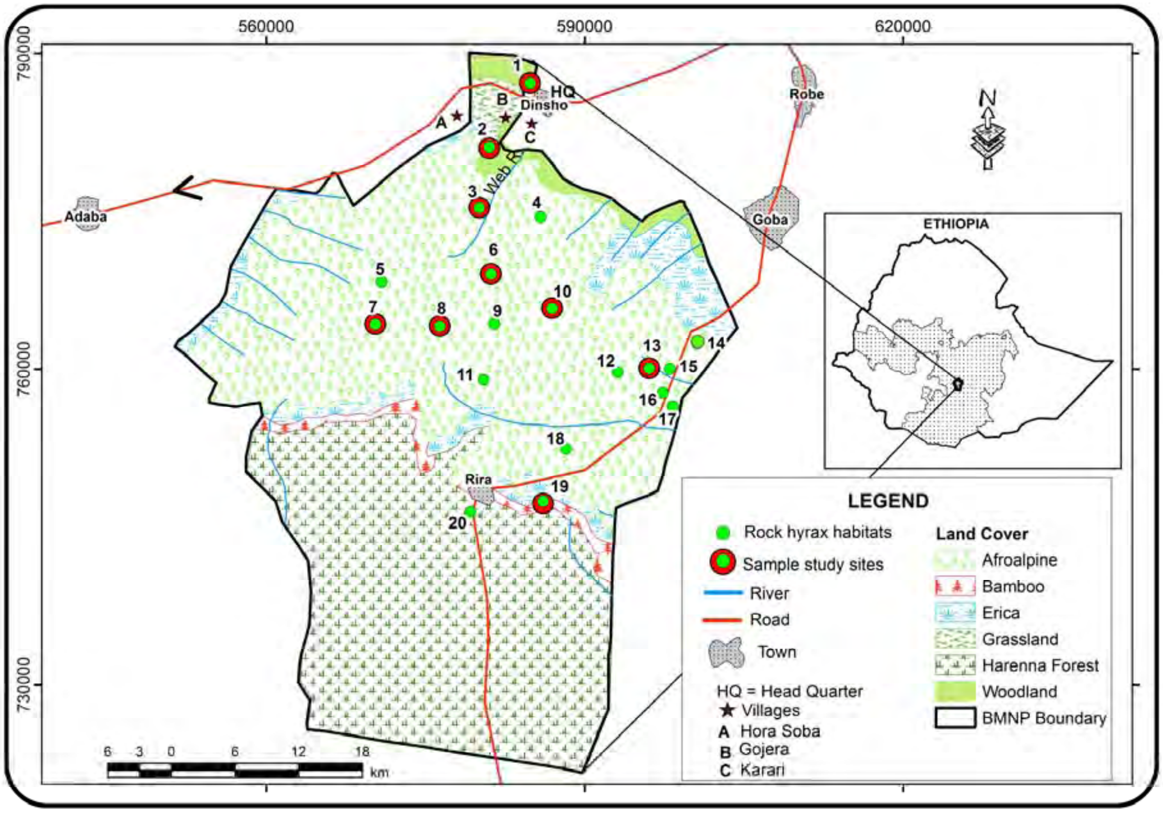


Figure 8. Map of Bale Mountains National Park showing the distribution of vegetation types, the rock hyrax potential habitats (Site 1–20) and sample study sites (Sites 1 = Gaysay Valley, 2 = Adelay Ridge, 3 = Web Valley, 4 = Small Batu, 5 = Goda Senga, 6 = Meraro, 7 = Morebawa, 8 = Keyrensa, 9 = Hujuba, 10 = Worgona Valley, 11 = Rafu, 12 = Large Batu, 13 = Garba Guracha, 14 = Angesu, 15 = Togona Valley, 16 = Sanetti Plateau (EWCP campsite), 17 = Mt. Konteh, 18 = Sanetti Plateau (below Tullu Deemtu), 19 = Harenna Escarpment (around Yadot River) and 20 = Harenna Forest (towards Rira Town) (Adapted from Tallents, 2007).

Adelay Ridge (37N 0581677, UTM 0785059): This area is located at about 3406 m a.s.l altitude towards the south of Gaysay Valley, characterized by interconnected cliffs under which scattered rocky piles are found within which rock hyraxes reside. Common wild animals in this area include mountain nyala, Menelik's bushbuck, colobus monkey, olive baboon, common warthog, Bohr reedbuck, spotted hyaena, carcal and serval cat. Raptors like Black eagle and Lammergeyer are occassionaly seen flying above the ridges. *E. arborea* and *H. revolutum* trees, shrubs like *Helichrysum citrispinum* and *Carduus schimperi*, herbs such as *Alchemilla* spp. and grasses of *Festuca* and *Andropogon* spp. conistitute the dominant vegetation above the cliffs. Below the cliffs, thick woodland comprising mainly of *H. abyssinica*, *J. procera*, *H. revolutum* and *Myrsine melanophloeos* trees are found. Common shrubs in the area include *S. marginatum, E. dumalis* and *D. eremanthum*. The area also has herbs like *Urtica simensis* and different grass species. The greatest diversity of flora is found in this northern woodlands (61.6% of all species recorded), followed by the northern grasslands (36.7%) (Hillman, 1986). One can encounter grazing livestock and human activities like firewood collection, timber cutting and wild honey collection in the area.

Web Valley (37N 0580069, UTM 0775314): This is a broad valley at about 3450 m a.s.l., located towards the southwest of Adelay Ridge, and consists of swampy area through which Web River flows. It is bordered to the west by the ridge that forms the western boundary of BMNP, and to the east by 50–80 m cliffs of condensed lava. Piles of rocks, gorges and a big cave characterize the area towards the lower end of the valley. Rock hyrax, Bush hyrax, Ethiopian wolf, Mountain nyala, Common warthog, Golden jackal and different rodent species are found in this area. The vegetation is largely of the Afroalpine type, dominated by *Alchemilla* pasture (*Alchemilla abyssinica*, *Alchemilla rothii* and *Alchemilla cyclophylla*), scattered *Helichrysum* shrubs (*H. citrispinum*, *H. cymosum*, *H. gofense* and *H. splendidum*) and *A. afra.* The area has typical open grass afroalpine habitats (Sillero-Zubirii, 1994; Marino, 2003). The cliffs and slopes are covered with *Helichrysum/Artemisia afra* scrubs and scattered stands of giant lobelia *(*Sillero-Zubiri, 1994). Low ridges support short alpine grasses mainly of *Festuca* spp., *Carex monostachya*, *F. communis* and *K. foliosa.* The valley walls support thick ericaceous vegetation (*E. trimera)* and scattered *H. abyssinica* and *J. procera* trees. Several settlements are found around the edge of the valley, and livestock are seen at high concentrations grazing all over the habitats.

Meraro (37N 0581152, UTM 0769012): This area is situated towards the southeast of Web Valley at about 3789 m asl, and is characterized by some open plains with swampy area, interconnected cliffs and rock piles over a wide area. The cliffs and rock piles harbour several rock hyrax colonies. Klipspringer, Anubis baboon, Common warthog and Starck's hare are commonly seen in this area. The area is dominated by *E. arborea* shrubs under the cliffs and some scattered *L. rhynchopetalum* trees around the open plains at higher altitudes. *H. abyssinica*, *H. revolutum* and *J. procera* trees are found scattred under the cliffs. Thick *E. arborea* shrubs are the dominant vegetation of the area. Some *H. splendidum*, *H. citrispinum* and *Carduus schimperi* shrubs, herbs like *U. simensis*, grass of the genera *Festuca*, *Andropogon* and *Carex* also occur in the area. There are human settlements towards higher altitude in this area.

Morebawa (37N 0570262, UTM 0764289): This area is located towards the southern side of Web Valley at about 3680 m a.s.l. This area is characterized by a relatively open area with some cliffs and rock piles, where two rock hyrax colonies are sheltered in. Animal and plant diversity is relatively less in this area. Wild mammals like the Ethiopian wolf, rock hyrax, several rodent species and black eagle are commonly seen in this habitat. Scattered *J. procera* trees, *Conyza nana* shrubs, herbs of *K. foliosa*, *Alchemilla* spp., *U. simensis* and few *Festuca*, *Andropogon* and *Carex* spp. grow in this area, mainly sheltered under rock boulders and cliffs.

Keyrensa (37N 0576332, UTM 0764096): This study site is situated towards the east of Morebawa and west of Rafu at about 3807 m a.s.l. This site is characterized by interconnected cliffs over a wide area, open grassland, rock piles and gorges. A relatively large number of rock hyrax and some bush hyrax shelter in these habitats. Commonly seen wild animals of the area include Klipspringer, Ethiopian wolf, Starck's hare and raptors like black eagle, golden eagle and lammergeyer. This area is dominated by *Erica trimera* trees, grasses of *Festuca* spp. and *Andropogon* spp. *J. procera, H. abyssinica* and *L. rhynchopetalum* trees and *E. arborea* and *Echinops longisetus* shrubs. Human settlements are common especially at the base of the cliffs. Livestock grazing is common in the open grassland habitat and hillsides of this site.

Worgona Valley (37N 0586927, UTM 0765785): This area is situated towards the northern side of Meraro on the Way to Garba Guracha at about 3925 m asl. It is characterized by a valley surrounded by mountains/cliffs on both sides. Rock piles with numerous holes spread over a wide area of the valley where rock hyraxes are sheltered in. This valley has open grazing land and mineral water source, where livestock visit from different areas of the Park, congregate for drinking mineral water mainly during the dry season. Sedges and grasses of the genera *Festuca* and *Andropogon* dominate the area. *E.*

arborea and *H. splendidum* shrubs are common around the mountains/cliffs and hillsides with scattered *L. rhynchopetalum.*

Garba Guracha (37N 0596082, UTM 0760093): It is located towards the north of Sanetti Plateau at about 4037 m a.s.l. This area has extensive rock piles spread over a wide area under steep cliffs in which many holes that serve as rock hyrax shelters are seen. There are two lammergeyer nest sites at the side of the cliffs. Below the cliffs is an alpine lake, known as Garba Guracha (locally meaning 'black lake') around which a small open grazing ground is present. A shrubby lady's mantle (*Alchemilla haumannii*), endemic to the mountains in southern Ethiopia, is the dominant vegetation of this area (Miehe and Miehe, 1994). In areas of relatively lower altitudes of Sanetti Plateau, as in Garba Guracha, herbaceous communities, short tussock grasses, rosette plants, cushions and mosses are found (Miehe and Miehe, 1994; Marino, 2003). Few *E. trimera* trees also grow under the cliffs. There are 10–15 temporary/permanent houses in this locality. Livestock accompanied by herders and domestic dogs are commonly seen in this area.

Harenna Escarpment (37N 0585957, UTM 0748944): This is an escarpment boardering the Harenna forest and Sanetti Plateau, which is characterized by interconnected cliffs with rock piles underneath at an altitude of about 3831 m a.s.l. Commonly seen wild animals in this area include the Rock hyrax, Klipspringer, Grey duiker, Starck's hare, raptors like Black eagle and Lammergeyer (and also Leopard, personal communication). Ethiopian wolf and different rodent species are also found in the plateau above the escarpment. *Erica arborea* shrubs dominate the area facing towards the Harenna forest.

Scattered *H. abyssinica*, *J. procera* and *H. revolutum* trees grow at the base of the cliffs. Grasses including *Festuca* spp. and *Carex monostacha*, shrubs such as *H. splendidum*, *H. gofense* and *H. citrispinum* and herbs of *Alchemilla* spp. grow around the escarpment towards the plateau, less abundantly.

Prior to the actual data collection of population size, field assistants and scouts were trained on how to conduct the census and on morphological and behavioural features that enable to distinguish the age and sex of the rock hyraxes and rock hyraxes from bush hyraxes. Global Positioning System (GPS) was used to locate and record the rock hyrax potential habitats and sample census sites. Global Positioning System readings of the potential rock hyrax habitats and the sample study sites and population counted in the sample study sites were entered to GIS (Geographic Information System) and the extent or area of each site and population estimate of the study area was calculated. To estimate the total population of rock hyrax in the study area, data obtained from the sample sites were extrapolated to the total area of rock hyrax potential habitats in BMNP using GIS.

Based on the extent of the sample study sites and number of rock hyrax colonies in the respective sites, each sample site was further subdivided into smaller census colony sites. Due to the restricted and patchy distribution of rock hyraxes in the study area and the species do not venture far from their shelter due to predation risk (Druce *et al*., 2006), they were around their shelter during counts. Due to the difficulty in most rock hyrax habitat structure and terrain, line transect method was not feaseable to determine the abundance of the species. Hence, point count method by direct count was used following the method of Barry and Mundy (1998) for the rock hyrax, Walker *et al*. (2008) for determining the abundance of mountain vizcachas (*Lagidium viscacia*) which are, like the rock hyraxes, diurnal, colonial, large rock dwelling rodents restricted to discrete patches of rocky habitats and Bibby *et al*. (1992) for birds.

To increase detectibility and hence minimize bias in population census, double observer method was used as adopted by Barry and Mundy (1998) for rock hyraxes, Sutherland (2006) and Walker *et al.* (2008). In this method, two observes (trained assistants/scouts) sat separately at different points where visibility of the rock hyraxes was maximum in a particular colony site. Due to the difference in the habitat structures or terrain, all counting sites were not equally accessible to the observers and thus visibility of rock hyraxes was evaluated at each of the cliffs or rock outcrop before attempting counts as accurate census of populations were not possible if large portions of an outcrops were not visible to the observers (Walker *et al*., 2008). Accordingly, observation or vantage points were selected on each census site based on the view and maximum accessibility of the rock hyraxes in the cliffs, rocky outcrops or valleys in which the rock hyraxes inhabit and directly counted the species independently. Care was taken to minimize disturbance of the rock hyraxes while selecting vantage points and counting. Moreover, movement of the observers followed against the directions of the wind inorder to minimize smell by the rock hyraxes, and noise was minimized to avoid disturbance on individuals. To maximize detection probability and minimize bias, counts were done twice a day during the early morning (06:30h to 09:30h) and late afternoon (16:00h to 18:00h) when the rock hyraxes were active and bask on rocky surfaces or actively forage and when visibility was good using unaided eyes and/or 10×42 Bushnell binoculars depending on the distance between the observers and the topography of the habitat in each census point for five days in each month, both during the wet and dry seasons, following the method of Barry and Barry (1996), Barry and Mundy (1998) and Wimberger *et al.* (2009) for rock hyraxes. During each census period, the total number, colony size and composition, age and sex (when possible) of the rock hyraxes, location, type of habitat and the weather at the time of observation were recorded (Appendix 1). Individual rock hyraxes were identified to their respective age as adults, sub-adults and juveniles on the basis of their relative body size (Fourie, 1983; Barry, 1994; Barry and Barry, 1996; Barry and Mundy, 1998; Wimberger *et al*., 2009). Population count of the two observers in a particular colony site was recorded and the average data of the observers was taken for that particular site. When ever rock hyraxes were found in association with bush hyraxes (as in Web Valley and Gabra Guracha), the rock hyraxes were distinguished from bush hyraxes by morphological characteristics such as the dark brown fur colour of rock hyraxes, dark brown spot or fur surrounding the dorsal gland, blunter snout and rounded head and also their relatively larger body size as compared to the pale (gray) fur, yellow spot surrounding the dorsal gland, sharper snout and a relatively smaller body size of bush hyraxes visible by binoculars (Hoeck, 1989; Skinner and Smithers, 1990; Barry and Mundy, 1998; Estes, 1999; Zimman, 2003). When two or more cliffs, kopjes, caves or gorges were found in close proximity and mixing-up of the hyraxes suspected, counting was conducted simultaneously by the observers in each colony site to avoid double counting as adopted by Barry and Mundy (1998) and Walker *et al*. (2008). In such circumstances, each site was delineated by natural land markings such as rocks, shrubs, gorges, rivers and plains. To increase detectability of the hyraxes and for more precise and reliable results or to reduce bias in the census that may be introduced by habitat structure and weather that affect detectability of the species, counting was conducted repeatedly in each census site and month both during the wet and dry seasons including the peripheral males. All observations were made from a distance of 20 – 40 meters based on accessibility of the site and habituation of the rock hyrax to the observers. Close approaches to the hyraxes in most counting sites and repeated counts over a long period revealed a reasonable degree of accuracy in the number of individuals. Population census was conducted in the sample study sites and rock hyraxes counted in all counting points in a particular sample site were pooled together giving the total population of that sample site as adopted by Barry and Mundy (1998).

Density of rock hyrax population was determined from the counted population in the sample sites divided by the area of the study sites.

$$\text{Population Density} = \frac{\text{Number of individuals}}{\text{Area (km}^2\text{)}}$$

In addition to their small size, juveniles were distinguished from sub-adults and adults by their relatively darker brown fur in the field (personal observation, Fig. 9). Sex of some rock hyraxes were identified in the field based on observations of different morphological and behavioural features. The sex of adult rock hyraxes was determined by careful observation of the shape and size of the exposed upper incisors using binoculars, while the hyraxes were calling, grooming or watching.

Figure 9. Physical appearance of a juvenile male rock hyrax, (Photo: Gebremeskel Teklehaimanot, January 2011).

Adult males were distinguished from adult females by their larger, sharp or pointed, tusk-like upper incisors separated one from the other by about the width of a tooth (Fourie, 1983; Rifai *et al*., 2000), which is shorter and blunter in females (Fourie, 1983). Further, adult males have relatively thick neck (Olds and Shoshani, 1982; Skinner and Chimimba, 2005). Some adult females were also distinguished from adult males by their nipples visible when their belly is exposed while basking on rocky surfaces or while grooming (Estes, 1991), when they were continuously followed by juveniles, and when suckling (Kunz *et al*., 1996; personal observation). Accordingly, age and sex of rock hyraxes were assigned as adult male and female, sub-adult male and female unidentified juvenile sex.

But, due to the lack of complete visible morphological or behavioural features that enables to distinguish sex of the rock hyraxes, it was not possible to determine the sex of most adults, sub-adults and juveniles using the aforementioned methods in the field. Hence, to confirm their sex, rock hyraxes were live-trapped following Barry and Mundy (1998), Milner and Harris (1999) and Gerlach and Hoeck (2001).

Permission to trap rock hyraxes was issued by the Ethiopian Wildlife Conservation Authority (EWCA). The sites were prebaited with cabbage and/or fresh grass as adopted by Jacobson *et al*. (2003) and Wimberger *et al*. (2009) before setting the trap following Barnett and Dutton (1995). Rock hyraxes were trapped by locally made and previously tested string snare traps (Gebremeskel Teklehaimanot, 2004) as snare traps are the most effective traps (Fa and Brown, 2009) and traditional wooden traps (locally known as "Gemo") (Fig. 10) placed at the mouths of crevices and along the walking paths of hyraxes. Thirty to eighty five traps were used in the study sites depending on the population size, extent and accessibility of the trapping sites. In all cases, equal number of both types of traps was placed in each trapping site. Traps were set at dawn or before sun rise (before the hyraxes start to emerge from their shelter) under rock boulders or shades in order to provide shade for the trapped ones to minimize stress or not to get overheated (Rana, 1986; Gerlach and Hoeck, 2001) for the hyraxes and Rathbun and Rathbun (2005) for dassie rat. Traps were closely monitored until 10:00h, then again from 16:00h until sunset for checking trapped rock hyraxes.

(a) (b)

Figure 10. Traps baited with fresh grass and set around the shelter of rock hyraxes: (a) String snare trap, (b) Wooden traps ("Gemo") (Photo: Gebremeskel Teklehaimanot, October 2011).

Trapped rock hyraxes were measured (Fig. 11), sexed, marked and released back the same day at the capture site itself. They were assigned to the respective age classes based on their relative body size, breeding status, tooth eruption and body measurements (Fairall, 1980; Barry, 1994; Skinner and Smithers, 1990; Milner and Harris, 1999).

Figure 11. Taking body measurements of a trapped adult male rock hyrax in the field (Photo: Esleman Mohammed, February 2013).

Body measurements of the trapped rock hyraxes were taken according to standard procedures (Smithers, 1973) and recorded following the method of Fourie (1983) as body mass (kg), hind foot length from the tip of the middle toe to the end of the heel with the foot bent at an angle of 90^0 to the tibia (cm), height at shoulder length from tip of the fore feet to the shoulder while the hyrax is in a straight standing position (cm), body length of the animal lying on its side and taken as the direct distance from the tip of the nose to the end of the vertebrae (cm) and body girth measured directly behind the shoulders (cm) (Table 1). They were sexed on the basis of their genitalia and the presence or absence of teats (Barry and Mundy, 1998). Accordingly, the rock hyraxes were categorized into different age and sex categories as adult male and female, sub-adult male and female, juvenile male and female. To identify whether the rock hyrax was trapped earlier or not, individuals were marked by cutting hair from a distinct spot at their back at first capture, following the method of Gerlach and Hoeck (2001) and Wilson and Reeder (2005).

Table 1. Biometric data collected from rock hyrax trapped in the Web Valley area from different habitats. Age and sex classes were defined as follows: mature males – adult males with fully erupted permanent dentition; young males – sub-adult males with incomplete permanent dentition; juvenile males – immature males that lack permanent dentition; mature females – females with fully erupted permanent dentition; young females – sub-adult females with incomplete permanent dentition; juvenile females – immature females that lack permanent dentition (Milner and Harris, 1999; personal observation). Standard errors of means are given in parentheses

Age and sex class	Number of rock hyraxes measured	Mean body mass (kg)	Mean hind foot length (cm)	Mean height at shoulder (cm)	Mean total length (cm)	Mean girth (cm)
Adult males	5	3.9 (0.82)	7.2 (1.4)	28 (3.3)	49.5 (4.8)	30.4 (3.7)
Sub-adult males	5	2.76 (0.41)	5.8 (1.0)	20 (2.4)	38.7 (3.6)	24 (3.1)
Juvenile males	5	1.9 (–)	2.9 (0.7)	14.3 (2.1)	22 (2.3)	16 (2.4)
Adult females	5	3.5 (0.50)	6.7 (1.1)	23.2 (2.1)	44.7 (3.9)	28.7 (2.5)
Sub-adult females	5	2.6 (0.22)	5.5 (1.1)	17.6 (1.9)	35.3 (2.8)	22.4 (2.7)
Juvenile females	5	1.2 (0.10)	2.6 (0.6)	10 (1.6)	20.4 (1.9)	13.3 (1.9)

Detailed data on the colony size and composition were collected while conducting population census. The size of each colony of the rock hyrax was recorded before sub-dividing into the respective age and sex classes. Colony size of the rock hyraxes was studied in permanent colony sites situated in different areas of the sample study area when the animals bask and/or actively forage and when the hyraxes were more readily visible and easier to count (Hoeck, 1989) both during the wet and dry seasons. As rock hyraxes inhabit restricted and patchy areas and do not move far from their shelter site, counting and determining colony size and composition was easier. A given colony was considered as aggregation of two or more spatially associated individuals, in obvious visual, auditory and/or olfactory communication with each other, basking on the same rock outcrop usually in close proximity (within 15 m, and generally much closer) and move in group in the same direction for foraging following the method of Barry and Mundy (2002). Colonies were assigned using two criteria. First, by observing the hyraxes during emergence from their shelter during early morning hours as members of each social group share the same sleeping hole (Fourie, 1983; Koren, 2000) and the frequency of association between individuals in the colony. Colony composition was determined after five minutes of careful observation and classified by age and sex (whenever possible). Peripheral males around a particular hyrax colony were included within the term 'colony' for the purposes of analysis following the method of Arcese *et al*. (1995).

