Addis Ababa University

School of Graduate Studies

Department of Zoological Sciences

Ecological study of Salt's dik-dik (*Madoqua saltiana* Blainville, 1816) in Awash National Park, Ethiopia

By

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This is to certify that the thesis prepared by Selamawit Geta, entitled "Ecological studies of Salt's dik-dik (*Madoqua saltiana* Blainville, 1816) in Awash National Park, Ethiopia", and submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in Biology (Ecological and Systematic Zoology) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Ecological study of Salt's dik-dik (*Madoqua saltiana* Blainville, 1816) in Awash National Park, Ethiopia

Selamawit Geta, Ph.D Thesis, Addis Ababa University, 2020

An ecological study of Salt's dik-dik was conducted during July 2017-August 2019. The study was aimed investigating the population size, habitat association, diurnal time budget and diet composition of the animal. In addition, conservation challenges and opportunities rooting from the local community in ANP was investigated. For the study of population size and habitat association, eight sampling sites were identified and, line transect distance sampling method was employed. Behavioral activity budget was assessed using focal scan sampling method. Similarly, diet composition was studied using feeding duration record coupled with feeding quadrat survey in order to assess accessibility and availability of forage species. Purposive sampling method was used to assess conservation challenges and opportunities rooting from the local community of the Park. Population size of the animal was 555 (range: 495–615) during the wet and 726 (range: 658–794) during the dry season over the surveyed region. Seasonal impact was remarkable on population size ($\chi 2=12.8$, df =1, P=0.001). Mean population density was 28.4/km^2 during the wet season and 37.3/km^2 during the dry season. It significantly varied between seasons ($F_{1, 159}$ = 5.95, P=0.048). Population size significantly varied across the study sites both during the wet ($F_{2, 96}$= 7.9, P=0.043) and dry seasons ($F_{2, 96}$= 4.12, P=0.012). The animal was occurred in four habitat types; thickets (38.6%), bushlands (25.3%), open bushlands (19.94%) and shrub grasslands (16.1%). Variation in habitat preference was noticed during the wet ($\chi 2$ =27.3, df = 3, P=0.001) and dry seasons ($\chi 2$ =25.1, df = 3, P=0.005). Seasonal impact was observed on herd sizes ($F_{1, 230}$ = 30.6, P=0.019) and encounter rates ($F_{1, 158}$ = 9.6, P=0.023). Three distinct herd sizes were identified with percentage frequency of occurrence: solitary dik-diks (62.6% and 33.8%), a family of two dik-diks (32.7% and 41.1%) and mate pair with young (25% and 4.7%) during the wet and dry seasons, respectively. Population categories showed significantly high adult males during the wet season ($\chi 2$ =29.4, df= 4, P=0.0001). Contrary to this, it was insignificantly varied to adult females during the dry season. Similar activity budgets were recognized across seasons and sexes. The highest activity budget was recorded for feeding (34.1%) followed by resting (25.7%) and rumination (21.9%). Twenty forage plant species were identified, with higher percentage contributions of Acacia senegal (41.27%), A. millifera (20.5%) and Balanites aegyptiaca (12.67%). Variations of dietary contribution across seasons were found for A. millifera and B. aegyptiaca. Conservation challenges of ANP, arising from the local community outweighs the opportunities due to critical dependence and exploitation of the Park resources. Therefore, enforcement of wildlife conservation laws, scaling up and supervision of community awareness programs, designing alternative ways for livestock production which avoids dependence on the resources of the Park, and provision of alternative economic opportunities are indispensable.

Keywords/Phrases: Activity budget, Awash National Park, conservation threats, dietary composition, Salt's dik-dik, territoriality

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DEDICATION

To my mother, Askale Haile for her life lesson of dedication, and my daughters Loza and Wengel Dereje, for making me determined in completion of this study.

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ACRONYMS

ANP	Awash National Park
IBC	Institute of Biodiversity Conservation
IUCN	International Union for Conservation of Nature and Natural Resources
MDP	Mean Detection Probability
MER	Mean Encounter Rate
MOHS	Mean Observed Herd Size

1. INTRODUCTION

Ecosystems of Africa are well known for their charismatic mega-fauna, appealing for ecological study, tourism and conservation efforts. Coupled with the mega-fauna, diverse species of small antelopes constitute the complete picture of the diverse habitats. The significant evolutionary events that took place on the continent resulted in diverse landscapes, vegetation zones and climatic features providing an ideal habitat for the diverse fauna. One of the most prominent geologic events, the East African Rift System, describes the climatic and topographic features of the Eastern African countries, including Ethiopia (Ring, 2014). The diverse habitats ranging from arid and semi-arid lowlands located in the Rift Valley, to the cooler highland, Ras Dashen, enabled Ethiopia to support a wide array of floristic diversity and associated fauna (Yalden and Largen, 1992; IBC, 2005). Consequently, the country is categorized among the endemic-rich countries of the world with respect to vertebrate species. Besides this, Ethiopia is known to be one of the world's leader countries with regard to harboring endemic mammal species (Groombridge, 1992; Lavrenchenko and Afework Bekele, 2017).

Salt's dik-dik (*Madoqua saltiana*) is among the smallest antelope species found in Ethiopia and other Eastern African countries (East, 1998). Dik-dik is a common name for the different dwarf antelope species of *Madoqua* or *Rhinchotragus* as indicated in Table 1 (Kranz, 1991; Dujardin and Fox, 1997). These small antelopes inhabit the arid and semi-arid woodland and scrublands of eastern and southwest Africa. Out of the different species of dik-diks, only *M. giinther* is found in southern Africa (Tinley, 1969; East, 1998). Besides *M. giinther*, the remaining species of dik-dik are known to be native to the northeastern arid zones, with their distribution centered along Ethiopia and Somalia (Glass, 1965; Tinley, 1969; East, 1998). Salt's dik-dik is known to confine to the semi-arid parts of the East African countries. Ethiopia, Sudan, Eritrea, Djibouti, Somalia, and Kenya are the distribution ranges of the species. In Ethiopia, the species is widespread and common in the northern and eastern lowlands of its historical range. These antelopes confine to bushland habitats of Awash Valley within protected habitats of Awash and Yangudi Rassa National Parks, and Ogaden regions. Habitat overlap was reported between Salt's dik-dik and Guenther's dik-dik in Ogaden, Ethiopia (Ono *et al*., 1988; East, 1998).

Table 1. The species and sub-species of dik-dik

Species	**Subs-pecies**
M. kirkii	*kirkii, cavendishi, thomasi, damarensis*
M. saltiana	*saltiana, hararensis, swaynei, phillipsi,lawrancei*
M. guentheri	*guentheri, smithii*
M. paicentinii	*Monospecific*

Regular assessment of the population size of wild animals provides relevant data for timely conservation and management action (Dennis *et al*., 2006; Pérez *et al*., 2015). However, to date, no study has been conducted in any of the natural ranges of Salt's dik-dik regarding population status and ecology of the animal. Comparative physiological study is the only study available about *Madoqua saltiana* (Hebel *et al*., 2011). Among the species of dik-diks, few studies are available only for the southern as well eastern African populations of Kirk's dik-dik. Earlier study conducted to estimate the population density of Kirk's dik-dik employed dung matching techniques (Komers and Brotherton, 1997), while recently line transect and distance sampling methods have been used (Shorrocks *et al*., 2008). Diet and behavioral aspects of Kirk's dik-dik were assessed and available only for the single sub-species, the Damara dik-dik (*M. k. damarensis*) of southwest Africa (Tinley, 1969 and Manser and Brotherton, 1995; Otieno *et al*., 2019). A study dealing with Nitrogen metabolism and renal function was as well conducted for this relatively known species of dik-dik (Maloiy *et al*., 2000). Thus, data on the population status and ecological aspects of Salt's dik-dik in one of its natural ranges is indispensable to fill the knowledge gap.

Awash National Park is the first protected conservation area of Ethiopia. The vegetation types are classified under *Acacia-Commiphora* woodland (Sebsebe Demissew and Friis, 2009). The Park is well known for its spectacular diversity of mammals and birds, as well as for its magnificent habitats (EWCA, 2011; Belay Zerga, 2015). Despite this, the rapid loss of habitats and decline of population of wildlife species is overwhelming. According to ICUN (2008), a decline in the population status of the prominent mammalian fauna of the Park (Appendix I), is an indication of the conservation status of the area. In the surrounding locality of the Park, human interference and the associated impacts are highly pronounced due to its proximity to town and associated infrastructure development. The pastoralist activity of arid rangelands of Africa is prominent in the vicinity (Daniel, 2011; Shimelis Beyene, 2012; Belay Zerga, 2015). At present, human influence is threatening the existence of wildlife and the entire habitat of the Park (Molla Mekonnen *et al*., 2010; Solomon Belay *et al*., 2012; Belay Zerga, 2015; Mengistu Wale *et al*., 2017). In the face of the rapidly changing environmental condition of the world, the existence of wildlife is determined by anthropogenic influences. Thus, assessing the challenges and opportunities rooting from the local community of Awash National Park is mandatory.

Rationale of the study

Unpredictable climatic conditions and the associated ecological impacts resulting from the rapid human population growth impose a great deal of challenge on the population and ecology of wildlife (IPCC, 2012). Any sort of conservation and management strategy requires a reliable data on the population status of wildlife species. Without prior knowledge about the reliable population estimate and ecological requirements of a wildlife animal, conservation and management strategies may not meet their target (Norton-Griffiths, 1978; Williams *et al*., 2002; Pérez *et al*., 2015). Lack of detailed previous studies on population status and ecology of Salt's dik-dik was the impetus to propose the present study. On top of that, presence of the species in one of the protected areas of Ethiopia facing a number of threats (Mengistu Wale *et al*., 2017) challenges its continuity as a protected area was significant. Thus, lack of previous data on this mini-antelope which has peculiar physiological and behavioral features, coupled with its presence in the highly threatened ecosystem, made the study, a priority. The present study was designed with the aim of providing baseline data about the population status, habitat selection, feeding ecology and activity time budget of Salt's dik-dik. The finding of the present study may encourage others to carry out ecological studies in other geographic ranges, and enable to take suitable conservation actions. The astonishing morphological and physiological features of such mini-antelopes made them ideal for comparative physiological study (Hebel *et al*., 2011). Accordingly, knowledge about the population and ecological aspects of Salt's dik-dik may attract researchers from different biological disciplines to take initiatives for further studies, contributing for the species and habitat conservation strategies.

2. OBJECTIVES

2.1 General objective

The general objective of this study was to investigate the ecology of Salt's dik-dik and, analyze the challenges and opportunities of wildlife conservation rooting from the attributes of the local community of ANP.

2.2 Specific objectives

- To assess the abundance of Salt's dik-dik in ANP
- To identify population density of Salt's dik-dik
- To assess the habitats used by Salt's dik-dik
- To assess the diurnal activity budget of Salt's dik-dik
- To evaluate the diet composition of Salt's dik-dik
- To identify the conservation threats and opportunities attributed to the local community of ANP

2.3 Research hypothesis

- ✓ Abundance of Salt's dik-dik does not vary between seasons.
- ✓ Population density of Salt's dik-dik does not vary between seasons and study sites.
- ✓ Different habitat types of ANP support comparable population sizes of Salt's dik-dik.
- ✓ Habitat association of Salt's dik-dik doesn't vary across habitats and seasons.
- ✓ Herd sizes of Salt's dik-dik are the same across season and habitat types.

- ✓ The diurnal activity patterns of Salt's dik-dik vary between time blocks, seasons and sexes.
- ✓ Salt's dik-dik is a browser species.
- ✓ The proportion of the principal browsed species of Salt's dik-dik varies across seasons.
- ✓ Availability of the forage species of Salt's dik-dik is comparable between seasons.
- ✓ Overgrazing is a prominent conservation threat in ANP.

3. LITERATURE REVIEW

3.1 Population estimate

Knowledge about the population size of wildlife animals is a crucial step in the management and conservation strategies (Varman and Sukumar, 1995; Buckland *et al.*, 2000; Eggert *et al*., 2003; Noon *et al*., 2012; Pérez *et al*., 2015). Regular assessment of the population dynamics and pattern of spatial distribution of wild animals are mandatory in the face of the ever changing environmental condition of the world (Dennis *et al*., 2006; Parmesan, 2006). Moreover, the population size of an animal can give an insight about its interaction with the environment and associated constraints (Messier, 1994; Sinclair *et al*., 2003; Laliberte and Ripple, 2004; Namgail *et al*., 2010). Despite the demand for population data of a wildlife species, several factors determine the process of finding a reliable estimate. For instance, low detectability of animals which can root from inherent behavioral features and anthropogenic activities was found to challenge population estimates (Petit and Valiere, 2006; Guschanski *et al*., 2009). Nevertheless, identifying an effective method suiting the features of the animal of interest is an important requirement in order to provide dependable data (Ogutu *et al*., 2006; Pérez *et al*., 2015).

Over the years, a wide variety of field and statistical techniques have been developed and used to estimate ungulate's population density and abundance (Eberhardt, 1978; Norton-Griffiths, 1978; Burnham *et al*.,1980; Komers and Brotherton, 1997; Buckland *et al*., 2004). However, selection of a particular method requires knowledge about the reliability (accuracy and precision), costs, and previous information obtained and time period required (Pérez *et al*., 2015; Le Moullec *et al*., 2017). On top of this, prior to selection of a particular method, the inherent behavioral and physical aspects of the study species, and the nature of its associated habitat features determining the detection probability need to be considered. The cumulative behavioral and ecological aspects of animals may result in altered detectability, and consequently may cause biased population estimates (Petit and Valiere, 2006; Guschanski *et al*., 2009). Accordingly, time and resource can be managed by selecting a method suitable for the target species (Buckland *et al*., 2004; Fewster *et al*., 2005).

Previous study conducted to estimate the population density of a species of dik-dik, Kirk's dik-dik, employed pellet matching technique (Komers and Brotherton, 1997). In this technique, unlike the principles employed to other wild animals which lack communal dung sites, population estimation in dik-dik was entirely on the basis of uniquely identifiable pellet groups of individual pairs. Identification of the pellets of an individual pairs of dik-dik in the study area was conducted without prior knowledge of the identity and location of individuals. The effectiveness of the technique was indicated by comparing the density found from capture and radio telemetry study (Komers and Brotherton, 1997). Of the direct method used to study population density and abundance of wildlife species, strip transect count and distance sampling methods were widely used for the study of ungulates of the African savanna. Consequently, distance sampling was efficiently used for the population study of Kirk's dik-dik in Mpala, Laikipia District, Kenya (Shorrocks *et al*., 2008).

3.2 Habitat association

The distribution pattern and habitat preference of animals are associated with physical, historical and biotic factors (Pienaar, 1974). There are different kinds of density-dependent and independent factors which contribute for different patterns of distribution of ungulates in certain habitats (Mobæk *et al*, 2009). Factors influencing habitat association include suitability and quality (Evangelista *et al*., 2008; Heinze *et al*., 2011; Yosef Mamo *et al*., 2012), competitive or predatory impacts faced by other sympatric species (Latham, 1999; Stensland *et al*., 2003), and human interference and disturbance (Stankowich, 2008; Polfus and Krausman, 2012). Species of animals differ in the range of temperature they adapt, which has attributes to latitudinal and altitudinal gradients in determining the range of occurrence and activity (Aublet *et al*., 2009; van Beest *et al*., 2012). Similarly, rainfall pattern and soil characteristics of a habitat are important aspects for the occurrence of herbivores in an area as it determines the vegetation quality and distribution at spatial and temporal scales (Pianaar, 1974; Zweifel-Schielly *et al*., 2009).

Habitat preference is indicated by the frequency distribution of animals in different vegetation types of an area. Vegetation type is a determinant factor in habitat association of wild animals as it provides the resources on which the animal depends for foraging, resting, and safe sites for hiding from predators (Illius and Connor, 2000; Pérez-Barbería *et al*., 2001). The pattern of habitat use is highly determined by the energy and nutrient required for growth, maintenance of body mass, reproduction and survival of animals (Belovsky, 1986; Owen-Smith, 1994; van Beest *et al*., 2012). Strive for such physiologic needs are influenced by predation risks, which in turn affect the pattern of habitat use (Leslie *et al*., 1999; Blumstein and Daniel, 2002; Fortin and Andruskiw, 2003). Therefore, the preference of a habitat by herbivore species is a function of complex biological and physical requirements. As a result, the preferred habitat has to include a minimum size of an area considered as territory and activity zone, which serves as a refugia as well as resource provisioning (Mahere and Lott, 1995; Kiel *et al*., 2010).

Habitat use and feeding habits of ungulates are highly interlinked (Pérez-Barbería *et al*., 2001). The idea was supported by fossil evidences about the evolution of grazers inhabiting open habitats from a browser and dense forest-dwelling ancestral species. It was assumed that the evolution of this feature is facilitated by the increased availability of open habitats which is utilized by a wide array of diverse species of herbivores (Janis, 1982). In closed habitats, a large body is not necessarily advantageous in relation to foraging, movement or anti-predation. Accordingly, larger ungulates adapt open habitats as an anti-predatory strategy (Ford, 2015). Contrary to this, smaller ones associate predation risk to open habitats, as seen in dik-diks (Brotherton and Manser, 1997; Ford, 2015; Ford and Goheen, 2015).

Dik-diks are browsing mini-antelopes with a rather reduced distribution range compared to other antelopes of Africa such as klipspringer, steenbok, and grey duiker. Salt's dik-dik has a confined distribution in the arid and semi-arid parts of eastern Africa as indicated in Figure 1 (East, 1998). In their distribution ranges, dik-diks inhabit closed habitats and scrub bushlands. This is an adaptation to rely on crypsis in order to reduce the risk of predation which would be maximized in glades. In closed habitats, inconspicuous body pattern and small body size appear to be anti-predatory strategies (Ford and Goheen, 2015). In a comparative study, a sympatric species of dik-dik which has a biomass about 10 fold bigger, impala, is reported to predominantly occur in glades rather than in closed habitats (Brashares *et al*., 2000; Ford *et al*., 2014).

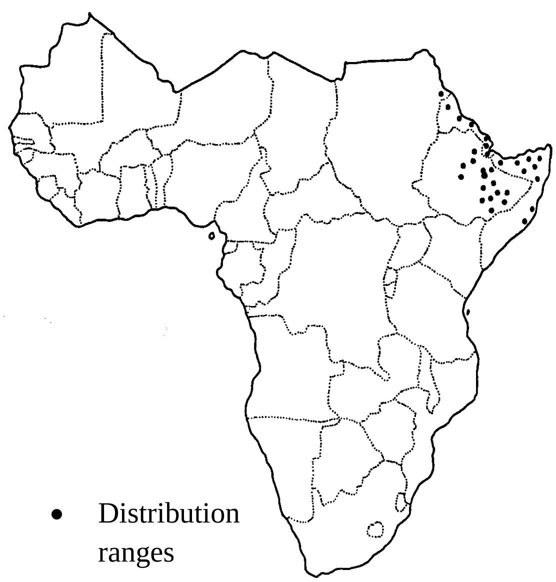

Figure 1. Distribution ranges of Salt's dik-dik (East, 1998).

Knowledge about habitat use of herbivore species is crucial to understand the relationship between their distribution and abundance. As vegetation and landscape features determine the distribution pattern of ungulates, the diversity, abundance, regeneration, structure and composition of vegetation of a habitat are influenced by the grazing pressure (Mc-Intyre and Lavorel, 2001; Rodríguez *et al*., 2003; Torre *et al*., 2007). Therefore, understanding the spatial need of herbivores and their associated ecological features are important steps in wildlife management, nature protection and landscape conservation (Morrison *et al*., 2006). Besides this, acquiring data on the habitat requirement of an animal in one habitat may help to predict its presence or abundance in comparable ecosystems, and its associated potential contribution or impact in the process of habitat transformation (Arthur *et al*., 1996; Ri´os-Uzeda *et al*., 2006).

3.3 Activity budget

The activity pattern of an animal is a significant biological process manifested by the regular allocation of time for specific activity. It is also a reflection of the animal's physiological and ecological attributes (Tobler *et al*., 2009; Norris *et al*., 2010; Blake *et al*., 2012; Kasiringua *et al.*, 2017). Herbivores indicate varied frequency of incidents and time budgets for different behavioral manifestations such as; foraging, vigilance, resting, rumination and others (du Toit and Yetman, 2005; Kasiringua *et al.*, 2017). The patterns may scale up to some extent with body size of animals as most physiological and ecological features are influenced by this attribute (Pérez -Barberia and Gordon, 1999; du Toit and Yetman, 2005). For instance, differences in the time budget required for foraging activity among smaller and large herbivores are highly pronounced. This is partly because, the requirement for the larger gut size is satisfied by increased intake rate and reduced food quality contrary to small herbivores (Mysterud, 1998; Pérez - Barberia and Gordon, 1999). However, this assumption can be contradicted by the influence of habitat type and forage preference. Studies show that the temperate and tropical browsing ruminants show different relationships between body sizes and investment in foraging activity. Besides body size, other factors can influence the activity patterns of animals (du Toit and Yetman, 2005).

Browsing ruminants spend a significant amount of time in rumination. Therefore, ruminants are capable of offsetting the minimized food quality in some browse by increased oral processing. This process can greatly minimize the particle size and facilitate digestion and passage rate. In the African savanna, thorns and spines of the woody browse, accompanied by the presence of leaves in lignified twigs reduce bite-size during the dry season (Cooper and Owen-Smith, 1986). When diet quality declines small browsing ruminants spend more time in oral processing (Gross *et al*., 1995). Thus, higher time of feeding to ruminating ratio is found in larger browsing ungulates than in that of the smaller ones in the times of the year when forbs, soft shoots and younger leaves of woody plants are scarce (du Toit and Yetman, 2005). However, small ruminants can reveal a constant feeding rumination ratio in both the dry and wet seasons if the key resources are available (du Toit, 1993; du Toit and Yetman, 2005).

Vigilance is among the important activities of ungulates which requires a significant portion of time, as that of resting, foraging, rumination and other activities (du Toit and Yetman, 2005; Kasiringua *et al.*, 2017). In the smallest ungulate species, vigilance is an important activity manifested by each member. This is partly because of their occurrence in small groups; either in solitary or mate pairs. The second reason which can be associated for this behavior can be their vulnerably to a wide range of predators (Sinclair *et al*., 2003; Radloff and du Toit, 2004). As a result, small ungulates cannot share the cost of vigilance behavior among group members as the larger and gregarious trophic guild ungulate species. In small ungulates, lack of gregarious behavior leads them to spend individually more time for vigilance, and depend on hiding and camouflaging with the habitat as their major anti-predator behavior (Brashares *et al*., 2000).

Activity pattern of an animal is regulated by endogenous biochemical processes. However, stimulation of such pattern is induced by external environmental factors (Dibner *et al*., 2010). For instance, photoperiod influences the activity budget of different species and leads them to specialize in various activities in different times of the day (Mistlberger and Antle, 2011). The impact of day length has a pronounced impact on the activity pattern of animals in various seasons, particularly for inhabitants of extreme environmental conditions.

In arid and semi-arid ecosystems, ambient environmental temperature, especially during the dry season, greatly affects the activity patterns of animals. Ungulates dwelling in such habitats allocate more proportion of time for foraging in the cooler hours of the day while engaged in behavioral thermoregulation in the hot mid-days (Owen-Smith, 1998). Risk of predation, varied food availability across seasons, and synchrony for socialization can also affect the major activities of mammals (Mistlberger and Skene, 2004). At present, human-induced factors are highly pronounced to affect the activity pattern of wild animals in different ecosystems (Fortin and Andruskiw, 2003; Bonnot *et al*., 2012; Leuchtenberger *et al*., 2018). These anthropogenic activities include habitat fragmentation, encroachment, hunting and tourism (Kitchen *et al*., 2000; Martin and Reále, 2008; Norris *et al*., 2010).

3.4 Diet composition

Foraging is a crucial process in the ecology of an animal as it determines the energy needed for survival, growth, reproduction and fitness. Fulfilling the energy and nutritional demands needed for the basic life processes of an animal is the most fitness-relevant task (Parker *et al*., 2009). Comprehensive understanding of the foraging ecology of an animal is central for ecological study and management actions (Petrides, 1975; Johnson, 1980; Krebs, 1989). Dealing with the feeding ecology of a herbivore requires evaluation of the relationship between the animal's pattern of utilization of a resource and the availability of forage species in the environment (Johnson, 1980; Owen-Smith *et al*., 1983; Owen-Smith, 2002).

Vegetation in a given habitat provides herbivores with a wide array of plant species to be utilized. However, different species of ungulates depend selectively on preferred forage plant species. As a result, some species of plants are palatable and accepted, while the rest are rejected (Owen-Smith, 1982). The degree of acceptability of plants in the diet of herbivores is measured from the relative probability of occurrence in their diet (Owen-Smith and Cooper, 1987). Among the forage species which are highly accepted, proportion of representation in the environment may be determinant in the forage utilization and habitat use of animals (Pienaar, 2013).

Ungulate species have a defined dietary habit, and thus, their diverse community is often described and categorized by dietary niches. The most widely accepted functional classification of their dietary habits categorizes them as browsers, mixed-feeders and grazers (Hofmann and Stewart, 1972; Van Soest, 1996). Clearly, the categorization in this manner depends on the proportion of grass and browse species the animal utilizes. Browsers utilize woody plants predominantly, while grazers utilize higher proportion of grass in their diet. Unlike browsers and grazers, mixed feeders are intermediate groups of herbivores which utilize both browse and grass in significant proportions (Hofmann and Stewart, 1972; Codron *et al*., 2005). Some studies consider browsers as those herbivores which consume >75% browse, and grazers which consume similarly >75% grass and intermediate feeders that consume either grass or browse with proportions between 25% –75% in their diet (Gagnon and Chew; 2000; Mendoza *et al*., 2002). The proportion of grass and browse in their diet may be determined either by forage availability (Hobbs *et al*., 1981), or physiological requirements (Seccombe-Hett and Turkington, 2008; Christianson and Creel, 2009).

Anatomical, morphological, physiological and behavioral features of ungulates have been used in understanding their food habits. Morphology of the skull, mandible and dentition of ungulates were correlated with their dietary adaptations, and thus can be used for estimating their feeding ecology (Mendoza *et al*., 2002). Mouth and gut morphology and digestive physiology are important aspects in determining feeding category as well (Hofmann, 1989). Besides morphological and physiological features, the activity pattern of herbivores provides a great deal of information about the forage selection (Mysterud, 1998; Zweifel-Schielly *et al*., 2009). In addition, habitat occupation is considered as a clue to deal with the feeding habit of ungulates. Some morphological features used to differentiate browsers from grazers indicate a similar pattern with ungulates dwelling in open versus closed habitats (Spencer, 1995; Kappelman *et al*., 1997). Thus, ungulates that inhabit closed (dense forested habitats) are considered as browsers. In contrast, those ungulates which inhabit open habitats are generally considered to have a feeding habit of grazing. However, mere categorization based on the clues is not an easy task due to complex functional, biomechanical and historical constraints in different phylogenetic groups that have developed convergent adaptations to utilize the same forage with varied ecological and anatomical features (Mendoza *et al*., 2002).