Each rock hyrax colony was recognized by features such as colony size and harem composition (Wilson *et al*., 1996). The largest number of hyraxes recorded during any ten minute time period in a particular colony site both during the wet and dry seasons was recorded and the average of the two observers was taken as an estimate of colony size of that point or colony as adopted by Druce (2005) and Wimberger *et al*. (2009). Great care was taken by the observers to ensure that individual rock hyraxes would not be counted twice especially in areas where two or more hyrax colonies occupy in close proximity. Data on colony size of the rock hyrax in all observation points in the study area were collected, tabulated and analysed.

2.2.2.3 Feeding ecology

Diet of the rock hyraxes was determined both by direct observation of the hyraxes while feeding as adopted by Fourie and Perrin (1989), Milner and Harris (1999) and Zimman (2003) and by rumen content analysis (Fourie, 1983; Fourie and Perrin, 1989). As rock hyraxes have disjunct and patchy distribution and live in colonies in specific sites and do not disperse or move longer from their shelter for foraging (Hoeck, 1975; Brown and Downs, 2005), it was easier to locate their foraging ground and specific food items they consumed. Detailed data concerning feeding ecology of the rock hyrax was obtained from focal animal surveys of individual hyraxes by hide observations of five colonies situated in various places of the Web Valley area for an average of five days in each colony site in each month during both the wet and the dry seasons. Overall, diet observations were conducted for 800 hours (400 hours in the wet season and 400 hours in the dry season) in all colony sites. Focal sample observations were done on a single individual for a predetermined length of time in its natural habitat (Altmann, 1974). Diet observation was conducted by counting bites as bite counts are useful for identifying the principal items in the diet of herbivores (Wallmo *et al*., 1973; Risenhoover, 1989; Mofareh *et al*., 1997) and recording the time taken to consume that particular plant (Litvaitis *et al*., 1994).

Before diet observations, the investigator got familiarized with the hyraxes and the available forage by approaching the hyraxes while foraging for three consecutive days in each of the colony refuges. As a result, it was possible to approach and observe hyraxes at a distance of 20–40 m based on the timidity of the hyraxes and location of observation/vantage points of each site to recognize the forage plants eaten using binoculars. A sample focal hyrax was selected randomly from among the actively foraging hyraxes. Care was taken to sample rock hyraxes on different days, locations and habitat types within the study site to minimize the chance of sampling the same individual twice. Focal subject was observed for five minutes at every 10 seconds interval as soon as it began foraging following the method of Risenhoover (1989), Milner and Harris (1999) and Fanson *et al*. (2011). Then, another hyrax in the colony was selected for the same procedure. Because vegetation on the cliffs or other refuges was mostly patchy, hyraxes foraged in fairly distinct groups were easily distinguishable. Each individual was observed continuously during the early morning (06:30h–09:30h) and late afternoon hours (16:00h–18:00h) by taking vantage points and hide observations. Diet data were recorded on a data sheet (Appendix 2) prepared prior to the commencement of the investigation. During feeding observations, the date and time of observation, the plant species eaten, habit (grass, herb, shrub, tree), part consumed (leaf, stem, flower, fruit), time of bite, the age and sex of the hyrax (as much as possible), habitat type, and weather conditions were recorded as adopted by Litvaitis *et al*. (1994). A stopwatch was used to record the duration of time spent in foraging a particular plant and part (s) of the plant species. The feeding records of each species consumed during each season were analyzed and expressed as a percentage of all feeding records for that season (i.e. frequency of occurrence).

The plant species in each habitat was carefully examined after foraging of rock hyraxes, to record the plants consumed by looking at the bite. Foraging types such as grazing (feeding at ground level) and browsing (feeding above ground level), and the time taken in each case were recorded both during the wet and dry seasons. Observations were continued until most hyraxes had retreated to their refuge or if they noticed the presence of the observer. In other cases, observations were terminated at 10 minutes or when the hyrax was lost from sight. Feeding bout (the time continuously handling or eating food items excluding movement between food patches) was recorded for each food item separately to determine the percentage contribution of each food item in the overall diet (Milner and Harris, 1999; Shrestha *et al*., 2005). Bites were distinguished from other activities by the distinct pulling head and plant leaf/branch (especially for shrubs and trees) movements (Ungar, 1996). If the focal animal changed its activity, other than feeding and was involved in another activity, the time spent in performing that activity was recorded and excluded from the feeding time data. Additional food plant species were also recorded when rock hyraxes were casually encountered feeding outside of normal data collection periods. When the focal rock hyrax was observed feeding, its feeding location was identified using nearby signposts such as rocks, bushes and/or animal tracks. When the animal moved away from the site, the feeding ground was examined and fresh bites were carefully identified. Fresh bites were readily identified because bitten plant remains fresh, whereas old bites turn brown very quickly (Arsenault and Owen-Smith, 2008). Occasionally, indirect methods such as examination of clipped vegetation at the entrance or the immediate vicinity of the rock hyrax refuge (beyond the reach of other herbivores) were also carried out for additional data as adopted by Fourie (1983) and Kotler *et al*. (1999) for the rock hyraxes. The plant food items were identified in the field with the help of ecologists, local guides and knowledgeable scouts of the Park, who have the ability to identify species using local or common names. Those food plants, which were difficult to identify in the field were collected with all morphological components needed for identification, pressed in plant press following standard procedures (Bridson and Forman, 1992), dried and taken to the National Herbarium, Addis Ababa University for identification. Specimens were identified by comparing with the already identified specimens in the National Herbarium. Species names were recorded following flora of Ethiopia and Eritrea (Edwards *et al*., 1995; Edwards *et al*., 2000; Hedberg *et al*., 2003).

According to Barnes (1976), in order to define principal foods and food preferences, a measure of food availability has to be obtained. Thus, relative availability of plant species was determined in different habitats of Web Valley area both during the wet and dry seasons. Systematic plot (qaudrat) sampling technique was used to estimate the vegetation composition and abundance of the plant species in the study sites, following the methods of Kent and Coker (1992) and Peet *et al*. (1998). Data on vegetation were collected using systematic sampling techniques in which 3–7 transect lines of 50–100 m length in each of the sites (based on extent of the sites), each laid along specified direction using natural and artificial sign posts. Along each transect, sample quadrats made of wooden frame (1m x 1m) were laid at a distance of 10 m interval. Availability and/or abundance of each plant species in each quadrat and the study sites was evaluated by visually estimating the proportion of the aerial cover or ground area occupied by that plant species or by calculating the frequency of occurrence of the species (% of quadrats in which the species was found) both during the wet and dry seasons (Daubenmire, 1968).

The plant species recorded from all the quadrats in the study site were pooled and used to determine the relative percent cover or estimate the relative forage availability/abundance in terms of frequency of occurrence of each plant species in that particular site. Plant species found in each quadrat were identified as mentioned earlier. The data for forage availability and abundance were used to estimate the seasonal forage preference of rock hyraxes in the study sites.

As some plant species, especially those that are small in size were difficult to fully recognize and identify by direct observation while the rock hyrax was foraging and also confirm the rock hyrax diet determined by direct observation, diet composition of the rock hyrax was complemented by and compared with micro-histological technique of rumen content analysis as described by Mofareh *et a*l. (1997), Kronfeld and Dayan

(1998) and Shrestha *et al*. (2005) as rumen content analysis provides a direct and more reliable data on food and feeding preferences of an animal species (Junaid *et al*., 2012).

To produce a photographic reference collection of their cuticle, plant specimens were first collected from different habitats following Buys (1990) before rumen content analysis. Accordingly, 38 plant species (12 grasses, 11 herbs, 13 shrubs and two trees) were sampled from Web Valley area with their leaves from various habitats, such as the foraging and basking areas, walking trails and also from around the entrance to the rock hyrax shelter, for the preparation of reference slides on the basis of their abundance and which appeared to have been eaten by the rock hyrax by direct observations as adopted by Garcia-Gonzalez and Cuartas (1992) and Chetri (2006) during both the wet and dry seasons (Table 2). The pieces of fresh plant samples were collected, identified and packed in polythene bags, labelled and taken to the Addis Ababa University, Zoological Sciences Department laboratory. Reference slides for each plant species were prepared following the method of Gaylard and Kerley (1995) and De Boer *et al*. (2000). The leaves were cut into small squares with scissors and boiled for about five minutes in 10% nitric acid until the mesophyll or chlorophyll and epidermis were separated. After the completion of the boiling process, the epidermis was rinsed with tap water to clear epidermis, and the remaining mesophyll (if any) was removed gently with a scalpel under a light microscope. The epidermis was then placed on labelled microscope slides for each plant species as adopted by Chapuis *et al.* (2012), the adaxial and abaxial surfaces were then mounted on the slides and stained with haematoxylin and covered with a cover slip.

Table 2. List of plant species collected from Web Valley area that were used for photographic reference in microhistological analysis (G= grass, H= herb, S= shrub, T= tree).

Plant species	Family	Growth form
Urtica simensis Steudel	Urticaceae	H
Artemisia afra Jacq. ex Willd.	Asteraceae	S
Alchemilla abyssinica Fresen.	Rosaceae	H
Carduus schimperi Sch. Bip. ex A. Rich	Asteraceae	S
Agrostis quinqueseta (Hochst. ex Steud.) Hochst.	Poaceae	G
Alchemilla haumannii Rothm.	Rosaceae	S
Lobelia rhynchopetalum Hemsl.	Campanulaceae	S
Andropogon amethystinus Steud.	Poaceae	G
Kniphofia foliosa Hochst.	Asphodelaceae	H
Festuca simensis Hochst. ex A. Rich.	Poaceae	G
Anthemis tigreensis A. Rich	Asteraceae	H
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	T
Agrostis gracilifolia C.E. Hubb.	Poaceae	G
Hypericum revolutum Vahl	Hypericaceae	T
Carex conferta Hochst. ex A. Rich.	Cyperaceae	H
Helictotrichon elongatum (Hochst. ex. A. Rich.) C.E. Hubb.	Poaceae	G
Thymus schimperi Ronniger	Lamiaceae	H
Festuca abyssinica Hochst. ex A. Rich	Poaceae	G
Senecio ragazzii Chiov.	Asteraceae	H
Koeleria capensis (Steud.) Nees	Poaceae	G
Helichrysum citrispinum Del.	Asteraceae	S
Erica arborea L.	Ericaceae	S
Helichrysum splendidum Lees.	Asteraceae	S
Valpia bromoides (L.) S.F. Gray	Poaceae	G
Inula confertiflora A.Rich.	Asteraceae	S
Helichrysum gofense Cufod.	Asteraceae	H
Conyza nana Sch. Bip. Ex Oliv. & Hiern	Asteraceae	S
Solanum benderianum Schimper ex Dammer	Solanaceae	S
Andropogon pratensis Hochst. Ex Hack.	Poaceae	G
Colutea abyssinica Kunth & Bouche	Fabaceae	S
Andropogon lima (Hack) Stapf	Poaceae	G
Carex simensis Hochst. exA.Rich	Cyperaceae	H
Colpodium hedbergii (Meld.) Tzvel.	Poaceae	G
Trifolium simense Fresen.	Fabaceae	H
Rytidosperma subulata (A.Rich.) Cope	Poaceae	G
Euphorbia dumalis S. Carter	Euphorbiaceae	S
Senecio nanus Sch. Bip. ex A. Rich	Asteraceae	H
Discopodium penninervium Hochst.	Solanaceae	S

For the plant species collected, photomicrographs of both the adaxial and abaxial surfaces were taken and recorded by using microscope eye piece camera with universal attachment set in order to compare with the rumen plant fragments to be identified later following the method of Holechek *et al.* (1982) and Chetri (2006). The reference photos of the pieces recovered from each slide were prepared, showing diagnostic histological features such as cell wall and cuticle structure, shape and size of cells, presence/absence and type of hairs and trichomes, stomatal shape, size and density, inter-stomatal cells and arrangement of veins as described by Chetri (2006) and Junaid *et al*. (2012). Among the photographic reference slides used, the adaxial and abaxial leaf surfaces of the most available and highly utilized plant species, *Festuca abyssinica* and *Festuca simensis*, respectively, is given in Figure 12.

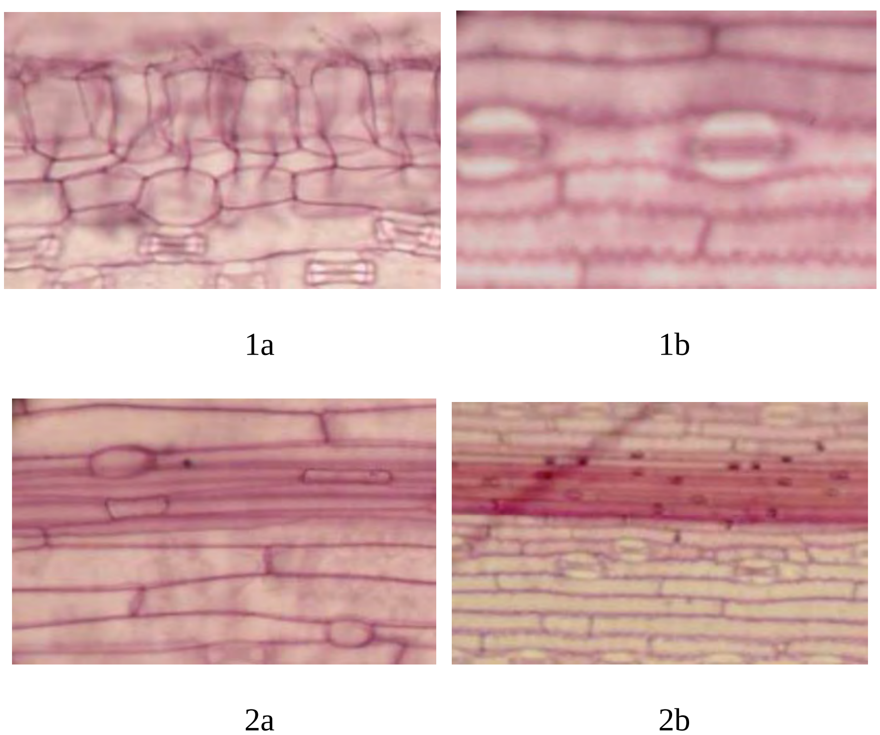


Figure 12. Photomicrographs of the adaxial and abaxial leaf surfaces, respectively, of *Festuca abyssinica* (1a and 1b) and *Festuca simensis* (2a and 2b).

For the rumen content analysis, rock hyraxes were trapped from the Web Valley area from different representative habitats (cliffs, rock boulders, open areas, gorges and caves) as recommended by Gaare *et al*. (1977), both during the wet and dry seasons. Eight rock hyraxes were trapped both during the wet and dry seasons. To minimize the bias due to digestion, trapping was conducted in the early morning and late afternoon hours (peak foraging time of the rock hyraxes) to collect the food items immediately before the onset of intestinal digestion. The trapped hyraxes were sacrificed, dissected, rumen contents were collected (Fig. 13), kept in separate containers, labelled and immediately preserved in 5% formalin solution in order to minimize postmortem digestion and autolysis, and taken to the Addis Ababa University, Department of Zoological Sciences Laboratory for detailed analysis. Permit to scarify the rock hyraxes and collect rumen contents was issued by EWCA.

Rumen contents collected from the study area were mixed thoroughly in the laboratory to form uniform mixtures. The whole sample was then rinsed with tap water in order to clear up the epidermis as described by Butet (1985). The samples were then macerated in sodium hypochlorite (bleach water) as adopted by Abbas (1988) and sieved through a 0.2 mm mesh sieve to eliminate small unidentifiable fragments following the method of Sparks and Malechek (1968).

Figure 13. Rumen content collection in the field (Photo: Esleman Mohammed, January 2012).

The samples were then dried in open air for two days, uniformly mixed and lightly ground in a mortar to separate out the epidermal fragments into small pieces in order to overcome bias due to differential plant fragmentation. From the samples, 10 g was placed in a test-tube and mixed with 5 ml of concentrated nitric acid and boiled in order to kill chlorophyll and digest non-epidermal tissues (Vavra and Holechek, 1980; Garcia-Gonzalez, 1984). Then, two slides were marked with a 1mm squared grid. The samples were then spread out uniformly on to the slides using pipette so as to avoid overlap of fragments, stained with haemotoxylin and mounted between slide and cover slip in a drop of glycerin following Bartolomé *et al.* (1995).

The slides were traversed systematically and every second vertical line of the girded slide was sampled to avoid double counting of the fragments. Each slide was examined carefully under an optical microscope and compared with photographs of the plant reference collections prepared earlier.

Maximum effort was made to identify and count all the plant fragments found in the rumen samples to species level. Fragments that did not match any species in the reference collection were recorded as "unidentified". Unidentifiable fragments were classified as monocots or dicots depending on the arrangement of the cells of the epidermis. Each food fragment was counted from both slides, pooled and converted to mean percentage (Bartolomé *et al*., 1995). The relative percentage frequency of each plant species in the rumen sample was estimated using the following formula (Katona and Altbacker, 2002; Chetri, 2006):

$$Rf\% = \frac{n_i}{N} \times 100$$

Where $Rf\%$ = Relative percentage frequency,

n_i = Number of fragments identified for a given food species or forage category, and

N = Grand total number of fragment counts made in the sample.

In evaluating the overall character of the diet, the components were pooled to form primary forage classes: grasses, herbs, shrubs and trees as adopted by Kamler and Homolka (2011).

Diet information obtained from rumen content analysis was compared with the diet information derived from direct field observation to establish relative preferences of forage species (Sanders *et al*., 1980; Mofareh *et al*., 1997). Plants eaten by each hyrax were ranked according to percent composition in the hyrax's diet and percent of total plant availability in the study area. In other words, food plant species were ranked based on the use and availability of each plant species. Diet composition was determined by identifying the different species of plants consumed by the rock hyraxes, computing the relative frequency of each item in the diet (relative utilization) and their relative abundance (availability or cover) in the study area both during wet and dry seasons. Plant species were assigned as principal food items if the rock hyrax eats in greatest quantities regardless of their availability in the environment while preferred food species were those species which were proportionately more frequent in the diet of the hyrax than in the available environment (Petrides, 1975). Preference was quantified by calculating preference indices for the plant species in the diet. Preference index was calculated by dividing percentage utilization by the percentage availability in the environment (Caister *et al.*,2003; Parker *et al.,* 2003; Roux, 2006; Kassa *et al*., 2007) using the following formula:

$$\text{Preference Index (PI)} = \frac{\text{Percentage utilization}}{\text{Percentage availability in the environment}}$$

Where, percentage utilization is the percentage of a given plant consumed as food and is a ratio of species in the diet to all species consumed, while availability in the environment is a ratio of the total number of individuals of a single species to the total number of individuals of all species observed in all the observation sites. Preference index (PI) of each food item was assigned in such a way that a preference index greater than one indicated selection for that species, whereas a value of less than one implied that the species was consumed in proportion less than its availability in the environment (MacLeod *et al.*, 1996).

2.2.2.4 Threats to rock hyrax

Data on the status and potential threats of the rock hyrax were collected mainly through semi-structured face-to-face questionnaire survey and interview and field observations during the study period. To assess human activities around the study area, questionnaires were distributed to sample households and interviews were conducted. Field observations were also made exhaustively along the study area to collect additional data and to verify information and compare responses gathered from the respondents and interviwees on the status and threats of the species. Various human activities presumed to impact rock hyrax and its habitats were also recorded. This was intended to investigate the effects of encroachment by the local people and livestock on rock hyraxes and their habitats in the northern part of BMNP, where the surrounding farmers are predominantly dependent on subsistence farming and livestock rearing.

Domestic dogs roaming around rock hyrax shelters were carefully followed during the study period to check whether they hunt rock hyraxes or not. In order to evaluate their diet, fresh faecal samples of dogs were collected whenever observed defecating around rock hyrax natural habitats to avoid the potential bias of collecting scats of other wild carnivores. Accordingly, 116 fresh faecal samples (60 during the wet and 56 during dry seasons) were collected from different sites of the study area. Additionally, to check whether dogs prey on rock hyraxes or not, hair and other peculiar body parts of the rock hyrax were collected earlier for comparision while conducting diet analysis of domestic dogs (Brunner and Comman, 1974; Anagaw Atickem *et al.*, 2009; Ogara *et al.*, 2010). The scats were air-dried and broken carefully by hand and examined both by naked eye and a hand-held lens. Hair found in the scats was compared with the hair collected from rock hyraxes earlier.

As questionnaire surveys are more suitable especially for widely distributed species (Gese, 2004), semi-structured questionnaire consisting of both close ended and open ended questions were addressed to different individuals consisting of local farmers, pastoralists, scouts, herders, local guides and students to collect additional data on ecological aspects of the rock hyrax (Appendix 3). The questionnaire focused on demographic variables such as sex, age, household size, educational level, occupation and years as residents in the respective villages as these entities can partially determine attitudes of local people towards protected areas (Heinen and Shrivastava, 2009; Shibia, 2010). Moreover, the socio-economic background of the respondents, resource utilization from the Park, impact of wild animals and the Park on their livelihood, status and threats to the rock hyrax and overall attitude on the Park and wildlife were also addressed to the respondents. Questionnires were administered to sampled households from three villages with households defined as ‘the people who normally eat and sleep under the same roof’ (Rowland and Gatward, 2003). A total of 235 households (85, 60 and 90 from Karari, Gojera and Hora Soba, respectively) were randomly selected for the questionnaire survey. These villages were selected for the present study because they were inside and/or around the Park's boundary, and households in these villages were observed encroaching into BMNP areas, and using different resources with their livestock from the Park during the reconnaissance survey. Moreover, residents in these villages were expected to have more knowledge about the Park and wildlife found in it. Households involved in the questionnaire survey were drawn by simple random sampling from the three villages. The selected samples represented 15% of all households in the respective villages. It is the household head, who had a better knowledge and those who where long lived participated mostly. In case of their absence, another permanently resident adult (≥18 years) of the households took part in the questionnaire survey.

Prior to the actual data collection, pre-testing of the questionnaire was undertaken in the three villages with a small number of households (n =15) that were not part of the selected sample. Pre-testing of the questionnaire was aimed to assess how the respondents understand the questions and to identify any problem encountered in providing answers. Based on this, questions were revised and finalized. Visiting or cons-ulting the sampled informants was scheduled earlier before one or two days so as to avoid busy times of the informants such as harvest season, market day and prayer times following the method of Gandiwa *et al*. (2013). The objective of the study was first introduced to the informants to understand the purpose clearly and forward their views freely.

Issues related to the ecology and threats of the rock hyrax and socio-economic status of the households were discussed with the informants. As questionnaire assessments may be more appropriate to gather information for widely distributed species (Gese, 2004), issues related to the distribution and habitat in which the rock hyraxes are frequently observed were also addressed to the respondents. Questions about dietary observations, social nature, time of the year when young were seen and the preferred habitat and vegetation were also raised. Questions about threats to the Park and rock hyrax populations, current and historical hunting pressures, purposes for which hyraxes were hunted, methods of hunting, whether they have ever encountered wild fire in the Park area and prevalence/extent and reason to put fire and its impacts on wildlife, particularly rock hyraxes, and their habitats, habitat or vegetation type in which wild fire observed and also other threats to the species (if any) were asked.

To supplement the data gathered by the questionnaire survey, key informant interviews were conducted with 26 individuals (21 Males and 5 females) comprising BMNP warden, the Park's staff members, Ethiopian Wolf Conservation Programme (EWCP) staff, local administration heads and pastoralists (Table 3). Issues addressed to the interviewees include awareness creation and knowledge about the Park and wildlife including rock hyrax in the Park to the local people, relationship of the Park administration and the local people, whether the local community use natural resources from the Park or not, impact of wildlife and the Park on the local community, threats to the Park and wildlife and the population trend of the rock hyrax in the Park. Interviews took approximately 40–60 minutes to complete.

Table 3. Key informant interviwees involved to collect data on the ecology and status of rock hyrax in Bale Mountains National Park.

Interviewees	Number of interviewees		
		Sex	
	Age (in years)	Male	Female
BMNP warden	36	1	–
BMNP staff	26–55	6	1
EWCP staff	28– 46	4	–
Karari village administration head	51	1	–
Gojera village administration head	49	1	–
Hora Soba village administration head	55	1	–
Pastoralists	21–58	7	4

One research assistant and/or scout participated both in the questionnaire survey and the interview for the purpose of the local language (*Oromiffa*) translation. Inforamtion collected through the questionnaires and interviews were validated through actual field observations in the study area, following the methods of Martin (1995) and Alexiades and Sheldon (1996). Photographs demonstrating different impacts of the local people on the Park and the rock hyrax were also taken.

2.2.3 Data Analyses

Data collected during the study period were entered in Microsoft Excel data sheets, crosses checked and transferred and were analyzed using SPSS software for windows version 17. Descriptive statistics for analysis of data, Chi-square test (χ^2) and student's t-test (t) for independent samples and one-way ANOVA were used. The results were presented in percentages, bar graphs and frequency tables. Arch GIS software was used to estimate population size of the rock hyraxes in the study area.

One way ANOVA was used to compare the population size of rock hyraxes among the study sites and between the seasons. The sex ratio and age structure of rock hyrax during wet and dry seasons were computed using Chi-square and descriptive statistics. Colony size of the rock hyrax populations among the different study sites during the wet and dry seasons was compared by using t-test. Data collected on seasonal dietary composition and preferences were coded, analyzed and the time taken for feeding different plant species across seasons was compared using Chi-square test. The percentage contribution of food items and the species of plants consumed by the rock hyraxes were compared using Chi-square test between seasons. Chi-square test was also used to compare the proportion of different forage groups within habitats across seasons.

Data collected through questionnaire were coded and run in SPSS, analyzed and compared using one-way ANOVA and expressed by descriptive statistics, frequency and percentage. Data from formal and informal interviews were pooled and summarized using a text analysis method and described.

3. RESULTS

3.1 Distribution

The present investigation has revealed that the rock hyrax is distributed from Gaysay Valley (3050 m) through the base of Tulu Dimtu towards southwest direction (4134 m) to Rira, and at the northern edge of the Harenna forest (2774 m). The species inhabites various habitat types, including cliffs, rock boulders (kopjes), plains with kopjes, valleys and caves that have crevices in which they can occupy. They favour habitats having enough vegetation cover like *Erica* shrubs and grasses. These habitats are mainly found in Adelay Ridge, Upper Web Valley, Meraro, Goda Senga, Keyrensa, Rafu, Worgonna Valley, Garaba Guracha and Sanetti Plateau in the Bale mountains (Fig. 14). Distribution of rock hyrax also extends to Togona Valley, Angesu, Sanetti Plateau including the base of Tulu Dimtu and Harenna escarpment. Additionally, isolated populations occur in Morebawa, situated in the west of Keyrensa in a small cliff and rock boulders and in Small Batu, located along the way from Sanetti plateau to Dinsho town.

Rock hyraxes are not evenly distributed across the BMNP habitats. They are absent in open plains that are devoid of rocky piles with crevices. The species showed more preference to interconnected cliffs and rock piles with many crevices situated mainly around *Erica* dominated shrubs and rocky areas in a relatively open area, while less or absent in cliffs and/or kopjes within forest areas. Interconnected cliffs and *Erica* shrubs is abundant in the Web Valley, Kyrensa and Sanetti plateau at the base of Tulu Dimtu and these habitats harbour numerous rock hyrax populations.

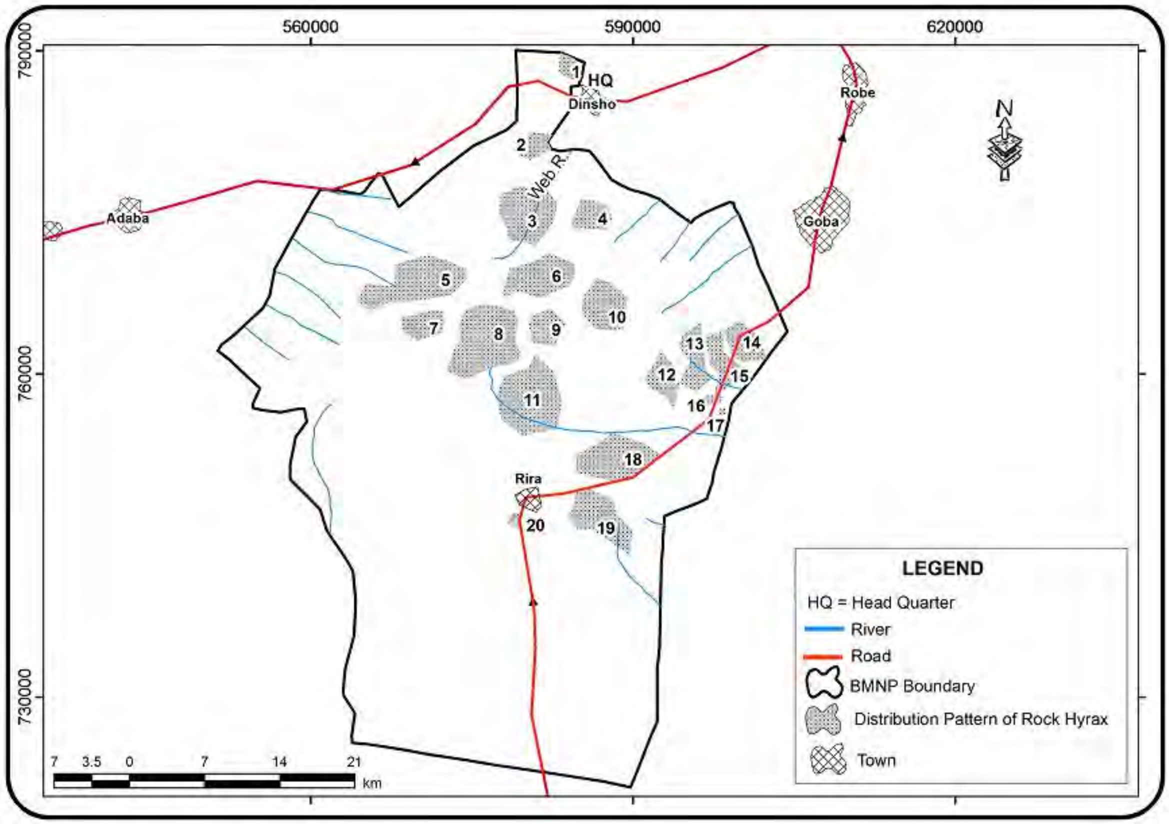


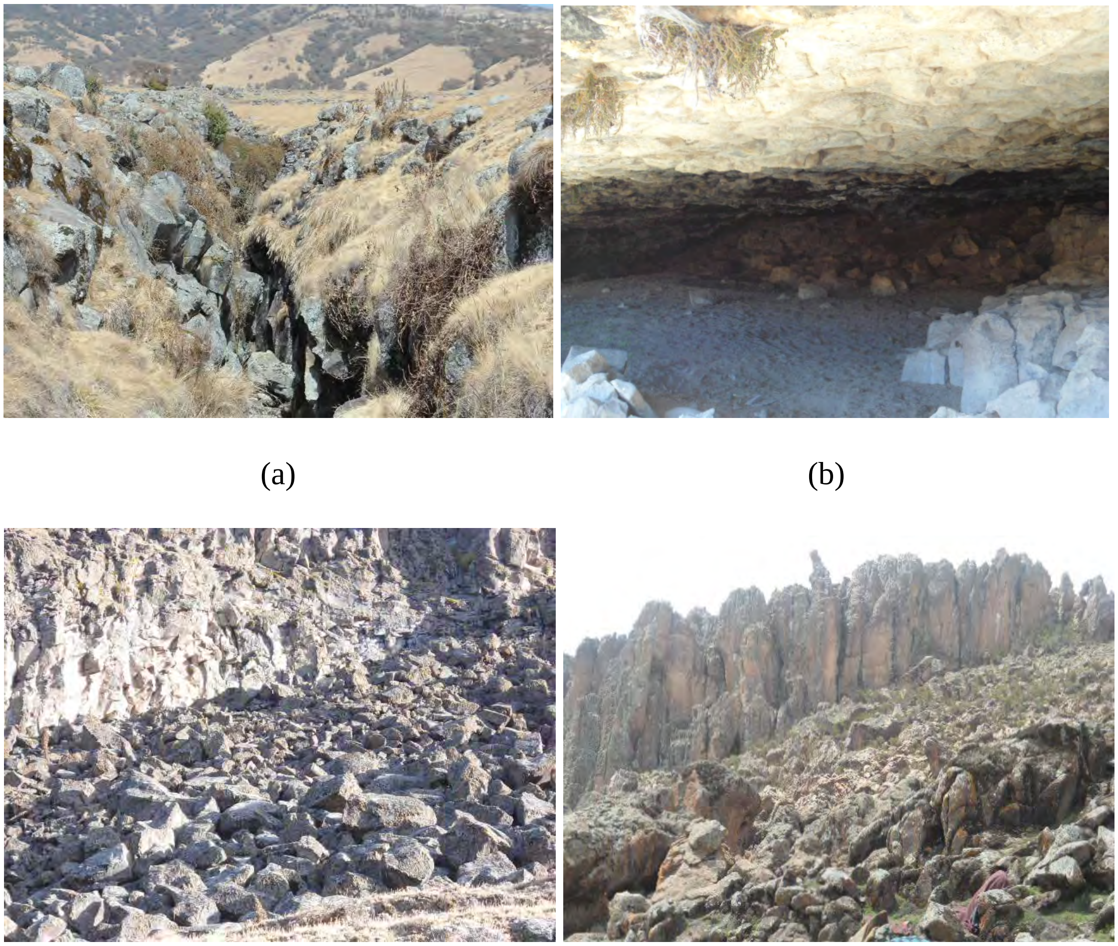
Figure 14. Distribution map of rock hyrax in Bale Mountains National Park (1–20 are distribution sites of the species: Site 1 = Gaysay Valley, 2 = Adelay Ridge, 3 = Web Valley, 4 = Small Batu, 5 = Goda Senga, 6 = Meraro, 7 = Morebawa, 8 = Keyrensa, 9 = Hujuba, 10 = Worgona Valley, 11 = Rafu, 12 = Large Batu, 13 = Garba Guracha, 14 = Angesu, 15 = Togona Valley, 16 = Sanetti Plateau (EWCP campsite), 17 = Mt. Konteh, 18 = Sanetti Plateau (below Tullu Deemtu), 19 = Harenna Escarpment (around Yadot River) and 20 = Harenna Forest (towards Rira Town).

Rock boulders spread over a wide area is also found in Garba Guracha with numerous holes in which rock hyraxes shelter in. These populations are found under two active lammergyer nests built on the sides of the cliffs (Fig. 15). One rock hyrax colony inhabiting burrows and rock piles, comprising 8–10 individuals at the northern tip of the Harenna forest situated very close (10–15 m) to the main road that leads from Goba to Delo Mena.

Figure 15. Lammergyer nest (within the rectangle) on the wall of a cliff in Garba Guracha, Bale Mountains National Park (Photo: Gebremeskel Teklehaimanot, February 2012).

Two colonies in Gaysay Valley were situated in a gorge through which Danka River flows underneath, and where large numbers of livestock graze around regularly, where construction activities were seen and settlements were expanding towards the colony site. Two rock hyrax colonies were also sheltered in caves in Web Valley. Moreover, some rock hyrax colonies in Web Valley, Meraro, Keyrensa, Goda Senga, Rafu, Garba Guracha and Sanetti plateau were situated in the vicinity of human settlements.

Rock hyraxes are distributed almost all over the BMNP except in thick forests of the Harenna forest, provided there are rock outcrops, cliffs with crevices, caves and gorges having rock piles or crevices. They are distributed widely in rock piles situated in open areas or within sparsely grown *Erica* vegetation, and have patchy distribution occupying various habitat types in the Park (Fig. 16).



(a) (b)

(c) (d)

Figure 16. Rock hyrax habitat, (a) A gorge at Gaysay Valley, (b) Cave in Web Valley, (c) Rock boulders at Garba Guracha, and (d) Cliffs at Sanetti plateau (Photo: Gebremeskel Teklehaimanot, January and February 2012).

In general, the rock hyrax is distributed in a wide range of areas over the BMNP and occupies variety of habitats ranging from relatively low altitude as in the edge of Harenna forest to higher elevations as in the base of Tulu Dimtu to Gaysay Valley at the northern tip of the Park. But, their distribution is discontinuous and patchy and mainly depends on the presence of cliffs and kopjes with *Erica* and/or other shrubs and grasses.

3.2 Population status

The total area of the sampled rock hyrax habitats calculated was 50.24 km^2 and that of the rock hyrax potential habitats in the Park was 168.5 km^2. A mean of 30,003 rock hyraxes were counted in the nine sample study sites during the present investigation. The maximum number counted was 9618 in Keyrensa and the minimum was 15 in Gaysay Valley (Table 4). There was significant difference in the population size of rock hyraxes among the sample study sites ($F_{8\ 121}$ =156.4, $P<0.05$). Counting rock hyraxes was relatively simpler and reliable during the dry season and in kopjes and open habitats than during the wet season and in the mountain cliffs.

Table 4. Number and density of rock hyraxes in different sample counting sites.

Counting site	Area (km^2) of census site	No. of colony sites	Mean count	Mean density (Individual/km^2)
Gaysay Valley	0.59	2	15	25.4 ± 4.2
Adelay Ridge	2.94	7	636	216.3 ± 21.4
Web Valley	14.90	12	7401	496.7 ± 38.9
Meraro	5.86	10	4304	743 ± 45.7
Morebawa	0.97	3	303	312.4 ± 24.3
Keyrensa	12.85	15	9618	748.5 ± 74.7
Worgona Valley	4.93	5	811	164.5 ± 20.4
Garba Guracha	2.75	3	4665	1696.4 ± 172.3
Harenna Escarpment	4.44	6	2250	506.7 ± 76.8
Total	50.24	63	30,003	597.2 ± 53.2

Extrapolation of the number of rock hyraxes counted in the nine sample counting sites to the overall rock hyrax potential habitats in the Park was 100,629 individuals. The mean (±SE) of rock hyraxes was 33,383 ± 3419.7 and 26,623 ± 2918.3 individuals during the wet and dry seasons, respectively, in the sample study sites. Counts in different sites during the wet and dry seasons were significantly different ($F_{1\ 38.7} = 198$, $P<0.05$). The mean number of rock hyraxes counted in the nine sample sites during wet and dry seasons are given in Figure 17. The highest count was 10,568 in Keyrensa during the wet season and the least was 13 in Gaysay Valley during the dry season.

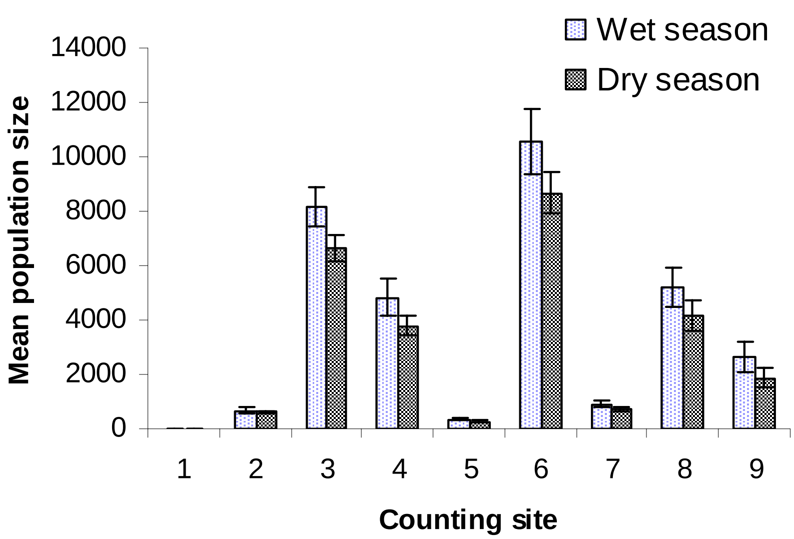


Figure 17. Mean (± SE) of rock hyraxes counted in different sites during wet and dry seasons (1= Gaysay Valley, 2= Adelay Ridge, 3= Web Valley, 4= Meraro, 5= More-bawa, 6= Keyrensa, 7= Worgona Valley, 8= Garba Guracha, 9= Harenna Escarpment).

Mean population density of the rock hyrax in the nine sample sites during wet and dry seasons was estimated to be 664.5 ± 66.2 and 529.9 ± 49.3 individuals/km^2, respectively.

The highest population density recorded was 1696.4± 172.3 individuals/km^2 in Garba Guracha and the lowest density was 25.4 ± 4.2 individuals/ km^2 in Gaysay Valley.

Out of the total population of rock hyraxes recorded during the study period (N= 30, 003), adults constituted 70.5%, while sub-adults and juveniles comprised 8.3% and 21.2%, respectively (Fig. 18). There was significant difference among the different age groups (χ^2 = 43.7, df= 2, P<0.05). The number of adults, sub-adults and juveniles counted during the wet season was 23,623 ± 2624.2, 2870 ± 919.5 and 6830 ± 1190.9, respectively. On the other hand, the number of adults, sub-adults and juveniles counted during the dry season was 18,681 ± 1307.8, 2110 ± 420.3 and 5892 ± 1292.9, respectively. There was significant statistical difference between the number of adults and juveniles recorded during wet and dry seasons (χ^2 = 8.06, df= 1, P<0.05), but not between the number of sub-adults recorded during the wet and dry seasons (χ^2 = 2.2, df = 1, P>0.05). The ratio of sub-adults to adults was 1:8.5 and that of juveniles to adults and sub-adults to juveniles was 1:3.3 and 1:2.6, respectively. More rock hyraxes (55.6%) were counted during the wet season than during the dry season (44.4%), with a significant difference in the population count between the two seasons (χ^2 = 72.6, df= 1, P<0.05).

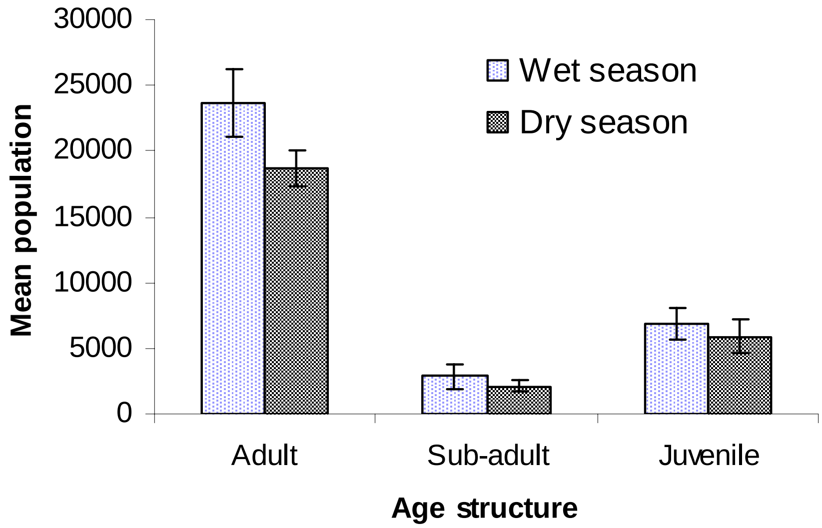


Figure 18. Age structure of rock hyraxes recorded during wet and dry seasons (Mean ± SE).

Sex distribution of rock hyraxes recorded during wet and dry seasons in the study sites is given in Figure 19. The sex of 18,263 (60.9%) rock hyraxes was determined both by field observation and trapping during the study period, while that of 11,740 (39.1%) rock hyraxes was not determined.

Out of those hyraxes sexed, 68.7% was determined by field observation and only 31.3% was determined by trapping. Season-wise comparison revealed that the sex of 7704 rock hyraxes (61.4%) was determined during the wet season and 4843 (38.6%) during the dry season by field observation (χ^2 = 79.94, df=1, <P0.05).

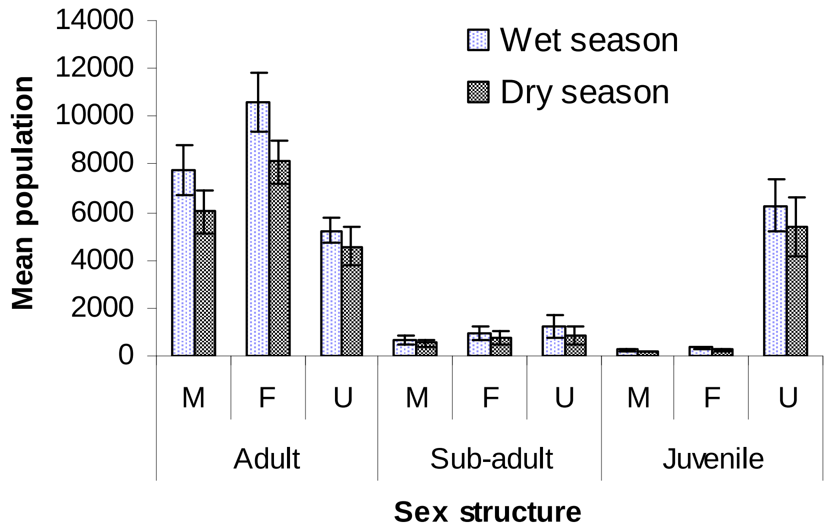


Figure 19. Sex structure of rock hyraxes recorded during wet and dry seasons (Mean ± SE) (M= Male, F= Female, U= Unidentified sex).

However, more hyraxes were trapped during the dry season than during the wet season, and hence the sex of 58.6% was determined during the dry season and 41.4% during the wet season by trapping (χ^2 = 31.43, df= 1, P<0.05) (Fig. 20).

During the study period, the sex of more adults (16,246, 89%) was determined than that of sub-adults (1469, 8%) and juveniles (548, 3%) (χ^2 = 121.83, df= 2, P<0.05). Out of the sexed rock hyraxes, 7725 (42.3%) were males and 10,538 (57.7%) were females. Adult male to adult female ratio was 1:1.5 and that of sub-adult male to sub-adult female and juvenile male to juvenile female ratio was 1: 1.3 and 1: 1.1, respectively. Overall, the population was female biased. The sex ratio of adults was also more skewed in favour of females as compared to the sub-adults. However, the juvenile sex ratio was around 1:1.