Dik-diks are among the smallest extant ungulates which inhabit closed habitats and are selective browsers (Pérez-Barbería *et al*., 2001). Due to their dwarf size, dik-diks consume twigs about a height of 1 m (Plate 1) (Otieno *et al*., 2019). As a result of this feature, it was reported that dik-diks can utilize efficiently their selected forage within their restricted height sympatrically with an antelope species which has a bigger biomass through a resource partitioning strategy. Dik-diks consume leaves from plants foraged in common with impala primarily in the closer bushlands, exclusively at lower branches. In contrast, for example, impala, a sympatric species of dik-dik, inhabit open habitats and forage similar browse primarily in glades from higher branches, and rarely in bushlands. Besides avoiding competition for the same forage species through resource partitioning, dik-diks can efficiently forage in habitats safer from the risk of predation (Ford and Goheen, 2015).

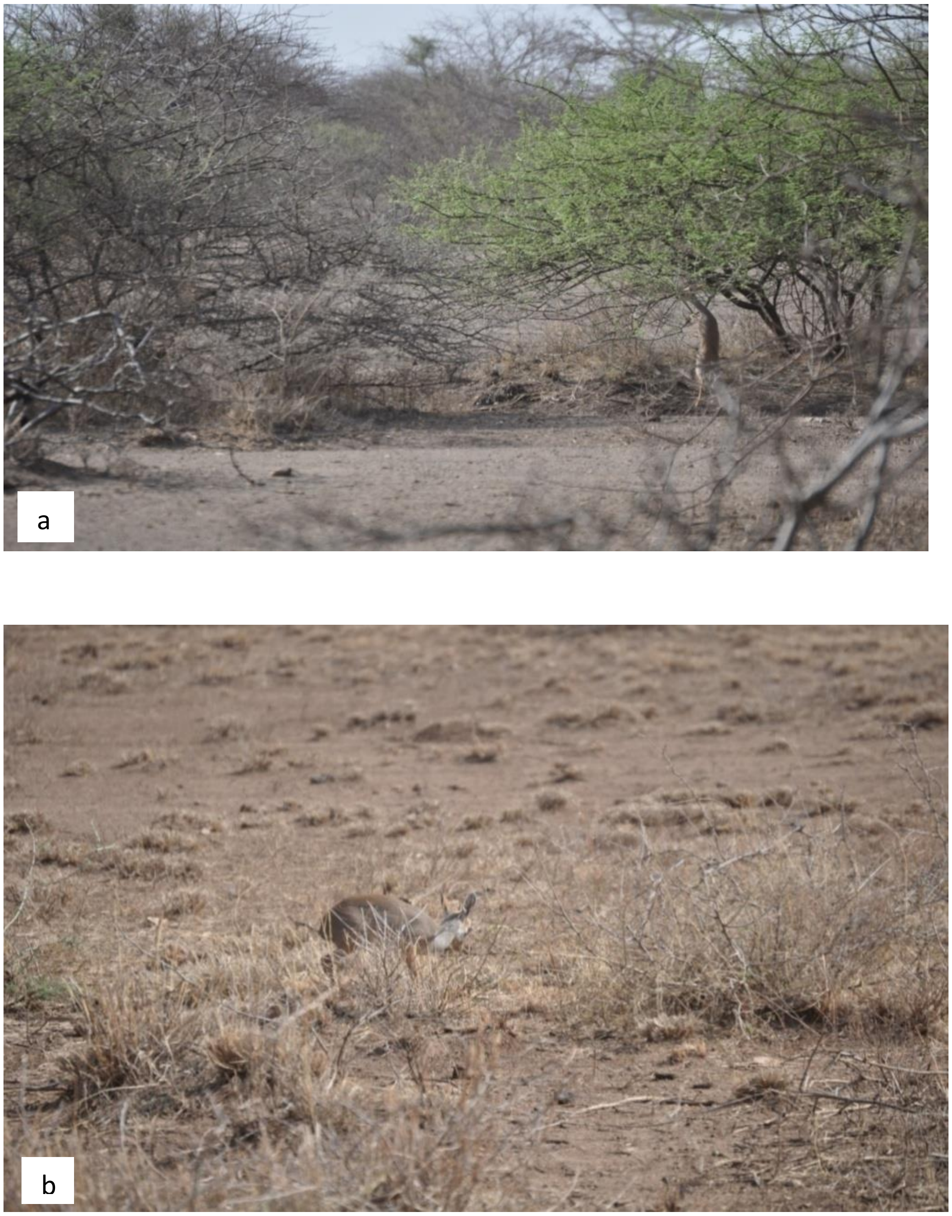

Plate 1. Foraging height of Salt’s dik-dik (a, in bushland; b, in shrub grassland habitats) (Photo by Selamawit Geta, Jan. 2018).

Ecological studies of foraging describe diet selection, forage accessibility and impacts of forage quality and quantity changes on the feeding behavior of animals (Bailey *et al.*, 1996; Paul, 1998; Katona and Altbäcker, 2002). Seasonality, can highly affect the availability of forage plants associated with biomass and quality in various habitats with varied spatial and temporal scales. As a result, the strategy of selective foraging becomes influenced by multiple environmental constraints (Searle *et al*., 2005; Owen-Smith *et al*., 2010; Zweifel-Schielly *et al*., 2012). Thus, understanding the foraging ecology of mammalian herbivores requires observation of forage decisions from various dimensions as the animals make decisions at various spatial and temporal scales (Senft *et al*., 1987; Hernández and Laundré, 2005; Zweifel-Schielly *et al*., 2009).

3.5 Conservation challenges and opportunities

The continuous loss of habitat through increased human pressure emphasizes the importance of ecosystem conservation (Jenkins and Joppa, 2009; Bertzky *et al*., 2012; Pullin *et al*., 2013). The practice of protecting wildlife and it's habitat in Ethiopia can be traced back to decades since the 1960s and expanded to include 21 national Parks, 4 sanctuaries, 8 wildlife reserves, 20 controlled hunting areas, 6 open hunting areas, 6 community conservation areas and 58 national forest priority areas (Young, 2012). However, effective conservation practices in such habitats are becoming a challenge due to a number of factors which emerge from different perspectives of organizational set up of the stakeholders, gaps in implementation and monitoring of conservation practices, and attributes of the local community of protected areas (EBI, 2015; Mengistu Wale *et al.,* 2017).

The semi-arid rangelands of East Africa exhibit a high degree of overlap in habitat use among the pastoral livestock and wildlife species (Sitters *et al*., 2009; du Toit, 2011). Conflict between the officials of the Park and the pastoralist communities is prevalent as the livestock compete for scarce resources in the Park during the times of prolonged drought (Georgiadis *et al*., 2007; Yihew Biru *et al*., 2017). In such national Parks, large herds of livestock of the pastoral and agro-pastoral community consume the resources intended for wildlife use inside the protected area (Plate 2).

Plate 2. Livestock encroachment in ANP (**a**, camels browsing in bushland habitats of the park; b, herds of goat in the territories of dik-dik) (Photo by Selamawit Geta, August 2019).

Awash National Park is an important conservation area in the semi-arid parts of Ethiopia. Due to its habitat diversity, ANP supports a wide array of flora and fauna. However, the Park is facing various threats arising from different sources. According to Belay Zerga (2015), more than two-thirds of land coverage of the Park is either temporarily or permanently used for activities apart from conservation which range from use for livestock grazing to permanent settlements. The Park is under continuous threat which results from human interference through overgrazing, unsustainable use of resources for fuelwood and charcoal, settlement, and habitat loss related to infrastructure development. The main livelihood activities around ANP include pastoralism, agro-pastoralism and harvesting natural resources (Fig. 2).

Figure 2. Illegal firewood collection in ANP (Photo by Selamawit Geta, Nov. 2018).

The pastoralist communities settled around the Park are from Afar and the Oromo tribes (Kereyu and Ittu) along the western and southern parts. As a result, a growing strain is prevalent among the pastoralist communities and the Park officials due to livelihood versus conservation. Previous studies assessed the attitude of pastoralists and agro-pastoralists of the study area towards wildlife conservation and revealed varied levels of understanding across age classes, ethnic groups and educational status (Yihew Biru *et al.,* 2017). Various conservation threats ranging from those rooting from livelihood attributes of the local community to inefficient organizational set up among the stakeholders were recognized. Mengistu Wale *et al.* (2017) pointed out, overgrazing by livestock, shortage of finance, inefficient management, human population increase, invasion by alien species, weak law enforcement, human-wildlife conflict and lack of alternative livelihoods as major threats of some protected areas of Ethiopia. As a result, the Park has been facing habitat loss (e.g. Fig. 3) due to land use/land cover change (Solomon Belay *et al.,* 2012) and complete loss of large mammal species such as Grevy's Zebra, Bushbuck, Leopard, Cheetah, Ostrich, Giraffe, Grey duiker, Swayne's hartebeest and Beisa oryx of the Park is also being threatened (IUCN, 2008).

Figure 3. Former grassland habitat of ANP with invasive species (Photo by Selamawit Geta, August, 2019).

Community based conservation effort is effective. Nevertheless, the quality of the human-wildlife interaction is shaped by a mix of biological, social, historical, geographic, political, economic, institutional, cultural and legal factors (Adams and Heinen, 2001; Madden, 2008). The attitude and values of local communities towards conservation and management of wildlife vary across different societies (Messmer, 2000), and such aspects are negatively affected by the pattern of interaction between human and wildlife, particularly in developing countries (Boer and Baquete, 1998). The situation becomes aggravated as human population increases, development expands, and changes in the global climate. Such factors put human and wildlife in intense competition for the shrinking resources of the protected habitats (Madden, 2004; Dickman, 2010; Gandiwa *et al*., 2013; Leta Gobosho *et al.*, 2016). Previous studies evaluated the degradation status (Belay Zerga, 2015), attitude of livestock-wildlife interaction (Yihew Biru *et al.*, 2017) and threats of the Eastern Ethiopian protected areas in general (Mengistu Wale *et al.*, 2017). The present study will assess the challenges and attributes of conservation activities, particularly rooting from the attributes of the local community of ANP.

4. THE STUDY AREA AND METHODS

4.1. Description of the study area

Awash National Park is among the conservation sites of Ethiopia categorized under the Somalia-Massai Regional Center of Endemism. It is located about 230 km east of Addis Ababa between $8^o5'$ and $9^o8'$ N and $39^o50'$ to $40^o10'$ E. The Park is part of the Great Rift Valley, located between the Afar and Oromia regional states with altitudes ranging between 740 near the Hot spring to 1820 m at about the tip of mount Fentale (Abule *et al*., 2005; Zewdu Tessema *et al*., 2011; Tezera Cherinet, 2015). The area of the Park was about 756 km^2 as demarcated earlier, and latter re-demarcated to cover an area of 598 km^2 since 2002 (Tezera Cherinet, 2015; Yihew Biru *et al*., 2017).

There are several permanent water sources around ANP, which include Awash River (with tributaries; Kesem and Kebena Rivers), Lake Beseka, and the Hot springs located at different parts of the Park (Tinsae Bahiru *et al*., 2012). Awash River passes along the south and southeast part of the Park and forms part of the boundary between east Hararghe and Arsi Zones of Oromia Region. The river has a waterfall, south of Gotu camp which is among the attractions of the Park. Hot spring is also found at the far northern part. Besides this, man-made watering points are located within the Park designed in the early days to make it accessible for wild animals (Tezera Cherinet, 2015).

The main rainy months of the study area are from July to September, with a short rainy season from February to April. The nature of rainfall is irregularly distributed with mean annual rainfall of 456 mm ranging between 100 and 1080 mm. The mean monthly minimum temperature is 20°C (ranging between 16°C and 24°C) and the average monthly maximum temperature is 35°C (ranging between 31 and 38°C) (Fig. 4). Both the temperature and rainfall data were collected from the Ethiopian National Metreological Service Agency (ENMSA) from the station located in Awash 7 Killo town, as there is no metreological data for ANP.

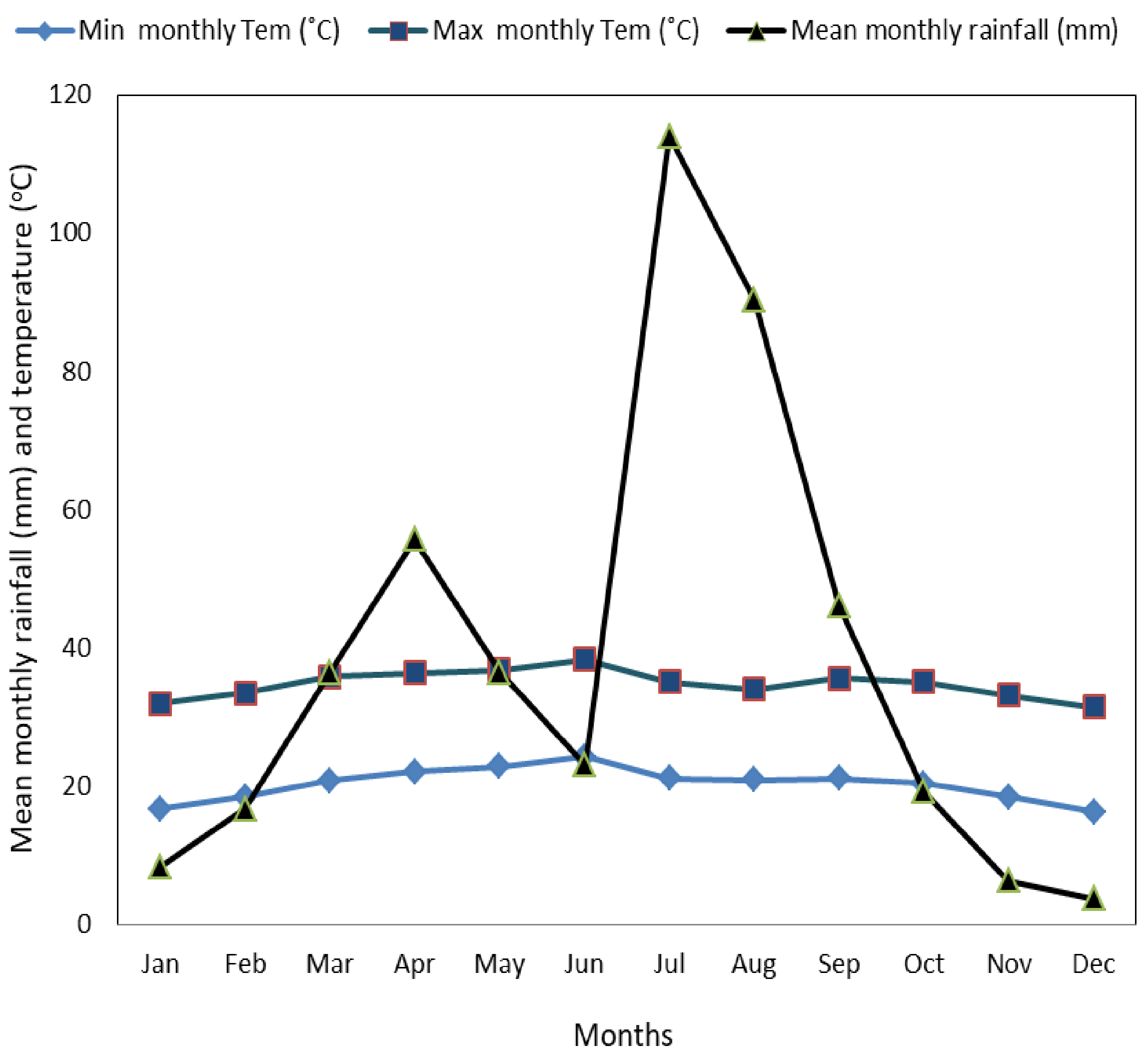

Figure 4. Mean monthly rainfall and temperature of the study area from 2009 to 2018 (Source, NMSA).

The vegetation of the Park is classified under *Acacia*-*Commiphora* woodland and shrub land ecosystem type (Sebsebe Demissew and Friis, 2009). It is dominated by grasses, shrubs, and *Acacia* woodland adapted to periods of prolonged drought (Abule *et al*., 2005; Sebsebe Demissew and Friis, 2009). Overgrazing, fire, infrastructure developments and expansion of settlement have been greatly contributing to the rapid transformation of the vegetation types of the Park. According to Tezera Cherinet (2015), eight different land use/cover classes were identified in ANP with proportional coverage of the major types; grassland with scattered shrub (27.42%), grassland with scattered tree (23.67%), thicket (22.86%) and bushland (14.26%). The remaining land cover (4.16%) is constituted by grassland, palm forest, exposed surface and lava flow.

4.2 Methods

4.2.1 Population estimate

Prior to data collection, eight sampling sites were selected. The parts of the Park are classified as core zone, intensive conservation zone, limited resource utilization zone (buffer zone) and development zones. The sampled sites were considered to be representatives of the former three categories. Thus, the sampling sites were categorized as Core conservation zone, Intensive conservation zone and Limited resource use area. Three of the study sites (Gotu (GT), Ayer Marefia (AY) and Ras Hotel (RH)) are located on the western part of the Park and separated from the remaining sampling sites by Addis-Djibouti Road and Railway intersecting the Park into mid-eastern and southwestern portions. While, Geda (GD) and Hot spring (FL) study sites are located on the eastern part of the Park. The remaining three sampling sites; Amareti (AM), Kudu

Valley (KV) and Gimel Bet (GB) were sampled due to proximity to the Road, and considered as highly prone to anthropogenic activities (Fig. 5).

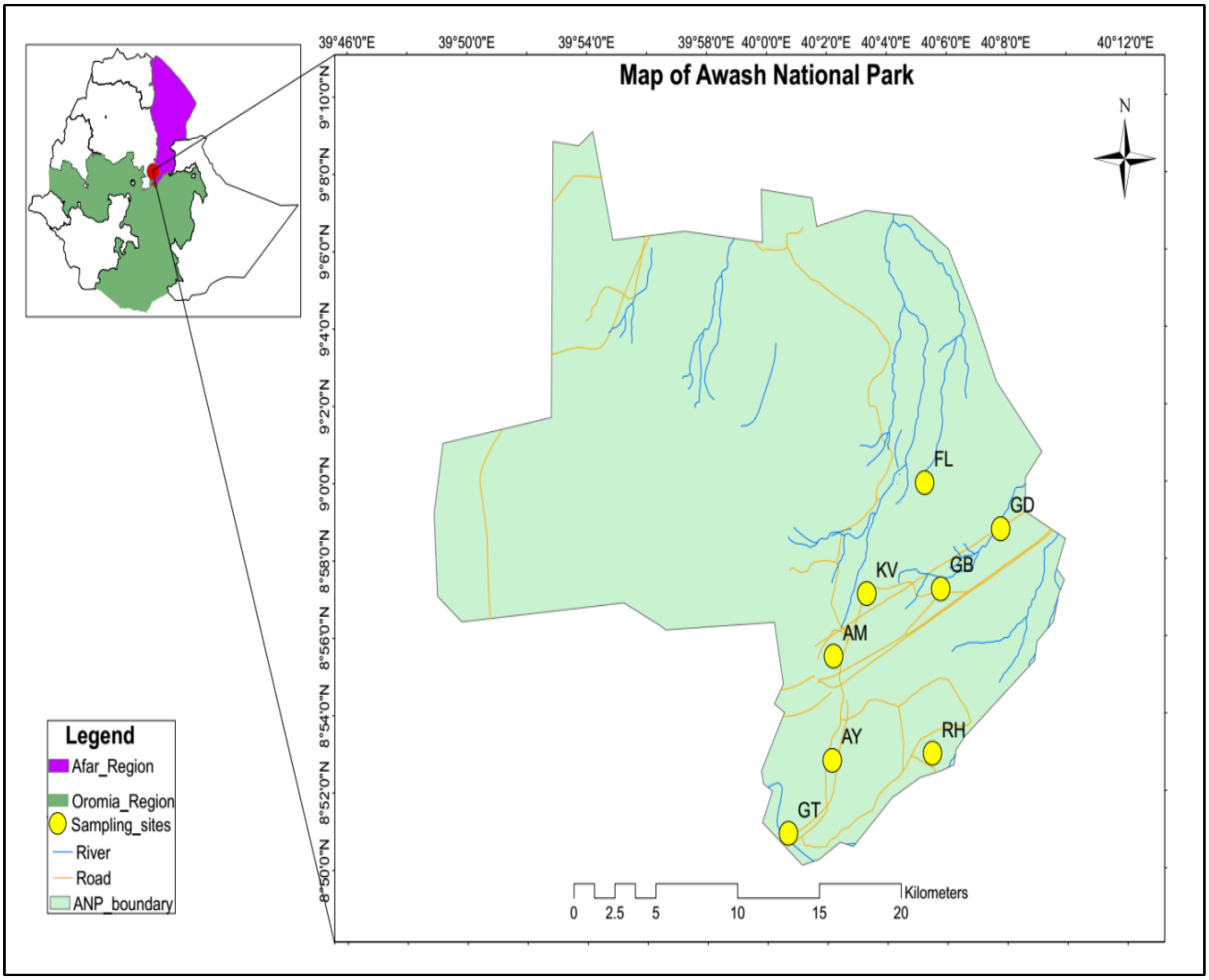

Figure 5. Map of Awash National Park with study sites' location (GT= Gotu, RH=Ras Hotel, AY=Ayer Marefia, AM=Amareti, KV=Kudu Valley, GB=Gimel Bet, FL=Hot Spring and GD=Geda).

Among the sampling sites located on the western part, two sites, Gotu and Ayer Marefia were selected due to their harboring diverse vegetation types. Besides possession of comparable vegetation types, Gotu is the site where headquarter is located. It is a restricted site for livestock encroachment as it is part of the core zone. Ras Hotel, besides its rich habitat diversity, is known for frequent tourism activity as it serves as a viewpoint for the Awash Gorge. Thus, it was considered to have reduced livestock encroachment, and sampled as core zone as well. Contrary to this, Ayer Marefia was sampled from intensive conservation zone of the park.

From the eastern part of the Park, Geda (intensive conservation area), and Hot spring sites (core zone) were selected due to their rich vegetation cover. Both sites are close to campsites, and thought to be well protected, though they are prone to human interference due to proximity to Awash. The remaining three sites were highly exposed for temporary and permanent anthropogenic impacts as recognized from the preliminary survey of the present study. Thus, such study sites were considered as sites for limited resource use.

Eighty transects, ten in each study site, were laid randomly to estimate the population size of Salt's dik-dik during the wet and dry season study periods of 2017 to 2019. The total length of transects laid per study site ranged between 12.1 km and 12.5 km, and the overall length of transects used for the survey was 98.15 km (Appendices II and III). Starting and end points of transects were marked with GPS (Azhar *et al.*, 2008; Bekhuis *et al.*, 2008; Wanyama *et al*., 2009), and the transect lines in each study site were laid at least 300 m apart. Each transect was surveyed twice a day, in the morning (6:00-10:30 h) and late afternoon time blocks (4:00-6:30 h) throughout the wet and dry season study periods. Dry season data were collected in the months of both cold and hot dry seasons (between October to December in the former case and, January and May in the later), while the wet season data were collected between June and September.

Detection of animals may be influenced by their inherent physical and behavioral features as well by the habitat attributes of the study area (Petit and Valiere *et al*., 2006; Guschanski *et al*., 2009). The small body size of the study animal coupled with occurrence in small herds made detection difficult, especially in the early days of data collection. Moreover, the daily ambient temperature made the animals out of sight. These limiting factors were resolved by switching to the cooler periods of the day when the animal is more active, working with field assistants who had better experience serving in the Park, using clues (like dung sites, hoof mark and alarm calls) in order to locate their sites, and by using binoculars. Besides this, the occupation of permanent territories by the monogamous pairs of dik-diks provided a better understanding of their occurrence in habituated areas (Tilson and Tilson, 1986; Kranz, 1991; Brotherton and Manser, 1997; Dujardin and Fox, 1997).

Distance sampling method was selected for the present study as it provides flexibility in the detection distances of animals (Buckland *et al*., 2004; Thomas *et al*., 2009) with a right truncation of 50 m regardless of the habitat features (Norton-Griffiths, 1978). Compared to fixed strip width, distance sampling was reported to provide a higher estimate of density of Kirk's dik-dik with better precision and reliability (Shorrocks *et al*., 2008). Along transects, all the relevant information such as; herd size with composition of age and sex of sightings, radial distance (r) of observation, sighting angle (θ) of the study animal and coordinates were recorded (Appendix IV). The radial distance and sighting angles were used to calculate the perpendicular distances, and in turn the perpendicular distance was used to calculate detection probability and population size of the animal (Shorrocks *et al*., 2008; Thomas *et al*., 2009). Herds of Salt's dik-dik at zero distance from the initial point of transects, where g (*0*) = 1, were assumed to be fully detected (Buckland *et al*., 2004; Buckland *et al.*, 2010; Horcajada–Sanchez and Barja, 2015).

Population abundance of Salt's dik-dik in the "i^{th}" herd was calculated using the herd size along the line transect and detection probability "*p*" as follows assuming herd observation *zi* =*si* and pi= detection function for the "i^{th}" herd (Buckland *et al.*, 2004).

$$N = \sum_{n=1}^{n} \frac{zi}{pi} = \sum_{n=1}^{n} \frac{si}{pi}$$

An estimate of the abundance (N) in transects or study sites of Salt's dik-dik were calculated using the mean herd size (E[s]) alternatively (Buckland *et al.*, 2004).

$$\hat{N} = \sum_{i=1}^{n} \frac{1}{\hat{P}_i} \hat{E}[s].$$

An estimate of the mean herd *E*[*s*] is calculated as:

$$\hat{E}[s] = \frac{\sum_{i=1}^{n} s_i / \hat{P}_a(z_i)}{\sum_{i=1}^{n} 1 / \hat{P}_a(z_i)}$$

The overall abundance of Salt's dik-dik in the surveyed area was calculated as:

$$\hat{N} = \frac{A}{2Lw}\hat{N}_c = \frac{A}{2L}\sum_{i=1}^{n} s_i \cdot \hat{f}(0 \mid \underline{z}_i).$$

Where, *si* =denotes the size of the i^{th} detected herd, *Pa* (x_i) = (f (0)/x_i is the estimated probability of detection for the i^{th} detected herd, *Nc*= total number of herds within the covered strips, A= surveyed area, L= total transect length, w= effective strip width or truncation distance of sighting.