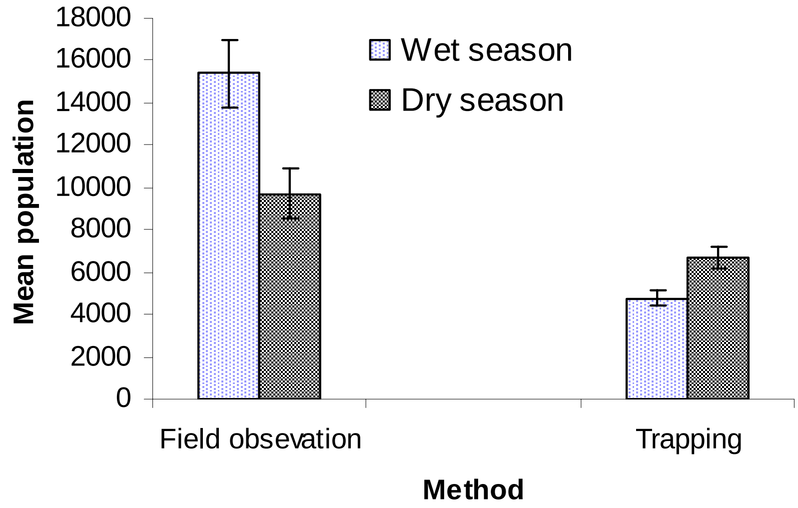


Figure 20. Mean (± SE) of rock hyraxes sexed by field observation and trapping during wet and dry seasons.

More rock hyraxes were trapped by snare trap than the locally made wooden trap. Out of the trapped rock hyraxes during the wet and dry seasons, 3224 ± 589.4 were trapped by snare trap, whereas 2492 ± 423.8 were trapped by the wooden trap (Table 5). Number of rock hyraxes trapped by snare traps and the wooden traps was significantly different (χ^2 = 10.93, df=1, $p<0.05$).

Out of the individual rock hyraxes trapped by snare traps, 61.1% were adults, whereas 22.3% were sub-adults and 16.6% were juveniles (χ^2 = 13.64, df=2, $P<0.05$). More adults were trapped by wooden traps, followed by sub-adults and juveniles.

Table 5. Number of rock hyraxes trapped by snare traps and wooden traps during the wet and dry seasons (A= Adult, Sa= Sub-adult, J= Juvenile).

Season	Number of hyraxes trapped using different traps						Total
	Snare trap			Wooden trap			
	A	Sa	J	A	Sa	J	
Wet	1678	613	456	1297	474	352	4870
Dry	2261	825	615	1750	646	465	6562

Some rock hyraxes were found injured and even dead (by snare traps) as they try to escape from the trap in Adelay Ridge and Morebawa sites. Rock hyraxes trapped by snare traps at Web Valley and by wooden traps at Keyrensa are shown in Figure 21.

(a) (b)

Figure 21. Trapped rock hyrax, (a) by snare trap, and (b) by wooden trap (Photo: Gebremeskel Teklehaimanot, January 2012).

Sex-wise comparison of the rock hyraxes trapped both by snare and wooden traps revealed that majority of the trapped rock hyraxes (3704, 64.8%) were females and 2012 (35.2%) were males. The difference in the number of trapped females and males was significant (χ^2 = 162.09, df=1, P<0.05).

During the study period, number of colonies and colony size of rock hyraxes varied with season. There were 38 colonies during the wet season and 46 during the dry season (Table 6). There were significant differences in the number of rock hyrax colonies recorded during wet and dry seasons (t= 3.27, df= 1, P<0.05). The maximum colony size recorded was 86 during the wet season and the minimum was 4 during the dry season. The colony size range was 6–86 individuals during the wet season and 4–77 during the dry season.

Table 6. Colony size of rock hyraxes observed during wet and dry seasons in the study area.

Season	Individuals observed	Number of colonies	Colony size	
			Range	Mean
Wet	1846	38	6–86	49 ± 9.68
Dry	1690	46	4–77	37 ± 6.44
Mean	1768	42	5–81.5	43 ± 8.05

The mean colony size was 49 ± 9.68 and 37 ± 6.44 during wet and dry seasons, respectively, with a significant difference in the mean colony size between the seasons (t= 4.21, df=1, P<0.05). There was significant difference in the range of colony size among the different colonies in the study sites ($t= 58.49$, $df= 42$, $P<0.05$). Rock hyrax colonies consisting of around 46 and 35 were commonly encountered during the wet and dry seasons, respectively. A colony of less than four members was not recorded in the study area.

During the wet season, rock hyraxes congregated in large colony sizes especially in areas where there is enough forage. However, during the dry season, large sized colonies get dissociated into smaller groups. Large rock hyrax colonies were observed in sites with more cover and food supply and also when juveniles were present. In addition to this, large colonies were recorded in areas where they share similar shelter with bush hyraxes.

A given colony consisted of a dominant territorial male, one to several adult females and sub-adults and juveniles of both sexes. One to several adult males were also observed inhabiting the periphery of a colony and in some cases recorded attempting to join one of the colonies around. In most cases, the peripheral males sit alone in the periphery of the colony. But, sometimes male bachelor groups of 2–4 hyraxes were recorded in some of the study sites as in Keyrensa and Garba Guracha.

3.3 Diet composition

During the study period, a total of 1980 feeding observations were recorded in scan sampling conducted to examine the feeding ecology of the rock hyrax. Out of these, 940 ± 43.7 (47.47%) activities were recorded during the wet season and 1040 ± 58.0

(52.53%) recorded during the dry season. The dry season feeding observation was significantly greater than that of the wet season (χ^2 = 17.29, df = 1, P<0.05).

The rock hyrax utilized 41 and 44 plant species as identified by direct observation and rumen content analysis, respectively, during the study period. Based on direct observation, 33 species belonging to 10 families and other three unidentified monocots were utilized by the rock hyrax during the wet season and 36 plant species belonging to 13 families and other five unidentified monocots and dicots were utilized during the dry seasons (Table 7 and 8). More plant species were utilized during the dry season than during the wet season, but the difference was not statistically significant (χ^2 = 0.61, df = 1, P>0.05). *Senecio nanus* and *A. tigreensis* were the plant species utilized only during the wet season, whereas *E. dumalis* (poisonous plant), *A. haumannii*, *L. rhyncho-petalum*, *C. schimperi*, *Helichrysum forsskahlii*, *K. foliosa* and *C. abyssinica* were utilized only during the dry season. There were 12 (71.91%) species of grass, 10 (15.32%) species of herbs, nine (10.67%) species of shrubs, two (1.26%) species of trees and three (0.84%) unidentified monocots during the wet season food and 11 (50.67%) species of grass, eight (16.54%) species of herbs, 15 (29.61%) species of shrubs, two (1.83%) species of trees and five (1.35%) unidentified monocots and dicots during the dry season. There were seasonal differences in the intake of the different growth forms. *Hagenia abyssinica* and *H. revolutum* were the only two tree species utilized by the rock hyrax both during the wet and dry seasons. The most utilized part during the wet season was fresh leaves, but during the dry season, bark of trees and dry and fallen leaves were also consumed. As a generalized herbivore, the rock hyrax was observed grazing and browsing on different plant species during both the seasons.

However, grass species contributed to 71.91% of the diet, while 27.15% was contributed by browse species during the wet season. In the dry season, there was an increase in the intake of browse to 47.98% with 50.67% contributed by grass species. It was recorded that the rock hyrax favoured young plants and fresh leaves when available. They were also observed to eat insects during the wet season. However, intake of fresh leaves by climbing up on the branches, and dry fallen leaves and bark of *H. abyssinica*, and mosses growing on rocky surfaces were common during the dry season.

Table 7. Plant species utilized by rock hyrax (% utilization) in the Web Valley area during the wet season as compared to their mean percentage availability in the field (-- denote absence from the diet, PI= Preference Index, G= grass, H= herb, S= shrub, T= tree).

Plant species	Family	Growth Form	Sighting frequency	Percentage utilization	Percentage availability	PI
Carex simensis Hochst. ex A.Rich	Cyperaceae	H	20	2.13	2.57	0.83
Euphorbia dumalis S. Carter	Euphorbiaceae	S	--	--	1.53	--
Agrostis gracilifolia C.E. Hubb.	Poaceae	G	57	6.06	1.10	5.51
Thymus schimperi Ronniger	Lamiaceae	H	25	2.66	0.51	5.21
Discopodium penninervium Hochst.	Solanaceae	S	9	0.96	0.14	6.86
Carex conferta Hochst. ex A. Rich.	Cyperaceae	H	19	2.02	3.23	0.62
Hypericum revolutum Vahl.	Hypericaceae	T	8	0.85	0.53	1.60
Andropogon pratensis Hochst. ex Hack.	Poaceae	G	41	4.36	3.28	1.33
Helichrysum citrispinum Del.	Asteraceae	S	13	1.39	2.21	0.63
Urtica simensis Steudel	Urticaceae	H	24	2.55	0.80	3.19
Festuca simensis Hochst. ex A. Rich.	Poaceae	G	146	15.53	5.35	2.90
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	T	4	0.43	0.16	2.69
Andropogon amethystinus Steud.	Poaceae	G	68	7.23	2.73	2.65
Helichrysum schimperi (Sch.Bip. ex A. Rich) Moeser.	Asteraceae	H	6	0.64	2.43	0.26
Erica arborea L.	Ericaceae	S	17	1.81	2.23	0.81
Agrostis quinqueseta (Hochst. ex Steud.) Hochst.	Poaceae	G	38	4.04	2.62	1.54
Festuca abyssinica Hochst. ex A. Rich	Poaceae	G	167	17.77	13.04	1.36
Alchemilla haumanii Rothm.	Rosaceae	S	--	--	1.90	--
Conyza nana Sch. Bip. ex Oliv. & Hiern	Asteraceae	S	18	1.91	1.75	1.09
Koeleria capensis (Steud.) Nees	Poaceae	G	43	4.57	2.16	2.11
Artemisia afra Jacq. Ex Willd.	Asteraceae	S	2	0.21	2.19	0.09
Lobelia rhynchopetalum Hemsl.	Campanulaceae	S	--	--	0.19	--
Conyza spinosa Sch. Bip. ex Olivo & Hiern	Asteraceae	S	10	1.06	1.26	0.84

Senecio nanus Sch. Bip. ex A. Rich.	Asteraceae	H	8	0.85	1.18	0.72
Andropogon lima (Hack.) Stapf	Poaceae	G	24	2.55	3.20	0.79
Helichrysum splendidum Lees.	Asteraceae	S	11	1.17	1.94	0.60
Carduus schimperi Sch. Bip. ex A. Rich	Asteraceae	S	--	--	1.12	--
Alchemilla abyssinica Fress.	Rosaceae	H	7	0.75	4.90	0.15
Helichrysum forsskahlii (J.F. Gmel.) Hilliard & Burtt	Asteraceae	S	--	--	1.18	--
Helichrisum gofense Cufod.	Asteraceae	H	16	1.70	3.09	0.55
Valpia bromoides (L.) S.F. Gray	Poaceae	G	22	2.35	1.02	2.29
Kniphofia foliosa Hochst.	Asphodelaceae	H	--	--	0.86	--
Inula confertiflora A.Rich.	Asteraceae	S	4	0.43	0.38	1.13
Colpodium hedbergii (Meld.) Tzvel.	Poaceae	G	20	2.13	2.30	0.93
Rytidosperma subulata (A.Rich.) Cope	Poaceae	G	21	2.23	0.83	2.69
Colutea abyssinica Kunth & Bouche	Fabaceae	S	--	--	0.90	--
Helictotrichon elongatum (Hochst. ex. A. Rich.) C.E. Hubb.	Poaceae	G	19	2.02	1.12	1.80
Trifolium simense Fresen.	Fabaceae	S	17	1.81	3.09	0.58
Senecio ragazzii Chiov.	Asteraceae	H	14	1.49	1.74	0.86
Anthemis tigreensis A. Rich	Asteraceae	H	15	1.60	1.15	1.39
Unidentified			7	0.74		
Total			940	100		

The principal food items of the rock hyrax were *F. abyssinica* (17.77%), followed by *F. simensis* (15.53%) and *A. amethystinus* (7.23%). The least utilized plant was the shrub *Artemisia afra* (0.21%) during the wet season. On the other hand, *F. abyssinica* (14.52%), followed by *F. simensis* (12.79%) and *E. arborea* (4.24%) were the principal food items of the hyrax during the dry season. The herb, *H. schimperi* (0.67%) was the least utilized species during the dry season. Grass formed the largest percentage of the diet of rock hyrax with *F. abyssinica* contributing for the greatest percentage during both the seasons (Fig. 22). Trees contributed a small proportion in the diet of rock hyraxes. There was a significant difference between the number of plant species consumed during wet and dry seasons (P<0.05). Eighteen and 30 plant species were preferred as diet by the rock hyrax (PI >1, Table 7 and 8) during wet and dry seasons, respectively.

Relatively large number of plant species were preferred during the dry season than during the wet season and the difference was statistically significant (χ^2 = 3.12, P<0.05). *Discopodium penninervium* (PI= 6.86) was the most preferred species of diet of the rock hyrax in the study area, followed by *A. gracilifolia* (PI= 5.51) and *T. schimperi* (PI= 5.21) during the wet season. On the other hand, *D. penninervium* (PI= 18.42), *H. abyssinica* (PI= 9.64) and *L. rhynchopetalum* (PI= 8.15) were the most preferred species of diet of them during the dry season. The shrub, *A. afra* (PI= 0.09) and the herb, *A. abyssinica* (PI= 0.19) were the least preferred diet species o f the rock hyraxes during wet and dry seasons, respectively.

Figure 22. An adult rock hyrax grazing in the Web Valley area, Bale Mountains National Park (Photo: Gebremeskle Teklehaimanot, January 2012).

Table 8. Plant species utilized by rock hyrax (% utilization) in the Web Valley area during the dry season as compared to their mean percentage availability in the field (-- denote absence from the diet, PI= Preference Index, G= grass, H= herb, S= shrub, T= tree; * plants, mosses and insects).

Plant species	Family	Growth Form	Sighting frequency	Percentage utilization	Percentage availability	PI
Carex simensis Hochst. ex A.Rich	Cyperaceae	H	30	2.88	2.35	1.22
Euphorbia dumalis S. Carter	Euphorbiaceae	S	19	1.83	1.29	1.42
Agrostis gracilifolia C.E. Hubb.	Poaceae	G	37	3.56	1.00	3.56
Thymus schimperi Ronniger	Lamiaceae	H	22	2.11	0.45	4.69
Discopodium penninervium Hochst.	Solanaceae	S	23	2.21	0.12	18.42
Carex conferta Hochst. ex A. Rich.	Cyperaceae	H	41	3.94	2.71	1.45
Hypericum revolutum Vahl.	Hypericaceae	T	18	1.73	0.39	4.43
Andropogon pratensis Hochst. ex Hack.	Poaceae	G	27	2.60	2.82	0.92
Helichrysum citrispinum Del.	Asteraceae	S	15	1.44	1.29	1.12
Urtica simensis Steudel	Urticaceae	H	30	2.89	0.48	6.02
Festuca simensis Hochst. ex A. Rich.	Poaceae	G	133	12.79	4.27	2.99
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	T	11	1.06	0.11	9.64
Andropogon amethystinus Steud.	Poaceae	G	34	3.28	2.17	1.51
Helichrysum schimperi (Sch.Bip. ex A. Rich) Moeser.	Asteraceae	H	7	0.67	1.61	0.42
Erica arborea L.	Ericaceae	S	44	4.24	1.95	2.17
Agrostis quinqueseta (Hochst. ex Steud.) Hochst.	Poaceae	G	27	2.60	1.78	1.46
Festuca abyssinica Hochst. ex A. Rich	Poaceae	G	151	14.52	10.12	1.43
Alchemilla haumanii Rothm.	Rosaceae	S	18	1.74	1.40	1.23
Conyza nana Sch. Bip. ex Oliv. & Hiern	Asteraceae	S	24	2.32	1.63	1.42
Koeleria capensis (Steud.) Nees	Poaceae	G	39	3.74	1.90	1.97

Artemisia afra Jacq. ex Willd.	Asteraceae	S	15	1.44	1.15	1.25
Lobelia rhynchopetalum Hemsl.	Campanulaceae	S	11	1.06	0.13	8.15
Conyza spinosa Sch. Bip. ex Olivo & Hiern	Asteraceae	S	17	1.63	1.22	1.34
Senecio nanus Sch. Bip. ex A. Rich.	Asteraceae	H	--	--	0.84	--
Andropogon lima (Hack.) Stapf	Poaceae	G	19	1.83	2.32	0.79
Helichrysum splendidum Lees.	Asteraceae	S	32	3.08	1.58	1.95
Carduus schimperi Sch. Bip. ex A. Rich	Asteraceae	S	12	1.17	0.51	2.25
Alchemilla abyssinica Fress.	Rosaceae	H	8	0.73	4.12	0.19
Helichrysum forsskahlii (J.F. Gmel.) Hilliard & Burtt	Asteraceae	S	8	0.73	0.92	0.84
Valpia bromoides (L.) S.F. Gray	Poaceae	G	23	2.21	0.59	3.74
Kniphofia foliosa Hochst.	Asphodelaceae	H	15	1.44	0.22	6.54
Inula confertiflora A.Rich.	Asteraceae	S	23	2.21	0.44	5.02
Rytidosperma subulata (A.Rich.) Cope	Poaceae	G	25	2.41	0.55	4.38
Colutea abyssinica Kunth & Bouche	Fabaceae	S	14	1.35	0.82	1.65
Helictotrichon elongatum (Hochst. ex. A. Rich.) C.E. Hubb.	Poaceae	G	17	1.64	0.98	1.67
Trifolium simense Fresen.	Fabaceae	S	28	2.70	2.33	1.15
Senecio ragazzii Chiov.	Asteraceae	H	9	0.87	1.06	0.82
Anthemis tigreensis A. Rich	Asteraceae	H	--	--	0.25	--
Unidentified*			14	1.35		
Total			1040	100.00		

Data recorded from rumen analysis also confirmed that grass contributed for the major proportion of the diet of rock hyrax. Thirty eight (35 identified and 3 unidentified) and 44 (39 identified and 5 unidentified) plant species were utilized as diet of the rock hyrax during wet and dry seasons, respectively. The number of forage classes identified and their contribution to the rock hyrax diet varied with seasons. Grass (n = 11) contributed for 64.8% ± 6.2, while herbs (n = 10), shrubs (n =12), trees (n = 2) and unidentified plants (n = 3) contributed for 13.3% ± 3.3, 11.1% ± 2.6, 1.5% ± 0.4 and 9.4% ± 2.5, respectively, during the wet season. On the other hand, grass (n= 12), herbs (n = 11), shrubs (n = 14), trees (n = 2) and unidentified plants (n = 5) contributed for 54.0% ± 3.5, 13.8% ± 1.9, 20.4% ± 4.4, 3.0% ± 1.7 and 9.6% ± 3.8 of the diet, respectively, during the dry season (Fig. 23).

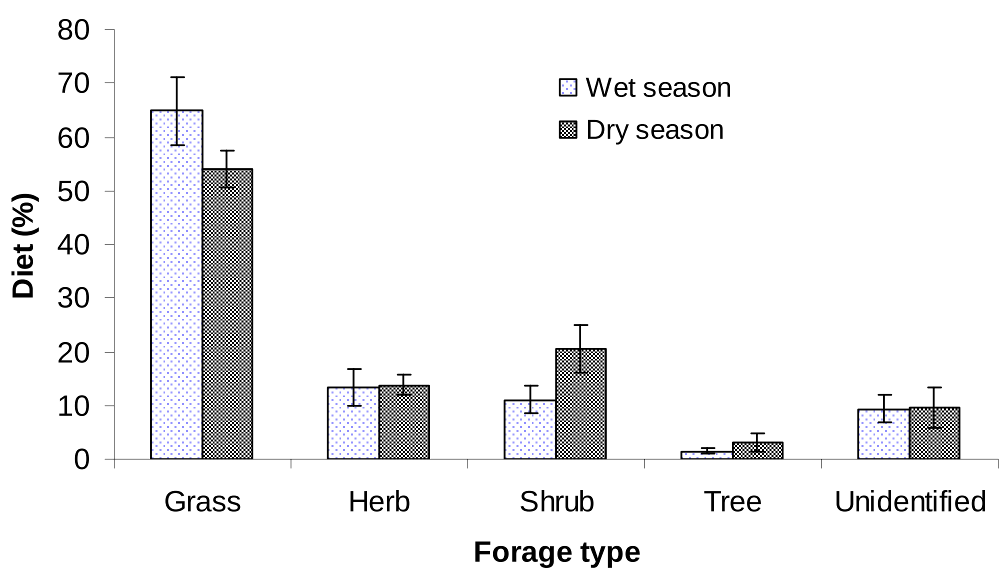


Figure 23. Relative contribution (%) of forage types of rock hyrax during wet and dry seasons in the Web Valley area based on rumen analysis (Mean ± SE).

Rumen analysis revealed that *F. abyssinica* (17.61%), *F. simensis* (14.34%) and *A. gracilifolia* (5.17%) were the principal food items during the wet season, whereas *F. abyssinica* (15.01%), *F. simensis* (11.91%) and *A. amethystinus* (4.60%) were the principal food items during the dry season (Table 9 and 10). The least utilized plant species were *S. ragazzii* (0.11%) and *S. nanus* (0.23%) during the wet and dry seasons, respectively. From rumen contents of the rock hyrax, *L. rhynchopetalum* was also identified as diet of rock hyrax. In addition to the unidentified plant species consumed by the rock hyrax, fragments of wings of insects and shells of eggs were also recorded in the rumen, mainly during the dry season.

Table 9. Plant species identified in rock hyrax rumen (% utilization) collected from theWeb Valley area during the wet season as compared to their percentage availability in the field (-- denote absence from the diet, PI= Preference Index, G= grass, H= herb, S= shrub, T= tree; * plant species and insect wings).