Population density of Salt's dik-dik was calculated based on Thomas *et al.* (2002), Buckland *et al.* (2004) and Strindberg (2012). Variability in the estimated density and abundance of animals across transects, study sites and habitats were attributed from variability in sightings of herds, encounter rates of animals per kilometer, and detection probability. These inherent causes of variability were reduced by stratification of habitats and population herds (Norton-Griffiths, 1978; Strindberg, 2012).

4.2.2 Habitat association

The habitat types of ANP, where Salt's dik-dik was associated, were identified by the preliminary survey, and classified as thickets, bushlands, open bushlands and shrub grasslands. These habitats were described following Kindt *et al*. (2011).

Thicket

Thickets are described as closed stands of bushes which are about 3-7 m tall. These habitats are formed as the bushes are highly interlaced forming a dense cover. This is the case especially during the wet season, in which the habitats were impermeable except along the track lines made previously (Plate 3).

Plate 3. Salt's dik-dik in thicket habitat of ANP during the wet (a) and dry season (b) (Photo by Selamawit Geta, June and Jan. 2018).

The habitats were dominated by woody species such as; *A. senegal, A. seyal, A. tortalis, A. etbacea, A. negri, A. orfota, B. aegyptiaca, B. rotundropha and Dobera glabra.*

During the wet season, shrubs such as *Grewia* species and herbs made the understory cover quiet dense. However, during the dry season, most of the plants shade their leaves, and lack of perennial and annual ground cover made the habitat open and easily accessible. Despite this, this habitat still provides better cover and shade during the hottest periods of the year (Plate 3). Thickets, in the study sites of ANP, are least distributed and found as small patches in bushlands, and their proportion of coverage is highly declining.

Bushland

Bushlands are described as open stands of bushes not exceeding the heights in thicket habitats. The species composition of thickets and bushlands are more or less the same. However, they differed by their extent of openness and denseness (Kindt *et al*., 2011). In bushlands, the tree species that occurred in thickets were dominant with relatively sparse distribution. During the wet season, plant species provide the habitat green ground and canopy cover. However, during the dry season, most trees and shrubs of the habitat shed their leaves and give it an open appearance. Due to differences in moisture content of soil in different sampling sites, or drought adaptive features, green leaves and buds of *A. senegal* were prevent in the middle of the habitat with fully dry and deciduous vegetation appearance (Plate 4). Bushland habitats are the most dominant and evenly distributed habitat types of the study area.

Plate 4. Salt's dik-dik foraging on *A. senegal* in bushland habitat of ANP during the dry season (a) and during the wet season (b) (Photo by Selamawit Geta, Feb. and Aug. 2018).

Open bushland

Open bushland is described as separate habitat type due to the lower proportion of coverage of bushes in the area. The habitat harbors less than 40% of bush. The other features which distinguish it from bushland habitats are the presence of highly degraded and stony ground which makes it unsuitable for grass and herbaceous layers (Plate 5).

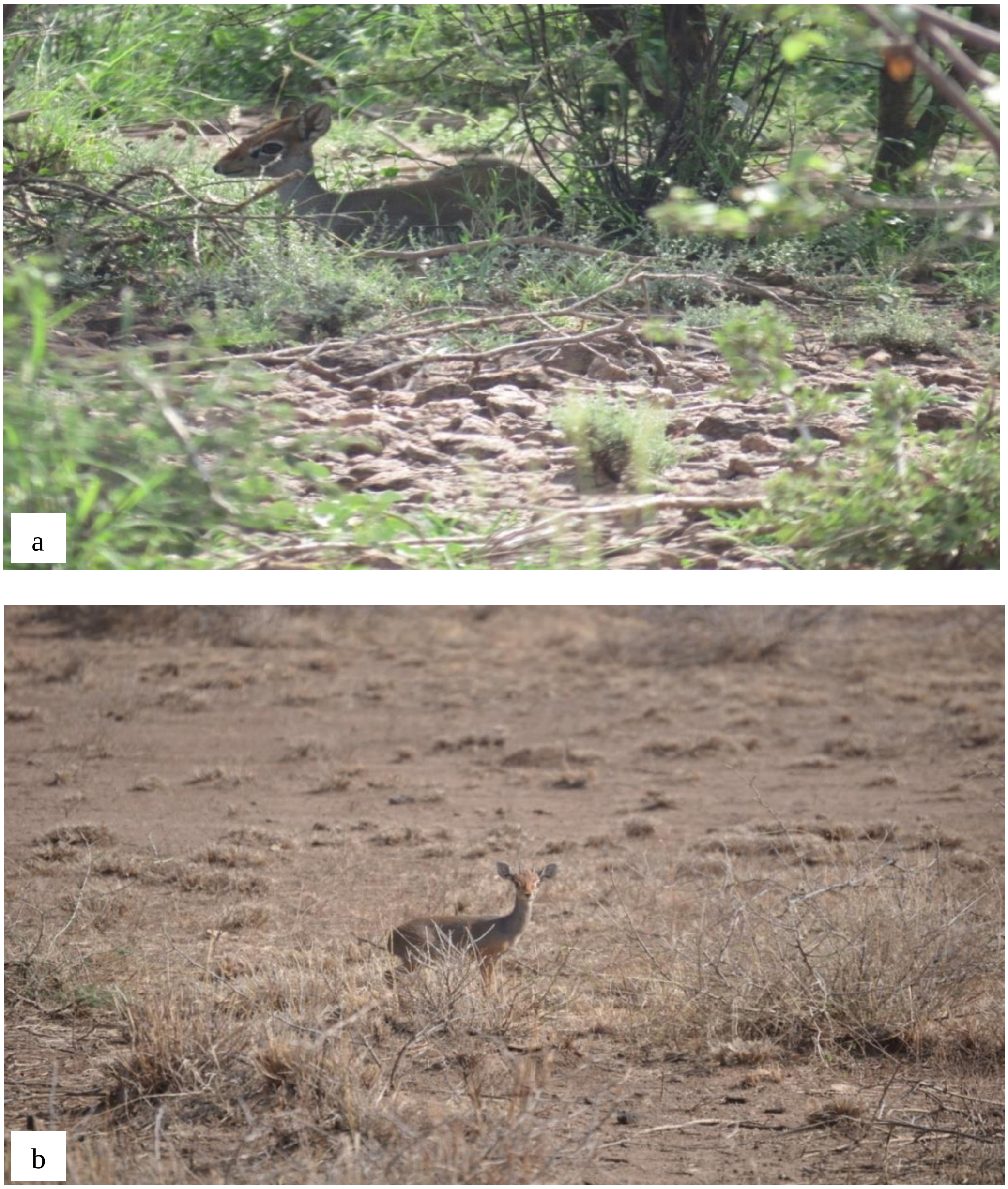

Plate 5. Salt’s dik-dik resting in open bushland habitat of ANP during the wet season (a), in shrub grassland during the dry season (b) (Photo by Selamawit Geta, April 2018).

The habitats had stony grounds supporting tree and shrub species with sparse distribution and minimized growth rate and canopy cover. In the study sites of ANP, open bushlands are frequently occurring habitat types. This may be associated with the rapid habitat degradation leading to degraded and sparsely distributed bush and grass cover with unsuitable ground, leading to further habitat loss.

Shrub grassland

Shrub grasslands are habitats with open or closed appearance of shrubs which grows about 2 m. These habitat types are more open and have sparse distribution of shrubs in grassy habitats. The habitats are dominated by shrub species of *Grewia*, annual and perennial herbs, saplings of *Acacia* species; such as *A. senegal, A. millifera and A. nilotica* as well as *B. aegyptiaca*. During the wet season, the habitat had thick grass and herbaceous cover as well as green and well developed shrubs. However, this condition changes drastically as the dry season emerges, thus the habitat seems highly devoid of green shrubs and appears highly degraded (Plate 5).

Distribution of the animal was studied from the study sites and transects laid for the study of the population size of the animals. The length of transects laid across habitat types range; in thickets (from 0.5 to 1.1 km), in bushland habitats (from 1 to 2.1 km, in open bushland, it ranged between 0.6 to 2 km and in shrub grasslands between 1 and 2 km (Appendices III and IV). Along the already established transects for the study of population size, observation of herds of Salt's dik-dik with description of age and sex classes were recorded. Group size category was considered as "solitary dik-dik", "pair of dik-dik" (mate pair or single adult with young), and "mate pair with young" (Dujardin and Fox, 1997). Identification of adult male and female individuals was based on superficial features like horns and reproductive features. Body dimorphism among the sexes was also used to distinguish adult individuals. Adult males were distinguished from sub-aduls by the size of the horns and skin coloration. Adult females differed from sub-adult females by body coloration and size. Generally, younger individuals have brightly colored skin. Despite this, identification of individuals in a family was an easy task as dik-dik possesses a defined family size and members. In most cases, the features mentioned were used to describe solitary individuals and adults which appear with young.

4.2.3 Activity budget

Study on the diurnal activity budget of Salt's dik-dik was conducted in ANP from June 2018 to August 2019 during the wet and dry seasons. Preliminary observation on the behavior of Salt's dik-dik gave an insight to see variation in the behavioral activity patterns due to the daily ambient temperature. As a result, data collection was made by dividing observation hours into three time blocks as morning (7:00‒10:00 h), mid-day (12:00‒3:00 h) and late afternoon (5:00‒6:00 h). Varation of durations across the time blocks were resulted from shorter cooler hours of the afternoon time block due to the environmental condition of the area. To make the observation manageable, four study sites were randomly selected and focal animals were identified in the sampled area. Sixteen mate pairs (adult male and female) of Salt's dik-dik, four pairs from each study site were used as focal animals for behavioral data collection. Identification of focal monogamous pairs for the study period was attributed to the territorial behavior of dik-dik species occupying the same location year-round (Tilson and Tilson, 1986; Kranz, 1991; Brotherton and Manser, 1997; Dujardin and Fox, 1997; Brotherton *et al*., 1997). The locations for the focal pair were recorded using GPS for successive observations.

The major activities identified for the assessment of the diurnal activity budget of Salt's dik-dik were feeding, walking, ruminating, resting, vigilance and 'other' activities. Activities categorized as "other" include infrequent activities such as; defecation, scratching, salt licking, root digging, alarm calls and scent marking.

Observations of focal animals were made every 5 minute and durations of the major activities were recorded for adult male and female individuals, using continual focal scan sampling method (Altmann, 1974). Mate pairs of Salt's dik-dik from the study sites were observed from a vehicle at an acceptable distance ($\leq$ 30 m) with an aided eye or using binoculars. Besides, observations were easily made from clear viewing points in the study sites where the animals are habituated to human presence. Observation from a vehicle was frequently used in order to have the focal animals for longer time without destructing them, as they are well habituated to vehicles. When the focal pairs move into *Acacia* cover and became out of sight due to their size and habitat features, the observer followed them walking and the activity record continued uninterrupted. However, when the focal animal was more alert and run away, the recoding was switched to other focal pairs in the study site (Ryan and Jordaan, 2005). The duration of each activity was measured using an electronic stopwatch, and video recordings were taken as needed. Totally, 2,088 observations of daily activities of adult male and adult female Salt's dik-dik were made during the wet and dry seasons of the study period. The activities recorded from four mate pairs in the same study area were pooled as single focal observation of study sites separately for each sex and season.

4.2.4 Diet Composition

Diet composition of Salt's dik-dik was studied using direct observation of foraging individuals (Owen-Smith *et al.*, 1983; Kirby *et al.*, 2008). Before conducting the actual feeding duration record, foraged plant species were identified (Holecheck, 1982) both during the wet and dry seasons preliminary survey. The plants were recorded by their vernacular name, and samples were collected and transported to Addis Ababa University herbarium for further identification. Using direct observation, the duration of time spent feeding on each forage plant species was quantified in order to reflect the proportional significance of the species in the diet (Bjugstad *et al.,* 1970; du Toit, 1988). Forage species and forage forms were evaluated for their percentage contribution in the animal's diet through the proportional distribution of times spent for forage species.

The selection of this method for diet analysis of the animal over others was based on different reasons. Firstly, it was reported to be an accurate method for quantifying ingested food for browsing ruminants, than bite count method (Bjugstadt *et al.*, 1970; Owen-Smith, 1979), especially in the wild where counting of bites is difficult (du Toit, 1988). The method was used in different large browsing ruminants with success (Parker *et al*., 2003; Parker and Bernard, 2006; Chinomona *et al*., 2018). Secondly, possibility of identification of forage plants and measuring duration, which was facilitated by the selective browsing habit of the animal from a foraging height (Otieno *et al*., 2019), separately for male and female dik-diks. Furthermore, studies have revealed considerable differences in the feeding ecology of sexually dimorphic species (Bowyer *et al*., 2004; Shannon *et al*., 2006). Therefore, evaluating diet composition for both adult male and females in the wild is possible through direct observation of the foraging behavior of one of the sexually dimorphic species of dik-dik (Owen-Smith, 1988). The need for the study of the diet composition of male and female Salt's dik-dik separately, was facilitated by habituation of the animal for vehicle which allowed observation possible even from a shorter distance with an aided eye (Plate 6). On top of that, observation of feeding behavior of Salt's dik-dik was possible in highly human habituated areas like in localities of campsites. Thus, in the present study, diet composition of the study animal was analyzed entirely based on direct observation technique.

Plate 6. Observation of foraging Salt's dik-dik during the wet season (a) and the dry season (b) (Photo by Selamawit Geta, Aug. 2018 and April 2019).

Four study sites were randomly selected for the assessment of activity budgets of Salt's dik-dik, as well as for observation of dietary composition. Direct observation method was used to evaluate the diet preference of the animal (Leuthold, 1971). Sixteen mate focal pairs were selected for evaluation of the foraging duration of a foraged species per every 5 min. Observations of focal animals were made in the cooler hours of the day; in the morning (7:00–11:00 h) and late afternoon (4:00–6:30 h) for the wet and dry seasons. Records were carried out for feeding duration on each foraged species by the focal animal using stop watch. As it was done for behavioral observation, observations were switched to another mate pairs in the same study site as the previously observed individuals became out of sight. If the plant foraged had not been clearly observed and identified, close observation was made for confirmation from feeding sign at the forage site. The plant species was considered browsed by dik-dik, if freshly removed tissues were evident. The foraging sites were marked by GPS for the analysis of preference and availability of forage species (Watson and Owen-Smith, 2000).

A feeding quadrat survey (du Toit, 1988; Watson and Owen-Smith, 2002) around the feeding station of the animal was carried out to evaluate the availability and acceptability of forage species. In the feeding stations (du Toit, 1988), 320 plots each (1X10 m) 10 m^2 were designed for plant forms of tree and shrub around a 1 m^2 of herbs and graminoids (Greenwood and Robinson, 2006). The plot areas were randomly selected from the locations marked for Salt's dik-dik observed while foraging (Watson and Owen-Smith, 2000). Browsed species identified were considered as available when accessible for the foraging height of the animal (≤1 m) (Otieno *et al*., 2019), and their respective frequency of occurrences were recorded.

Plant species utilized by the animal were categorized into four plant forms which have growth forms of tree, shrub, herbs and graminoids. Accordingly, foraged species having a growth form of tree and shrub were classified as directly browsed species (browse) or consumed as plant litter (leaf litter).

4.2.5 Conservation challenges and opportunities

Before conducting the actual study, field observations were conducted to investigate the interference of local community in the Park. During that time, it was easy to notice, the extent of occupation of land by grazing livestock, interaction of herders with the field officers, clumps of charcoals and fire wood collection and settlement expansion. Conservation challenges and opportunities which emerge from the local community near the Park were identified from the preliminary field observation, discussion with field officials and from secondary data. Data collection from the local community was not possible due to frequently happening instability in and around the Park.

Purposive sampling method was employed to identify 20 field personnel working in ANP. Selection of respondents was based on their involvement in community services, experience in the Park and knowledge about conservation and community roles. The respondents were interviewed about their perspective regarding the conservation challenges the Park is facing, interaction between the local community and the Park workers, contribution of the local community in facilitating conservation activities and the threats that the Park face from the local community and to suggest possible remedial actions (Appendix V). The respondents were provided with open and close ended interview, and it was proceeded individually to avoid biasness and manipulation of the information.

4.3 Data analysis

Estimates of the population abundance and density as well habitat association of Salt's dik-dik were analyzed following the methods of Buckland *et al*. (2004), Thomas *et al*. (2007) and Thomas *et al*. (2010). Conventional distance sampling software (Distance version 6.0 Release 2) and SPSS version 24, software for social sciences were used for data analysis. Mean (M±SE) density and abundance per transects, study sites and habitats for each seasons were described. Confidence intervals and coefficient of variations were used to measure precision and variability of population density and abundance. One way ANOVA was carried out to evaluate the variances between the mean population sizes of the animal among sampling sites and habitats for each season (Jha *et al.,* 2011). After one way ANOVA, Tukey test was used for multiple comparisons of the population sizes recorded per study sites as well per habitat types. Population abundance and density between seasons, per study site and habitats type were computed using one way ANOVA.

Mean number of sightings, herd sizes and encounter rates across the study sites and habitat types were analyzed using one way ANOVA, and other Kruskal-Wallis H Test. Varience analysis between the wet and dry season population size was carried out using one way ANOVA and Chi–square tests ($\chi 2$). Comparison between the different age and sex categories were computed using Mann–Whitney U test and Wilcoxon W tests. Comparison between the wet and dry season population proportions of occurrence of the age and sex categories were analyzed using Chi–square tests ($\chi 2$) (Buckland *et al*., 1993; Thomas *et al*., 2007).

Using the activity budget data, the mean time (Mean±SE) spent by Salt's dik-dik for the six major activities were computed for the three time blocks separately per sex and season (Shannon *et al.,* 2008). Variations in the mean time budget allocated for each activity per time block were analyzed using one–way ANOVA and Kruskal–Wallis H test. Evaluation of the mean duration engaged for each activity across seasons per time blocks was performed. Analyses were used for multiple comparisons of mean time spent for each behavioral activity and identified the differences that existed in the diurnal time budget among the six behavioral activities. Seasonal influences on the time budget allocated for the behavioral activities by Salt's dik-dik were analyzed using Chi–square test. Evaluation of the time budget found for each activity between the sexes was carried out. Non-parametric tests were used for comparison of the proportion of time budget found for each activity separately for sexes across seasons. Comparisons of the activity budgets for each activity between sexes were computed using one way ANOVA. The time budget found for each activity per sex was used to calculate the proportion of time spent on each activity on daily as well as seasonal bases (Neuhaus and Ruckstuhl, 2002; Neuhaus and Ruckstuhl, 2009). Positive or negative correlations between the major behavioral activities of Salt's dik-dik were performed using Spearman's Correlation.

Total time of foraging on a particular plant species across the study sites were pooled separately for sex and season. The mean time spent per day for foraging on a particular species was computed for adult male and female Salt's dik-dik for wet and dry seasons to find the proportion of foraging time distribution. Therefore, the contributions of foraged species and plant forms that accounted for the diet of Salt's dik-dik were calculated as:

$$ps_i=(t_i/t)x100$$

Where ps_i is the proportion of contribution of species or plant form, t_i is time spent while foraging on species *i* or forage form *i* and *t* is the total observation time for each of the wet and dry seasons observation (Pienaar, 2013).

Availability of forage species of Salt's dik-dik was computed as the ratio of the total number of feeding quadrats where a species was recorded to the total number of feeding quadrats surveyed across seasons (Tomlinson, 1980; Magome *et al*., 2008; Hensman *et al*., 2012). Acceptability of forage species was computed as the ratio of the number of quadrats in which a species was consumed to the total number of quadrats in which the species was available (Owen-Smith and Cooper, 1987; Magome *et al*., 2008; Venter and Watson, 2008). Acceptability of forage species was categorized as low (0.0 – 0.29), moderate (0.3 – 0.49) and high (> 0.5) (Macandza *et al*., 2004; Pinnar, 2013).

Mean duration (Mean±SE) spent foraging on a particular forage species per day was used to analyze the proportion of dietary contribution to the animal separately for male and female Salt's dik-dik across seasons. Proportion of the foraging time distribution among the foraging species was computed using Kruskal–Wallis test. Representations of forage species in the growth forms and plant categories were computed using one way ANOVA and Chi–square tests. The proportions of foraging time distribution for each plant species between male and female Salt's dik-dik were computed using Chi–square test. Seasonal influences on the proportion of dietary contributions of the principal forage plants were analyzed using Kruskal–Wallis test. Mean seasonal availability and acceptability of the forage plants of Salt's dik-dik were computed. Percentage contributions of each forage plant to the diet of the animal were analyzed using Chi–square test.

Mean scores (Mean±SE) were computed and the Relative Threat Factor Severity Index (RTFSI) were analyzed for each factor identified as opportunity, or challenge of conservation. The remedial methods used so far were computed using Mean scores (Mean±SE) given by respondents. Kruskal–Wallis test was used for ordering of the mean scores and, percentages of threat categories were analyzed using Chi–square test.

5. RESULTS

5.1 Population estimate

During the wet and dry seasons 2±0.13 and 2.89±0.2 mean populations of Salt's dik-dik per transects, were recorded. The population records were significantly higher during the dry season than the wet season ($F_{1, 158}$ = 13.4, P=0.007). The highest record per transect was found from Geda (4.6±0.69) followed by Gotu (3.5±0.27) sampling sites during the dry season, while the lowest record was from Gimel Bet (1.4±0.34). Thus, the mean population of Salt's dik-dik recorded from transects significantly varied ($F_{7, 72}$= 4.4, P=0.001). Similarly, during the wet season, the highest mean population record (3±0.37) was found from Geda followed by Gotu (2.3±0.37), while the lowest mean population per transect was from Gimel Bet (1.1±0.35). As a result, statistically varied population sizes of Salt's dik-dik were recorded from transects of the sampling sites ($F_{7, 72}$ = 3.35, P= 0.002) (Appendix VI).

Sightings of herds were 108 and 119 during the wet and dry seasons, respectively. It was not influenced by seasonal attributes ($\chi 2$ =9.6, df = 1, P =0.055). The highest MER was found from Intensive conservation zone (2.12±0.35), while the lowest was observed in Limited resource use area (1.38±0.35). Thus, significantly different encounter rates were found across the study sites during the wet season ($F_{2, 72}$ = 2.43, P=0.032). During the dry season, the highest and lowest MERs were recorded from Intensive conservation and Limited resource use zones of the study area. Thus, it was varied significantly among the study sites ($F_{2, 72}$ = 5.46, P=0.041). Besides, significantly higher MER was noticed during the dry season (2.4±0.15) than wet season observation (1.78±0.13) ($F_{1, 158}$ = 9.6, P= 0.023) (Table 2).

Table 2. Population sighting, mean encounter rate per km (MER±SE), Mean probability of detection (MDP±SE) and mean observed herd size (MOHS±SE) of Salt's dik-dik in the study sites.

Study site	Season	Sighting	MER±SE	MDP±SE	MOHS±SE
Core conservation area	W	41	1.76±0.33	0.49±0.06	1.44±0.16
	D	46	2.52±0.37	0.58±0.06	2.04±0.26
Intensive conservation zone	W	46	2.12±0.35	0.63±0.06	1.47±0.17
	D	49	2.84±0.38	0.65±0.04	1.97±0.19
Limited resource use area	W	35	1.38±0.35	0.55±0.08	1.24±0.11
	D	39	1.59±0.39	0.5±0.07	1.54±0.17
Total	W	108	1.78±0.13	0.5±0.02	1.4±0.06
	D	119	2.4±0.15	0.59±0.02	1.91±0.07

During the wet season, the highest mean detection probability (MDP) was recorded, 0.63±0.06 from Intensive conservation area, while the lowest (0.49±0.06) from Core zone. During the dry season, the highest MDP of dik-dik was found from Intensive conservation sites (0.65±0.04), while the lowest (0.38±0.07) from buffer zone (0.5±0.07). ANOVA revealed insgnificantly varied MDP both during the dry ($F_{2, 116}$ = 2.5, P=0.140) and wet seasons ($F_{2, 106}$ = 1.94, P= 0.320). Similarly, detection probabilities were insignificantly varied between the wet and dry seasons ($F_{1, 243} = 1.23$, P=0.268).

During the wet season, MOHS was 1.4±0.06. The highest MOHS (1.47±0.17) was found from Intensive conservation zone of the study area while, the lowest (1.24±0.11) was recorded from Limited resource use zone. However, comparison among the study sites revealed insignificant variation ($F_{2, 100} = 1.22$, P = 0.182).

Herd sizes of the animal recorded during the dry season was 1.91±0.07. The highest MOHS was 2.04±0.26 and recorded from Core conservation area, while the lowest herd size record was 1.54±0.17, found from buffer zone. Thus, ANOVA revealed statistical significant across the sampling sites during the dry season ($F_{2, 116} = 2.69$, P = 0.007). Besides, significantly different herd sizes were found between seasons ($F_{1, 230} = 30.6$, P 0.019).

The recorded herd sizes of the animal ranged between 1 and 5, but the commonly observed group sizes were “solitary dik-dik” (single adult or sub-adult individuals), “a family of two dik-dik” (mate pairs or single adult with young), and “pair with young” (mate pair with juvenile) (Fig. 6).

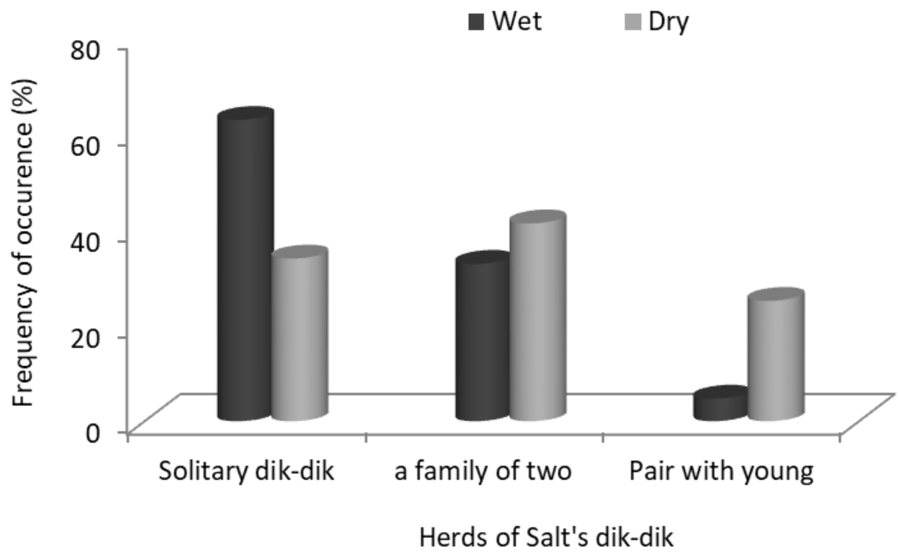

Figure 6. Percentage frequency occurrences of the different herds of Salt’s dik-dik during the wet and dry seasons.