Plant species	Family	Growth Form	Percentage consumed	Percentage availability	PI
Carex simensis Hochst. ex A.Rich	Cyperaceae	H	1.25	2.57	0.49
Euphorbia dumalis S. Carter	Euphorbiaceae	S	0.55	1.53	0.36
Agrostis gracilifolia C.E. Hubb.	Poaceae	G	5.17	1.10	4.70
Thymus schimperi Ronniger	Lamiaceae	H	2.19	0.51	4.29
Discopodium penninervium Hochst.	Solanaceae	S	1.24	0.14	8.86
Carex conferta Hochst. ex A. Rich.	Cyperaceae	H	1.98	3.23	0.61
Hypericum revolutum Vahl.	Hypericaceae	T	0.84	0.53	1.58
Andropogon pratensis Hochst. ex Hack.	Poaceae	G	4.52	3.28	1.38
Helichrysum citrispinum Del.	Asteraceae	S	0.42	2.21	0.19
Urtica simensis Steudel	Urticaceae	H	2.08	0.80	2.60
Festuca simensis Hochst. ex A. Rich.	Poaceae	G	14.34	5.35	2.68
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	T	0.61	0.16	3.81
Andropogon amethystinus Steud.	Poaceae	G	4.14	2.73	1.52
Helichrysum schimperi (Sch.Bip. ex A. Rich) Moeser.	Asteraceae	H	--	2.43	--
Erica arborea L.	Ericaceae	S	1.63	2.23	0.73
Agrostis quinqueseta (Hochst. ex Steud.) Hochst.	Poaceae	G	4.01	2.62	1.53
Festuca abyssinica Hochst. ex A. Rich	Poaceae	G	17.61	13.04	1.35
Alchemilla haumanii Rothm.	Rosaceae	S	--	1.90	--
Conyza nana Sch. Bip. ex Oliv. & Hiern	Asteraceae	S	1.04	1.75	0.59
Koeleria capensis (Steud.) Nees	Poaceae	G	3.39	2.16	1.57
Artemisia afra Jacq. ex Willd.	Asteraceae	S	0.33	2.19	0.15
Lobelia rhynchopetalum Hemsl.	Campanulaceae	S	--	0.19	--

Conyza spinosa Sch. Bip. ex Olivo & Hiern	Asteraceae	S	1.17	1.26	0.93
Senecio nanus Sch. Bip. ex A. Rich.	Asteraceae	H	1.25	1.18	1.06
Andropogon lima (Hack.) Stapf	Poaceae	G	3.14	3.20	0.98
Helichrysum splendidum Lees.	Asteraceae	S	1.35	1.94	0.69
Carduus schimperi Sch. Bip. ex A. Rich	Asteraceae	S	--	1.12	--
Alchemilla abyssinica Fress.	Rosaceae	H	0.64	4.90	0.13
Helichrysum forsskahlii (J.F. Gmel.) Hilliard & Burtt	Asteraceae	S	1.07	1.18	0.91
Helichrysum gofense Cufod.	Asteraceae	H	1.92	3.09	0.62
Valpia bromoides (L.) S.F. Gray	Poaceae	G	2.97	1.02	2.91
Kniphofia foliosa Hochst.	Asphodelaceae	H	1.55	0.86	1.80
Inula confertiflora A.Rich.	Asteraceae	S	0.56	0.38	1.47
Colpodium hedbergii (Meld.) Tzvel.	Poaceae	G	2.97	2.30	1.29
Rytidosperma subulata (A.Rich.) Cope	Poaceae	G	2.50	0.83	3.01
Colutea abyssinica Kunth & Bouche	Fabaceae	S	0.82	0.90	0.91
Helictotrichon elongatum (Hochst. ex. A. Rich.) C.E. Hubb.	Poaceae	G	--	1.12	--
Trifolium simense Fresen.	Fabaceae	S	0.96	3.09	0.31
Senecio ragazzii Chiov.	Asteraceae	H	0.11	1.74	0.06
Anthemis tigreensis A. Rich	Asteraceae	H	0.31	1.15	0.27
Unidentified *			9.37		
Total			100.00		

Table 10. Plant species identified in rock hyrax rumen (% utilization) collected from the Web Valley area during the dry season as compared to their percentage availability in the field (-- denote absence from the diet, PI= Preference Index, G= grass, H= herb, S= shrub, T= tree; * Plant species, insect wings and egg shells).

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Plant species	Family	Growth Form	Percentage utilization	Percentage availability	PI
Carex simensis Hochst. ex A.Rich	Cyperaceae	H	2.09	2.35	0.89
Euphorbia dumalis S. Carter	Euphorbiaceae	S	2.67	1.29	2.07
Agrostis gracilifolia C.E. Hubb.	Poaceae	G	4.06	1.00	4.06
Thymus schimperi Ronniger	Lamiaceae	H	1.30	0.45	2.89
Discopodium penninervium Hochst.	Solanaceae	S	0.91	0.10	9.10
Carex conferta Hochst. ex A. Rich.	Cyperaceae	H	4.01	2.71	1.48
Hypericum revolutum Vahl.	Hypericaceae	T	0.92	0.39	2.36
Andropogon pratensis Hochst. ex Hack.	Poaceae	G	3.52	2.82	1.25
Helichrysum citrispinum Del.	Asteraceae	S	1.93	1.29	1.49
Urtica simensis Steudel	Urticaceae	H	2.04	0.48	4.25
Festuca simensis Hochst. ex A. Rich.	Poaceae	G	11.91	4.27	2.79
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	T	2.10	0.13	16.15
Andropogon amethystinus Steud.	Poaceae	G	4.60	2.17	2.12
Helichrysum schimperi (Sch.Bip. ex A. Rich) Moeser.	Asteraceae	H	0.56	1.61	0.35
Erica arborea L.	Ericaceae	S	1.40	1.95	0.72
Agrostis quinqueseta (Hochst. ex Steud.) Hochst.	Poaceae	G	2.39	1.78	1.34
Festuca abyssinica Hochst. ex A. Rich	Poaceae	G	15.01	10.12	1.48
Alchemilla haumanii Rothm.	Rosaceae	H	0.32	1.40	0.23
Conyza nana Sch. Bip. ex Oliv. & Hiern	Asteraceae	S	1.88	1.63	1.15
Koeleria capensis (Steud.) Nees	Poaceae	G	4.21	1.90	2.21
Artemisia afra Jacq. ex Willd.	Asteraceae	S	1.46	1.15	1.27
Lobelia rhynchopetalum Hemsl.	Campanulaceae	S	0.40	0.11	3.64

Conyza spinosa Sch. Bip. ex Olivo & Hiern	Asteraceae	S	0.76	1.22	0.62
Senecio nanus Sch. Bip. ex A. Rich	Asteraceae	H	0.23	0.84	0.27
Andropogon lima (Hack.) Stapf	Poaceae	G	2.76	2.32	1.19
Helichrysum splendidum Lees.	Asteraceae	S	1.42	1.58	0.89
Carduus schimperi Sch. Bip. ex A. Rich	Asteraceae	S	1.26	0.51	2.47
Alchemilla abyssinica Fress.	Rosaceae	H	1.27	4.12	0.31
Helichrysum forsskahlii (J.F. Gmel.) Hilliard & Burtt	Asteraceae	S	1.77	0.92	1.92
Helichrysum gofense Cuf.	Asteraceae	H	0.49	1.17	0.42
Valpia bromoides (L.) S.F. Gray	Poaceae	G	1.74	0.59	3.00
Kniphofia foliosa Hochst.	Asphodelaceae	H	0.39	0.22	1.77
Inula confertiflora A.Rich.	Asteraceae	S	1.55	0.44	3.52
Colpodium hedbergii (Meld.) Tzvel.	Poaceae	G	1.07	2.18	0.49
Rytidosperma subulata (A.Rich.) Cope	Poaceae	G	1.22	0.55	2.22
Colutea abyssinica Kunth & Bouche	Fabaceae	S	1.73	0.82	2.11
Helictotrichon elongatum (Hochst. ex. A. Rich.) C.E. Hubb.	Poaceae	G	1.51	0.98	1.54
Trifolium simense Fresen.	Fabaceae	S	1.26	2.33	0.54
Senecio ragazzii Chiov.	Asteraceae	H	--	1.06	--
Anthemis tigreensis A. Rich	Asteraceae	H	0.31	0.25	1.24
Unidentified*			9.57		
Total			100.00		

From rumen content analysis, it is revealed that the rock hyrax showed preference for more plant species during the dry season than during the wet season (18 and 27 during the wet and dry seasons respectively) (PI>1, Table 8 and 9 above), but the difference was not statistically significant (P>0.05). Some of the principal food items were also preferred items during both seasons. *Discopodium penninervium* (PI= 8.86) was the primarily preferred shrub, followed by the grass, *A. gracilifolia* (PI= 4.70) and the herb *T. schimperi* (PI= 4.29) during the wet season. On the other hand, the tree, *H. abyssinica* (PI= 16.15), followed by the shrub, *D. penninervium* (PI= 9.10) and the herb, *U. simensis* (PI= 4.25) were the preferred species during the dry season. The least preferred plants were *S. ragazzii* (PI= 0.15) and *A. haumannii* (PI= 0.23) both during wet and dry seasosn. *Discopodium penninervium* and *U. simensis* found in the vicinity of the shelter were highly favoured and utilized by them (Fig. 24).

(a) (b)

Figure 24. Highly clipped (cropped) plant species at the entrance to the rock hyrax den in the Web Valley (a) *Discopodium penninervium,* and (b) *Urtica simensis* (Photo: Gebremeskel Teklehaimanot, February 2012).

Grass and browses were identified in relatively large quantities than herb species in the rock hyrax rumen. Although more grass species were identified in the rumen during both the seasons as compared to the other forage types, relatively more grass species were identified during the wet season (64.8% ± 6.4) than during the dry season (54.0% ± 4.3). There was no significant variation in the contribution of different growth forms between seasons (P>0.05). There was a slight decline of grass intake during the dry season, which was compensated by increased intake of browse. The contribution of browse to the diet of rock hyrax was higher in the dry season (36.4% ± 3.9) compared to the wet season (25.9 ± 2.2) (χ^2 = 7.58, P<0.05) (Fig. 25).

Based on rumen analysis, more (N= 44) plant species were recorded in the diet of rock hyrax than those recorded by direct observation (N= 41) in the Web Valley area during the study period. However, the difference was not statistically significant (P>0.05).

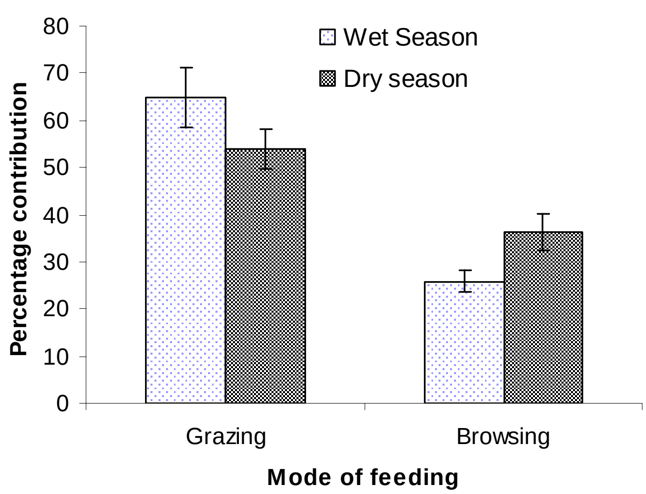


Figure 25. The contribution of grass and browse species in the diet of rock hyrax during the wet and dry seasons based on rumen analysis (Mean ± SE).

3.4 Threats to rock hyrax

3.4.1 Demographic and socio-economic characteristics of the respondents selected from Karari, Gojera and Hora Soba villages

Out of the 235 respondents, 68.5% were males while 31.5% were females. There was significant difference between the male and female respondents ($F_{1\ 196}$ = 98.4, P<0.05). Most respondents (34.5%) were within the age range of 38–47 years, followed by 28–37 years (26.8%), $\geq$ 48 years (23.4%) and 18–27 (15.3%). Summary of the demographic and socio-economic characteristics of the respondents is given in Appendix 4.

3.4.2 Respondents' views on the population trend of rock hyrax

Surveys conducted in the three villages revealed population trends of the rock hyrax in the study area (Table 11). Most respondents (77.9%) reported that rock hyrax populations have declined in number and area of distribution over the last 10 years in their locality. However, 3.8% of the respondents remarked that the rock hyrax populations have increased while 7.2% replied population size of the rock hyrax remained the same. But, 11.1% of the respondents were not sure whether the population of rock hyrax is increasing or decreasing. The difference on the respondents' view on the population trend of rock hyrax was statistically significant ($F_{3\ 226}$ = 120.4, P<0.05).

Field observations during the study period also revealed that the rock hyrax populations have dramatically decreased in number in many areas of its distribution as in Gaysay

Valley and even totally lost from some localities as in one site (a gorge) in Gojera village and one site (a kopje) in Karari, which were in tens in 2003–2004, following expansion of settlements, farmlands and livestock in the rock hyrax natural habitats.

Table 11. Feedback of respondents on the trend of the population of the rock hyrax in their locality in Bale Mountains National Park.

Factor	Population trend in different villages			Frequency	Percent (%)
	Karari	Gojera	Hora Soba		
Increasing	3	2	6	9	3.8
Decreasing	62	46	73	183	77.9
Remained the same	6	4	7	17	7.2
No idea	14	8	4	26	11.1

3.4.3 Threats to the rock hyrax and the Park

Respondents were asked whether rock hyraxes have potential threats or not and 178 (75.7%) replied that they are threatened by various factors. Only 19 (8.1%) replied that there are no potential threat to the species and 38 (16.2 %) had no idea about it. There was significant difference among the views of the respondents ($F_{2\ 78} = 102$, $P<0.05$). Out of the 178 respondents who replied that there are threats to the rock hyrax, 48.3% replied that the major threats to the rock hyrax was habitat loss, followed by depredation and illegal hunting, which accounted for 19.7%, other threats like flood, for those inhabiting valleys and gorges, and human disturbances (17.4%) and wild fire (14.6%) ($P>0.05$)(Fig. 26).

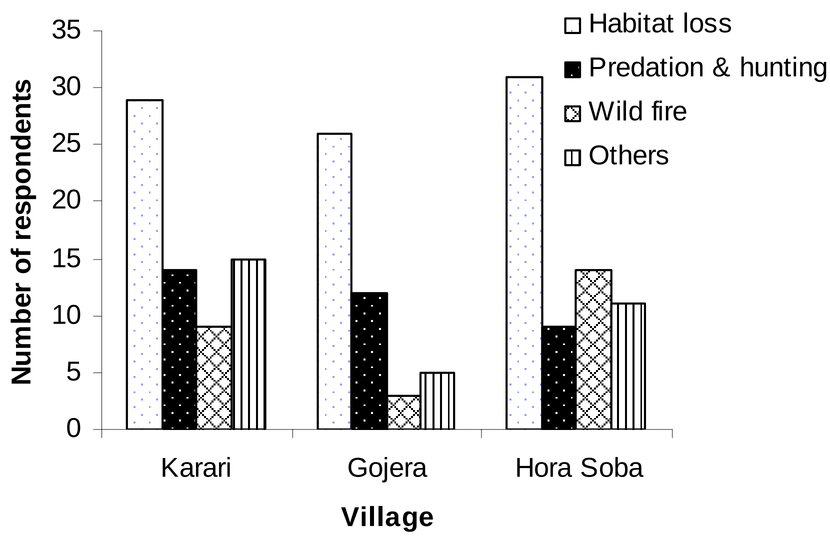


Figure 26. Respondents' view on potential threats to rock hyrax in the study area.

Nine respondents from Karari village and 13 from Hora Soba village reported that wild fire that occurred in the Upper Web Valley towards Meraro in 2008 and around Mt. Darkena in 2010, respectively, burnt Ericaceous vegetation in a wide area and consequently killed and/or displaced rock hyraxes. Furthermore, five respondents from Karari also remarked that they have witnessed 23 dead rock hyraxes in a gorge at Tingo (towards the southern part of the village) due to heavy flood that occurred in August 2012.

To assess additional threats to the rock hyrax, respondents were asked whether they possess domestic dogs or not. Majority of them (97.5%) owned dogs whereas only 6 (2.5%) had no dogs. Out of the respondents who own dogs, most 88.6% do not keep their dogs at home, and either given food at home or forage by themselves in the surrounding areas. They were asked whether domestic dogs prey on rock hyraxes, and most respondents (75.7%) replied that they have observed at different times and places while dogs roaming around rock hyrax habitats and attempting to prey on rock hyraxes. Three respondents from Karari and five respondents from Hora Soba reported that they have witnessed dogs successfully hunting rock hyraxes at different times in their locality. However, 14.1% of the respondents reported that dogs do not prey on rock hyraxes, while 10.2% reported that they have no information on this issue ($F_{2\ 97}$ = 113.8, P<0.05).

The respondents also reported trapping of rock hyraxes by the local people as another potential threat to the species. Out of the 235 respondents, majority (47.6%) reported that local people trap rock hyraxes for different purposes, 22.6% replied that local people do not trap rock hyrax, and 29.8% had no information about it (P<0.05) (Table 12).

Additionally, 112 of the respondents explained that local people trap rock hyraxes for different purposes. Majority of them (56.2%) reported that local people trap rock hyraxes for medicinal purposes, followed by both for medicinal purposes and for food (31.3%). Only 7.1% replied that people trap rock hyraxes for other purposes including fattening their oxen and as food for their dogs, while 5.4% replied that people trap for food. There was significant difference among the respondents in their views on the reasons for trapping rock hyraxes ($F_{3\ 67}$ = 93.2, P<0.05). Respondents reported that the local community trap rock hyraxes by traditional means like locally made wooden trap and string snare traps.

Table 12. Respondents views on trapping rock hyraxes by the local people.

Factor	Response	No. of respondents in different villages			Total frequency	Percent (%)
		Karari	Gojera	Hora Soba		
Do local people trap rock hyraxes?	Yes	39	28	45	112	47.6
	No	18	13	22	53	22.6
	No info.	28	19	23	70	29.8
Reason (s) for trapping rock hyraxes	Medicine	21	16	26	63	56.2
	Food	3	1	2	6	5.4
	Food & medicine	13	8	14	35	31.3
	Others	2	3	3	8	7.1

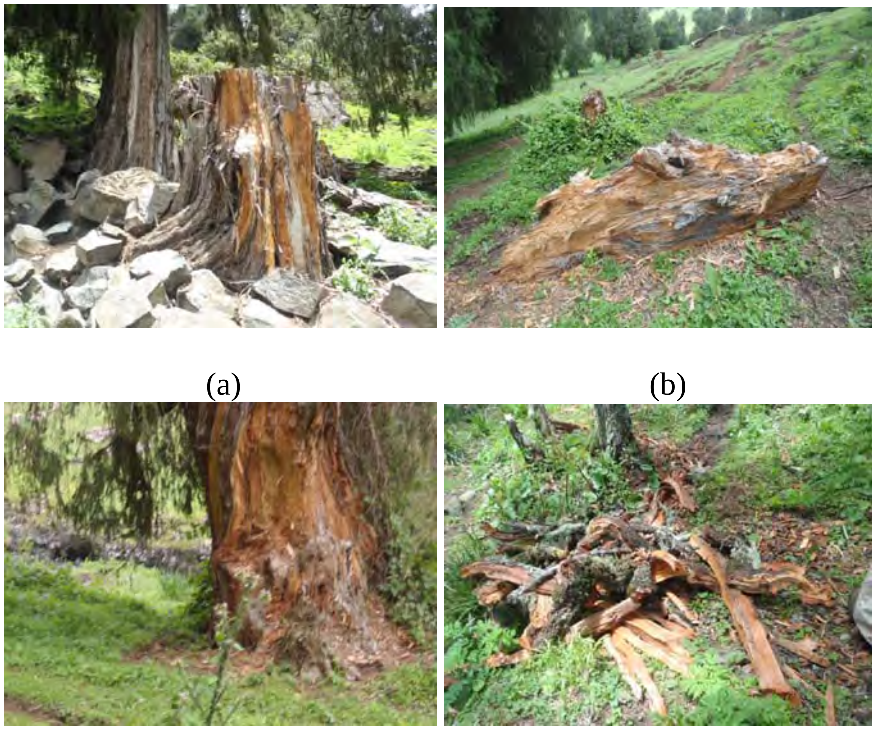
The respondents also mentioned that natural predators of the rock hyrax like Ethiopian wolf (*C. simensis*) (17.4%, n = 31 respondents), Black-backed jackal (*C. meso-melas*) (10.7%, n = 19) and birds of prey including Black eagle (*A. verreauxii*) (26.4%, n = 47), Lammergyer (*G. barbatus*) (30.3%, n = 54) and Golden eagle (*A. chrysaetos*) (15.2%, n = 27) are other potential threats to the rock hyrax populations in the BMNP. Predation of the rock hyrax by Lammergyer, Ethiopian wolf and black eagle was also confirmed by field observation during the study period in Web Valley and Sanetti Plateau.

Field observations during the study period also revealed fencing around the rock hyrax shelter (Fig. 27), settlements (Fig. 28), cutting trees for fire wood and construction (Fig.

29) and various other forms of human disturbances in rock hyrax habitats like shouting, throwing stones and even killing by herders (Fig. 30) as potential threats to rock hyrax.

Figure 27. Fencing around rock hyrax shelter in Gaysay Valley (Photo: Gebremeskel Teklehaimanot, February 2013).

Figure 28. Human settlement around rock hyrax shelter in Meraro (arrow indicates heap of livestock dung piled for years) (Photo: Gebremeskel Teklehaimanot, February 2012).



(a) (b)

(c) (d)

Figure 29. The impact of local people on trees in Adelay area towards Gojera village (a & b) and Hora Soba village (c & d) (Photo: Gebremeskel Teklehaimanot, October 2012; January 2013).

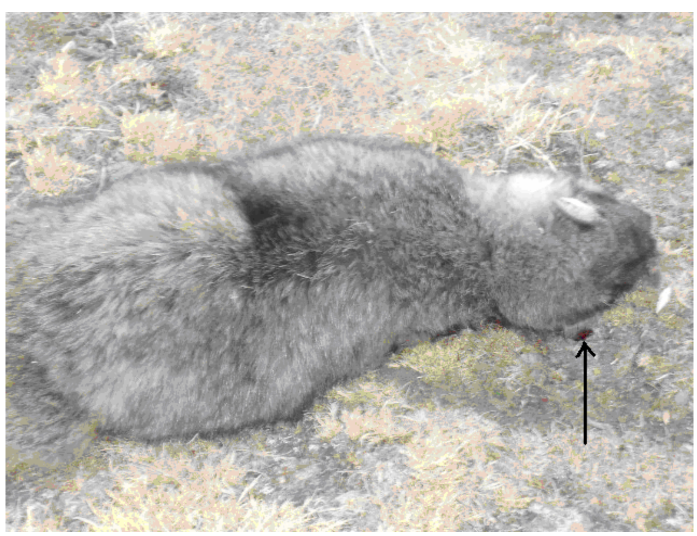


Figure 30. A sub-adult female rock hyrax killed by herders in the Web Valley (arrow indicates blood flown from injured ear) (Photo: Gebremeskel Teklehaimanot, February 2013).

Domestic dogs frequently accompany their masters when they take livestock for grazing and/or for mineral water in and around the Park area. Domestic dogs were also observed regularly roaming around rock hyrax shelters in the Web Valley (Fig. 31), Garba Guracha and Sanetti Plateau and recorded hunting rock hyraxes in the Web Valley and in Sanetti Plateau.

Figure 31. A domestic dog roaming in the rock hyrax habitat in the Web Valley (Photo: Gebremeskel Teklehaimanot, October 2012).

In addition, domestic dog scats collected and analyzed during the study period also confirmed that their diet contained remains of rock hyraxes (2.9%), roasted barley (locally known as '*kollo*') (15.1%), barley husks (53.1%), rodents (2.8%), bone/teeth/skin (12.6%), grass (3.7%), potato peels (5.1%) and unidentified items (4.7%) (Table 13).

Table 13. Frequency of occurrence of food items of 116 scats of domestic dogs collected during the wet and dry seasons.