During the dry season, the most frequent herd size was a family of dik-dik containing two individuals (41.1%). The percentage frequency of occurrence of “solitary adult or sub-adult” was 33.8%. Herds of dik-dik, occupying mate pairs with young accouted for 25% of the observation. The percentage occurrences were not statistically different ($\chi 2$ =4.9, df = 2, P=0.066). However, during the wet season, solitary dik-diks indicated the highest frequency of occurence. Percentage frequency of occurrence of solitary individuals was 62.6%, family size with two individuals was 32.7% and mate pairs with young were 4.7%. Consequently, proportions of the three family sizes in the population during the wet season revealed significant variation ($\chi 2$ =55.2, df = 2, P =0.039).

Population densities of Salt’s dik-dik recorded during the wet season across the sampling sites ranged between 17.7 to 45.6/km^2 with mean values of 28.4/km^2. During the dry season, a range of densities between 23.7 and 53.5/km^2 were recorded (Appendix VII). Overall, significantly higher population size of the animal was estimated during the dry season than the wet season ($F_{1, 159}$= 5.95, P =0.048).

Intensive conservation area revealed the highest density of the animal during the wet season (37.5±3.4). Density recorded from Core conservation zone showed 32.4/km^2 and 45.1/km^2 during the wet and dry seasons, respectivly. However, it was insignificantly varied among the sampling sites recognized under this zone during the wet ($F_{2, 33}$ = 0.3, P = 0.241) and dry season ($F_{2, 36}$= 5.1, P=0.057). However, between seasons, signifcantly varied population densities were found ($F_{1, 72}$=4.2, P=0.002). The lowest density of the animal was found from buffer zone. Comparison among the study sites indicated significant variation both during the wet ($F_{2, 96}$= 7.9, P=0.043) and dry season ($F_{2, 96}$= 4.17, P=0.012) (Fig. 7).

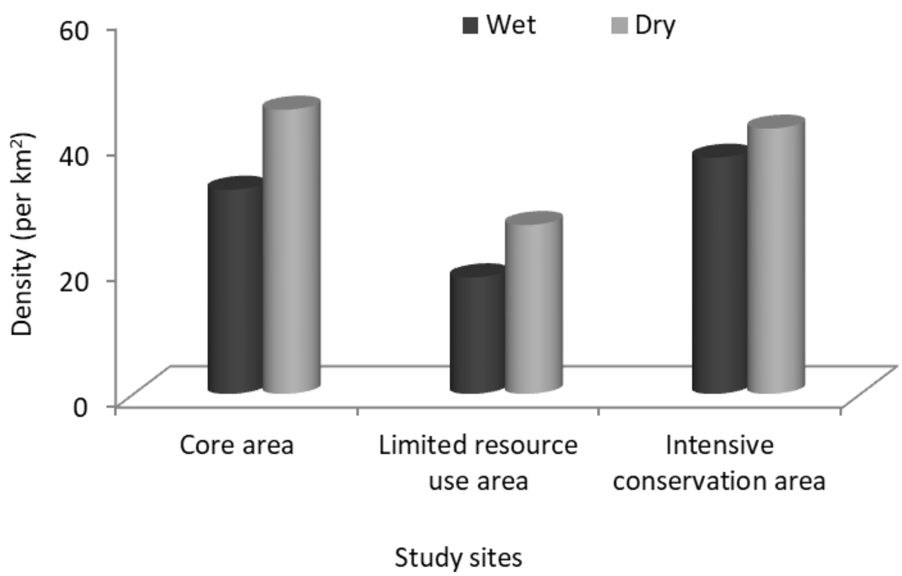

Figure 7. Comparison of the population density estimates of Salt's dik-dik from the three sampling site categories during the wet and dry seasons.

Core conservation zone harbored 41.8% (232) of the estimated population of the animal during the wet and, 45.9% (331) during the dry season. Variation between seasons was significant ($\chi 2$=10.4, df = 1, P=0.01). Besides this, this site harbored the highest population of the animal during the wet ($\chi 2$= 18.1, df = 2, P=0.0023) and dry seasons ($\chi 2$=21.4, df=2, P=0.001). Intensive conservation area harbored 33.7% (184) of the population recorded during the wet and 28.5% (207) during the dry season (Fig. 8). Thus, insignificantly varied population sizes across seasons were remarked ($\chi 2$=0.8, df=1, P=0.160).

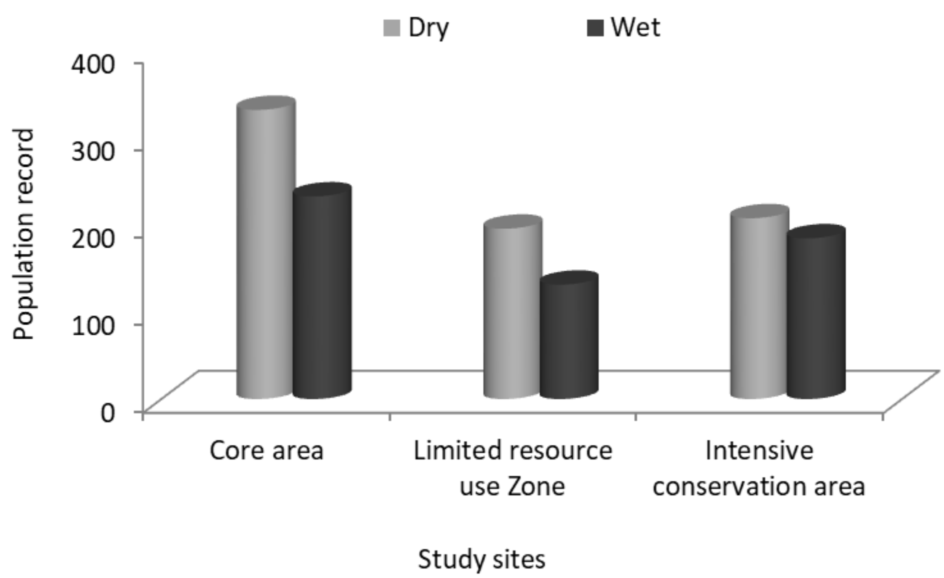

Figure 8. Population abundance estimates of Salt's dik-dik from the three sampling site categories of the surveyed region of ANP during the wet and dry seasons.

Limited resource use zone harbored 24.6% (131) and 26.8% (195) of the population size recorded from the surveyed area during the wet and dry seasons, respectively. Population abundance of the animal was significantly higher during the dry season than the wet season ($\chi 2$=12.8, df=1, P=0.001).

During the dry season population survey, 72 and 81 adult male dik-diks were recorded (Fig. 9). Adult females, during the wet and dry seasons were recorded as 49 and 82, respectively. Seasonal impact was observed on the detection of females ($\chi2$ =5.02, df = 1, P = 0.0227). Compared to adults, numbers of sub-adults or juveniles were lower. Unlike the significant difference observed for adult females, number of sub-adult males indicated insignificant varation between the wet and dry season ($\chi2$ =0.76, df = 1, P=0.877). Proportion of sub-adult females in the population was indicated insignificant variation across the wet and dry seasons ($\chi2$ =5.55, df = 1, P=0.05). Contrary to this, the dry season record for juveniles was significantly higher than that of the wet season ($\chi2$ =7.3, df = 1, P= 0.014).

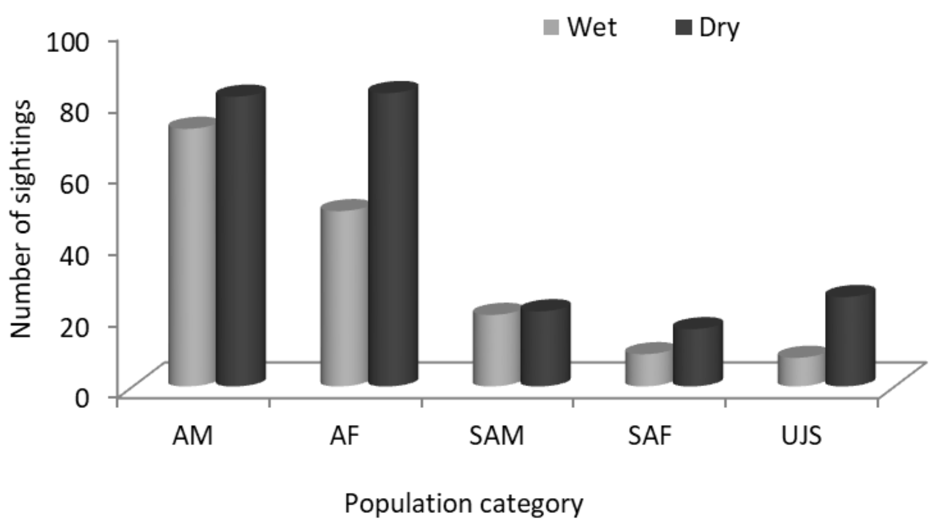

Figure 9. Comparison of the population categories of Salt's dik-dik during the wet and dry season survey (AM= adult male, AF= Adult female, SAM= sub-adult male, SAF= sub-adult female, UJE= unidentified juvenile sex).

Multiple comparisons among the population categories revealed significantly higher adult male size over the remaining age and sex categories, during the wet season ($\chi2$

=29.4, df = 4, P=0.0001). Comparison between number of adult male and females indicated significantly higher number of males than females (U=13, P=0.05). Similarly, Mann-Whitney test supported the statistical difference between adult female and sub-adult male representation in the population (U=7.5, P = 0.05). Comparison between adult female and sub-adult females during the wet season was significantly different (U=1.5, P =0.001). Likewise, adult female and juvenile sizes were statistically different (U=1.5, P =0.001). Besides this, sub-adult males were significantly higher than sub-adult females (U=10.5, P =0.01) and juveniles (U=12, P =0.05).

Similarly, during the dry season, comparison among the age and sex categories revealed significant variation ($\chi2$ =28.2, df = 4, P=0.001), though only adult male and female were insignificantly different. In line with this, statistically varied number of adult and sub-adult females (Wilcoxon W= 36, P=0.001) were observed. Comparison between adult female and unidentified juvenile sex, during the dry season, revealed significant variation (Wilcoxon W= 37.5, P = 0.001).

Percentage contributions indicated; adult male = 39.13% (153), adult female = 33.5% (131), sub-adult male = 10 % (41), sub-adult female = 6.4% (25) and juvenile =8.4% (33). Consequently, the percentage occurence of the different age and sex classes in the population recorded from the surveyed region of the study area revealed significant difference ($\chi2$ =53.7, df = 4, P = 0.001) (Fig. 10).

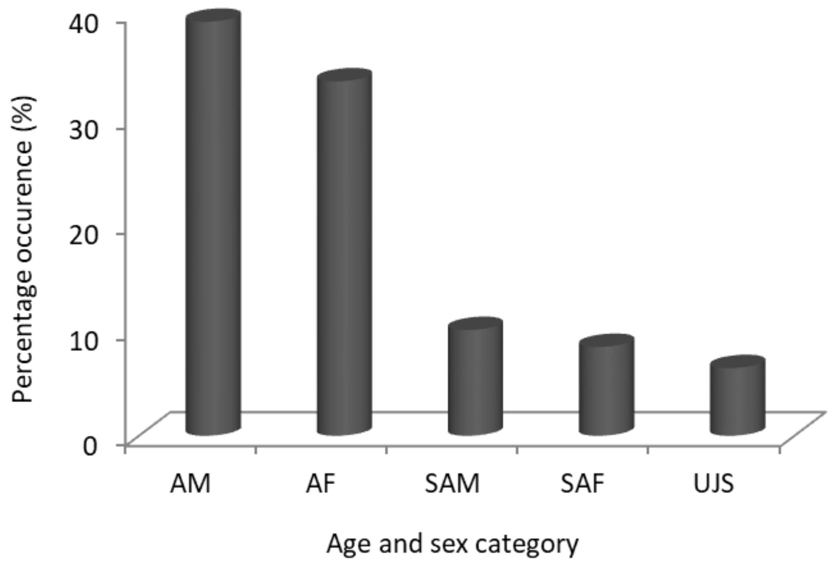

Figure 10. Percentage contributions of age and sex categories of Salt's dik-dik in the surveyed sites of the study area.

5.2 Habitat association

High population size of the animal was recorded in bushlands both during the wet and dry seasons, while lowest record was found from shrub grasslands. Thickets supported 18.75% (30) and 20.78% (48) of the animal recorded during the wet and dry seasons, respectively. Bushlands supported 36.2% (58) and 40.25% (93) during the wet and dry seasons, respectively. A total of 45 (28.1%) dik-diks during the wet season and 54 (23.4%) during the dry season were observed in open bushland habitats. Shrub grassland was found to support the lowest population record during both seasons. It harbored 16.8% (27) and 15.6% (36) of the observed population during the wet and dry seasons, respectively (Fig. 11).

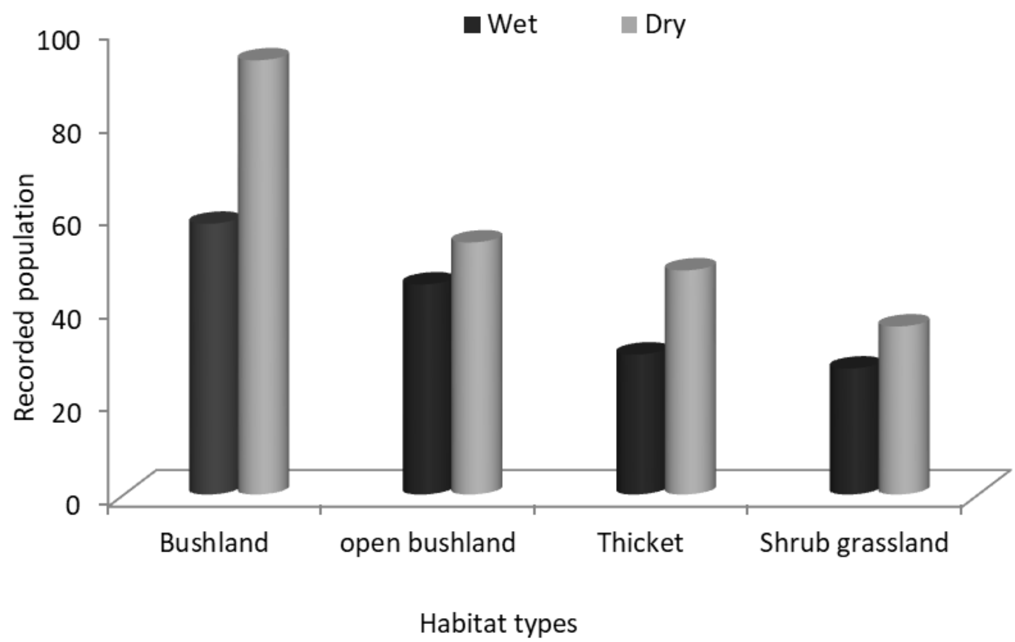

Figure 11. Population record of Salt's dik-dik from the habitats associated during the wet and dry seasons.

In thickets ($F_{1, 18}$ = 5.1, P=0.05) and bushlands ($F_{1, 19}$ = 6.3, P=0.05), significantly varied population record between the wet and dry season were observed. However, seasonal influence on the population record of Salt's dik-dik was not evident for both open bushlands ($F_{1, 14}$ = 0.9, P=0.446) and shrub grassland ($F_{1, 12}$ = 0.76, P=0.392).

On annual basis, the patterns of distribution of the animal in the four habitat types were in a descending order from bushland to open bushlands then thickets and lastly shrub grasslands. Bushlands harbored 38.6%, open bushland = 25.3%, thicket = 19.94% and shrub grassland=16.1% of the population of Salt's dik-dik recorded from the sampling sites of the study area. Significantly varied distribution of the animals among the four habitat types were observed ($\chi2$ =15.3, df = 3, P=0.004).

The highest sightings of the animal were recorded in thicket habitat during the wet (20; %CV=25.5) and dry (25; %CV=34) seasons. However, it was insignificantly varied between seasons ($F_{1,\ 12}$ = 0.4, P =0.651). The lowest sightings were recorded in shrub grassland habitats during the wet (18; %CV=31.5) and dry (20; %CV=37.2) seasons. Comparison among the different habitats revealed insignificant varation during the dry ($\chi2$ =3.86, df = 3, P = 0.442) and wet seasons ($\chi2$ =7.3, df = 3, P = 0.129).

Table 3. Salt's dik-dik population sightings, encounter rates (ER/km), Mean detection probability (MDP) and mean observed herd size (MOHS±SE) from the habitat types during the wet and dry seasons (W= wet, D= dry).

Habitat	Season	Sighting	%CV	ER/KM	%CV	MDP	%CV	MOHS±SE	%CV
Thicket	W	20	25.5	2.32	27.3	0.44	39.2	1.4±0.1	35.7
	D	25	34	3.62	21.8	0.66	40.32	2.12±0.15	34.2
Bushland	W	35	22.6	1.8	23.3	0.5	50	1.47±0.1	40.8
	D	41	32	2.5	32.9	0.55	52.1	2.23±0.1	33.7
Open Bushland	W	30	26.2	1.7	39.8	0.5	48.4	1.27±0.1	49.3
	D	31	22.3	2	25.6	0.6	45.8	1.63±0.13	46
Shrub grassland	W	18	31.5	1.27	40.3	0.55	45.2	1.33±0.15	40.8
	D	21	37.2	1.67	20.5	0.52	49.1	1.5±0.1	34

High MERs of the animal were found from thickets both during the wet (2.32/km) and dry (3.62/km) seasons. It was significantly higher during the dry season than the wet season ($F_{1, 27}$ =5.13, P =0.008). However, the lowest encounter of the animal was recorded in shrub grasslands, during the wet (1.27/km) and dry (1.67/km) season. However, seasonal influence on MER of the animal was not observed in shrub grassland habitats of the study sites ($F_{1, 28}$ = 1.4, P =0.138).

Comparisons of MER among the different habitat types of the study area revealed significant varation for the wet season ($\chi2$ =6.4, df = 3, P=0.0145) and dry season ($\chi2$ =16.5, df = 3, P=0.008). Insignificantly varied MERs were observed between thickets and bushlands during the dry season ($\chi2$ =1.86, df=1, P=0.172). However, comparison of MER among bushlands, open bushlands and shrub grasslands were significantly different ($\chi2$ =11.54, df = 2, P=0.003).

High detection probability of the animal was recorded from shrub grassland (0.55), while low in thickets (0.44) during the wet season. During the dry season, the highest MDP (0.66) was found from thickets, while the lowest (0.52) from shrub grassland. Comparison among the different habitats of the study area showed insignificant difference both during the dry ($\chi2$ =5.2, df = 3, P=0.127) and wet seasons ($\chi2$ =1.3, df = 3, P = 0.064).

During the wet season, the highest herd size was recorded in bushlands (1.47±0.1 with %CV=40.8) followed by thickets (1.4±0.1 with %CV= 35.7). The lowest MOHS was observed in open bushlands (1.27±0.1 with %CV= 49.3). However, herd sizes of the animal observed among the habitats during the wet season were insignificantly different ($\chi2$ =3.52, df = 3, P=0.319).

Bushlands indicated the highest herd size of the animal during the dry season. However, thicket and bushlands showed insignificantly varied group sizes ($\chi2$ =0.4, df = 1, P=0.515). Besides, comparison among thickets, bushlands and open bushlands revealed significant difference ($\chi2$ =11.6, df = 2, P=0.0001). However, open bushlands and shrub grasslands supported insignificantly varied MOHS ($\chi2$ =0.1, df = 1, P=0.739).

Comparison of MOHS of the animal in different habitats across seasons indicated significant difference for thicket ($F_{1,\ 43}$ = 14.2, P=0.0001), bushland ($F_{1,\ 79}$ = 24.7, P=0.0001) and open bushland ($F_{1,\ 63}$ = 4.23, P=0.044) habitats. Contrary to this, herd sizes of the animal were not influenced by season in shrub grasslands ($F_{1,\ 39}$ = 0.03, P =0.869).

The overall population abundance estimates of Salt's dik-dik for the surveyed region of the study area were 555 and 723 during the wet and dry seasons, respectively (Fig. 12). During the wet season, population abundance ranged between 82 and 221 across the four habitats. The lowest and highest population sizes of the animal during the wet season were found from shrub grassland and bushlands, respectively. Comparison of the population sizes of the animal across habitats revealed statistical difference ($\chi2$ =27.3, df = 3, P = 0.001).

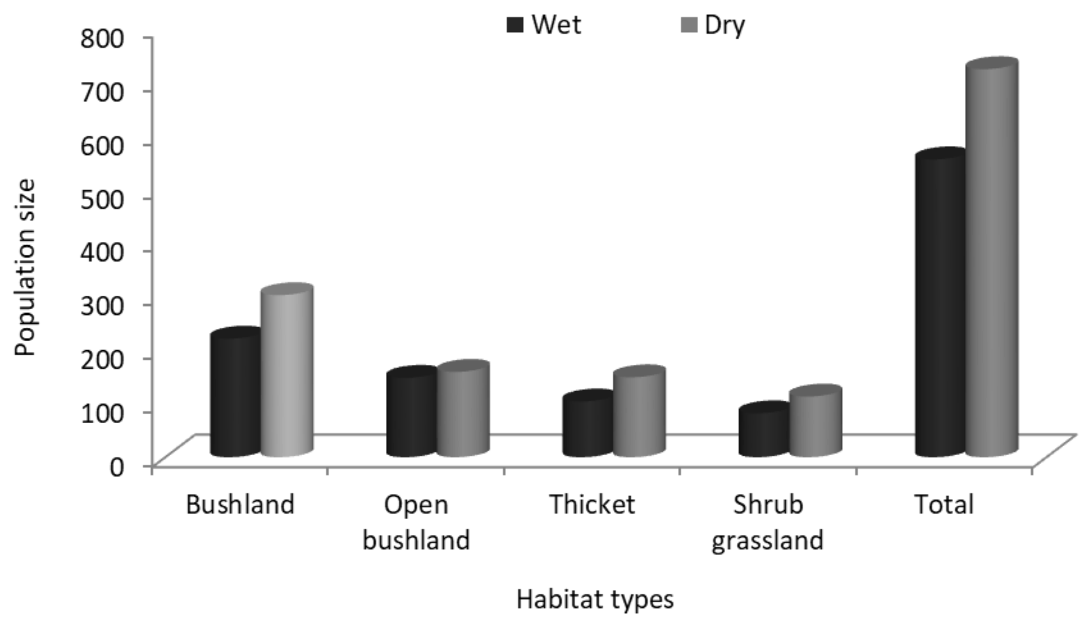

Figure 12. Comparison of the estimated population abundance of Salt's dik-dik per habitat types in the surveyed area during the wet and dry seasons.

Statistically different population sizes between bushland and thickets were recorded ($\chi2$ =12.84, df = 1, P = 0.022). Bushlands revealed higher abundance than open bushlands or shrub grasslands ($\chi2$ =20.3, df=2, P = 0.003). Similarly, shrub grassland and open bushland habitats of the study area showed statistically varied population sizes ($\chi2$ =10.2, df = 1, P = 0.05).

Population abundance during the dry season ranged between 113 and 302 among the different habitats. The maximum and minimum population sizes of the animal were recorded in bushland and shrub grassland habitats, respectively. Thus, significant varation was noted across the habitats ($\chi2$ =25.1, df = 3, P = 0.005). Comparison among thickets, open bushes, and shrub grasslands revealed statistically different population estimates ($\chi2$ =2, df= 2, P = 0.07). Similarly, during the dry season, open bushland habitats harbored significantly higher population than shrub grasslands ($\chi2$ =9.4, df= 1, P = 0.032).

Comparison of the population abundance per habitats between the wet and dry seasons revealed significant difference; thicket (Man–Whitney U = 0, P=0.001), bushlands (Man–Whitney U = 1, P = 0.05), open bushlands (Man–Whitney U = 9.5, P = 0.05) and shrub grasslands (Man–Whitney U = 1.5, P=0.05).

Thickets harboured the highest density of Salt's dik-dik both during the wet and dry seasons. It was estimated as 36.74/km^2 during the wet and 53.1/km^2 during the dry season. The lowest density of the animal was recorded from shrub grasslands both during the wet (18.74/km^2) and dry (25/km^2) seasons (Table 4).

Table 4. Density estimates of Salt's dik-dik in different habitats of the study area during the wet and dry seasons (W=Wet, D=Dry).

			95% CI		
			Lower	Upper	
Habitat	Season	Density/km^2	Bound	Bound	%CV
Thicket	W	36.74	23	50.5	46.6
	D	52.1	43.1	61	31.7
Bushland	W	32.6	25.6	39.6	38.6
	D	44.2	35.5	52.8	43.1
Open Bushland	W	24.2	16.6	31.8	40.6
	D	28	20.1	35.84	39
Shrub grassland	W	18.74	11.9	25.6	34.4
	D	25	16.5	33.6	37.1

Comparison of density of the animal among the different habitats showed variation both during the wet ($\chi2$ =3.2, df = 3, P=0.028) and dry seasons ($\chi2$ =21.9, df = 3, P=0.001). During the wet season, comparison of densities of the animal among bushlands, open bushland and shrub grasslands revealed significant difference ($\chi2$ =5.8, df =2, P = 0.05). However, open bushlands and shrub grasslands indicated insignificantly different density estimates ($\chi2$ =0.52, df = 1, P=0.47).

Bushlands were found to support insignificantly varied population sizes ($\chi2$ =1.82, df = 1, P=0.172) as thickets during the dry season. Despite this, densities among bushlands, open bushlands and shrub grasslands were significantly different ($\chi2$ =11.54, df =2, P=

0.003). Bushlands revealed significantly higher population sizes than open bushlands ($\chi2$ =7.86, df =1, P=0.005). However, open bushland and shrub grassland habitats harbored insignificantly varied population sizes of the animal ($\chi2$ =0.1, df = 1, P=0.740).

5.3 Activity budget

Foraging was found to be the most dominant activity of Salt's dik-dik during the morning and late afternoon time blocks (Fig. 13). During the dry season, mean durations of this activity were 3.18±0.15 (morning) and 2.95±0.2 minutes (late afternoon). Contrary to this, during the mid-days, it was the lowest with mean duration of 0.12±0.07 minutes. Adult females engage in diurnal foraging for significantly different durations across the time blocks ($F_{2, 165}$=413.9, P= 0.0001).

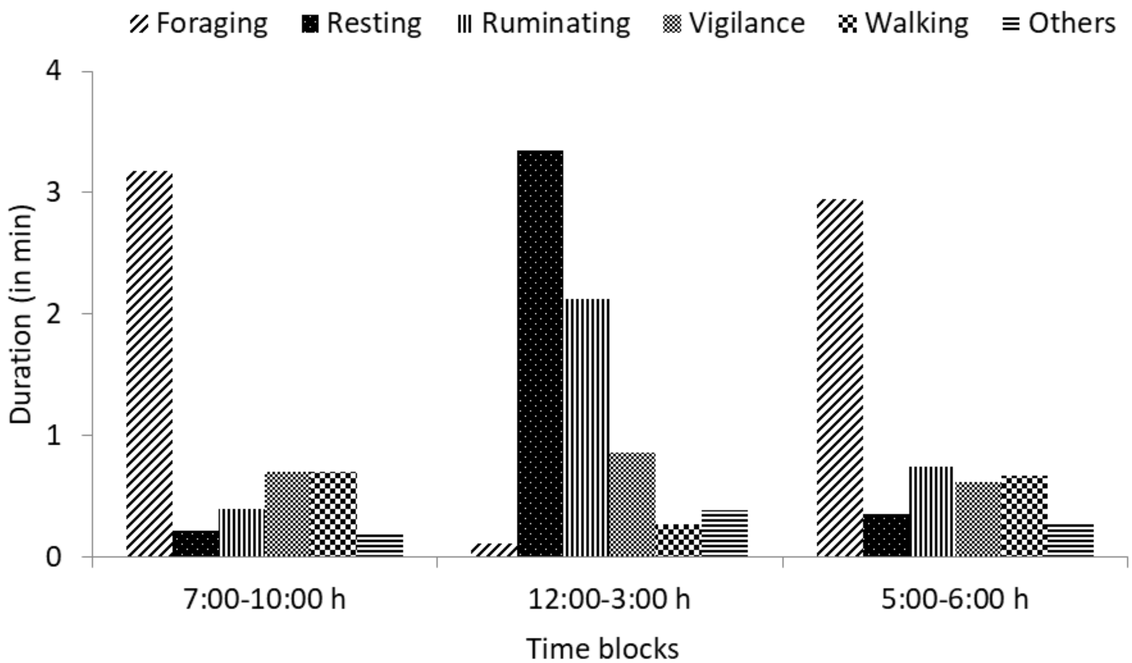

Figure 13. Activity budget of adult female Salt's dik-dik across the three time blocks during the dry season (7:00-10:00 h= morning, 12:00-3:00 h= mid-day and 5:00-6:00 h = late afternoon time blocks).

During the wet season, the mean durations engaged were 2.65±0.18, 1.17±0.23 and 3.05±0.2 minutes, during the morning, mid-day and late afternoon time blocks respectively. Thus, significant variations across the time blocks were observed ($F_{2, 165}$=86.1, P=0.0001). However, impact of season was insignificant on duration of foraging ($\chi 2$=0.44, df = 1, P=0.747).

Vigilance reached its peak in the mid-day hours during both the wet and dry seasons. Mean durations during the mid-days were 0.75±0.11 and 0.86±0.11 minutes during the dry and wet seasons, respectively. The time spent for this behavioral activity was significantly different across time blocks both during the wet ($F_{2, 165}$ =7.29, P = 0.001).

and dry seasons ($F_{2,\ 165}$ =24.7, P = 0.001). Besides this, mean durations spent for this activity were insignificantly varied between seasons ($F_{1,\ 104}$=2.36, P=0.005).

Walking was generally found to be high in the cooler hours of the day. Mean durations spent for this activity during the dry season across the three time blocks were 0.7±0.07 minutes (morning), 0.27±0.09 minutes (mid-day) and 0.67±0.09 minutes (late afternoon). Accordingly, significantly varied durations were noted across the time blocks ($F_{2,\ 165}$ = 29.37, P=0.0001). During the wet season, dik-diks engaged for considerable duration in walking during the mid-days. However, varations in mean durations across the time blocks were significant ($F_{2,\ 165}$= 8.7, P=0.0129). Between seasons, insignificantly varied durations were recorded ($F_{1,\ 334}$= 0.14, P= 0.254).

Dik-diks were engaged in resting mainly during the mid-days. Thus, during the dry season, significantly higher duration (3.35±0.2 minutes) was observed during this time block than the morning and late afternoon. The peak of resting activity in mid-days during the dry ($F_{2,\ 165}$= 104, P = 0.0001) and wet ($F_{2,\ 165}$= 102, P= 0.0001) seasons were statistically significant. However, diurnal resting was not influenced by seasonal attributes of the study area ($F_{1,\ 335}$ = 0.06, P=0.806).

Rumination is among the major behavioral activities which scale up with the daily ambient temperature, while the animal was inactive during mid-days. Thus, high duration for ruminating activity (2.13±0.14 and 1.6±0.15 minutes) were recorded in the mid-days during the dry and wet seasons, respectively. However, the lowest (0.4±0.07

minute) duration was recorded during the morning time blocks during the wet season. In line with this, significantly varied durations were recorded across the time blocks during the wet ($F_{2, 164}$ = 595.3, P = 0.0001) and dry seasons ($F_{2, 164}$ = 89.4, P = 0.0001). However, seasonal influence was insignificant on rumination ($F_{1, 165}$ = 0.6, P = 0.435).

During the wet season, mean time spent for ‘other activities’ during the three time blocks were insignificantly varied ($F_{2, 165}$ = 0.24, P = 0.786). However, during the dry season, significantly higher duration was recorded during the mid-days ($F_{2, 165}$ = 8.7, P = 0.05). These activities required insignificantly varied durations between the wet and dry seasons ($F_{1, 335}$ = 1.23, P = 0.268).

Adult females were engaged in foraging for 36.7% of the diurnal activity budget during the dry season and 32.9% during the wet season (Fig. 14). It was the dominant activity both during the wet ($\chi2$= 15.3, df = 5, P=0.001) and dry seasons ($\chi2$= 16.8, df = 5, P=0.005) over the remaining major behavioral activities. Following this, resting was the second activity which required 31.6% of the diurnal activity time budget during the dry season. Consequently, it required significantly higher duration over the remaining four activities ($\chi2$= 13.6, df = 4, P=0.004). During the wet season, this activity required 21.1% of the diurnal time budget. However, it was insignificantly varied to ruminating, vigilance and walking ($\chi2$= 6.6, df = 3, P=0.254), while significantly higher than ‘other activities’ ($\chi2$= 11.3, df = 4, P=0.031).

Rumination required 23.2% and 20.4% of the diurnal activity budget during the dry and wet seasons, respectively. It was insignificantly varied from walking, resting and vigilance during the wet season, though significantly varied during the dry season ($\chi2$ = 5.9, df = 2, P=0.05). Vigilance accounted for 15.5% during the dry season and 17.3% during the wet season. Significantly higher proportion of time was used for vigilance over the remaining two activities during the dry ($\chi2$ = 6.5, df = 2, P = 0.002) and wet season ($\chi2$= 7.2, df = 2, P=0.05). Following vigilance, adult females allocated 10.2% and 12.1% of the diurnal time for walking during the dry and wet seasons, respectively. The lowest proportion was observed for 'other activities' (6% = during the dry season and, 6.4%= during the wet season). Therefore, compared to walking, significantly lower activity budget was noticed during the wet ($\chi2$= 3.85, df = 1, P=0.05) and dry season ($\chi2$= 3.7, df = 1, P=0.0088).

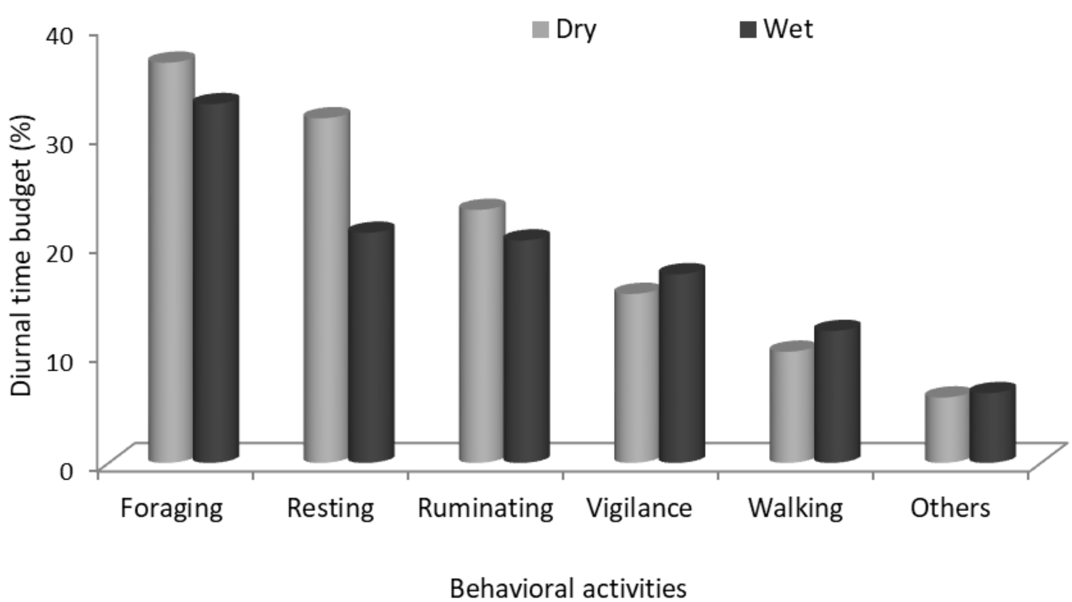

Figure 14. Activity budget for the major diurnal activities by adult female Salt's dik-dik during the wet and dry seasons.

Behavioral data of the major activities of adult male Salt's dik-diks recorded during the wet and dry seasons' study periods are summarized in Appendix VIII. The proportion of time budget distribution for the major behavioral activities of adult male and female are indicated in Table 5. The mean diurnal time females and males engaged in all the major activities were insignificantly varied; foraging ($\chi2=1.6$, df = 1, P=0.255), resting ($\chi2=1.3$, df = 1, P=0.213), rumination ($\chi2=0.7$, df = 1, P=0.446), vigilance ($\chi2=0.1$, df = 1, P=0.745), walking ($\chi2=2.3$, df = 1, P=0.086) and 'others' ($\chi2=0.2$, df = 1, P=0.824).

Table 5. Proportional distribution of the activity budgets of adult male and female Salt's dik-diks across the wet and dry seasons.

	Wet season		Dry season		Total
Diurnal activities	AM	AF	AM	AF	
foraging	8.07%	8.03%	8.85%	9.17%	34.12%
Resting	5.80%	5.30%	6.70%	7.90%	25.70%
Ruminating	5.30%	5.10%	5.70%	5.80%	21.90%
Vigilance	4.80%	4.30%	5.70%	3.87%	18.67%
Walking	3%	2.55%	2.40%	2.55%	11%
Others	1.80%	1.60%	1.60%	1.50%	6.50%
Total					117.39%

Correlations between behavioral activities indicated positive or negative values among one another. Among the behavioral activities observed during the mid-days, resting indicated positive correlation with rumination (Spearman's correlation r_s=0.78, P=0.01). Similarly, resting showed positive correlation with vigilance (r_s =0.45, P=0.01). Like to vigilance and rumination, 'other activities' indicated positive correlation to resting (r_s =0.25, P=0.01). Contrary to this, resting and foraging (r_s =0.85, P=0.01); foraging with rumination were negatively correlated (r_s =-0.79, P=0.01). Similarly, foraging was found to be negatively correlated to walking (r_s =-0.38, P=0.01). Among the active behaviors, walking and vigilance were positively correlated (r_s =0.24, P=0.01).

5.4 Diet composition

In the present study, 20 plants species were identified as annual dietary components of the animal. During the wet season, 20 plant species and 16 plant species during the dry season were consumed. The identified plant species were (tree, shrubs, herbs and grass) with varied representation in the diet of the animal. Foraged species recognized with a growth habits of tree were =10 (*A. senegal*, *A. millifera*, *B. aegyptiaca*, *A. oerfota*, *A. etbaica*, *Ficus capreaefolia*, *A. tortilis*, *F. sycomorus*, *Ziziphus spinachristi* and *B. rotundifolia*), shrubs =5 (*Grewia tenax, Ximenia americana, Solanum incanum, Lantana trifolia* and *G. villosa*), herbs =4 (*Fagonia schweinfurthi*, *Withania somnifera*, *Sida collina* and *S. ovate*) and grass species (*Chrysopogon plumulosus*). Tree were found to be the most significantly foraged compared to shrub, herb and grass ($\chi 2$ =33.5, df = 3, P= 0.0001).

Salt's dik-diks were observed foraging from leaves and shoots of plants of their height reach. All the four *Acacia* species except *A. tortlis* were directly browsed. In addition, *B. aegyptiaca* and all the five forage species recognized as shrubs were browsed. The animal was observed while feeding on plant litter of five forage species; *A. tortilis, Z. spinachristi, F. capreaefolia, B. rotundifolia* and *F. sycomrus.* Besides these, four herbs and one graminod species were recognized.

Observation of foraging revealed allocation of varied proportion of time per day for different forage species and forage forms. During the wet season, Salt's dik-dik spent the highest proportion of foraging duration for *A. senegal* followed by *A. millifera.* Thus, the highest dietary contribution (39.2%) was recorded from *A. senegal* followed by *A. millifera* (26.6%). These two species accounted for 65.8% of the wet season diet of female dik-dik. During the dry season, *A. senegal,* constituted 43.1% of the diet followed by *B. aegyptiaca* (17.82 %). Totally, 60.92 % of the dry season diet came from these two highly consumed plants. *B. aegyptiaca* and *A. millifera* were the third most consumed forage species during the wet and dry seasons, respectively (Appendix IX).

Among the foraged species, 9 species during the wet season and 11 plant species during the dry season were identified to have lower contribution (each contributing <1%) to the diet of the animal. Thus, the dietary contributions of the foraged species revealed significant variation both during the wet ($\chi2$ =69.6, df = 19, P = 0.001) and dry seasons ($\chi2$ =72.2, df = 19, P= 0.001).

Similarly, percentage contributions of foraged growth forms revealed significant variation both during the wet ($F_{3, 73}$ = 3.26, P=0.002) and dry ($F_{3, 73}$ = 4.9, P=0.001) seasons. Foraged species which have a growth form of tree accounted for 83.14% and

90.62% to the diet of the animal during the wet and dry seasons, respectively. Contrary to this, graminoids contributed the lowest proportion during the wet season (1.76%) and herbs (0.45%) during the dry season (Fig. 15).

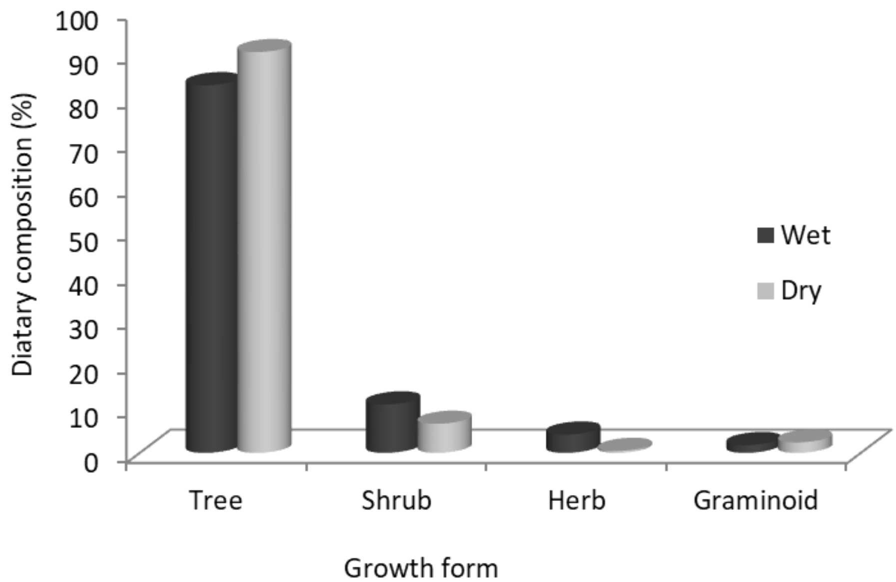

Figure 15. Percentage contributions of the foraged growth forms to the diet of adult female Salt's dik-dik during the wet and dry seasons.

Female dik-diks browsed on the forage species with growth forms of tree and shrub to their height reach in order to constitute 91.91% and 93.27% of their diet during the wet and dry seasons, respectively. Significantly higher proportion of browsed species was found in the diet of the animal ($\chi 2$ =6.1, df = 3, P=0.0031). However, dietary contributions of browsed species showed insignificant varation between seasons ($\chi 2$=0.2, df = 1, P=0.824). Plant litter constituted 2.18% and 3.92% of the dietary composition during the wet and dry seasons, respectively. Significantly higher plant litter was consumed during the dry season than the wet season ($\chi 2$ =1103, df = 1, P=0.001). Contrary to this, the animal consumed herbs in significantly higher proportion during the wet season than the dry season ($\chi2$ =9.53, df = 1, P=0.0042). However, insignificantly varied amount of grass was used between the wet and dry seasons ($\chi2$ =0.8, df = 1, P=0.651) (Fig. 16).

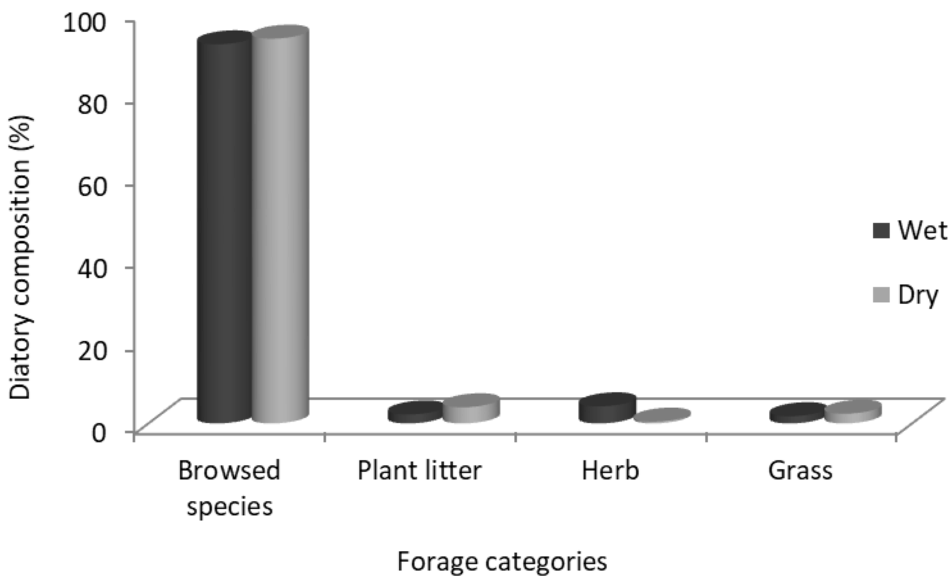

Figure 16. Percentage (%) contributions of forage categories to the diet of Salt's dik-dik during the wet and dry seasons.

Out the identified plant species, 11 species were recognized as the principal forage species. Among these, 9 species were foraged during the dry season, while the remaining 2 species were absent in the dry season diet. *A. senegal*, *A. millifera* and *B. aegyptiaca* were recognized as highly consume, and accounted for 74.46% of the wet season and 74.62% of the dry season diet. Similar proportion of *A. senegal* during the wet and dry seasons, while significantly varied dietary contributions of *A. millifera* and *B. aegyptiaca* across seasons were evident (Table 6).

Table 6. Percentage contribution of principal forage species which accounted for ≥1% to the diet composition of adult female Salt's dik-dik during the wet and dry seasons.

Family	Species	Wet	Dry	Kruskal -Wallis Test
	Tree=5	**80.96%**	**86.70%**	
Fabaceae	*A. senegal*	39.2± 3.4	43.1± 3.6	$\chi2$ =2.1, df = 1, P=0.875
Fabaceae	*A. millifera*	26.6±4.9	13.7±2.1	$\chi2$ =4.74, df = 1, P=0.05
Balanitaceae	*B. aegyptiaca*	8.66±2	17.82±1.5	$\chi2$ =5.3, df = 1, P=0.043
Fabaceae	*A. oerfota*	3.8±1.6	7.38±2.1	$\chi2$ =3.86, df = 1, P=0.05
Fabaceae	*A. etbaica*	2.7±1.2	4.7±1.7	$\chi2$ =1.37, df = 1, P=0.235
	Shrub=4	**10.25%**	**5.91%**	
Tiliaceae	*G. tenax*	3.4±1.4	2.6±0.6	$\chi2$ =1.1, df = 1, P=0.151
Olacaceae	*X. americana*	1.32±0.65	1.67±0.2	$\chi2$ =1.1, df = 1, P=0.221
Verbenaceae	*L. trifolia*	3.8±1.1	0	$\chi2$ =6.14, df = 1, P=0.07
Tiliaceae	*G. villosa*	1.73±0.1	1.64±0.4	$\chi2$ =0.2, df = 1, P=0.272
	Herb=1	**2.30%**	**0%**	
Malvaceae	*S. ovate*	2.3±0.4	0	$\chi2$ =4.36, df = 1, P=0.05
	Graminoid =1	**1.76**	**2.36%**	
Poaceae	*C. plumulosus*	1.76±0.18	2.36±0.27	$\chi2$ =1.05, df = 1, P=0.065
Total		**95.27%**	**94.97%**	

The remaining seven principal forage species were accounted for about 25% of the dietary requirement of the animal. Among the shrubs, significantly varied consumption across seasons was recognized only for *L. trifolia. Sida ovate* and *C. plumulosus* were the only herb and graminoid, respectivly identified as principal forage species.

Out of the three staple forage species, significantly higher amount of *A. senegal* was consumed ($\chi2$ =108.5, df =19, P=0.0023). Contrary to this, *A. millifera* and *B.*

aegyptiaca were found to constitute insignificantly different dietary contributions ($\chi 2$ =1.34, df = 1, P=0.252).

The diet compositions of adult males are indicated under Appendix IX. Comparison of the dietary contributions of the principal foraged species between adult male and female Salt's dik-dik are shown in Table 7. Male and females consumed similar forage species with insignificantly varied proportion in their diet during the wet ($\chi 2$ =0.5, df = 1, P=0.446) and dry seasons ($\chi 2$ =0.1, df =1, P=0.721). The three staple forage species: *A. senegal*, *A. millifera* and *B. aegyptiaca*, contributed 74.4% to the dietary composition of the animal. The remaining eight principal forage species constituted significantly lower dietary composition (20.8%) compared to the three staple forage plants ($\chi 2$ =74.8, df = 8, P=0.0001).

Table 7. Proportional (%) distribution of the principal forage species in the diet of adult male and female Salt's dik-dik

		Dry season		Wet season		Average
Family	Species	AF	AM	AF	AM	
	Tree=5					**83.80%**
Fabaceae	*A. senegal*	10.8± 4.2	11.1±3.3	9.8± 2.4	9.57±3.7	41.27± 6.4
Fabaceae	*A. millifera*	3.4±1.1	3.47±1.7	6.65±5.1	7±2.2	20.52±5.3
Balanitaceae	*B. aegyptiaca*	4.3±1.5	4±1.3	2.17±1.4	2.2±1.4	12.67±2.16
Fabaceae	*A. oerfota*	1.8±1	1.9±0.8	0.9±0.6	0.95±0.4	5.55±1.1
Fabaceae	*A. etbaica*	1.17±0.9	1.24±1	0.67±0.1	0.77±0.33	3.85±0.87
	Shrub=4					**8.40%**
Tiliaceae	*G. tenax*	0.65±0.2	0.68±0.44	0.85±0.7	0.77±0.4	2.95± 1.3
Olacaceae	*X. americana*	0.41±0.2	0.37±0.4	0.33±0.35	0.3±0.08	1.41±0.4
Verbenaceae	*L. trifolia*	0	0	0.95±0.31	0.94±0.3	1.89±0.8
Tiliaceae	*G. villosa*	0.41±0.4	0.43±0.32	0.43±0.1	0.4±0.35	2.1±1
	Herb=1					**1.17%**
Malvaceae	*S. ovate*	0	0	0.57±0.51	0.6±0.4	1.17±1.02
	Graminoid =1					**1.93%**
Poaceae	*C. plumulosus*	0.59±0.2	0.52±0.3	0.44±0.23	0.38±0.07	1.93±0.64
Total						**95.30%**

The principal forage species were represented by seven plant families. *Fabaceae* is the dominant family which is represented by four species accounting for 71.33% to the diet of the animal. Following this, a single species from the family *Balanitaceae* constituted 12.67%. Subsequently, the two *Grewia* species of the family *Tiliaceae* have dietary contribution of 5%. The remaining four families were represented by single plant species and accounted for; 1.4%=*Olacaceae*, 1.89= *Verbenaceae*, 1.17%= *Malvaceae* and 1.93%= Poaceae.

The top four available forage species during the wet season were *A. senegal* (82.7%), *A. millifera* (43.3%), *G. villosa* (44%) and *G. tenax* (42.5%). Similarly, *A. etbaica* (39.5), *B. aegyptiaca* (33.4 %) and *A. oerfota* (31%) were highly available. These forage species accounted for 76.5% of the available diet. Out of these, the lowest availability was observed for *S. ovate* (18.5%). Thus, availability of the foraged species in the sampled quadrats indicated significant variation during the wet season ($\chi 2$ =25, df = 10, P =0.005) (Fig. 17).

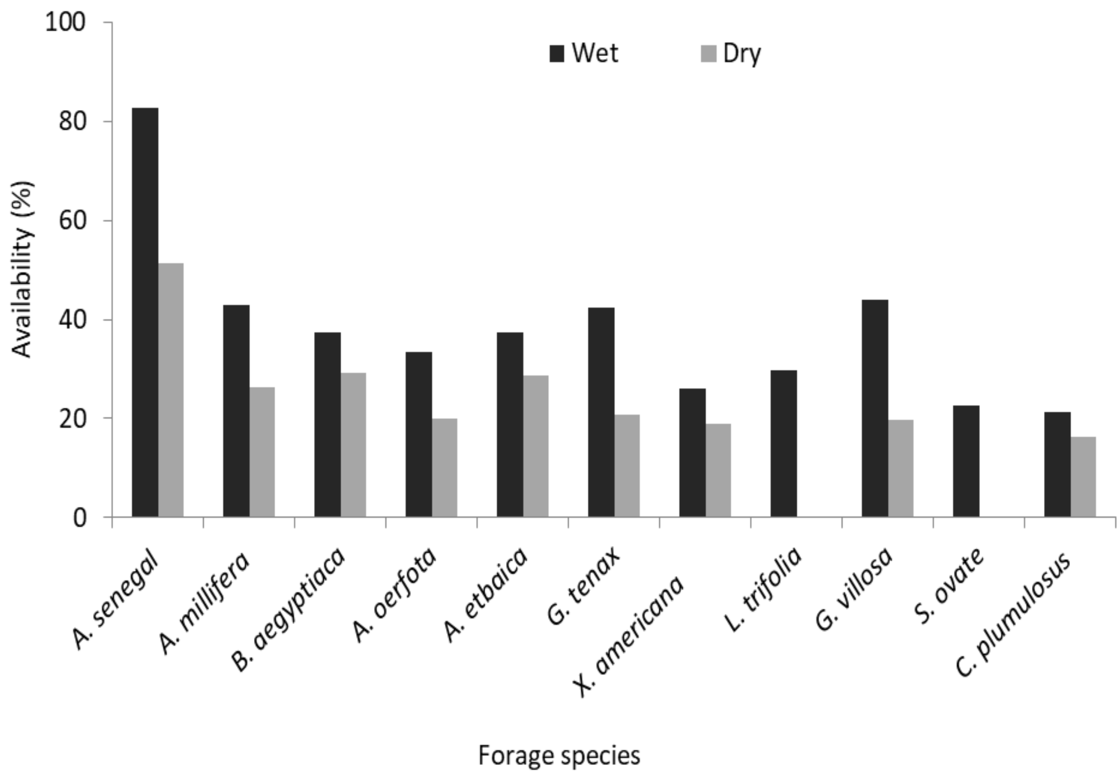

Figure 17. Comparison of seasonal availability of the principal forage species of Salt's dik-dik from the sampled quadrats of the study area.