Food items	Frequency of occurrence of food items				Mean (%)
	Wet season		Dry season		
	Frequency	%	Frequency	%	
Rock hyrax	2.5	1.6	5.75	4.3	2.9
Roasted barley	24.5	16.3	18.75	13.9	15.1
Barley husks	71.25	47.3	79.5	59.0	53.1
Rodents	2.25	1.5	5.5	4.1	2.8
Bone/teeth/skin	21.5	14.3	14.75	10.9	12.6
Grass	8.5	5.6	2.25	1.7	3.7
Potato peel	13.25	8.8	1.75	1.3	5.1
Unidentified	7.0	4.6	6.5	4.8	4.7
Total	150.75	100.0	134.75	100.0	100.0

Signs that indicate trapping of rock hyraxes by the local people were also recorded in different areas of the Park. Two string snare traps and *Gemo* were found set in Adelay and Web Valley areas, respectively, at the enrance to the rock hyrax shelter. Two rock hyraxes escaped from the trap with ropes on their neck and legs were also seen in Gaysay Valley. Moreover, a plastic sack locally used for temporarily wrapping trapped rock hyrax was seen in Gaysay Valley left at the entrance of a rock hyrax den (Fig. 32).

Figure 32. A plastic sack (usually used for wrapping a trapped rock hyrax by the local people) left around rock hyrax shelter in the Gaysay Valley (Photo: Gebremeskel Teklehaimanot, January 2012).

Respondents were asked whether they have seen wild fire within the Park area or not over the past 10 years, and majority (77.5%) stated that they have observed fire in different areas of the Park at various times, 14.9% replied that they have not seen fire in the Park, and 7.6% of the respondents had no idea on this question (Table 14). There was significant difference among the views of the respondents on this ($F_{2\ 38}$= 67.3, $P<0.05$).

Most respondents who have observed fire (84.1%) remarked that the cause of the fire incidents was man-made, while 15.9% stated that fire incidents that occurred in the Park were unknown and the difference in the respondents was significant ($P<0.05$). Out of the respondents who have observed fire in the Park, majority (N=146, 80.2%) reported that fire incidences were mostly observed in the Ericaceous vegetation of the Park, while 19.8% observed fire burning in *Hagenia*/*Juniperus* vegetation. The number of respondents who observed burning fire in Ericaceous vegetation was significantly more than those who observed fire in the *Hagenia/Juniperus* vegetation ($F_{1\ 67}$ = 99.5, P<0.05).

Regarding reasons for putting fire, most respondents (48.4%) replied that local people put fire for promoting fresh grass growth for their livestock, while 32% reported as to clear land for crop cultivation. But, 13.7% and 5.9% of the respondents replied for deterring wild predators and insects and for other reasons such as fire accidentally spread from the fire left after the traditional honey collection, respectively ($F_{3\ 21}$= 32.8, P<0.05).

Table 14. Respondents' views on incidence and reason for putting fire in and around the Park.

		Number of respondents of different villages				
Factor	Response	Karari	Gojera	Hora Soba	Frequency	Percent (%)
Have you ever observed wild fire in the Park area?	Yes	69	36	77	182	77.5
	No	11	15	9	35	14.9
	No response	5	9	4	18	7.6
Cause of the fire?	Man made	61	27	65	153	84.1
	Unknown	8	9	12	29	15.9
Reason for putting fire?	New grass growth	31	11	32	74	48.4
	Clear land for crop cultivation	19	10	20	49	32.0
	Deterring wild animals	8	4	9	21	13.7
	Others	3	2	4	9	5.9

Wild fires were witnessed in different areas of the Park during the study period such as in Darkena area in December 2011 and in the Upper Web Vally in January 2012. Signs that indicate incidence of wild fire such as burnt and sprouted *Erica* shrubs at the base were also recorded in Meraro and around Togoda Valley in October 2011.

3.4.4 Responses about awareness of the local people on the Park, conservation and status and threats to the rock hyrax

Out of the total interviewees (N= 26), majority (80.8%) replied that the local community lacks awareness and knowledge about the Park and the role of conservation, whereas only 19.2% reported that they have some understanding about the Park and the role of conservation ($F_{1\ 58}$= 77.4, P < 0.05). Majority of the interviwees (73.1%) replied that the relationship between the Park administration and the local community is not strong and hence awareness raising programmes about the role of conservation are not held regularily.

Regarding the use of natural resources from the Park, most interviewees (92.3%) replied that local communities use different resources from the Park, while only 7.7%% replied that the local community do not use resources from the Park ($F_{1\ 86}$ = 93.2, P < 0.05). They further responded that the local people perform illegal activities like grazing their livestock, drinking their livestock with mineral water, collection of fuelwood, construction materials and honey in the Park. The local people also put fire in wildlife habitats intentionally or unintentionally.

Majority of the interviewees (96.2%) responded that wild animals found in the Park affect the socio-economic activities of the local people. Only 3.8% had no information about the impact of wild animals in the Park. Animals such as common warthog, mountain nyala and porcupine cause crop damage. Furthermore, spotted hyaena, olive baboon and common jackal prey on livestock. All the interviewees also reported that no compensation was given for crop and livestock losses. Most interviewees' (61.5%) view that the local community has negative attitude on the Park and wildlife due to crop damage and livestock depredation by wild animals, and due to restriction in the use of natural resources in the Park. But, the rest (38.5%) replied that due to some benefits obtained from the Park such as employment opportunity, horse renting, guiding tourists and serving as labourer, the local people have positive attitude towards the Park and wildlife ($P<0.05$).

Regarding threats to the rock hyrax, majority (92.3%) of the interviewees replied that the major threats to the rock hyrax were habitat loss and fragmentation, predation and illegal hunting and natural factors like flood. Only two (7.7%) mentioned that they have no information on the threats to the rock hyrax and their response was significantly different from those who listed the threats to the hyrax ($F_{1\ 97} = 112.4$, $P < 0.05$). Among interviewees, 19 (73.1%) replied that the rock hyrax is decreasing in its range and number as compared to the past. Only five (19.2%) mentioned that the number of the rock hyrax remained constant in the last 10 years, and two (7.7%) had no information about the status of rock hyrax ($P< 0.05$).

3.4.5 Suggestions given by the respondents to ensure sustainability of wildlife and the Park

Respondents (N= 235) were asked about the measures that should be taken by the Park and other authoroties so that the local community develop positive attitude on the Park and wildlife and ensure the sustainability of the resources. Giving compensation to losses by wild animals, allowing controlled utilization of resources from the Park and creating more employment opportunities for the local people were among the suggestions given by the respondents (Table 15).

Table 15. Respondents' suggestions to ensure sustainability of the Park and wildlife (most respondents forwarded more than one suggestion).

Suggestion	No. of respondents from different villages			Frequency	Percent (%)
	Karari	Gojera	Hora Soba		
Give compensation to losses by wild animals to the local people	24	29	31	84	35.7
Allow utilization of resources in a controlled way from the Park	20	23	26	69	29.4
Create more employment opportunities for the local people	31	12	24	67	28.5
Share income generated from the Park to the local community	15	13	11	39	16.6
Participate the local community in conservation activities of the Park	11	9	10	30	12.8
Enhance education and awareness programmes to the local people	8	7	11	26	11.1
Strengthen park-community relationships	6	4	7	17	7.2

4. DISCUSSION

4.1 Distribution

Rock hyrax is widely distributed over different parts of BMNP ranging from Gaysay Valley to the Afroalpine habitats including Web Valley and Sanetti Plateau and extends to the Harenna forest area. The present study revealed that the presence of rock hyraxes in the Park is mainly associated with the presence of mountain cliffs, rocky outcrops and rock boulders having crevices and holes in which they can inhabit. They are seen in various habitat types ranging from valleys with water supply around, through open grassland with rock piles to dry cliffs and kopjes. Similarly, Yound and Evans (1993) documented that the distribution of rock hyrax is delineated by the presence of appropriate shelter. On the other hand Haltenorth and Diller (1988) recorded that the species is found at elevations as high as 5500 m in Mt. Kenya and occupy a wide range of habitats from arid deserts to rainforest, and are typically associated with rocky outcrops, cliffs or boulders. The low water requirements of the hyrax, its effective adaptive mechanisms in reducing water loss and the ability to feed on a wide variety of plant species are major factors contributing to the wide distribution of the hyrax (Fourie, 1983). This species was not recorded in kopjes or rocky areas in the dense Harenna forest, but few in the cliffs at Adelay Ridge. Estes (1991) also noted that rock hyraxes prefer to live in kopjes found in savanna zones, semi-desert vegetation and mountains while avoiding kopjes in forested areas. Furthermore, Olds and Shoshani (1982) documented absence of the species in the dense jungle of the Congo basin and Madagascar. This shows that rock hyraxes do not prefer of dense forest localities. They prefer open rocky areas or other similar sites where protection is ensured by way of good visibility of the surroundings in addition to shelter sites where they can easily escape from predators. As the hyraxes are slow moving animals, visibility in open areas and escape from predators where they forage, resting and sleeping sites where predators can not enter are important for their survival.

Distribution of the species is limited by the presence of rocky terrain, cliffs, gorges and/or some vegetation cover like *Erica* shrubs. Studies carried out else where noted that mammalian distribution and their habitat associations are mostly correlated mainly with better availability of water, foraging opportunities and protection (Reed, 1998). The distribution of the rock hyrax is limited by the presence of rocky terrain and steep mountains (Rifai *et al.*, 2000). In the present study, it was noted that rock hyrax distribution was not continuous rather patchy and clumped, interrupted by open areas devoid of rock piles that serve as shelter to the species and human disturbances. Clumped distribution pattern is generally exhibited by biological populations in natural habitat (Odum, 1996). Absence of the species or diminished numbers around human settlements and farmlands might be attributed to hunting and killing of the species by the local people and domestic dogs. The patchy distribution of vegetation on the kopje resulted in patchy distribution of hyraxes (Fanson, *et al*., 2011). Hanse (1962) documented that a hyrax could survive without drinking water for 134 days. This was supported by Meltzer (1973) stating that due to an exteremely low water demand, hyraxes can live without drinking even during the drier months of the year. This ability of rock hyrax surviving without drinking water for longer times could also be the reason for inhabiting in dry, rocky areas and cliffs.

4.2 Population status

In the present study, a population size of 30,003 rock hyraxes was estimated in the nine sample counting sites. There was significant difference in the population size of the species recorded in each of these sites. The variation could be due to the differences in the availability of suitable cover and/or forage in the different sites, and also due to human impacts on the rock hyrax populations and their natural habitat. The highest population size recorded was in Keyrensa, where there were rocky outcrops, cliffs, and grasses and shrubs in abundance in the vicinity of their shelter to serve as food. Moreover, anthropogenic impact was relatively low in this area. The distribution of food and predators play important roles in the spatial behaviour and population dynamics of animals in natural habitats (Stephens and Krebs, 1986). The lowest population count recorded was in Gaysay Valley. Availability of less cover in this area and increased human activities such as grazing, hunting, construction and disturbances both by herders and domestic dogs make this a less suitable habitat and therefore the low population.

Population density of the rock hyrax showed significant statistical differences ($P<0.05$) between the different sites. The highest population density recorded was in Garba Guracha and the lowest was in Gaysay Valley. The highest density in Garaba Guracha was mainly due to the availability of rocky areas having numerous holes in which the hyraxes shelter over a wide area, and grasses around; relatively low levels of predators and limited settlements and disturbance. On the other hand, the lowest density in Gaysay Valley was mainly due to anthropogenic impacts on the species and its habitat. Severe alterations in the habitat due to various human activities in the natural habitat influence its ecology, population dynamics and physiology (Geist and Lambin, 2002). Hoeck (1982) found a significant correlation between rocky outcrop size and hyrax numbers in Tanzania. Relative to refuges, food resources are believed to represent an additional limiting factor for the hyrax population in Mountain Zebra National Park, South Africa (Fourie, 1983). Rock hyrax populations have been increasing in northern Israel over recent decades due to increased availability of nearby residential gardens with high quality forage (Kershenbaum *et al*., 2011). Population densities of a number of herbivore species depend upon the biomass of plants in the habitat that satisfy the minimum characteristics sought by the animal (Belovsky, 1986). Rock hyrax population density studies elsewhere have revealed a density of 20 to 100 individuals/ km^2 in Mount Kenya (Young and Evans, 1993), 500 to 4000 individuals/ km^2 in the Serengeti National Park, Tanzania (Hoeck, 1982; Hoeck *et al.,*. 1982), 73 and 94 individuals/ km^2 in the Matobo National Park, Zimbabwe (Barry and Mundy, 1998) and from 2000 to 5300 individuals/ km^2 in the case of the bush hyrax (*H. brucei)* in the Serengeti (Hoeck, 1982; Hoeck *et al.,*. 1982). Hence, the observed densities in the present findings are higher than that recorded in Mount Kenya and Matobo National Park but within the density range documented in the Serengeti National Park.

During the present study, more rock hyraxes were recorded during the wet season than during the dry season all over the sample study sites. This was probably due to the birth of pups during the wet season and availability of fresh grass that can satisfy their nutritional demands during this season. As Marcello *et al*. (2008) stated, wet season is full of more nutritious food items, which could promote breeding of animals and birth of new ones. Rock hyraxes show seasonality in breeding activities and peak birth coincides with the rainy season (Hoeck, 1977; Macdonald, 1985). A number of studies have demonstrated a correlation between the size of birth pulse and rainfall patterns. Large birth pulses are associated with seasons of high rainfall (Fourie, 1983; Davies, 1994). On the other hand, low population during the dry season could also be attributed to juvenile mortality owing to physiological stress, predation and scarcity of nutritious grass during the dry season. During the study period, it was recorded that rock hyraxes move relatively farther away from their shelter in search of food during the dry season as compared to the wet season as food was scarce around their shelter during the dry season. Consequently, they were susceptible to predation. Studies elsewhere show that during dry periods, hyraxes expose themselves to greater predation risk as they seek food farther from cover and refuges (Hoeck, 1989; Davies, 1997; Druce *et al*., 2006). Hyrax populations fluctuate mainly due to predation, droughts and infectious disease (Druce *et al*., 2006; Parsons *et al*., 2008). The small body size and the slow movement of rock hyrax makes them extremely vulnerable to aerial predators when they are exposed at large distances away from the shelter of their crevices (Brown *et al.*, 1993). Emigration of rock hyraxes to nearby kopjes in search of forage might also affect rock hyrax population size during the dry season.

Despite the availability of potential rock hyrax habitats over a vast area in the Park, due to the increasing human activities almost all over the Park, population size of the rock hyraxes recorded was relatively small. Secondly, as most rock hyraxes reside in mountain cliffs and kopjes and graze around their shelter among rocks, some rock hyraxes are expected to be invisible and so not counted. Hence, the number of rock hyraxes in such areas might be underestimated during the population counts of rock hyraxes.

Information on the age and sex distribution of animals is important in wildlife management practices. As Wilson *et al*. (1996) stated, knowledge of age distribution and sex ratio of mammalian species is crucial for the evaluation of the viability of the species, because these variables reflect the structure and dynamics of the population. The age and sex of a species gives an understanding about the reproductive potential, growth and status of the population. It gives us an idea about the life span, age at puberty and age-specific reproductive potential of the species concerned (Steyn and Hanks, 1983). As Woolf and Harder (1979) explained, sex and age structure of a population at any given time is an indication of the status of the population.

The rock hyrax population in the present study showed significant differences among the different age classes. There were more adults, followed by juveniles and sub-adults. This might be mainly due to the vulnerability of juveniles and sub-adults to predators than to the adults due to their small size. The relatively large number of juveniles in the rock hyrax population and the decline in number of sub-adults is attributed to the birth of more individuals at first and mortality of juveniles by predation and food shortage stress during the dry season as juvenile rock hyraxes have a higher surface area to volume ratio and are more vulnerable to low ambient conditions than adults (Brown and Downs, 2005). There is a general tendency of declining the small mammal population during the dry season (Delany and Happold, 1979). As described by Happold and Happold (1991), dry season is the time of high temperature, minimal resources and cover, unlike the wet season, making small mammals to experience considerable seasonal variation in number. Juveniles and sub-adults are also susceptible to avian and mammalian predators. Barry and Mundy (2002) stated that in natural populations, juveniles are highly susceptible to predation. Juvenile rock hyraxes are susceptible to predation and mortality due to desiccation and drought (Boshoff *et al.*, 1991; Barry and Barry, 1996). In a study conducted in Matobo National Park, Barry and Mundy (1998) estimated mortality of 59.6 – 75.6% juvenile rock hyraxes. High level of mortality among the newborn and young individuals is recorded in ungulates as well (Mysterud *et al.*, 2002). Thus, infant mortality might be one of the possible reasons for low numbers of sub-adults and juveniles compared to adults in the population of rock hyraxes. The sex of adult rock hyraxes could be determined easily than that of the sub-adults and juveniles in the field. This was mainly due to some morphological and behavioural features of adults. Moreover, the sex of more adult rock hyraxes was determined by observations during the wet than during the dry season. During the wet season, females were recorded while lactating, and being continuously followed by juveniles than during the dry season.

The male to female ratio (1:1.4) in the population of the rock hyrax in BMNP was female biased. Sex ratio in animals signifies the proportion of each sex that is involved in the breeding process (Robinson and Bolen, 1989). High population of females and fairly high proportion of young indicate a healthy, increasing rock hyrax population in the study area. In polygynous animals such as the rock hyrax, adult females can be mated by one or few males and have offspring. The presence of relatively more adult females in a given population is important for the sustainability of the population (Fourie and Perrin, 1987b).

The disparity in sex ratio of the rock hyraxes was highest in adults, followed by sub-adults and juveniles. The relatively lower number of males among adults and sub-adults might be due to the higher rates of predation of males of these age groups. Territorial males have to stay out of their shelter to watch and defend their respective territories. Young males are also prone to mortality while being dispersed from their natal kopje to peripheral areas of the colony. Peripheral males also have to stay out in order to strictly follow the hierarchial position of the colony during which they will be exposed to predators. Moreover, peripheral males have their own hierarchy and agonistic behaviour displays throughout the entire year (Hoeck *et al*., 1982), which may account for their elevated mortality rate (Fourie, 1983). In contrast to peripheral males, territorial males have seasonality in agonistic behaviour (Hoeck *et al*., 1982). Through the intraspecific agonistic behaviour of the territorial male, non-territorial adult males are excluded from the breeding unit. During such occasions, they may fight and sustain serious wounds, or even die as witnessed in some study sites during the present study period. The wounds themselves may lead to increased levels of infestation of ticks as ticks prefer these wounds as attachment sites, or they may become secondarily infected with bacteria.

Mendelssohn (1965) also reported that adult male hyraxes also sometimes kill newborn pups. Mortality is probably higher for dispersing males than for females (Gerlach and Hoeck, 2001). The territorial male limits and so regulates the numbers of males contributing to male mortality. Krüger (2005) also stated that environmental conditions that affect nutritional stress in mothers can also have profound influence on offspring sex ratios. Primary sex ratio in the rock hyrax is 1:1, but the secondary sex ratio was skewed in favour of females, with males suffering from higher rate of mortality (Hoeck, 1982). This might be due to the fact that young males would disperse from the parent colony (Hoeck, 1982; Barry and Mundy, 1998), while female juveniles remain within the colony, maintaining the family bond (Fourie and Perrin, 1987a; Estes, 1991). The explanation for male mortality is that peripheral males are distributed often in less favourable habitats as the central core area is occupied by territorial males (Wronski, 2005). In most cases, adult males are solitary and are exposed to dangers (Smithers, 1983). Even though an equal sex ratio of animals at birth is assumed, there is an increased mortality in young male ungulates (Ndhlovu and Balakrishnan, 1991). Female biased population was also reported in the tree hyrax (*D. arboreus*) by Milner and Harris (1999). Unbalanced sex ratios and sexual dimorphism are often associated with polygamy (Anderson, 1994).

During this study period, relatively more rock hyraxes were trapped by snare traps than by woody traps. This was probably because the string snare set around the rock hyrax shelter was not easily noticed by the rock hyraxes as compared to the wooden trap and hence the hyraxes enter the snare trap unknowingly and get trapped. Comparatively, more rock hyraxes were trapped during the dry season than during wet season. This might be due to the fact that as food is scarce during the dry season, rock hyraxes wander more around or farther away in search of food during which they enter the traps. Wimberger *et al*. (2009) also trapped more rock hyraxes during the dry season (in winter), when there was scarcity of food. Age and sex-wise comparison of the trapped rock hyraxes also revealed that adults constituted the largest number, followed by sub-adults and juveniles. Moreover, among the trapped rock hyraxes, females comprised 64.8%, whereas males only 35.2%. This is probably attributed to the increased mobility of female rock hyraxes around their shelter where the traps were set, especially in the presence of juveniles. However, most of the time male rock hyraxes position themselves on top of rocks watching for predators and other intruders, especially in the case of the territorial rock hyraxes. In a study conducted in the Serengeti National Park, Gerlach and Hoeck (2001) documented that out of the total trapped rock hyraxes (124), 63.7% were females and 36.3% were males, which also shows similar levels of trapping of males and females.

Rock hyraxes are social animals living in colony of various size. During the study period, the colony size of 4–86 individuals was recorded. Such variation in the size of the colony was mainly attributed to availability of resources, mainly cover and food. According to Skinner and Chimimba (2005), rock hyraxes are gregarious, living in colonies that vary in size according to the size of the rocky habitat and the amount of food available. As Fourie (1983) stated, group size is discussed in terms of available refuges, and lack of sufficient refuges can be the primary factor limiting the colony size. Hence, large colonies having up to 86 individuals as recorded in Web Valley, Keyrensa and Garba Guracha can be attributed to the availability of abundant rocky outcrops and mountain cliffs in these areas. Barocas *et al*. (2011) recorded colonies comprising 3–4 individual rock hyraxes at the Ein Gedi Nature Reserve, Israel. On the other hand, Hoeck *et al.* (1982) and Fourie and Perrin (1989) documented that rock hyraxes live in colonies of up to 56 individuals in the Serengeti and Matobo National Park, respectively, depending on the size of the rocky outcrops. Kingdon (1971) and Walker (1975) also estimated 5 to 60 members in a rock hyrax colony. Furthermore, Olds and Shoshani (1982) stated that rock hyraxes are gregarious and live in colonies up to 80 individuals.

The presence of a large number of rock hyraxes in a colony has benefit for the survival of the colony. As recorded during the study period, the colony members, mainly adults, serve as sentinel when other individuals in the colony bask or forage. According to Alexander (1974), group living is thought to offer protection against predators and to increase foraging efficiency, two major factors, which may have favoured the evolutionary transition from solitary to group living. Barry (1994) and Barry and Mundy (2002) also stated that the effectiveness of vigilance in hyraxes increase with group size because large groups provide more eyes for detecting predators, which is one of the major advantages of group living animals. They can co-operate in defending themselves from relatively small sized predators by attacking in group and detecting its presence in advance. Isvaran (2007) also discussed that predator avoidance may increase with group size. Living in groups is generally associated with benefits such as protection from predators, increased foraging efficiency and communal defense of resources (Krause and Ruxton, 2002). As Wilson *et al.* (2003) stated, animals living in groups can save more energy and time. Larger groups offer better protection against infanticide (Packer *et al.*, 1990). Moreover, Hodge (2005) stated that group size has been shown to correlate with reproductive success in a number of plural breeders.