During the dry season, site availability of the foraged species indicated higher percentage of occurrence for *A. senegal* (51.4%), *B. aegyptiaca* (29.2 %), *G. villosa*

(19.8 %) and *A. etbaica* (28.7%). *Sida ovate* and *L. trifolia* were not totally recorded from any of the quadrats. It was clear that there was significant difference ($\chi 2$ =30.29, df = 10, P=0.001) in the availability of the forage species of the animal during the dry season similar to the findings of the wet season.

Comparison of seasonal availability of the foraged species revealed insignificance difference for *A. senegal* ($\chi 2$ =1.4, df = 1, P=0.153), while varied availabilities were recorded for *A. millifera* ($\chi 2$ =5.4, df = 1, P=0.05), *B. aegyptiaca* ($\chi 2$ =5.3, df = 1, P=0.059), *A. oerfota* ($\chi 2$ =4, df = 1, P=0.116) and *A. etbaica* ($\chi 2$ =8.1, df = 1, P=0.074) were recorded among the highly available species. The two *Grewia* species: *G. tenax* ($\chi 2$ =1.4, df = 1, P=0.0353) and *G. villosa* ($\chi 2$ =1, df = 1, P=0.0646) had insignificantly varied availability across seasons. Unavailability during the dry season feeding quadrat survey indicated statistical significance for *S. ovate* ($\chi 2$ =7.23, df = 1, P=0.005) and *L. trifolia* ($\chi 2$ =6.12, df = 1, P=0.044).

During the wet season, *A. senegal* (49.6%) and *A. millifera* (33.2%) indicated their highest availability in bushlands. While the lowest availability (12% and 19.4%) for the former and latter species, respectively were recorded from shrub grassland and thickets. *B. aegyptiaca* was highly available in open bushlands (31%) while least available in shrub grasslands (16.6%) (Fig. 18). During the wet season, insignificantly varied availability of the three top forage species across the four habitat types were evident for *A. senegal* ($\chi 2$ =4.6, df = 3, P=0.057), *A. millifera* ($\chi 2$ =3.8, df = 3, P=0.132) and *B. aegyptiaca* ($\chi 2$ =7.3, df = 3, P=0.089).

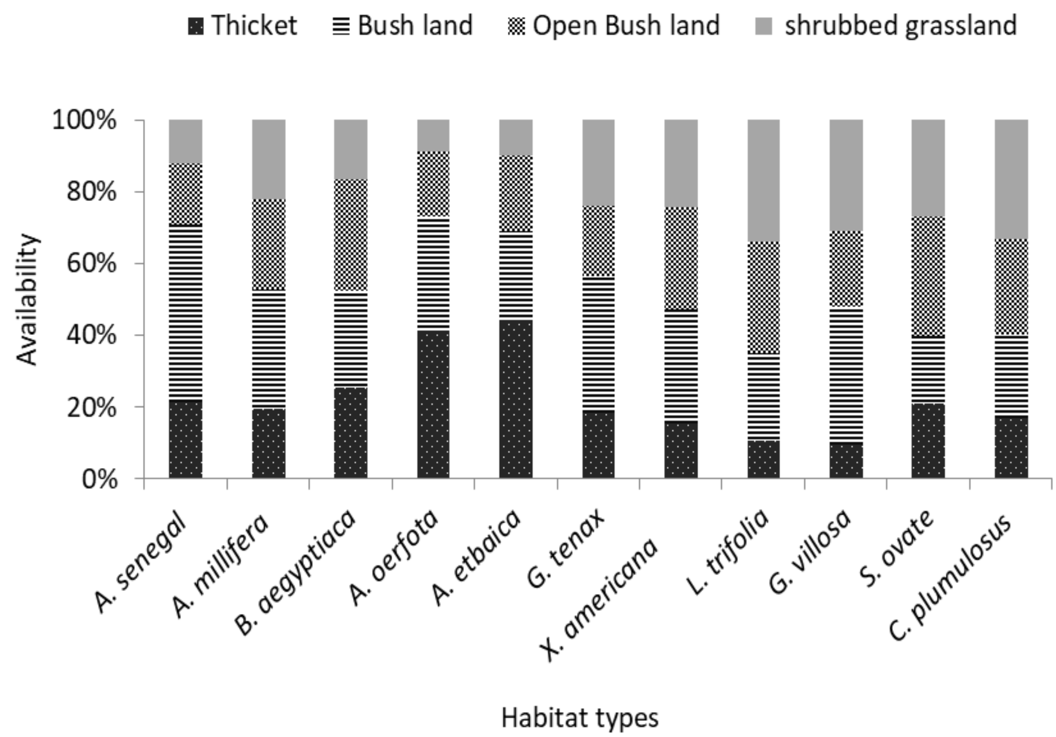

Figure 18. Proportion of occurrence of the principal forage species during the wet season in the four habitat types.

During the dry season, availability of the three staple forage species (*A. senegal*, *A. millifera* and *B. aegyptiaca*) were highest in bushlands, while lowest in shrub grassland habitats (Fig. 19). Availability of forage species across habitat types indicated significant variation for the former two species ($\chi 2$ =8.3, df = 3, P=0.005 and $\chi 2$ =9.97, df = 3, P=0.0341), respectively though insignificant varation for *B. aegyptiaca* ($\chi 2$ =6.16, df = 3, P=0.331).

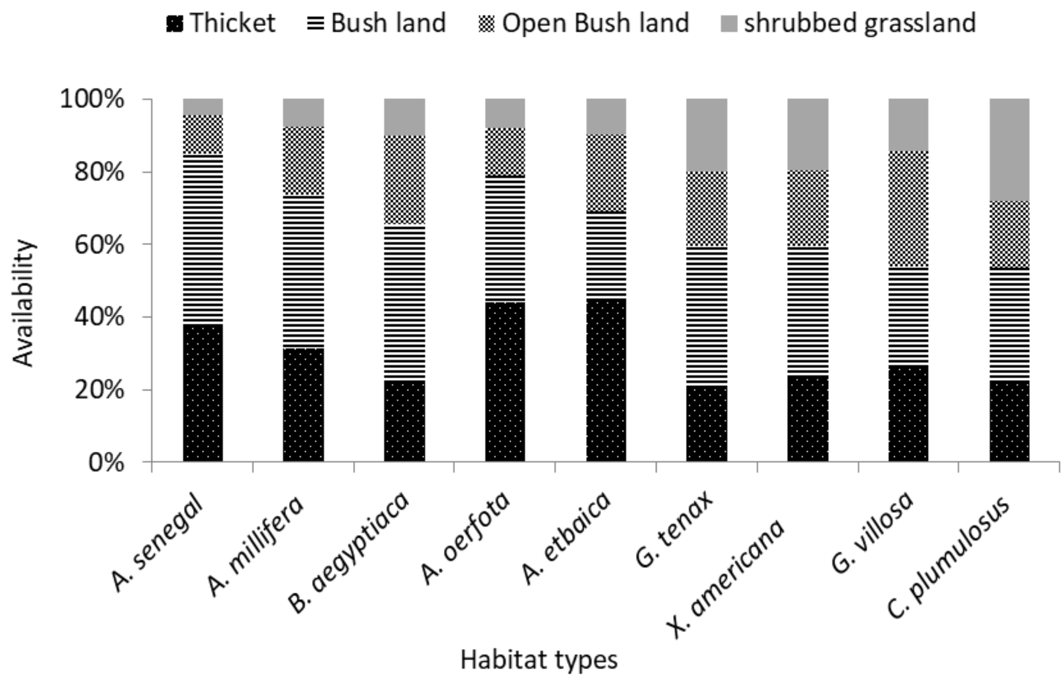

Figure 19. Proportion (%) of occurrence of the principal forage species of Salt's dik-dik from the sampled quadrats during the dry season in the four habitat types.

The highest and lowest percentage availability of the foraged species having a growth form of tree were 33.2% and 13.9%, and occurred in bushlands and shrub grasslands, respectively, during the wet season. Similarly, tree species are highly available in bushlands (38.5%) followed by thickets (35.8%) during the dry season. However, the lowest availability was noticed in shrub grasslands (8.2%). During the wet season, the highest availability of shrubs were recognized in bushlands (33%) followed by shrub grasslands (28.3%) (Fig. 20).

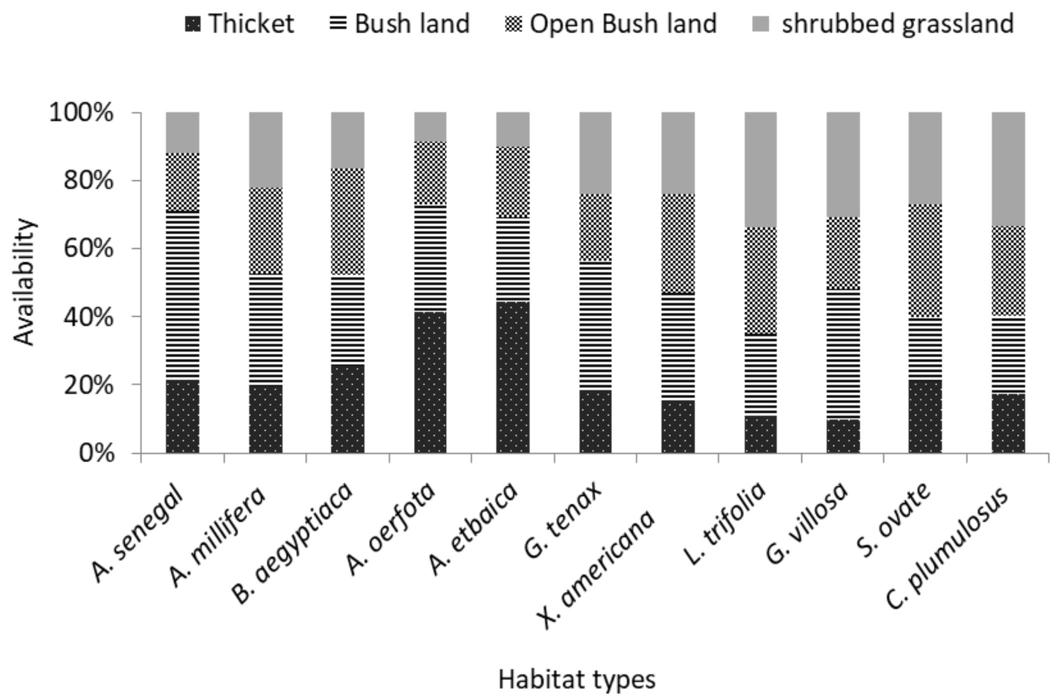

Figure 20. Availability of forage species of Salt's dik-dik categorized in the four growth forms during the wet and dry seasons in the sampled quadrats (w=wet season, d=dry season).

Open bushlands revealed the highest availability of foraged species identified as shrub during the dry season. Herbs are highly available in shrub grasslands during the wet seasons, though not represented in any of the habitats during the dry season. Graminoid revealed the highest availability in shrub grasslands (40%) and bushlands (31.2%) during the wet and dry seasons, respectively. Across the habitats, availability of the forage forms indicated significant variation during the wet ($\chi2$ =18.1, df = 3, P=0.001) and dry seasons ($\chi2$ =16.6, df = 3, P=0.0001).

During the wet season, *A. senegal* (0.61) and *A. millifera* (0.83) were highly acceptable. Besides this, *B. aegyptiaca*, *L. trifolia* and *G. tenax* were moderately accepted. While the remaining six species showed lower acceptability (Table 8).

Table 8. Seasonal variation in the acceptability of the important forage species for Salt's dik-dik in ANP (index with 95% confidence intervals, χ2 (Chi–square value).

	Acceptability index with 95% CI		
Species	Wet season	Dry season	χ2, df=2
A. senegal	0.61 (0.42-0.80)	0.93 (0.88-0.99)	5.8*
A. millifera	0.83 (0.71-0.95	0.67 (0.62-0.72)	3.1
B. aegyptiaca	0.33 (0.21-0.45)	0.82 (0.71-0.93)	13.3***
A. oerfota	0.13 (0.8-0.18)	0.3 (0.21-0.39)	2.4
A. etbaica	0.22 (0.16-0.28	0.34 (0.21-0.47)	1.1
G. tenax	0.3 (0.19-0.41)	0.52 (0.44-0.6)	4.67*
X. americana	0.19 (0.13-0.25)	0.25 (0.18-0.0.32)	2.3
L. trifolia	0.37 (0.24-0.5)	0	9.5***
G. villosa	0.11(0.8-0.14)	0.44 (0.35-0.53)	1.04
S. ovate	0.21 (0.18-0.24)	0	9.4**
C. plumulosus	0.26 (0.2-0.32)	0.33 (0.22-0.44)	1.07

** P < 0.05; ** P < 0.01; ***P < 0.001*

During the dry season, in addition to *A. senegal* (0.93), *A. millifera* (0.67) and *B. aegyptiaca* (0.83) appeared to be among the three highly accepted forage plants. Lower acceptability was observed to *X. americana* and *C. plumulosus* consistently between seasons.

Comparison of seasonal acceptability for the three staple forage plants revealed significant variation for *A. senegal* and *B. aegyptiaca*, while *A. millifera* remained consistently accepted. Though moderately accepted during the dry season, acceptability index for *A. etbaica* and *A. oerfota* indicated insignificant variation across seasons. *S. ovate, L. trifolia* and *G. tenax* showed statistically varied acceptability across seasons, while acceptability for *G. villosa, X. americana* and *C. plumulosus* indicated insignificant difference.

5.5 Conservation challenges and opportunities

Seven illegal practices showed threats were identified and their mean scores (Mean ±SE) and Relative Threat Factor Severity Index (RTFSI) were computed as recorded by the respondents (Table 9). Grazing by livestock in the Park was indicated as the highest challenge (4.57±0.8) followed by expansion of invasive alien species (4.23±0.9). Potching and expansion of agricultural activity prevail relatively lower impact ($\chi2$ =8.1, df = 6, P=0.022).

Table 9. Illegal practices of the local community which threaten the Park; Mean score (Mean±SE) and Relative Threat Factor Severity Index (RTFSI).

No	Illegal practices in the Park by the community	Mean±SE	RTFSI
1	Grazing by livestock in the Park	4.57±0.8	0.91
2	Encroachment and human settlement in the Park	3.9±1.1	0.78
3	Firewood and charcoal harvesting	3.76±1.6	0.75
4	Destruction of wild animal habitats through illegal cutting of tree	3.24±1.1	0.65
5	Expansion of agricultural land in and around the Park	1.7±0.5	0.34
6	Illegal hunting of wildlife	1.5±0.4	0.3
7	Expansion of invasive alien species in the Park	4.23±0.9	0.85

Relative Threat Factor Severity Index (RTFSI) showed a range of indexes between 0.3 and 0.91. The highest index was computed for livestock grazing activity inside the Park (0.91) followed by spread of invasive alien species in the Park (0.85). Following this, encroachment and human settlement (0.78), and harvesting of firewood and charcoal from the Park (0.75) indicated higher RTFSI. However, lowest indexes were recorded for illegal hunting of wildlife (0.3) and agricultural land expansion (0.34). Thus, statistical variation was observed about the severity of the threats ($\chi 2 = 24.6$, df = 6, P = 0.001).

Several factors have been accelerating the negative impacts of local community of ANP as indicated in Table 10. Out of these, inter-ethnic conflict indicated the highest mean score (4.68±0.9) followed by lack of alternative livelihood (4.38±1.1) and shortage of settlement and livestock grazing lands (4.2±1). However, lower scores were found for susceptibility to drought (2.2±1.6) and lack of equitable resource sharing (2.7±1.25) among the underlying causes resulting in conservation challenge in ANP by the local community.

Table 10. Underlying factors accelerating community conservation challenges in ANP.

No.	Factors underlying the threats	Mean±SE	RTFSI
1	Lack of alternative livelihood activities	4.38±1.1	0.87
2	Negative attitude about wildlife	3.5±1.3	0.7
3	Inter-ethnic conflict	4.68±0.9	0.93
4	Lack of awareness about wildlife conservation laws	3.3±1.5	0.66
5	Shortage of settlement and livestock grazing lands	4.2±1	0.84
6	Loose coordination in law enforcement among the concerned bodies	3.87±1.1	0.77
7	Lack of equitable resource sharing	2.7±1.25	0.58
8	Human population increase	3±1.4	0.6
9	Susceptibility to drought	2.2±1.6	0.44
10	Proximity of local community through infrastructure development	3.3±1.6	0.66
11	Lack of regular assessment of threats and remedial actions	3.4±1.8	0.68
12	Lack of effective capacity building strategies among the staff	3.1±1.2	0.62
13	Loose communication between the Park and conservation authority	2.97±1.7	0.59

Relative Threat Factor Severity Index (RTFSI) indicated a range of values between 0.44 and 0.93 for the underlying threats accelerating habitat degradation and impact on wildlife in ANP. In recent times, according to the respondents, inter-ethnic conflict indicated the highest RTFSI (0.93) followed by lack of alternative livelihood (0.87) and shortage of settlement and livestock grazing lands (0.84). Loose coordination in law enforcement among the concerned bodies and negative attitude towards wildlife were among the factors which lead the local community to engage illegal practices inside the conserved area. Respondents referred lack of equitable resource sharing between the Park and the locality as the lowest underlying factor with RTFSI 0.44 aggravating community induced conservation challenges in ANP.

Threats the habitats and wildlife of ANP was facing were accelerated by factors emerging from different sources (Fig. 21).

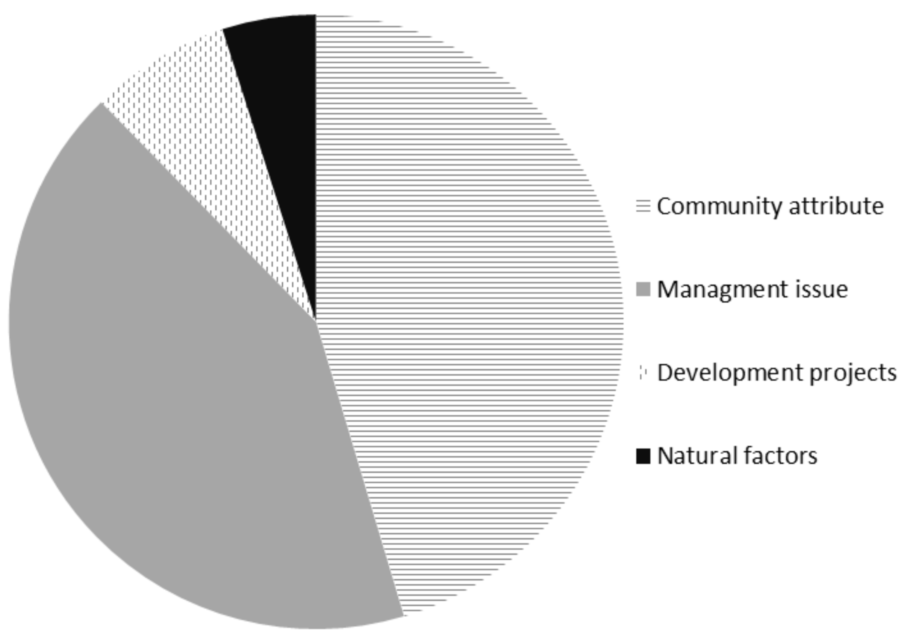

Figure 21. Percentages of threats in ANP catgorized under four classes (community attributes, management issues, development projects and natural factors).

Triggering factors emerging from community attributes (45.37%) and management issues (42.3%) were relatively high. The remaining underlying factors impact the conservation activity of ANP outsource from development projects (7.4%) and natural disasters (4.93%).

Respondents identified and evaluated community attributes which are considered as opportunities for conservation of wildlife in ANP (Table 11).

Table 11. Evaluation of the local community attributes considered as opportunity for conservation.

No	Community attributes as opportunity for conservation	Mean ±SE
1	Nomadic life, mostly	2.22±1.8
2	Limited resource requirement	3.73±1.4
3	Ethnic diversity	1.1±1.3
4	Cheap labor to mobilize for alternative economic sources	4.15±0.94

Presence of cheap labor to mobilize for alternative economic sources (4.15±0.94) followed by limited resource requirement (3.73±1.4) were considered as opportunities rooting from the community attributes of ANP. Diverse ethnicity of the local communities (1.1±1.3) was considered as least contributing community feature to the conservation activities of ANP followed by nomadic life in the majority of the pastoralist communities (2.22±1.8). Statistical variation was observed on the mean rank of the community attributes considered as opportunities of conservation activity in ANP ($\chi 2=14.2$, df = 3, P = 0.05).

Re-demarcation of the Park's boundary was found to be an effective measure as rated by the respondents (4.21±1.1). Local employment (2.8±0.9) was implemented in ANP to alleviate the threats that the Park is facing. Awareness creation among the local communities about conservation of wildlife and habitats was a strategy implemented in ANP (Table 12). Following this, law enforcement (2.3±1.2) has contributed a lot for conserving the Park from the past experience. Incentive measures were considered as the least implement method accordingly of the respondents (1.9±1.8).

Table 12. Evaluation of habitat restoration activities carried out (Mean ±SE) in ANP.

No.	Restoration activities	Mean ±SE
1	Re-demarcation of the Park's boundary	4.21±1.1
2	Law enforcement	2.3±1.2
3	Incentive measures	1.9±1.8
4	Local employment	2.8±0.9
5	Awareness creation	2.4±1.3

6. DISCUSSION

6.1 Population estimate

Knowledge about the population size and change trends of a wildlife species are fundamental steps for conservation activities, especially in the contemporary ecosystems of the world in which anthropogenic activities are threatening the habitats and associated biota (Vestnes and Nellemann, 2008; Tamene Yohannes *et al*., 2011; Yosef Mamo and Afework Bekele, 2011; Polfus and Krusman, 2012). Due to lack of previous studies conducted on the population status of the study species in any of its ranges, comparisons of the present finding was constrained by data limitations.

Compared to the population size of Salt's dik-dik estimated in ANP, previous study conducted on Kirk's dik-dik using pellet matching technique indicated higher population density (111/km^2) (Komers and Brotherton, 1997). Besides this, the density estimate of Salt's dik-dik in the present study is by far lower compared to the highest population density of Kirk's dik-dik. This was observed using distance sampling method in Mpala, Laikipia District, Kenya (Shorrocks *et al*., 2008). Contrary to this, the lowest density estimate of Salt's dik-dik among the study sites of ANP (17.7/km^2) were higher than the lowest density of Kirk's dik-dik found from the aforementioned previous study site (11.2/km^2). A range of density estimates of Kirk's dik-dik (11.2/km^2 with %CV= 94 and 299/km^2 with %CV=37.1) were reported from the sampling sites of Mpala, Laikipia District, Kenya (Shorrocks *et al*., 2008).

Even in a limited previous resource about the population size of a species of dik-dik (Komers and Brotherton, 1997; Shorrocks *et al*., 2008), variations in population size among the findings were evident. Differences in a population size among those related species of *Madoqua* may be partly linked to the spatial and temporal variation in the vegetation features across different ecosystems (Mobæk *et al*, 2009). However related, distinct species may have varied reproductive success which in turn can result in differences in population densities. Most importantly, conservation status of a particular ecosystem plays a significant role in determining not only the population dynamics, but also the ultimate survival of the species (Gill *et al*., 2001; Bjorneraas, 2011). Thus, this variation can be seen in different spatial and temporal scales, in which environmental and human induced factors operate.

Significantly varied population sizes of Salt's dik-dik were noticed among the study sites. This, can clearly reveal influence of anthropogenic activities on the spatial distribution and population size of wildlife species (Hebblewhite *et al*., 2005; Vestnes and Nellemann, 2008; Polfus and Krusman, 2012). Any form of anthropogenic disturbance may result in physiological or behavioral adjustments which may result in change in population abundance (Hebblewhite *et al*., 2005; Johonson and St-Laurent, 2011; Leuchtenberger *et al*., 2018).

Differences in the population size across the study sites can be associated to difference in suitability of habitats in providing the minimum resource requirement (Heinze *et al*., 2011; Yosef Mamo *et al*., 2012). In the present study, lower population sizes of the animal in habitats with high human interference can be associated to influenced detectability of animals (Johonson and St-Laurent, 2011; Leuchtenberger *et al*., 2018), or complete abandonment of territories (Hendrichs, 1975; Dujardin and Fox, 1997). Territory size expansion or total abandonment was reported as a compromise for territory quality decline in dik-dik species (Dujardin and Fox, 1997; Ono *et al*., 1988).

Habitat disturbance can affect wild herbivores in a number of ways. Among these; overgrazing by livestock and imposing pressure on wild species through resource competition, resource depletion and habitat transformation are highly pronounced (Latham, 1999; Stensland *et al*., 2003; Evangelista *et al*., 2008; Wondimagegnehu Tekalign and Afework Bekele, 2011; Polfus and Krausman, 2012; Leuchtenberger *et al*., 2018). Elusive animals which depend on vegetation cover as anti-predator strategy might be highly prone to risk of predation. For instance, change in the pattern of woody cover influences predator-prey dynamics (Augustine, 2004; Veblen, 2012; Ford *et al*., 2014).