Colony size and range also varied with season. They were relatively lower during the dry season than during wet season when food availability around the shelter was scarce during the dry season. According to Leuthold and Leuthold (1975), grouping patterns of herbivores may be indicative of the effects of a changing environment. The size of the herd of animals is a compromise between various advantages and disadvantages. In the present study, colony size was significantly larger during the wet season, as could be expected when food is plentiful and small colonies merge into larger ones, apparently as protection against predation and other disturbances and colony size would increase with forage abundance and distribution. However, during the dry season, as food becomes scarcer due to effect of grazing by livestock and also due to lack of rain and green herbs, colonies tend to break up to forage in wider areas in smaller family units.

During the present study, size of a colony increased when there were juveniles and when rock hyraxes were in association with bush hyraxes as in Web Valley and Garba Guracha. As Barry and Mundy (2002) documented, heterospecific association increased when offspring were present, and heterospecific groups were larger than homospecific ones. As Bicca-marques and Garber (2003) explained, the primary benefits of forming a mixed species group may include enhanced vigilance against predators, as well as increased ability to defend productive feeding sites. Isvaran (2007) also discussed that grouping within and/or association with other animal groups may reduce predation risk through earlier detection of predators, dilution and confusion effects, and/or cooperative defense.

Although peripheral male rock hyraxes do not form groups in most cases, some male bachelor groups of 2–4 were recorded in some sites. This observation contradicts with earlier reports by Fourie and Perrin (1987a) and Hoeck *et al.* (1982) that peripheral males of hyraxes do not form groups and always sit alone at the periphery of the colony. However, Koren *et al.* (2006) in Ein Gedi Nature Reserve documented that they have observed male bachelor groups among the peripheral males for several years.

4.3 Diet composition

Knowledge of a species' diet is essential to understand its position in an ecosystem and to organize effective management plans for its conservation (Chetri, 2006; Bradley *et al.*, 2007). Thus, a reliable method for measuring the species composition and proportion of food items in the diet of herbivores is required (Fitzgerald and Waddington, 1979).

In the present study, direct observation and rumen content analysis of the rock hyrax during the study period revealed that they utilized 41 to 44 different plant species, respectively, comprising grasses, and parts of herbs, shrubs and trees. Rock hyraxes are mainly grazers depending on grasses regardless of the seasons. A similar study by Fourie and Perrin (1989) on the feeding ecology of rock hyraxes in Mountain Zebra National Park, South Africa identified 44 plant species constituting diet by field observation and

35 additional plant species from 107 rock hyrax stomach contents. Feeding observations of the rock hyrax revealed that the species spent more time on grazing and less time on browsing during the wet season. But, during the dry season, when the availability and nutritional quality of grasses declined, rock hyraxes decreased grazing while browsing increased. During the wet season, grazing contributed 71.9% to the diet of the rock hyrax, while 27.33% was contributed by browse species. On the otherhand, during the dry season grasses comprised 51.18% and browse 47.18% of the diet of rock hyraxes. In both seasons, grass was the major food item for the species. Similarly, a study carried on the feeding ecology of the rock hyrax (*P. johnstoni)* in the Serengeti, grazing constituted 78% during the wet season and only 43% in the dry season due to the decrease in the nutritional quality of grasses (Hoeck, 1975).

The most utilized grass species during the wet season were *F. abyssinica*, *F. simensis, A. amethystinus* and *A. gracilifolia* contributing, 46.59% of the overall diet of the rock hyrax. On the otherhand, the principal food items of the rock hyrax during the dry season were *F. abyssinica*, *F. simensis*, *E. arborea* and *C. conferta* comprising 35.49% of the diet. *Festuca* species contributed the largest proportion of the diet of the rock hyrax in both seasons. This is probably due to the availability of abundant fresh *Festuca* species present around the rock hyrax shelter and its palatibility. Fourie and Perrin (1989), Hoeck *et al*. (1982) and Olds and Shoshani (1982) have reported grass as the main component of the rock hyrax diet as grass is fairly abundant close to its shelter throughout the year. Moreover, Kingdon (1997) documented that rock hyraxes forage on grasses such as *Festuca* species, which is more abundant along rock crevices and on cliff slopes. *Festuca* species are the most available soft grass species (Owen-Smith, 1994). However, certain plant species such as *Solanum benderianum* were avoided by rock hyraxes although relatively abundant in the field and around their shelter. The present findings are consistent with the observations made by Olds and Shoshani (1982) that explains *P. capensis* is a non-descriminating grazer, although some species are avoided, and may change from one plant species to another during feeding.

Relatively, rock hyraxes devoted less time for feeding and utilized less plant species during the wet season than during the dry season. The increase in feeding time and number of plant species eaten during dry seasons may be explained by the decline in the availability of high quality grasses during the dry season and to increase their niche breadth. According to Owen-Smith (1982), an increase in feeding time with decreasing food availability in the dry season is common for several African grazers. The increase of browse intake and number of plant species eaten by rock hyrax during the dry season are similar with other herbivores reported earlier including the common warthog (Treydte *et al*., 2006) and eland (Buys,1990).

During the dry season, both the quality and quantity of food are low, and animals must eat more to meet their essential energy requirements (Neuhaus, 2000). In response to low ambient temperatures, many mammals increase food intake to match energetic demands during the dry season (Haim *et al*., 1990). Similarly, earlier studies in other parts of Africa (Sinclair, 1975; Armstrong *et al*., 1997) also revealed that the availability of grass declines both in quantity and in quality during the dry season and during the drought period than during the wet season. The optimal foraging theory predicts that the initial less favoured food types will be incorporated in the diet to widen the diet breadths when food items become scarce (Owen-Smith and Novellie, 1982; Stephens and Krebs, 1986). During the wet season, rock hyraxes depend mainly on fresh leaves. Young plants and leaves are good sources of protein and minerals and have low fibre, tannin and toxin levels (Altmann, 1998). Similar observations made by Sale (1965b) and Epelu-Opio (1974) documented that rock hyraxes have more preference for succulent leaves and shoots of young plants. Such a diet has probably led to the various reports that the hyrax does not need to drink or atleast can stay for extended period without drinking. But, due to the decline in the availability of nutritious food items during the dry season, the hyraxes in the present study area consumed young leaves of shrubs and trees such as *H. revolutum* and *H. abyssinica* found in the vicinity of their shelter. They also supplemented their diet with barks of trees, fallen dry leaves of *H. abyssinica*, insects and eggs during this season. Sale (1966a) also reported that rock hyraxes may also eat coarse materials such as bark, lichens and liverworts during the dry and drought periods. Moreover, utilization of swampy plant species and those that grow under shades of *Erica* shrubs such as *C. conferta* and *C. simensis* increased during the dry season. This agrees well with the observation of Olds and Shoshani (1982) that documented utilization of swampy vegetation by rock hyraxes on the west slope of Mt. Kenya when the rock hyraxes were found close to a valley bottom.

Generally, rock hyraxes were recorded as opportunistic feeders and heavily consume almost any vegetation found around their shelter (see Fig. 24). Rock hyraxes have been observed feeding on a wide range of plants within the Augrabies Falls National Park, Northern Cape, South Africa (Druce, 2005). Supporting evidences for the marked diversity in the diet of the rock hyrax were also provided by Turner and Watson (1965) and Hoeck (1975). A similar study carried out in Jordan also confirmed that the rock hyrax (*P. c. syriaca*) is a generalist herbivore and feeds on a wide variety of plants, leaves, stems, fruits and buds (Rifai *et al*., 2000).

During the dry season, rock hyraxes were also recorded feeding on plant species such as *E. dumalis,* which are poisonous to other animal species. Young (1985) also reported that rock hyraxes occasionally feed on the toxic Lobelia (*Lobelia teleki*) and Giant Senecio (*Scenecio keniodendron*) especially during dry periods. Moreover, Sale (1965c) documented that rock hyraxes are opportunistic feeders and utilized the poisonous plant, *P. dodecandra,* without any ill effects in Kenya. Mendelssohn (1965) also noted the consumption of poisonous plants by rock hyraxes in Israel. Hyraxes have a tolerance for eating poisonous plants (Sale, 1965c; Fourie, 1983) and they have mechanisms to tolerate the effects of poisonous plants. The insusceptibility of hyrax to poisonous plants most probably is due to the caecal microbial detoxification and hydroxilase enzymes of the liver (Sale, 1965a). From the rumen content analysis, it was also revealed that rock hyrax utilized some insect species and eggs especially during the dry season. Diet analysis conducted by Sale (1965b) also revealed the presence of insects in the diet of the rock hyrax, *P. mackinderi johnstoni* (Thomas) as its diet, in addition to vegetation.

Rock hyraxes showed preferences for more plant species (18 during the wet season and 30 during the dry season) by direct observation and 18 and 27, respectively, during the wet and dry seasons by rumen analysis. The preference of such large number of plant species in the diet of hyraxes might be attributed to the small extent movement area of rock hyraxes as they do not move farther away from their shelter in search of food owing to predation risk and hence they have to eat whatever is available in the immediate surroundings. However, Hoeck (1975) and Lensing (1983) stated that rock hyrax tended to be opportunistic, feeding in proportion to availability. From direct observation, *D. peninnervium*, *A. gracilifolia* and *T. schimperi* were the most preferred plant species of hyraxes during the wet season and *D. peninnervium*, *H. abyssinica* and *L. rhynchopetalum* during the dry season. Rumen content analysis also revealed preference of *U. simensis* during the dry season in addition to the above preferred plant species. Similarly, Milner and Harris (1999) noted that the tree hyrax (*D. arboreus*) in the Parc National des Volcans, Rwanda, primarily feed on mature leaves of *H. abyssinica* and *H. revolutum*. In the BMNP, *H. abyssinica*, *T. schimperi* and *H. revolutum* are foraged by mountain nyala (Evangelista *et al*., 2007). Furthermore, Alphonse *et al.* (2010) reported that *D. penninervium* is eaten by mountain gorillas around Volcanoes National Park, Rwanda. Preference of *D. peninnervium* and *T. schimperi* from the other relatively abundant plants in the study sites by the rock hyrax might probably be due to the medicinal role of the plant species to the rock hyrax. According to Tigist Wondimu *et al*. (2007) and Biruktayet Assefa *et al*. (2010), *H. abyssinica* is used as a veterinary medicine against many livestock ailments and as an anthelmintic in ruminants. Moreover, *D. penninervium* is used as a medicinal plant to treat liver disease by Maale and Ari ethnic communities in southern Ethiopia (Berhane Kidane *et al*., 2014). Kesatebrhan Haile (2013) also documented that *T. schimperi* possess antibacterial activities and they can be used to control variety of pathogens that cause diseases in plants and humans. Preference of *U. simensis* during the dry season by the rock hyrax might be due to the availability of the plant with deep green foliage year round, which grows mostly under shaded shrubs, rock boulders and crevices. Young green leaves are good sources of protein and minerals and have low fibre, tannin and toxin levels (Altmann, 1998). According to Sinclair (1975), ungulates require an average of 4–5% crude protein to maintain their body weight, but due to decline in the quantity and quality of food during dry periods, animals could achieve this only by actively selecting small quantities of green food items. As reported by Bozinovic (1997), mammalian herbivores select plants rich in nutritional components and poor in fiber and secondary metabolites. Sauer *et al.* (1982) also documented seasonal changes in food preferences during the dry season by giraffe and this could be attributed to both changes in the availability of important food items and due to the difference in the presence of chemical compounds in the leaves.

4.4 Threats to rock hyrax

To address conservation issues of a given protected area and wildlife found in it, understanding the socio-economic aspects and attitude of the local community towards the protected area and the wildlife is imperative. Sustainable management of protected areas and understanding community attitude towards protected areas are key factors in developing successful management plans to conserve important natural areas over the long-term (Allendorf, 2007; Shrestha and Alavalapati, 2006). The questionnaire survey during the present study revealed that the local people residing in and around BMNP are mostly farmers and semi-nomadic pastoralists. Out of the respondents, about 92% are engaged either in crop farming or livestock rearing. Rural population like that in the Bale region depends on farming and livestock rearing as their main activities (Miehe and Miehe, 1994).

Therefore, in order to set conservation priorities and ensure peaceful co-existence of local people with the wildlife around including the rock hyrax and the Park, it is imperative to assess the awareness and understanding of the local community about the Park, wildlife in BMNP and the importance of conservation. An assessment of local people's knowledge and perceptions can reveal useful information that could be incorporated into the decision-making process, protected area management planning and to improve park–community relationships (Allendorf *et al.*, 2012). The present study has revealed that only 35.7% of the respondents had good knowledge about the Park, wildlife and the importance of conservation. On the other hand, 64.5% of the respondents have no or had poor knowledge, most of whom are illiterate, female, old age groups and relatively far from the Park area and the town. This is probably due to their limited ability to read written documents and less exposure to awareness programmes on wildlife and conservation issues. Local people's knowledge about conservation of natural resources are influenced by education and awareness programmes, services and benefits local people receive from conservation related projects (Jalilova and Vacik, 2012). Traditionally, rural females are engaged in firewood collection and other household activities, and have less access to education, reading and discussions. Similarly, it is unlikely that elder individuals have attended school and also participated in meetings and discussions related to wildlife and protected areas. Therefore, it is not surprising for women and elderly people to have poor understanding about the Park and wildlife. More respondents from Gojera (50%) had good knowledge and understanding about the Park and wildlife and the role of conservation than those from Karari (37.6%) and Hora Soba (27.8%). More respondents from Gojera having good knowledge and understanding about conservation is probably due to the close location of this village in BMNP and Dinsho town. Gojera is situated inside the Park and at the periphery of Dinsho Headquarters and Dinsho town. Thus, the people in this village have increased exposure to the officials of the Park and wildlife, and also access to education and awareness raising programmes. Zelealem Tefera (2001) also reported similar results stating that distance of village from Guassa area, central highlands of Ethiopia, is an important factor in developing knowledge and conservation awareness of the local people about wildlife.

Due to increasing human population, encroachment into the wildlife area increases and more lands adjacent to the wildlife area is used for farming, which creates pressure on wildlife populations. With the increasing human population in the area and their socio-economic activities, it is apparent that the local communities create pressure on the Park and wildlife population. As explained by Robinson and Bennett (2004) and Singh and Sharma (2009), humans are commonly physically inseparable from natural systems due to the heavy dependence of local people on natural ecosystems for their subsistence living in most of the tropical developing countries. Livestock grazing in the BMNP area is a common practice and especially during the wet season (months of cultivation), the livestock are moved in to open areas in the Park, where they graze until the end of harvest (Stephens *et al*., 2001). According to Newmark *et al*. (1994), the major problem facing protected areas in Africa today is the increase of human settlements in adjacent lands and the unauthorized harvesting of resources from protected areas. As Sebsbe Demissew (1996) stated, increases in human population have significantly disrupted and eliminated Ethiopia's highland habitats due to expansion of high-altitude agriculture, shifting cultivation, heather fires and overgrazing by livestock. Due to human settlements and encroachment into natural habitats, severe competition for natural resources between wild animals and the local communities occur (Yalden and Largen, 1992). Studies carried out in other areas have shown the adverse effects of human settlement and livestock and pack animal encroachments on the abundance and distribution of wild mammals (Stephens *et al*., 2001; Gundogdu, 2011). Even though most respondents (71.5%) denied the use of natural resources from the Park, the reality is different. It is common that the local people graze their livestock, collect firewood, construction materials, thatching grass, honey and medicinal plants for themselves and their livestock from the Park area illegally. Majority of the respondents (85.5%) use firewood for household activities collected from their surroundings including the Park. Most probably, the source of the purchased firewood used by the respondents (6.4%) is also the Park and surrounding areas. The most commonly collected firewood from the Park was *E. arboria*, *J. procera*, *H. abyssinica* and *H. revolutem*, which are big trees that can play major role in sheltering wild animals and regulating climate of the area. Besides, E. *arborea* is used as forage for livestock and fencing, in addition to its medicinal use by the local people. Bussmann *et al*. (2011) also noted that *E. arborea* is used by the local community for fire wood, forage and honey production in Odo-Bulu and Demaro Area of the Bale region. It is a well known fact that most landscapes in the Ethiopian highlands have been influenced by farming, grazing, firewood collection and grass cutting over the past several centuries (Zelalem Tefera *et al*., 2012).

The local people also take their livestock into the Park for mineral water and even stay longer in the Park for grazing. Moreover, expansion of settlements and farm lands around the rock hyrax habitat were common and certainly such human activities have been detrimental to the survival of the hyrax colonies inhabiting close to settlements, farmlands and grazing lands. With the increased human and livestock populations, the extent of agricultural areas and settlements have been on the increase at the expense of the natural wildlife habitats including the rock hyrax. The increase in human population and expansion of human settlements within and around the BMNP since early 1990s has intensified the competition among the wildlife, livestock and people (Ermias Derbie *et al*., 2008). According to EBI (2014), unsustainable utilization of biological resources is one of the major threats to biodiversity and ecosystems in Ethiopia. Habitat loss, fragmentation and degradation pose direct threats to wildlife species worldwide. Driven by human population growth, unsustainable consumption of natural resources and policies that do not fully value biodiversity, habitat destruction is widely accepted as the leading cause of wildlife extinction in the recent decades (Krauss *et al*., 2010). Habitat loss and fragmentation affect the survival of wildlife species in various ways including influencing bahavioural stress (Nour *et al*., 1997), reducing of the total amount of usable habitats, degrading habitat quality and creating edge effects (Evangelista *et al*., 2007; Anagaw Atickem *et al*., 2011).

Out of the respondents, around 90% have no enough land for grazing their livestock, and hence they use the Park area for grazing. Local community in particular those in Gojera village, residing within the Park have serious shortage of grazing land, and hence dependence of the local community on the Park is high. Such activities resulted in habitat loss and fragmentation, disturbances and competition on foraging with the rock hyraxes in the area and consequently led to decline in the number and distribution of the species, and have disappeared in some isolated localities such as in Gojera village and another site in Karari village. The impact of habitat loss and fragmentation, especially for wild animals such as the rock hyrax that have only patchy distribution, and cannot easily move to other safe areas is very severe. Such land-use changes have negative impacts on natural habitats of the rock hyrax. Data collected by questionnaire surveys and interviews also showed that the rock hyrax habitat is diminishing from time to time due to encroachment of the local people into the rock hyrax natural habitat. Consequently, the range and population size of the species has dwindled over the past. This observation is also supported by Ndibalema (2010) in Serengeti Ecosystem. As stated by Galanti *et al.* (2006) and Kideghesho *et al*. (2006), loss of habitats for wildlife can have ecological impacts including local extinctions of wildlife species. Shemweta and Kideghesho (2000) reported that some of the wildlife species in the Tarangire-Manyara Ecosystem, Tanzania, are locally extinct due to habitat destruction and overexploitation indicating high pressure of human impacts on wildlife. In wild habitats, animals might adapt to avoid localities where human interactions are frequent (Ndhlovu and Balakrishnan, 1991; Balakrishnan and Ndhlovu, 1992) and local extinction of small isolated populations may not be a rare event among hyraxes (Hoeck, 1982) or other wildlife species (Berger, 1990). Habitat loss and fragmentation caused by human impacts is by far the largest threat to the vast majority of Ethiopia's wildlife species (Hillman, 1993; Evangelista *et al*., 2008). Isolation and diminishing size of the remaining habitats increase the probability of extinction through demographic, environmental or genetic stochasticity (Noss and Cooperrider, 1994). Habitat loss and fragmentation due to human encroachment are probably the most common cause for the extinction of species (Mace and Balmford, 2000). Presently, extinction of species as a result of human activities is more than 100 times faster than the natural rate of extinction and far more rapidly than new species can evolve (Primack, 2002). Naturally, small populations become increasingly vulnerable to extinction as human disturbances increase (Pullin, 2002; Primack, 2002). Supporting this view, Befekadu Refera and Afework Bekele (2004) and Evangelista *et al.* (2007) documented that the northern edge of BMNP is heavily impacted by human and livestock encroachments such as deforestation, agricultural land expansion, illegal hunting, illegal settlements and free-ranging livestock grazing. Associated with these human impacts on the rock hyrax natural habitat disturbances and even killing of rock hyraxes by herders were evident during the study period in different sites in the Park such as Gaysay Valley, Adelay Ridge, Web Valley and Garba Guracha. Besides, the local people move in to the Park with their domestic dogs as guards for protecting their livestock from predators such as spotted hyaena and jackal. Many of the dogs are free-ranging and are direct threats to the rock hyrax as recorded while chasing and hunting the species during the present study period. Gottelli and Sillero-Zubiri (1992) documented that domestic dogs are present throughout BMNP, but only few of them are fed or looked after, rather they are feral. Anagaw Atickem *et al*. (2009) recorded domestic dogs while hunting rock hyraxes in BMNP. Besides, Stephens *et al*. (2001) documented that domestic dogs move into the Park area with the local people and kill nyala calves and juveniles each year and also observed chasing adult nyala in the same study area. Incidents of predation or killing of mountain nyala calves by domestic dogs have also been reported by Woldegebriel Gebrekidan (1996) in BMNP. As reported by Sillero-Zubiri and Macdonald (1997) and Stephens *et al*. (2001), the ever-increasing human population in BMNP has caused habitat fragmentation that has resulted in increasing contact of wildlife with human and domestic animals. This resulted in increased contact of dogs with wildlife resulting in hunting of wildlife. Hillman (1986) also documented that about 20% of wildlife mortalities recorded in BMNP was due to predation in which many were by feral or domestic dogs. Teklay Girmay *et al*. (2015) also reported that domestic dogs prey on rock hyrax. Similarly, Gingold *et al*. (2009) documented that guard dogs were observed several times chasing and eating gazelles in cattle and sheep enclosures in the Golan Heights, Israel. During the study period, it was noticed that the sentinel alarms the colony members about the approach of people to the colony site. But, the call was louder and more repetitive when people with dogs approach the colony site than without dogs, which might indicate that the hyraxes have previous experience of being harassed and threatened by domestic dogs. These findings are consistent with the observation in the behavioral response of mule deer to dogs. Miller *et al.* (2001) observed that mule deer were more sensitive and flushed at greater distances from pedestrians when they were accompanied by a dog, and that the behavioral response of deer was greatest when pedestrians with dogs are passing around than those without dogs.

Data collected through the questionnaire survey, interviews and field observations showed that wild fire was the other potential threat to the rock hyrax in the study area. The local people deliberately set fire at the end of the dry season so as to get fresh offshoots for their livestock that may grow in the beginning of the rainy season. Secondly, they do so for the security of their livestock from thieves and predators like jackal and hyaena. At the time, left over *Erica*, which is dry will serve for the purpose of firewood consumption. Wild fires that occur in the ericaceous zone, which is the ideal habitat for rock hyrax both for cover and forage, is a threat for the species as loss of vegetation cover can increase exposure of small mammals to predators and result in increased predation rates (Kotler, 1984). As Stephens *et al*. (2001) and Bonninston *et al*. (2007) stated, habitat degradation by deforestation, fire, livestock grazing and illegal hunting result in poor cover and foraging opportunities and hence limit breeding success of wild animals. A study conducted by Anteneh Belayneh and Temesgen Yohannes (2008) reported that the primary reason for burning *Erica* in BMNP in 2008 was for the purpose of facilitating grazing. About 84% of the recent fires occurred in BMNP burnt 60% of the “Ericaceous belt”, which is the major water catchments area of Bale Mountains massif (Anteneh Belayneh *et al*., 2013). Results showed that forest fire in Bale Mountains is likely a common phenomenon during the last few decades, but with increasing severity in recent years. According to the last 30 years data, the extent of fires increased from 210 ha to 12,825 ha (Anteneh Belayneh *et al*., 2013). Gutema Jira *et al*. (2013) and Yoseph Assefa *et al*. (2011) also stated that there area human settlements in BMNP area, and most of the settlers are pastoralists and they burn *Erica* during the dry season and the Ericaceous belt is seriously affected by human impacts, including fire and grazing.