The species of dik-dik are among the small antelopes having a wide range of predators (Ford, 2015), and require cover for predatory avoidance (Brashares *et al*., 2000; Ford, 2015). Thus, lack of such basic requirements in degraded habitats might have facilitated abandonment of territories, or facilitation of predation rate. Thus, lower population size of Salt's dik-dik in the study sites with elongated period of human settlement, can be attributed to continuous disturbance by domestic animals and herders. Such sites of the Park are unsuitable for wild herbivores due to their proximity to settlement, which is among the major drivers of habitat degradation in the Park (Solomon Belay *et al*., 2012; Mengistu Wale *et al*., 2017). Besides causing minimized resource availability, human interference might constraint detectability of animals through influencing their diurnal activity pattern (Gill *et al*., 2001; Hebblewhite, 2011) which in turn lead to underestimation of the population size.

Influence of seasonal variation on the population size of Salt's dik-dik was observed in the present study. Differences in the population size result from the cumulative effect of differences in the number of sightings, detection probability, encounter rates and herd sizes of the animal between seasons (Buckland *et al*., 2004; Msoffe *et al.*, 2009). Sightings of herds of Salt's dik-dik were not influenced by seasonal attributes. This might be associated with the feature of occupation of permanent territories (Hendriches, 1975), and association of different activities in comparable habitat patches. Unlike the number of sightings, encounter rates were significantly different across seasons. This can result from detection of varied herd sizes of the animal across the wet and dry seasons.

Detection of varied herd sizes of Salt's dik-dik per season may result from seasonal changes in the woody cover used for crypsis (Brashares *et al*., 2000; Ford, 2015) and timing of the reproductive cycle (Patry *et al*., 1995). The present finding was in line with Dujardin and Fox (1997) where seasonal influence on the family aggregates of dik-dik was reported. During the wet season, single individuals of Salt's dik-dik occur more frequently than mate pairs and pairs with young. This can be attributed to lack of young care in male individuals of the monogamous pairs (Brotherton and Rhodes, 1996). As a result, adult females may need to allocate significant amount of time nursing their young rather than synchronizing in monogamous group, which in turn caused reduced detectability of more family sizes.

Higher frequency of sightings of solitary Salt's dik-dik during the wet season does not go in line with the appealing environmental condition to occur in herds due to the presence of ample forage and minimized encroachment. Besides reproductive timing, the more closed habitat feature during the wet season may have limited coordinated vigilance among the monogamous pairs as anti-predatory strategy. Rather than using a raised head posture, which is possible during the dry season to identify and locate threats, individuals reduce risk of predation through crypsis (Brashares *et al*., 2000; Ford, 2015) as the habitat restricts visibility during the wet season. In general, the lower population size of Salt's dik-dik observed during the wet season may be attributed to behavioral adjustment in minimizing the risk of predation, reproductive timing and lack of young care in male individuals of the monogamous pairs.

Varied patterns of representation of the different age and sex categories of salts dikdik can be associated to occupation of permanent territories (Hendrichs, 1975). Besides this, reproductive timing (Dujardin and Fox, 1997), pattern of young care in monogamous pairs (Brotherton and Rhodes, 1996) and switching to discrete anti-predatory strategy as per the environmental conditions might have influenced detection of adult females. The hiding strategy of young antelopes (Estes, 1991) and high risk of predation (Ford, 2015) while discovering new territories, might have caused varied pattern of aggregations between seasons.

Dujardin and Fox (1997) reported one effective reproductive season in dik-diks in which the majority of females produce young per year, and females were less visible in that period when lactating and lambing of new born. Similarly, juveniles were not available during this time, however, they were observed to accompany the family activity after three months. Thus, significantly higher percentage of a family size of Salt's dik-dik with juvenile was found during the dry season (25%) than the wet season (4.7%). Subsequently, the juveniles grow into sub-adults and leave the territory of their family. The present finding, revealing significantly lower percentage of occurrence of juveniles and sub-adults was in line with the observation of *M. kirkii* in Ethosha National Park. High percentage of occurrence of solitary male dik-dik (21%) was reported compared to solitary females (13%) (Dujardin and Fox (1997), and this is supported by the present finding. In general percentage occurrence of the family sizes of Salt's dik-dik decreased from solitary individuals to a family of two dik-dik individuals, and then mate pairs with young.

6.2 Habitat association

Comparison of the population sizes of Salt's dik-dik among the four habitat types were in a descending order from closer habitats to habitats which are relatively open. Lower population record in shrub grassland was resulted from smaller herd size and encounter rate of the animal, where cover is scarce. This is in line with the finding of higher density of Kirk's dik-dik from transects laid in dense scrubs than in open savanna habitats (Shorrocks *et al*., 2008) and reduced predatory risk associated to woody cover (Ford and Goheen, 2015; Otieno *et al*., 2019). Moreover, it can be linked to occupation of smaller territory size in suitable habitats, and expansion of territories to compensate the resource limitation in degraded habitats (Dujardin and Fox, 1997).

High abundance of Salt's dik-dik in bushlands can be attributed to differences in the availability of habitats in the sampled area. Probability of sampling from bushlands and open bushland habitats was higher due to relatively higher coverage of the habitat in the study area (Tezera Cherinet, 2015). Seasonal influence on herd sizes and encounter rates (Buckland *et al*., 2004) resulted in higher population size of the animal during the dry season than the wet season.

Denser habitats, bushlands and thickets of the study area, were found to harbor more herd sizes than comparably open habitat types. Occurrence of larger family sizes (mate pairs with young, mate pairs, single adult with young) can be associated with better resource requirement for the formation of permanent territories among the monogamous pairs (Hendriches, 1975). Similarly, encounter rates of the animal were higher in thickets and bushlands. This can be explained by higher frequency of association of animals in habitats which are more suitable (Heinze *et al*., 2011; Yosef Mamo *et al*., 2012; Otieno *et al*., 2019). However, detection probabilities in different habitats were insignificantly varied. This can be due to their behavioral adjustments and hiding tactics from the radial distances of observation regardless of the habitat attributes. Occupation of permanent territories (Hendriches, 1975) coupled with selection of comparable habitats patches for their diurnal activities, might have made detection comparable across the different habitat types.

6.3 Activity budget

Foraging was the dominant activity in the cooler hours of the day. During this time, animals were mainly engaged in foraging by minimizing other activities. To compensate the foraging activity which is constrained by the mid-day ambient temperature, ungulates which dwell in arid environments confine their activities to the cooler hours of the day (Manser and Brotherton, 1995; Worsley–Tonks and Ezenwa, 2015).

The significantly higher proportion of time used for feeding can be inferred to the rapid passage rate (Maloiy *et al*., 2000), small bite size, selective foraging (Pérez-Barbería *et al*., 2001), nutritional requirements and environmental constraints (Manser and Brotherton, 1995). Similar foraging activity budget was found across sexes. This is in line with the finding of similar time allocation for this activity in male and female *M. kirkii* (Manser and Brotherton, 1995).

Salt's dik-diks were engaged in foraging for insignificantly higher duration during the dry season than the wet season as that of *M. kirkii* (Manser and Brotherton, 1995). The need for increased foraging time during the dry season can be correlated to maximize the intake rate of nutrient and water from the low quality dry fodder (Manser and Brotherton, 1995; Maloiy *et al*., 2000). Use of similar forage time between seasons can be inferred to selective foraging (Pérez-Barbería *et al*., 2001), minimum water requirement (Manser and Brotherton, 1995; Maloiy *et al*., 2000) and environmental conditions interrupting the activity differently during the wet and dry seasons.

Comparative study on the tropical browsing ungulates found relatively lower foraging duration for the smallest ruminant trophic guild, Steenbok (33.9% for feeding activity) (de Toit and Yetman, 2005). In the present study, Salt's dik-dik (5 kg), which has a lesser body mass than steenbok (10 kg), was found to spend 34.12% of the diurnal activity budget for foraging. Incomparable foraging duration between these small ungulate species need to be associated to differences in the habitat types, forage type, physiology and nutritional requirements, rather than merely associating the activity budget with body mass. Besides this, time budget in the diurnal to nocturnal foraging ratio need to be considered. For instance, according to du Toit (1993), steenbok indicated 0.58:1 diurnal to nocturnal foraging ratio. Thus, knowledge on the diurnal and nocturnal activity budget is also important to get complete data for further comparative behavioral studies.

Resting was the second dominant activity in the present finding. It has no physiological and ecological significances in most cases besides energy conservation. However, in smaller and solitary ungulates, it serves as anti-predator strategy (Jarman, 1974; Brashares *et al*., 2000). Behavioral activities of small ungulates, those dwelling in the tropics, significantly decline in the hottest time of the day (du Toit and Yetman, 2005). Due to the ambient temperature, they engaged in inactive behaviors in the most demanding times of the day and significantly reduce activities in order to minimize metabolic rates (du Toit and Yetman, 2005; Mahenya, 2016). Consequently, Salt's dik-diks switch foraging and walking into resting during the mid-days and spent significantly higher time under shades of *Acacia* either, lying or sanding.

Walking is among the major activities recognized in ungulates which result in energetic costs. Higher activity budget was found in Salt's dik-dik compared to steenbok (7.09%), among the smallest ungulates (duToit and Yetman, 2005). This activity frequently occur in bouts with feeding in search of food (Mahenya, 2016), looking for shade for resting and demarcation of territory through defecation process in particular for dik-diks (Hendrichs, 1975; Komers and Brothertoon, 1997), and escape from predators and human presence (Brashares *et al*., 2000; Hjertlöv, 2015). Besides this, environmental disturbance restricts movement of animals or increase the rate of bouts for movement in the middle of the dominant diurnal activity patterns.

Significantly different proportion of time observed for different activities are linked to synchronization of behavioral activities by circadian rhythm (Streicher *et al*., 2017; Leuchtenberger *et al*., 2018) and constrained by ambient temperature (Own-Smith, 2002; du Toit and Yetman, 2005; Dibner *et al*., 2010). The requirement of statistically similar activity budget across seasons and sexs for walking can be linked to possession of the same territory year round (Hendrichs, 1975). This might determine the total distance moved by. In addition to this, activity synchrony in most of the time between adult male and female dik-dik pairs may be determinant (Brotherton *et al*., 1997).

Habitat features vary across seasons, and may influence vigilance (Kuijper *et al*., 2014). Comparable vigilance activity budget among the sexes can be inferred to the need of higher vigilance among individuals in non-gregarious ungulates (du Toit and Yetman, 2005). However mate pairs of dik-diks were involved in activity synchronization during the majority of the time. Lack of synchronization in situation demanding was evident as it was reported in sexually dimorphic ungulates (Neuhaus and Ruckstuhl, 2002; Neuhaus and Ruckstuhl, 2009). Besides this, form of monogamy without young care in male individuals of dik-dik (Kranz, 1991) supports need of independent vigilance among the mate pairs with respect to reproductive timing.

During the dry season, males were more vigilant than females during the middays. This might be associated to the varied resting posture in male and female mate pairs. Resting by lying is a strategy for crypsis which decreases the need for vigilance (Jarman, 1974). The raised head posture in males may lead to a more alert and vigilant role over crypsis, though it sometimes overweighs the risk of detection. Thus, females benefit from the presence of more vigilant male and prioritize energy maximizing activities (Treves, 2000; Simpson *et al*., 2012). Besides this, since smallest and solitary ungulates are in higher risk of predation due to their exposure to a variety of predators (Sinclair *et al*., 2003; Radloff and du Toit, 2004; Ford, 2015), males and females are engaged in varied anti-predatory strategies. Animals which lie cryptical and immobile may reduce vigilance, which in turn outweighs the risk of predation (du Toit and Yetman, 2005). Thus, crypsis in females, and increased vigilance in males may be an effective strategy to offset the risk of predation in dik-dik.

During the mid-days, rumination and vigilance are more pronounced than foraging and walking. Specially, during the dry season, foraging and walking were extremely minimal in Salt's dik-dik. Thus, resting showed a strong inverse correlation with foraging and walking, and this finding is in line with Shannon *et al.* (2008), while positive correlation is observed for rumination and vigilance. Besides this, resting has an inverse relationship with body size, since smaller browsing ungulates spend more time resting in the demanding hours compared to larger tropic guilds (du Toit and Yetman, 2005). Due to the smaller body size which correlates to minimized energy requirement, Salt's dik-diks were able to avoid foraging during the mid-day hours, while predominantly engaged in resting. Thus, high hourly adjustment of diurnal activities in response to the daily ambient temperature in small ungulates was evident in Salt's dik-dik, as activity patterns of animals are stimulated by cyclical environmental factors (Streicher *et al*., 2017; Leuchtenberger *et al*., 2018).

Ruminants can maximize the energy intake (Hofmann, 1989), and the mid-day hours are ideal for this activity as observed in Salt's dik-dik. Both vigilance and rumination were observed to overlap with resting, though the animal could not ruminate and become vigilant simultaneously, which is the case only for giraffe among the extant ruminants (du Toit and Yetman, 2005). This activity showed its peak during the middays, and this can be linked to activity pattern variation in response to external stimuli (Dibner *et al*., 2010; Leuchtenberger *et al*., 2018). Rumination, as that of foraging, required insignificantly varied time between sexes. This might be linked to comparable energy requirements or, activity synchronization between the monogamous pairs (Brotherton *et al*., 1997).

Salt's dik-diks revealed decline of activities from morning to mid-day hours and gradual increase from the mid-day hours to the cooler late afternoon time. Hence, significant variations in behavioral activities were observed on the comparison of diurnal activity patterns among the three time blocks. When ambient temperature is equal or greater than body temperature, which is the case in the tropical ecosystems, small ungulates reach their thermal tolerance. As a result of this, Salt's dik-dik, like small ungulates dwelling in hot environments; allocate most of their activities to the cooler hours of the day (morning and late afternoon), and spent the mid-day (hottest) time for resting. In smaller ungulates, such as dik-dik, behavioral adjustments are known for thermoregulation than other physiological mechanisms which avoid heat stress (Mitchell *et al*., 2002). Thus, foraging and walking were negligible in the hottest hours of the day, as Salt's dik-diks are engaged in resting predominantly to avoid heat stress.

6.4 Diet composition

Dik-diks in general are understood as strictly browsers (Gagnon and Chew, 2000). The three staple forage species during both the wet and dry seasons were *A. senegal, A. millifera* and *B. aegyptiaca*. Species of *Acacia* and *Grewia* were reported in the diet composition of Kirk's dik-dik (Manser and Brotherton, 1995; Otieno *et al*., 2019) similar to that of Salt's dik-dik.

The relationships between availability of forage species and intake rate by herbivores are essential in understanding forage selection (Clauss *et al.*, 2007). Of the forage species of Salt's dik-dik, *A. senegal* was the top highly consumed as well as available plant species. Intake of forage species is determined by its availability and quality (Codron *et al.*, 2007; Zweifel–Schielly *et al.*, 2012). Thus, consistent and higher intake rate of this plant species may be linked to its availability as well to its nutritional content. Following *A. senegal*, *A. millifera* and *B. aegyptiaca* constituted the major portion of the diet of the animal. In the former case, reduced forage availability during the dry season might have implication for reduced intake rate. Contrary to this, despite its accessibility, *B. aegyptiaca* was less consumed during the wet season than the dry season. This might be associated with variation in the degree of selection of forage species based on nutritional content. As dik-diks strictly get water from the forage species (Manser and Brotherton, 1995; Maloiy, 2000), plants with higher moisture content might be preferred during the dry.

Dietary contributions of the different forage species to the diet of male and female Salt's dik-diks were not significantly varied. This can be linked to activity synchronization for the majority of the time which leading to foraging on similar species simultaneously. Besides this, metabolic requirements may determine the proportion of foraging time required between the sexes. High forage reqirment in females can be linked to body size dimorphism (Own-Smith, 1988; Estes, 1991) and higher energy expenditure in females for lactation (Neuhaus and Ruckstuhl, 2009).

Seasonal contribution of the important forage species indicated comparable proportions. Occupation of permanent territories year round (Herndrichs, 1975) might have enabled them to be confined to similar forage species preference through switching between narrow and broad forage preferences as per the environmental condition (Fryxell and Doucet, 1991; Brown, 1999; Otieno *et al*., 2019).

Varied preference of forage species across seasons were reported for Kirk's dik-dik (Manser and Brotherton, 1995). This difference can be associated to the physical and biological features of different ecosystems, in which the issue should be seen in broad spatial and temporal scales. Besides, in the present study, availability of some principal forage species of Salt's dik-dik were not highly influenced by seasonal variation due to their adaptive feature to the arid environment (Sebsebe Demissew and Friis, 2009) and moisture content of the soil. Thus, the availability of most of the principal forage species, coupled with occupation of permanent territories year round might have enabled Salt's dik-dik to have comparable dietary composition across seasons.

Thickets and bushlands were found to support higher proportions of shrubs and tree forage forms. Bushlands, in the same way, were found to support the highest proportion of herbs and graminoid, which were recognized among the principal forage species of Salt's dik-dik. Habitat association is a function of different physical and biological requirements of an animal (Hopcraft *et al*., 2010; Morris, 2011). The higher abundance of Salt's dik-dik in bushland and thicket habitats of ANP can be supported by better resource availability in such habitat types.

Salt's dik-diks do not principally consume on leaf litter. Contrary to the present finding, leaf litter was found to constitute the major diet of Kirk's dik-dik during the dry season (Manser and Brotherton, 1995). Incomparable observations of the forage selection among these related species of *Madqua* should be seen from various aspects ranging from attributes constraining distinct species in forage selection to landscape features of various ecosystems across temporal and spatial scales.

Acceptability of a particular forage species is determined by its availability and palatability. Higher acceptability of *A. senegal, A. millifera* and *B. aegyptiaca* can be linked to these attributes. Forage preference of animals is determined by a number of factors ranging from the physiological requirement and morphological features of herbivores to the ecological and landscape aspects of the habitat. Despite the proportional availability in the environment, palatability of a forage species is known to be determined by its inherent physical (Cooper and Owen-Smith, 1986; Hanley *et al.,* 2007), chemical (Caister *et al.,* 2003; Mithofer and Boland, 2012) and phenological aspects (Owen-Smith and Novellie, 1982; Turnley *et al.,* 2013).

6.5 Conservation challenges and opportunities

Effective and sustainable conservation activities rely partly on the contribution of local community. However, in different ecosystems of the world, the attributes of local community influence conservation activities differently. In developing countries, protected areas face intense pressure from the local community as livestock production and agricultural activities are important attributes of the livelihoods of the rural community.

For the majority of the households (69%), in ANP, the primary livelihood is obtained from livestock raring (Daniel, 2011; Yihew Biru, 2017). Similarly, as the Park lies between two regional states, three ethnic groups; Afar, Ittu and Kereyu communities constitute the pastoral community around the Park. The direct and indirect benefits as well as challenges of conservation activities in protected areas arise from the traits of the local community (Adams and Hulme, 2001; Gandiwa *et al*., 2013) as human induced ecological impacts are the major drivers of wildlife and habitat loss (Anagaw Atickem *et al*., 2011; Demeke Datiko and Afework Bekele, 2011; Yosef Mamo *et al*., 2012).

Grazing was one of the major threats which affect the habitats and wildlife of the Park. As pointed out by Yihew Biru *et al*. (2017), shortage of livestock feed, water, and climate change were the major drivers causing encroachment in the Park. Overgrazing by livestock was reported to have the highest threat index in the eastern protected areas of Ethiopia (Mengistu Wale *et al*., 2017). Grazing pressure has implications in affecting the vegetation diversity as well ecosystem stability (Augustine and Mcnaughton, 2004). Bush encroachment was widely observed in ANP, thus the local community switched from cattle to mixed feeder goat and camel herds (Yihew Biru *et al*., 2017), as it was evident in the present study. This is an implication how grasslands change to shrublands due to intense grazing (Roques *et al*., 2001). Grazing is also linked to expansion of invasive species in ANP (Tamene Yohannes *et al*., 2011).

Removal of forest and mis-utilization of the products promotes degradation of wildlife habitats in protected areas, especially in developing countries (Evangelista *et al*., 2007; McElwee, 2010), where firewood and charcoal remains the major energy sources (Bonjour *et al*., 2013). ANP is different from the other protected areas of Ethiopia that is located in the eastern part, with respect to threat related to poching and agricultural expansion (Mengistu Wale *et al*., 2017). Inefficient agricultural practices among the local communities aggravate natural resource exploitation of the protected areas as alternative livelihood (Butler, 2000). Thus, in ANP, following illegal settlement inside the Park, the pastoralists engage in large scale charcoaling activity to compensate the low return from the inefficient agricultural practices.

Infrastructure developments, such as highway and railway connecting Addis Ababa to Dire-Dawa and Djibouti, intersect the Park leading accessible for community interventions, besides resulting in road kill (Abule *et al*., 2005), risk of collusion and promotion of invasive species (Tamene Yohannes *et al*., 2011). Different development projects on the vicinity of the Park promote community settlement (Belay Zerga, 2015). Respondents claim that such projects are acting as a bridge between the pastoral and urban community in creating a new livelihood adaptation through generation of money from their dairy products. Such interaction aggravated the need for nearby settlement site which provides both the necessities for pasture land inside the Park and access for other means of money generating activities. Thus, the Park is considered as an ideal center for such interaction and the pastoralist community tries to sustain the benefit at any expense. One of the natural factors, susceptibility of the area for drought, promotes misuse of the Park’s resource by the local community. According to Yihew Biru *et al*. (2017), positive attitude about the Park, in most pastoralists communities arise from the assumption and use of the Park for their livestock during the critical dry seasons of the year, particularly, the Afar pastoralists.

The main livelihood of the pastoral communities around ANP is based on their large herds which require communal pasture land. Due to this, shortage of pasture leads the local community to share the grazing area and watering point with wild animals in the Park. The situation becomes highly aggravated, when it leads to conflict of interest among the Park officials and pastoralists (Mulonga *et al.,* 2003; Madden, 2004). Even the local community develop negative attitude towards the wild animals due to the restriction for free access of the resources of the Park. Previous study on the attitude of local community towards the protection of the Park revealed positive attitude among the majority of the communities (Yihew Biru *et al*., 2017). However, when it comes to practice, the existence of the Park is needed for the existence of their livestock as it provides fodder and water in the highly demanding seasons of the year. Injury and predation of cattle by wild carnivores were reported in some villages. Human-wildlife conflict is evident in different protected areas of Ethiopia (Getachew Gebeyehu and Afework Bekele, 2009; Mesele Yihune *et al.,* 2009).

Execution of law enforcement among the responsible bodies was weak in ANP. At present conflict between the Park officials and local community is intense. Lack of coordinated law enforcement among the stakeholders, is affecting the scouts who try to defend the Park. Feeling of insequrity among the scouts leads to disinterest in their job. Despite this, law enforcement is believed to be the best practice in minimizing wildlife loss and habitat destruction (Gibson *et al*., 2005).

Rapid human population growth causes land use/cover change and affects the resource basis of wild animals. The human population increase among the local pastoralist communities of ANP has resulted from the immigration of the Ittu tribe towards the locality of the Park. In addition to the resident Afar and Kereyu communities, the immigrant Ittu pastoralists put pressure on the Park. The human population growth trend of the three tribes indicated more than 65% increase in the past decade (CSA, 2007). Globally, human population growth has resulted in direct or indirect impacts on protected areas (Muhammed *et al*., 2007; Mackenzie 2012; Zerihun Girma *et al*., 2012).

Due to high human population growth among the local community, there will be an opportunities to mobilize the portion of the population in different economic projects, such as in Methara Sugar Factory. Educating and empowering the younger ones in different activities, such as enrolling them in ecotourism; an alternative livelihood activity as well reducing pressure on the Park through minimizing engagement in mere pastoral life. The personal attitudes and values towards wildlife and ecosystem conservation scale up with the levels of understanding (Mishra *et al*., 2003).

7. CONCLUSION AND RECOMMENDATIONS

The present study has assessed the population status, habitat association, behavioral aspects and dietary composition of Salt's dik-dik in ANP providing a base line data for further study and filling the knowledge gap. The population size of the species across sampling sites and different habitats of the study area indicated variation. Pronounced variation in population size was attributed to variation in habitat quality and conservation status of the study area. As small browsing ungulates dwelling in semi-arid ecosystem, it needs to maximize the foraging activity in the cooler hours of the day. Consequently, habitat overlaps of livestock accompanied with herders within the territory of the animals disturb them. ANP is among the protected areas of Ethiopia, known to be highly affected by anthropogenic activities. The present study focuses, in general on the possible impacts of habitat disturbance resulting from the local community on the population trends of the study animal. The pastoral and semi-pastoral livelihood activity of the majority of the surrounding community accompanied by inter-ethnic conflict amongst the pastoralists put the existence of the Park as a protected area in intense pressure. Therefore, the following recommendations are suggested for better conservation of the animal and habitats of ANP:

- Regular assessment of the population status of Salt's dik-dik in the study area should be carried out to take alternate conservation measures as needed.
- Further and detailed studies on the physiological and behavioral requirements of the animal need to be conducted in order to design a complete conservation strategy of the animal and its associated habitats.

- Enforcement of biodiversity conservation law is mandatory in order to sustain the Park as a conservation area.
- Habitat restoration programs in ANP need due attention from the stakeholders.
- Integration of the local community in conservation practice and employing them to benefit from the wellbeing of the Park is mandatory.
- Provision of alternative livelihood opportunities for the pastoralist and agro-pastoralist communities of the area is needed, in order to minimize land invasion by large herds. Educating and empowering the younger generation can make a bridge for a better livelihood opportunity through loosening the mere dependence on cattle raring and leading non sedentary lifestyle. Engagement in Agriculture and tourism sectors may be a promising livelihood. Provision of education access to the young with regular supervison, can bring sustainable remedy.
- Designing alternative ways for livestock production which avoids dependence on the resources of the Park is crucial.
- Empowering the younger generation through provision of education access, as well as regular supervision of the implementation of the measure is unquestionable.
- The federal government should resolve the instability in the area, since the conflict greatly constrained tourism and research in the Park. This needs due attention.

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9. APPENDICES

Appendix I. List of large wild mammals and their status in the IUCN Red List of species in ANP (IUCN, 2008).

English Name	Scientific Name	Status on IUCN Red List**
Beisa Oryx	*Oryx beisa beisa*	Near Threatened
Soemmering’s gazelle	*Gazella soemmeringi*	*
Defassa waterbuck	*Kobus defassa*	*
Lesser Kudu	*Strepsiceros imberbis*	Near Threatened
Greater Kudu	*Strepsiceros strepsiceros*	Least Concern
Salt’s dik-dik	*Madoqua saltiana*	Least Concern
Chanler’s Reed buck	*Redunca fulvorufula*	*
Klipspringer	*Oreotragus oretragus*	Least Concern
Bushbuck	*Tragelaphus scriptus*	Least Concern
Warthog	*Phacochoerus aethiopicus*	Least Concern
Ethiopian hare	*Lepus habessinicus*	Least Concern
Hippopotamus	*Hippopotamus amphibious*	*
Baboon	*Papio anubis baboon*	*
Baboon	*Papio hamadryas*	Least Concern
Vervet monkeys	*Crecopithecus aethiops*	Least Concern
Lion	*Panthera leo*	Vulnerable
Leopard	*Panthera pardus*	Near Threatened
Cheetah	*Acinoyx jubatus*	Vulnerable
Caracal	*Caracal caracal*	*
Porcupine	*Hystrix cristata*	Least Concern

Appendix II. Population record of Salt's dik-dik during the wet season (T.L = transect length in km, habitat types; thicket, bushland = bush, O. bush =open bushland, shrub=shrub grassland).