Data collected from the questionnaire survey and interview revealed that the source of most fire incidents in the Park is human induced. But, lightening towards the late dry period and ignitions would be expected when the humus is dry (Latham and Williams, 2001). In the middle and low elevation areas of BMNP, re-current fires are responsible for the present appearance of Afro-alpine vegetation (Miehe and Miehe, 1994). Wesche *et al*. (2000) elaborated that such fire in East African countries are mainly human induced due to the existence of similar human activities in this region.

The other likely threat to the rock hyrax is hunting of the species by the local people for meat and for medicinal purposes. During the study period, signs indicating trapping of hyraxes using snare traps and locally made wooden trap were observed set by the local people in different areas of the Park. Data collected from the respondents, and interviews have revealed that rock hyrax meat is an important therapy for treating asmathic patients and for fattening thinner/skinny cattle and also humans. Moreover, rock hyrax hair is believed to be useful in the treatment of fire burn skin. Olds and Shoshani (1982) have stated that rock hyraxes are eaten by humans in Africa. Furthermore, rock hyrax meat is considered a delicacy, and the local people hunt hyraxes in Jordan (Rifai *et al.,* 2000).

Barry *et al*. (2008) also stated that the rock hyrax is snared for skin and meat. The proximity of hyrax colonies to villages is also of concern because rock hyraxes serve as reservoirs of cutaneous leshmaniasis (Jacobson *et al*., 2003).

Certainly, all these factors affect forage availability, habitat use, behaviour and status of the rock hyrax negatively. Rifai *et al.* (2000) stated that with the accelerating rate of habitat degradation in Jordan, through intensive farming, road construction and urban expansion, the rock hyrax remains highly threatened. Similarly, Caro *et al*. (2009) stated that the extinction of nine large mammals in Kwakuchinja, northern Tanzania, was mainly due to over-exploitation of wildlife resources through legal and illegal hunting, loss of wildlife habitat to cropland expansion and human settlements. The present study area is exposed to severe human-induced threats from expanding settlements, agriculture and livestock grazing (Miehe and Miehe, 1994; Stephens *et al*., 2001; Williams *et al*., 2004).

Addressing the relationships among the local people, wildlife and the Park, around and the livelihood of the people and their attitude towards the Park and wildlife are crucial for proper mitigation of the problems associated with conservation issues. Out of the respondents, 95% believe that the wildlife and Park directly or indirectly affect their livelihood negatively. Crop damage and livestock depredation were the mostly cited impacts of wild animals to the local community in the study area. Conflict arises in the study area from economic losses as subsistence agriculture is the major livelihood activity in the area. Supporting this finding, Newmark *et al*. (1994) reported that over

70% of the local people living adjacent to protected area in Tanzania had conflict with wildlife. Obviously, the conflict between the local people and wildlife is mainly due to loss of wild natural habitats by the local community for different land-uses. As the habitats get lost and fragmented, the wild animals get compressed in narrow refuges. This leads to greater contact and conflict with humans as wild animals seek to fulfill their nutritional and ecological needs from the surrounding areas including farmland and villages (Sukumar, 1990). Recent increases in human population and changes in land-use patterns are jeopardizing the co-existence of wildlife and livestock around the globe (Wilson, 1989).

Although respondents from the three villages had complaints on crop damage by wild animals, the problem was severe in Gojera than the other two villages. This is probably due to the regular contact of wild animals with farmlands as the village is situated inside the Park. Secondly, Gojera is an important corridor for movement of wild animals such as mountain nyala, common warthog and Bohor reedbuck from and to Gaysay-Adelay and Dinsho Headquarters areas, relatively well protected from human activities hence with good pasture. Thus, wild animals damage crops on their tracks. A study conducted in BMNP also documented that the local community in and around the Park was mainly concerned about their crop damage by wild animals and those living closer to the Park was found to be more adversely affected than those far from the Park (Demeke Asmamaw and Verma, 2013). As Emerton and Mfunda (1999) and Kidegesho (2010) reported, farms that are close to the boundaries of protected areas are more vulnerable to the attack of wild animals. This is due to the edge effects as those living more closely to the boundary of the national park have more contact with wild animals (Woodroffe and Ginsberg, 1998). Studies elsewhere have shown that where farms are adjacent to protected areas, frontline farmers suffer more elephant crop raiding than those further away from the protected area boundary (Sukumar, 1990; Naughton-Treves, 1997). In addition to the above listed crop raiding wild animals, data collected during the study period also indicated that olive baboons, porcupine and rock hyraxes are also responsible for loss of crops including vegetables. Baboons consume and damage ripened barley, whereas porcupines damage potatoes. Besides, baboons are hated for preying lambs of sheep and goat. When rock hyraxes inhabit rock boulders or cliffs near farmlands or grazing lands as in Hora Soba, they heavily utilize barley seedlings and grass. Similar studies in different parts of Africa also revealed that wild animals posed major threats on crops and livestock (Kagoro-Rugunda, 2004). Baboons in particular are important crop raiders across much of their ranges in Africa and Arabia. In Tanzania, they are the most troublesome crop raiders (Sillero-Zubiri and Switzer, 2001). Teklay Girmay *et al*. (2015) also documented that rock hyraxes inhabiting close to farmlands damage crops. Moran (2003) also reported that rock hyraxes are considered as pests in residential gardens in northern Israel. Moreover, Mendelssogn and Yom-Tov (1999) documented that in Israel, where the rock hyrax is protected by law and has few natural enemies, their numbers have grown in cultivated areas resulting in damage to crops and necessitated implementation of effective control measures. As Olds and Shoshani (1982) stated, if rock hyraxes occur in areas of human settlement, they may become pests, living in road culverts and holes in stone walls.

The other source of complaints by the local community was livestock depredation by different predators including spotted hyaena, common jackal, mangoose and olive baboon. Although the problem was raised by respondents from Gojera, Karari and Hora Soba villages, it was severe in Hora Soba as compared to the other two villages. It was recorded during the study period that two horses in Hora Soba and one horse in Gaysay Valley were predated by spotted hyaena during different times of the study period. This is probably due to the fact that Hora Soba is bordering the Park over wide area and there are many spotted hyaena dens within the Park towards the village, and also within the village (personal observation). Supporting this finding, Woodroffe and Ginsberg (1998) and Woodroffe (2000) stated that in settlements close to a Park, the probability of predators coming in contact with livestock while searching for prey outside the Park is high. Human-wildlife conflict occurs when wildlife requirements overlap with those of humans, creating costs both to people and wild animals (Kissui, 2008). As stated by Newmark *et al*. (1994), in many parts of Africa, the conflict between local people and wildlife is a serious problem in areas adjacent to nature reserves. The conflict usually starts when wild animals consume resources intended for human consumption; i.e crops by herbivores and livestock by carnivores. The loss of livestock in Hora Soba led the local people to develop negative attitude on spotted hyaena and plug their dens and killing by poisoning (personal communication). Oli *et al*. (1994) disclosed that carnivores commonly generate negative attitude among the rural residents in many regions of the world as they prey upon domestic animals, and this leads to retaliatory killing of carnivores by livestock owners (Holmern *et al.,* 2007; Røskaft *et al.*, 2007).

In addition to crop damage and livestock depredation by wild animals, local community in the study area had complaints on restriction of free access to livestock grazing, farmlands and use of other natural resources from the Park. More respondents (30%) from Gojera, followed by Hora Soba (28%) and Karari (20%) reported socio-economic impacts of the Park due to such restrictions. Relatively large number of complaints by respondents from Gojera as compared to that of Hora Soba and Karari is probably due to the increased dependence of the local people on different resources of the Park in Gojera than the other two villages. This agrees well with observation of Zelealem Tefera (2001) that documented peasant association closer to the Guassa area used firewood from the community conservation area more frequently than those living farther away.

Sustainable management of protected areas and understanding people's beliefs and attitudes toward protected areas is a key factor in developing successful management plans to conserve those areas over the long-term (Allendorf, 2007). As local communities are now the focal point of conservation thinking (Nishizaki, 2005), assessing local people's attitudes, taking into account their needs and respecting their opinions should become a management priority (Macura *et al.*, 2011). Despite the use of various resources from the Park by the local community, the current study indicated that 70% of the respondents had the opinion that the Park is harmful to their livelihood and hence developed negative attitude on the Park. More respondents from Gojera (75%) had negative attitude on the Park and wildlife, followed by Hora Soba (70%) and Karari (67%). Restriction to free access of various resources from the Park and impact of wildlife (crop damage and livestock depredation) on their socio-economic activities were the reasons for developing negative attitude due to the fact that subsistence agriculture is the major livelihood activities of the respondents, and wildlife does not provide incentives directly to the local people. Studies have shown that conservation attitudes of local people living adjacent to wildlife habitats are strongly influenced by problems associated with wildlife (Newmark *et al.,* 1993). Therefore they have not realized the importance of wildlife, rather their attitude towards wildlife was negative (Ogutu *et al*., 2012). Moreover, it was revealed during the questionnaire survey and informal discussions that the local community, especially those residing in Gojera, had the suspicion that the Park management could displace them from their residence and farmland and resettle them somewhere else. Owing to this, some respondents were not happy in the presence of the researcher and data collection and were not willing to provide the required information. They were suspicious that the researcher may be connected to the Park, and possibly be paving the ground for their displacement from their home land. Thus, the local community developed negative attitude on the Park and wildlife. Fear of resettlement and lack of employment opportunities contribute the local community to develop negative attitude on protected areas (Allendorf, 2007). Majority of the local communities viewed no benefits from the Park, yet incurs costs from the damage of crops by wild animals and restrictions on the use of natural resources. Tewodros Kumsa and Afework Bekele (2014) stated that respondents living in the inner zone of Abijata-Shala Lakes National Park, Ethiopia, were almost entirely dependent on using resources from the Park and had strong negative attitude towards conservation efforts. Shrestha and Alavalapati (2006) also reported that households living closer to Koshi Tappu Wildlife Reserve, Nepal, were more likely to reveal negative attitude towards conservation. Similarly, in a study about Nanda Devi Biosphere Reserve (India), 75% of respondents inhabiting around expressed negative attitude towards the reserve (Maikhuri *et al.*, 2001). Conservation attitude of communities living adjacent to protected areas is highly influenced by the problems associated with wildlife (Balakrishnan and Ndhlovu, 1992). Generally, local people who have lost livestock by predators and crop loss by herbivores are more likely to have negative attitude towards the conservation of wildlife. Even small losses can generate negative attitude towards wildlife in communities with subsistence economy (Oli *et al.*, 1994).

Only 17.9% of the respondents believe that the Park is beneficial to them and have positive attitude towards the Park and wildlife. This is probably because a small number of the local people living in and around the Park do obtain benefits from it through employment as scouts, and tourist guides or in the Ethiopian Wolf Conservation Project functioning in BMBP, and through hiring of horses and selling fuel wood and traditional handicrafts. As stated by Balakrishnan and Ndhlovu (1992) and Ormsby and Kaplin (2005), people are more likely to appreciate protected areas if part of the benefits gained from them is spend for local developments. Benefits can be obtained through resource extraction, employment, development or tourism (Allendorf, 2007), but can also be non-economic, such as recreation and aesthetics (Allendorf *et al*., 2007; Silori, 2007).

Data collected through the questionnaire survey, interviews, informal discussions and field observations revealed that due to the various impacts of the local people on natural habitats of the rock hyrax and the species itself, the rock hyrax range is shrinking from time to time and the rock hyrax population size is decreasing in the study area even to the extent that some rock hyrax colonies are totally lost or extricated from areas where human pressure is high. So, if dependence of the local people on the Park for their subsistence and other related impacts on the species continues in the present pace, future fate of the rock hyrax in BMNP area will be in jeopardy.

Therefore, effective conservation strategies both for the rock hyrax and its habitats are needed if the species is to survive for long. As poor households that mainly depend on subsistence farming and livestock rearing are less concerned about conservation, the Park authorities and other concerned bodies have to give due attention towards improving the socio-economic status of the local community. Sustainable management of protected areas and local support for natural resource conservation would require socio-economic development of the local community (Silori, 2007). Income generated from the Park and tourism has to be shared for local development, and play significant role in improving the livelihood of the local community. Moreover, the local people have to participate or involve in conservation programs. The success of long-term sustainable management of natural resources depends on local people’s participation and support (Silori, 2007). Assessing local people’s attitudes, taking into account their needs and respecting their opinions should become a management priority. Besides, compensation for crop damage, livestock depredation and other property losses by wild animals has to be taken into consideration. Any action such as controlling problem animals as well as reconsidering compensation to property losses would reduce negative attitudes of local communities towards wildlife and protected areas (Sindiga, 1995; Seno and Shaw, 2002).

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The present study has revealed information on the distribution, population status, feeding ecology, habitat utilization and threats to rock hyraxes in the BMNP. The rock hyrax has a wide, spacial and altitudinal distribution all over the Park. Distribution of the species depends mainly on the presence of enough cover that ensures the species with protection against predators and bad weather conditions, in addition to the availability of forage. Population density of the species was associated mainly with the presence of enough shelter and forage.

The presence of more adult females and juveniles in the rock hyrax population demonstrates high reproductive potential and sustainability of the species in the study area. The rock hyrax is colonial, living in various sizes depending mainly on the amount of cover and forage. The species form large colonies during the wet season and split into smaller colonies during the dry season due to scarcity of suitable forage during this season.

Rock hyrax feed on a wide variety of plant species found around the vicinity of its shelter. They are mainly grazers but they also browse extensively during the dry season when availability of fresh forage decline. The rock hyrax is also a dietary item for the critically endangered Ethiopian wolf and raptors in BMNP. Rock hyraxes utilized mountain cliffs and rocky outcrops than valleys and open areas, both during wet and dry seasons. But, shifting of the species to nearby habitats was evident in both seasons associated mainly with the availability of resources. It is essential for the BMNP management to conserve the Park's ecosystems which includes suitable habitats for the rock hyrax. Due to the ongoing intensive human activities in the Park and the natural habitats of rock hyrax, the range and status of the rock hyrax is declining. Human associated disturbances in the habitats, illegal hunting and wild fire are factors threatening the survival of the species in the study area. With increasing human impacts in the Park, the existence of the rock hyrax is at risk. Therefore, sound management actions are instrumental to minimize the disturbances by the local community and livestock. The present findings suggest that increasing the awareness and knowledge of the local community about the Park, wildlife and conservation are essential for the sustainance of the ecosystem and its fauna and flora in BMNP. It is also necessary to improve the relationships between the local community and the Park management for sustainable management of the Park and the inhabiting rock hyrax populations.

5.2 Recommendations

Based on the findings of the present investigation, the following recommendations are suggested for the sustainable maintenance of the natural resources and ensure sustainability of the rock hyrax population in BMNP:

- Repeated census of rock hyrax and assessments on their habitat in BMNP is to be organized by the EWCA in collaboration with researchers.

☛ Comprehensive and detailed studies should be carried out on the rock hyrax population in the Park in order to address population dynamics and genetic relationships among the rock hyraxes within and around the Park and other relevant ecological parameters of the species.

☛ Control various illegal human activities like livestock grazing, agricultural expansion, illegal settlements, cutting trees, collecting fire wood and thatching grass and illegal killing of rock hyraxes and hunting, setting wild fire and different construction activities in the Park. Open grazing in the Park area should be discouraged.

☛ To minimize the impact of the increasing human population in the Park and natural resources, family planning awareness should be made. To make it practical, it is important to introduce at primary and secondary levels of education as one of the subjects to check population growth.

☛ As education raises knowledge and awareness of the people and help to develop positive attitudes towards wildlife conservation, the local people should be given basic education and awareness creation on the consequences of habitat destruction and the need for conservation of natural habitats and wildlife in the Park.

☛ Conservation measures can not be successful without active participation of the local people. Therefore, community based conservation programmes and active participation of the local people in conservation and different ecotourism activities should be encouraged as integral component of the conservation of BMNP and the rock hyrax. The local communities should have a role in designing, planning, implementation and evaluation of wildlife conservation programmes in the Park from time to time.

- The Park authority should provide compensation for the local people, who loss livestock and crops around. This would help the people in providing local support in conservation activities.

- As most of the households have livestock, alternative sources of energy, primarily biogas use should be promoted to minimize their dependence on firewood collection from the Park area.

- Large numbers of livestock regularly graze on the edges of and inside the Park. Hence, to avoid the impact of livestock buffer zone is to be established around the Park.

- In order to avoid the impact of the local people on the Park and wildlife, the Park has to be legally gazzeted as soon as possible.

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7. APPENDICES

Appendix 1. Data sheet used for collecting population census of rock hyraxes.

Date ____________ Site__________ Weather condition ___________Collector__________

Location	Habitat type	Number of rock hyraxes	Colony size and composition	Age and sex	Remark

Appendix 2. Data sheet used for collecting rock hyrax diet.

Date and time______________ Site__________________ Weather condition_______________

Food plant species	Habit	Habitat type	Part (s) consumed	Time utilized (min)

Appendix 3. Questionnaire used during the present study to interview local people in Karari, Gojera and Hora Soba Villages in and around Bale Mountains National Park.

Date ______________________ Village _____________________

1. Sex a) Male b) Female
2. Age (in years) a) < 18 b) 18 – 24 c) 25 – 34 d) 35 – 44 e) 45 –54 f) ≥ 55
3. Educational level a) Illiterate b) No formal education c) Primary d) Secondary e) College/University
4. Occupation? ____.
5. What is your household size? a) <5 b) 5 – 10 c) > 10
6. How long (in years) you have been living in this village? a) < 10 b) 10– 30 c) >30
7. Do you know what a rock hyrax is? a) Yes b) No
8. If your answer to the above question is yes, where is it found (distribution and habitat type where the species live)?____ ____.
9. What does the rock hyrax eat most of the time? a) Grass b) Browse c) Both d) No idea
10. How do you evaluate the population status and range of the rock hyrax over the past 10 years? a) Increasing b) Decreasing c) Remained the same d) No opinion
11. If your answer to the above question is decreasing, what do you think are the major Reasons for its decline?____.
12. Do you think that local people trap rock hyrax? a) Yes b) No

13. If your answer to the above question is yes, how and for what purpose? ________

____.

14. Do you have dog(s)? a) Yes b) No

15. If your answer to the above question is yes, how many and how do you feed it (them)? ____

16. Have you ever encountered dogs hunting rock hyraxes? a) Yes b) No

17. What do you suggest in order to conserve the rock hyrax and the Park? ________

____.

Thank you for taking your time filling in this questionnaire.

Appendix 4. Demographic and socio-economic characteristics of households selected from Karari, Gojera and Hora Soba villages.

Factor	Response	Village			Total
		Karari	Gojera	Hora Soba	
Sex	Male	59	42	60	161
	Female	26	18	30	74
Age (in years)	18–27	12	9	15	36
	28–37	24	18	21	63
	38–47	29	20	32	81
	≥ 48	20	13	22	55
Years as resident	< 10	19	12	20	51
	10–30	35	30	41	106
	>30	31	18	29	78
Education	Illiterate	23	18	31	72
	No formal education	33	25	30	88
	Primary	19	9	25	53
	Secondary	8	5	4	17
	College/University	2	3	0	5
Occupation	Only crop farming	41	30	48	119
	Only animal rearing	22	12	21	55
	Both crop farming and animal rearing	14	11	17	42
	Service provision and others	8	7	4	19
Household size	<5	23	17	19	59
	5–10	48	31	50	129
	>10	14	12	21	47

Appendix 5. List of mammalian species recorded in Bale Mountains National Park during the study period with respective orders (*endemic to Ethiopia, ** endemic to BMNP).

Common name	Local name	Scientific name	Order
Mountain nyala *	Gadamsaa Badaa	*Tragelaphus buxtoni*	Artiodactyla
Spotted hyaena	Worabessa	*Crocuta crocuta*	Carnivora
Common warthog	Goljaa	*Phacochoerus africanus*	Artiodactyla
Menelik's bushbuck*	Boroffa	*Tragelaphus scriptus meneliki*	Artiodactla
Golden jackal	Tera Kebero	*Canis aureus*	Carnivora
Red duiker	--	*Cephalophus natelensis*	Artiodactyla
Caracal	Afinch	*Felis caracal*	Carnivora
Ethiopian wolf *	Jedella Farda	*Canis simensis*	Carnivora
Bohor reedbuck	Godaa	*Redunca redunca*	Artiodactyla
Black-backed jackal	Jedella	*Canis Mesomelas*	Carnivora
Grey duiker	Kuruphee	*Sylvicapra grimmia*	Artiodactyla
Blick’s grass rat*	Hantuta	*Arvicanthis blicki*	Rodentia
Rock hyrax**	Osolee	*Procavia capensis capillosa*	Hyracoidea
Crested Porcupine	Dade	*Hystrix crystata*	Rodentia
Giant mole rat **	Tuqaa Gudaa	*Tachyoryctes macrocephalus*	Rodentia
Common genet	Tiriignii	*Genetta genetta*	Carnivora
Serval cat	Deeroo	*Felis serval*	Carnivora
Starck’s hare*	Hilleessaa	*Lepus starcki*	Lagomorpha
Common mole rat	Tuqaa	*Tachyoryctes splendens*	Rodentia
Leopard	Qerensa	*Panthera pardus*	Carnivora
Mohamet’s mouse*	Hantuta	*Mus mohamet*	Rodentia
Giant forest hog	Derrucha	*Hylochoerus meinertzhage*	Artiodactyla

Vervet monkey	Qamale	*Cercopithecus Pygerythrus*	Primates
Egyptian mongoose	Ama	*Herpestes ichneumon*	Carnivora
Bush hyrax	Osolee	*Heterohyrax brucei*	Hyracoidea
Stripped ground squirrel	Amagotta	*Euxerus erythropus*	Rodentia
Colobus monkey	Wenny	*Colobus guereza*	Primates
Wild cat	--	*Felis silvestris*	Carnivora
Bale monkey *	Qamalee Baalee	*Chlorocebus djamdjamensis*	Primates
Klipspringer	Boortee	*Oreotragus oreotragus*	Artiodactyla
Grivet monkey	Qamale	*Cercopithecus aethiops*	Primates
Bush pig	--	*Potamochoerus larvatus*	Artiodactla
Grass rat	Hantuta	*Arvicanthis abyssinicus*	Rodentia
Honey badger /ratel	--	*Mellivora capensis*	Carnivora
Desert warthog	Goljaa	*Phacochoerus aethiopicus*	Hyracoidea
Olive baboon	Jaldessa	*Papio anubis*	Primates
White-footed Rat*	Hantuta	*Praomys albipes*	Rodentia

DECLARATION

I, the undersigned, hereby declare that this PhD dissertation is my original work and it has not been presented in other University seeking for similar degree or other purposes. All sources of materials used for this dissertation have been duly acknowledged.

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