Site	Habitat	T.L	Width	Area	sightings	herd size	Total	p1	p2	Herd
1	Thicket	0.8	11	8800	1	2	2	0.17		AM, AF
2	O. bush	0.9	21	18900	2	2, 1	3	0.6	0.25	AM, AF, SAM
3	Bush	1.3	22	28600	2	1, 2	3	0.2	0.8	AM, AF, SAF
4	Bush	1.7	16	27200	2	2, 2	4	0.3	0.33	2AM, 2SAM
5	Bush	1.6	20	32000	1	1	1	0.4		SAM
6	Thicket	0.8	12	9600	2	2, 1	3	0.75	0.45	2AM, AF
7	O. bush	1.2	15	18000	2	1, 1	2	0.4	0.5	AM, AF
8	Thicket	1.1	11	12100	1	2	2		0.45	AM, AF
9	O. bush	1.06	36	30960	0		0	0		
10	Shrub	1.8	24	43200	2	1,2	3	0.4	0.7	AM, AF, SAM
Gotu		12.26		155200	13					
1	O.bush	1.45	27	39150	2	2,1	3	0.6	**0.27**	2AM, AF
2	Open bush	0.85	9	7650	1	1	2	0.84		AM, AF
3	Bush	2.1	16	33600	1	1	1	0.01		AM
4	Bush	0.9	30	27000	2	2,1	3	0.62	0.42	AM, AF, SAM
5	Bush	1.3	10	13000	2	1,1	2	0.17	0.8	AM, SAM
6	O. bush	1.4	9	12600	1	1	1	0.4		AM
7	Thicket	0.95	11	10450	0		0	0		
8	Thicket	0.85	21	17850	1	2	2	0.5		AM, AF
9	Thicket	1.1	17	18700	1	1	1	0.78		AM
10	O. bush	1.5	34	51000	1	2	2	0.43		AM, AF
Ras Hotel		12.4		161300	10					
1	Bush	1	31	31000	2	1,1	2	0.6	0.4	AM, SAM
2	Bush	1.5	10	15000	1	3	3	0.42		AM, AF, JUV
3	Bush	1.2	8	9600	2	2,2	4	0.6	0.3	2AM, 2AF
4	Shrub	1.5	17	25500	2	1,1	2	0.5	0.3	AM, SAM
5	Shrub	1.2	8	9600	1	2	2	0.75		AM, AF
6	Bush	0.8	21	16800	1	1	1	0.14		SAM
7	Thicket	1.1	16	11200	1	2	2	0.82		AM, AF
8	Shrub	1.5	28	42000	1	2	2	0.7		AM, AF
9	Bush	1.5	9	13500	1	3	3	1		AM, AF, JUV
10	Thicket	0.9	13	11700	1	1	1	0.56		SAM

Ayer marefia		12.2			11		21			
1	Bush	1.2	14	16800	1	1	1	0.7		AM
2	O. bush	1.5	19	28500	1	1	1	0.67		AF
3	Shrub	1.8	15	15000	0	0	0	0		
4	Bush	1	16	16000	2	1,1	2	0.33	0.7	AM, SAF
5	shrub	2	24	48000	1	2	2	0.7		AM, AF
6	Bush	1	13	13000	1	1	1	0.45		SAM
7	Open bush	1.5	11	16500	1	1	1	0.42		AM
8	Thicket	0.5	19	9500	1	1	1	0.67		AM
9	Bush	0.7	17	11900	2	2,1	3	0.87	0.7	AM, AF, SAF
10	Bush	1.3	10	13000	2	1,1	2	0.42	0.5	AM, AF
Amaret		12.5			8					
1	Thicket	0.9	16	14400	1	2	4		0.5	AM, AF
2	Thicket	0.6	17	10200	2	1,1	1	0.77	0.66	SAM, SAF
3	Bush	2	11	22000	2	2, 1	1	0.5	0.3	AM, AF, SAM
4	Shrub	1.5	24	36000	1	2	2	0.4		AM, AF
5	O. bush	0.7	19	13300	2	1,1	2	0.7	0.8	AM, SAF
6	O. bush	1.4	14	15400	2	3,1	4	0.9	0.4	AM, 2AF, UJS
7	Thicket	1.1	9	13500	0	0	0	0		
8	Bush	1.7	17	28900	2	1,2	3	0.4	0.8	AF, AM, UJS
9	Shrub	1.2	19	32300	1	2	2	0.7		AM, AF
10	Shrub	1.1	9	12600	1	3	3	0.87		AM, AF, UJS
Hot Spring		12.2			12					
1	Bush	1.5	17	25500	1	2	2	0.83		AM, AF
2	O. bush	1	16	24000	2	1,1	2	0.52	1	AM, SAM
3	Shrub	1.2	11	13200	3	2, 1,1	4	0.72	0.58	AM, AF, UJS,SAF
4	O. bush	1	19	19000	2	1,1	2	1	0.8	AM, SAM
5	O. bush	0.9	9	8100	0	0	0	0		
6	Thicket	0.9	10	9000	1	2	2	0.63		AM, AF
7	Shrub	1.1	31	34100	1	1	1	0.72		SAM
8	O. bush	2	29	58000	1	1	1	0.55		AM
9	O. bush	1.4	11	15400	2	2,1	3	0.9	0.4	AM, AF, SAM
10	Bush	1.5	9	13500	1	3	3	1		AM, AF, JUV
Kudu Valley		12.5								
1	Shrub	1.8	24	43200	2	1,2	3	0.4	0.7	AM, AF, SAM
2	Shrub	1.6	15	24000	1	2	2	0.4		AM, AF
3	Bush	0.7	26	18200	2	1,1	2	0.7	0.67	SAM, SAF

	4	Bush	0.8	12	9600	1	1	1	0.7		AM
	5	Bush	1.6	14	22400	0	0	1	0		
	6	Bush	1.5	9	13500	0	0	0	0		
	7	O. bush	1.15	27	22950	0	0	0	0		
	8	Shrub	1.3	31	40300	0	0	0	0		
	9	O. bush	1.2	28	33600	1	1	1	0.8		AM
	10	O.bush	0.6	24	14400	2	1,1	2	0.9	0.6	AM, SAM
Gimel Bet			12.25			7					
	1	Thicket	1	14	14000	3	1,2, 1	4	0.48	0.7	AF, AM, SAM, SAF
	2	Thicket	0.7	17	11900	2	2,2	4	0.83	0.5	2AM, 2AF
	3	Thicket	0.8	9	7200	2	1,1	2	0.7	0.43	AM, SAM
	4	O. bush	2	13	26000	2	1,3	4	0.88	1	2AM, AF, JUV
	5	Bush	1.8	12	21600	2	2,2	2	0.32	0.6	2AF, 2AM
	6	Bush	1.5	12	18000	2	2, 2	4	0.5	0.6	2AM, 2AF
	7	Bush	1.5	20	30000	2	1,1	2	0.9	0.3	AM, AF
	8	O. bush	0.6	20	12000	2	1,2	3	0.08	0.2	AM, AF, SAF
	9	Shrub	1.7	13	16900	1	1	1	0.45		AM
	10	O. bush	0.64	16	10240	1	2	2	0.16		AM, AF
Geda			12.24			17					

Appendix III. Population count of Salt’s dik-dik during the wet season**.**

Site	**Habitat**	**T.length (km)**	**Width (m)**	**Area (m^2)**	**Sightings**	**herd size**	**p1**	**p2**	**p3**	**Category**
1	Thicket	0.8	14	11200	1	3	0.38			1AM, AF, UJS
2	O. bush	0.9	24	16800	1	3	0.7			SAF, AM, AF
3	Bushland	1.3	19	24700	2	2,3	0.45	0.86		2AM, 2AF, UJS
4	Bushland	1.7	16	27200	2	2, 3	0.31	0.18		SAF, 2AF, 2AM,
5	Bushland	1.6	25	40000	2	2,1	0.4	0.2		AM, AF, UJS
6	Thicket	0.8	12	9600	1	3	0.67			AM, AF, UJS
7	O. bush	1.2	22	26400	2	1,2	0.2	0.5		SAM , AM, AF
8	Thicket	1.1	16	17600	1	3	0.68			AM, AF, SAF
9	O. bush	1.06	38	76000	2	1,1	0.16	0.45		SAM, SAF
10	Shrub	1.8	21	31500	2	1,1	0.7	0.5		AM, SAF
Gotu		12.26		173500	12		6.1			
1	O. bush	1.45	28	64400	2	1, 1		0.4	0.3	SAF, SAM
2	O. bush	0.85	15	12750	1	2		0.65		AM, AF
3	Bushland	2.1	26	54600	2	3,3	0.5	0.42		2AM, 2AF, 2UJS
4	Bushland	0.9	17	15300	1	2	0.7			AM, AF
5	Bushland	1.3	18	39600	1	2	0.6			AM, AF
6	O. bush	1.4	15	21000	1	2	0.94			AF, UJS
7	Thicket	0.95	18	17100	2	2,1		0.8	0.78	AM, AF, SAM
8	Thicket	0.85	17	30600	2	1, 3	0.4	0.7		AM, AF, SAF, UJS
9	Thicket	1.1	16	17600	1	2	0.86			AM, AF
10	O. bush	1.5	11	16500	2	1,2	0.43	0.82		2AM, AF
RAS Hotel		12.4			12					
1	Bushland	1	15	15000	2	3,2	0.9	0.66		2AM, 2AF, UJS
2	Bushland	1.5	18	27000	2	3,3	0.44	0.88		2AM, 2AF, 2UJS
3	Bushland	1.2	14	16800	2	2, 3	1	0.9		2AM, 3AF
4	Shrub	1.5	13	19500	2	2,1	0.63	0.36		AM, AF, SAM
5	Shrub	1.2	36	43200	2	1,2	0.73	0.9		AM, 2AF,
6	Bush	0.8	18	14400	1	2	0.45			AM, AF,
7	Thicket	1.1	12	8400	1	2	0.7			AF, JUV
8	Shrub	1.5	26	39000	2	2,1	0.6	0.25		AM, AF, SAM
9	Bushland	1.5	34	51000	2	1,2	0.43	0.7		SAM, AM, AF
10	Thicket	0.9	18	16200	1	3	0.83			AM, AF, UJS
Ayer Marefia		12.2			14					
1	Bushland	1.2	13	15600	1	2	0.5			AM, AF
2	O. b.land	1.5	31	46500	1	1	0.4			AF
3	Shrub	1.8	38	38000	0	0	0			
4	Bushland	1	16	16000	3	2, 1	0.6	0.07		AF, UJS, SAM
5	Shrub	2	22	44000	3	1, 1, 1	0.57	0.65	0.7	SAM, AM, SAF

	6	Bush	1	15	15000	2	2	0.7			AM, AF
	7	O. bush	1.5	21	31500	2	1,1	0.68	0.8		SAM, SAM
	8	Thicket	0.5	15	7500	1	2	0.9			AM, AF
	9	Bush	0.7	18	21600	1	1	0.5			SAM
	10	Bush	1.3	50	30000	0		0			
Amareti			12.5			11					
		Thicket	0.9	18	26250	1	2	0.33			AF, UJS
	2	Thicket	0.6			1	3	0.9			AM, AF, UJS
	3	Bush	2	23	44580	2	3,2	0.7	0.27		2AM, 3AF
	4	Shrub	1.5	33	49335	2	2,1	0	0.4		AM, AF, SAM
	5	O. bush	0.7			0		0			
	6	O. bush	1.4	19	46450	1	3	0.9			AM, AF, UJS
	7	Thicket	1.1	17	24570	3	1,3,2	0.35	0.9	0.5	2AM, 2AF, SAM, UJS
	8	Bush	1.7	22	29820	2	3,2	0.8	0.5		2AM, 2AF, SAF
	9	Shrub	1.2	21	35700	1	2	1			AM, AF
	10	Shrub	1.1	23	32200	2	1,1		0.68	0.71	SAM, SAF
Hot spring			12.2			12					
	1	Bush	1.5	25	33360	2	2, 3	0.86	1		2AM, 2AF, UJS
	2	O. bush	1	20	29100	2	2,1	0.85	0.53		AM, AF, SAM
	3	Shrub	1.2	26	31200	2	1,2	0.6	0.57		AM, AF, SAM
	4	O. bush	1	16	16000	1	3	0.9			AM, AF, UJS
	5	O. bush	0.9	37	33300	0	0	0			
	6	Thicket	0.9	22	19800	2	2,2	0.4	0.75		2AM, 2AF
	7	Shrub	1.1	18	19800	0		0			
	8	O. bush	2	17	34000	2	1,2	0.44	0.94		AM, AF, SAF
	9	O. bush	1.4	15	22500	2	1,2	0.67	0.84		2AM, AF
	10	Bush	1.5	28	50400	2	2,2	0.43	0.6		2AM, 2AF
Kudu Valley			12.5			11					
	1	Shrub	1.8	18	21600	2	1,1	0.53	0.5		SAM, SAM
	2	Shrub	1.6	22	26400	2	2	0.7			AM, AF
	3	Bush	0.7	25	17500	0		0			
	4	Bush	0.8	23	34500	1	3	0.42			AM, AF, SAF
	5	Bush	1.6	14	21000	0	0	0			
	6	Bush	1.5	17	25500	2	1,1	0.3	0.5		SAM, SAF
	7	O. bush	1.15	25	42500	1	2	0.6			AM, AF
	8	Shrub	1.3	18	21600	1	1	0.5			SAM
	9	O. bush	1.2	50	30000	0		0			
	10	O. bush	0.6	27	27000	1	2	0.6			AM, AF
Gimel Bet			10.15			8					
		Thicket	1	24	24000	3	2,2, 1	0.88	0.2	0.79	2AM, 2AF, 1SAF

	Thicket	0.7	17	11900	2	3, 2	0.9	0.58		2AM, 2AF, UJS
	Thicket	0.8	22	17600	2	2,1	0.82	0.3		AM, AF, SAF
	O. bush	2	20	40000	2	3,1,	0.9	0.4		2AM, AF, SAM,
	Bush	1.8	27	48600	3	3,3, 3	0.9	0.3	0.7	3AM, 3AF, SAF, 2UJS
	Bush	1.5	22	33000	2	3, 3	1	0.95		2AM, 2AF, UJS, SAF
	Bush	1.5	33	49500	3	1,2, 3	0.08	0.71	0.9	2AM, 2AF, UJS, SAM
	O. bush	0.6	27		1	3	1			AF, AF, UJS
	Shrub	1.7	19	24700	2	2,2,	0.75	0.6		2AM, 2AF
	O. bush	0.64			1	1		0.1		SAM
Geda		12.24								

Appendix IV. Salt's dik-dik population categories and distance data collecting sheet

Season _________ Date ___________ Site ______________
Transect_________ Length _______________________________
Time started ________________ Time completed __________________________
Start coordinate______________ End coordinates ________________________

No	Herd size					Distance (m)	Angle (0-90^o)	Habitat Type
	AM	AF	SAM	SAF	UJS			

AM= Adult Male, AF= Adult Female, SAM= Sub-Adult Male, SAF = Sub-Adult Female, UJS= Unidentified Juvenile Sex

Appendix V. Questionnaire for field officer and personnel of ANP regarding the challenges and opportunities of conservation rooting from community.

I express my kind gratitude in advance for your time and effort to respond to this questionnaire:

Personal information of respondents

i. Education level__________________
ii. Profession____________________
iii. Experience in the Park_________________

Overview

1. With what principles the Park and local community had coexisted successfully in the early times of the Parks establishment?
____
____
2. How the local people benefit from the Park? Please specify, and mention the trend in the past five years.
____
____
____
3. What the manner of resource use by the community in the Park looks like?
   a. Totally restricted
   b. Restricted to the core zone
   c. Freely accessed

Challenges

4. How community affect the habitat and Park. Rate the impacts.
   a. Settlement
   b. Overgrazing
   c. hunting
   d. Firewood, charcoal , hey and resin collection
   e. Causing conflict with the field officials
   f. Mention if any ____
5. Is the community interference in the Park increasing from time to time? If yes what do you think the reason is? Yes No
   a. Shortage of grazing land
   b. Population increase
   c. Increased livestock number
   d. Increased settlement due to ethnic conflict
   e. Unchanged livelihood
   f. Proximity to water sources
6. What the communication of the Park officials with the pastoralists of the community looks like? Please describe.
____
____
____

7. What are the causes of conflict with the Park officials?
   a. Demarcation question
   b. Conflict due to wild life
   c. Resource shortage
   d. Political strain
   e. Mention if any ________________________________
8. Rate the risk of conflict with the community
   1. High
   2. Low
   3. Moderate
9. Has the conflict affected your initiative in conservation activity? Yes No. if your answer is 'yes', explain____
   ____
10. Do you think the local community of ANP is threatening the Park in recent days? Rate if your answer is yes. a. To some extent b. Moderately c. Highly
11. What is your perception regarding the livelihood of the majority of the local community as challenge or opportunity for conservation. Please explain? Opportunity____
    ____
    ____
    Challenge
    ____
    ____
    ____
12. How the local people contribute for conservation activities? Please describe.
    ____
    ____
    ____
13. What are the attributes of the local people seems opportunity for conservation? Please describe.
    a. Diverse ethnicity (how?)____
    b. Attitude for wildlife conservation (how?)___________________________________
    c. Manner of settlement (how)____
14. What is your recommendation to improve community participation in conservation of the Park?
    ____
    ____
    ____
    ____

Appendix VI. Salt's dik-dik population record (Mean±SE) per transect (T1-T10) from the study sites of ANP during the wet and dry seasons (D= Dry, W= Wet).

Study Sites	Season	Mean±SE	Population per Transect										Total
			T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	
Gotu	D	3.5±0.27	3	3	5	5	3	3	3	3	4	3	35
	W	2.3±0.37	3	3	4	1	3	2	2	0	3	2	23
Ras Hote	D	2.8±0.42	2	2	6	2	2	2	3	4	2	3	28
	W	1.7±0.3	2	1	3	2	1	0	2	1	2	3	17
Ayer Marefia	D	3.2±0.5	5	6	5	3	3	2	2	3	2	1	32
	W	2.2±0.3	2	3	4	2	2	1	2	2	3	1	22
Amareti	D	2±0.3	2	1	0	3	3	2	2	2	2	3	20
	W	1.4±0.27	1	1	0	2	2	1	1	1	3	2	14
Hot Spring	D	3.1±0.57	2	3	5	3	0	3	6	5	2	2	31
	W	2.3±0.34	2	2	3	2	2	4	0	3	2	3	23
Kudu Valley	D	2.5±0.5	5	3	3	3	0	4	0	3	2	2	25
	W	2±0.37	2	2	4	2	0	2	1	1	3	3	20
Gimel Bet	D	1.4±0.34	2	2	0	3	0	2	2	2	1	0	14
	W	1.1±0.35	3	2	2	1	0	0	0	0	1	2	11
Geda	D	4.6±0.69	5	5	3	4	9	6	6	3	4	1	46
	W	3±0.37	4	4	2	4	4	4	2	3	1	2	30
Total	W	2±0.13											160
	D	2.89±0.2											231
Grand Total													391

Appendix VII. Density of Salt's dik-dik across the sampling sites of ANP.

Study site	Season	Mean±SE (km^2)	95% CI for Mean		%CV
			Lower Bound	Upper Bound	
Gotu	W	30.1±5.5	18.2	42	44.1
	D	53.5±4.7	42.6	64.3	42.3
Ras Hotel	W	37.4±5.9	22.9	51.9	33.4
	D	34.9±5.7	22	47.9	40.6
Ayer Marefia	W	29.5±6.3	15.2	43.8	26
	D	44.4±3.4	36.7	52.1	30.7
Amareti	W	19.7±4.5	9.5	29.9	30.5
	D	28±5	16.7	39.5	31
Hot Spring	W	29.5±5.4	17.4	41.7	41
	D	36±7.6	18.7	53.2	36.3
Kudu Valley	W	18.1±3.7	9.4	26.9	35.3
	D	29.3±6.5	14.56	44	39.7
Gimel Bet	W	17.7±5.3	5.7	29.6	34.1
	D	23.7±8.2	5.1	42.2	39.1
Geda	W	45.6±6.9	30	61.1	43.5
	D	48.8±6.4	34.4	63.3	47.2
Total	W	28.4±2.2	24.1	32.7	
	D	37.3±2.4	32.64	42	

Appendix VIII. Diurnal Activity Budget (Mean ±SE) of adult male Salt's dik-dik across the three time blocks during the wet and dry seasons in the study sites of ANP.

Site	Season	Time block	Activity budget (in min)					
			Feeding	Walking	Vigilance	Resting	Rumination	Others
Gotu	D	7:00-10:00	3.2±0.26	0.75±0.13	0.95±0.1	0.2±0.07	0.35±0.06	0.23±0.08
		12:00-3:00	0.1±0.11	0.38±0.2	1.5±0.2	2.5±0.24	2.3±0.18	0.5±0.15
		5:00-6:00	2.1±0.7	0.55±0.2	0.76±0.22	0.6±0.25	0.65±0.2	0.43±0.23
	W	7:00-10:00	2.35±0.39	0.65±0.12	0.8±0.2	0.65±0.18	0.92±0.2	0.49±0.13
		12:00-3:00	0.6±0.44	0.5±0.21	1.15±0.2	1.82±0.44	1.5±0.15	0.4±0.23
		5:00-6:00	2.15±0.7	0.56±0.19	0.8±0.22	0.62±0.25	0.65±0.18	0.43±0.22
R.Hotel	D	7:00-10:00	2.9±0.36	0.5±0.1	1.1±0.16	0.25±0.18	0.6±0.12	0.21±0.1
		12:00-3:00	0.1±0.1	0.2±0.13	1.3±0.18	2.9±0.34	2.4±0.3	0.5±0.14
		5:00 -6:00	3±0.6	0.6±0.16	0.75±0.3	0.35±0.16	0.5±0.14	0.31±0.2
	W	7:00-10:00	2.7±0.4	0.6±0.16	0.75±0.16	0.5±0.13	0.81±0.16	0.35±0.14
		12:00-3:00	0.5±0.3	0.73±0.18	1.03±0.12	2.15±0.48	2±0.21	0.3±0.16
		5:00-6:00	3.05±0.63	0.6±0.16	0.75±0.31	0.35±0.16	0.5±0.13	0.31±0.2
Amareti	D	7:00-10:00	2.5±0.36	0.81±0.18	1.15±0.16	0.2±0.1	0.46±0.08	0.26±0.9
		12:00-3:00	0.24±0.13	0.23±0.1	1.4±0.16	2.7±0.2	2.15±0.14	0.6±0.1
		5:00-6:00	2.4±0.64	0.65±0.23	0.65±0.18	0.6±0.17	0.75±0.23	0.4±0.3
	W	7:00-10:00	2.5±0.4	0.5±0.12	0.92±0.19	0.8±0.2	0.7±0.2	0.2 ±0.07
		12:00-3:00	0.7±0.42	0.65±0.21	1.02±0.1	2.1±0.2	2.06±0.24	0.27±0.16
		5:00 -6:00	2.4±0.64	0.65±0.23	0.65±0.18	0.62±0.18	0.75±0.23	0.4±0.27
Geda	D	7:00-10:00	3.3±0.27	0.5±0.1	0.9±0.15	0.15±0.1	0.4±0.11	0.15±0.1
		12:00-3:00	0.18±0.12	0.16±0.1	1.1±0.2	2.9±0.25	2.5±0.16	0.47±0.13
		5:00-6:00	2.9±0.5	0.49±0.13	0.7±0.17	0.5±0.14	0.63±0.17	0.29±0.2
	W	7:00-10:00	2.44±0.43	0.45±0.13	0.93±0.22	0.7±0.19	0.5±0.14	0.43±0.14
		12:00-3:00	0.6±0.56	0.82±0.3	1.3±0.3	1.15±0.35	1.3±0.17	0.63±0.23
		5:00-6:00	2.9±0.5	0.48±0.13	0.7±0.17	0.5±0.14	0.63±0.17	0.29±0.2

Appendix IX. Percentage contributions (Mean ± SE) of forage species to the diet of adult male and female Salt's dik-dik during the wet and dry seasons in ANP.

		AF		AM	
Family	Species	Wet season (%)	Dry season (%)	Wet season	Dry season
	Tree=10	**83.14%**	**90.62%**	**83.76**	**90.65**
Fabaceae	*A. senegal*	39.2± 3.4	43.1± 3.6	38.3±4.3	44.4±3.8
Fabaceae	*A. millifera*	26.6±4.9	13.7±2.1	28.3±1.8	13±2
Balanitaceae	*B. aegyptiaca*	8.66±2	17.82±1.5	8.4±1.85	16.2±1.7
Fabaceae	*A. oerfota*	3.8±1.6	7.38±2.1	3.5±0.8	7.54±2
Fabaceae	*A. etbaica*	2.7±1.2	4.7±1.7	3.1±1.8	4.97±1.65
Rhamnaceae	*Z. spina-christi*	0.53±0.1	0.88±0.23	0.5±0.07	0.84±0.03
Moraceae	*F. capreaefolia*	0.42±0.12	0.8±0.06	0.47±0.02	0.56±0.03
Fabaceae	*A. tortilis*	0.6±0.04	0.94±0.05	0.42±0.5	0.94±0.1
Moraceae	*F. sycomorus*	0.3±0.07	0.6±0.01	0.44±0.08	0.6±0.04
Balanitaceae	*B. rotundifolia*	0.33±0.06	0.7±0.04	0.43±0.06	0.7±0.09
	Shrub=5	**10.95%**	**6.57%**	**10.38**	**6.65**
Tiliaceae	*G. tenax*	3.4±1.4	2.6±0.6	3.1±0.4	2.6±0.3
Olacaceae	*X. americana*	1.32±0.65	1.67±0.2	1.2±0.3	1.67±0.4
Solanaceae	*S. incanum*	0.7±0.14	0.66±0.25	0.7±0.05	0.66±0.03
Verbenaceae	*L. trifolia*	3.8±1.1	0	3.77±0.5	0
Tiliaceae	*G. villosa*	1.73±0.1	1.64±0.4	1.6±0.55	1.72±0.4
	Herb=4	**4.15%**	**0.45%**	**4.35**	**0.6**
Zygophyllaceae	*F. schweinfurthi*	0.4±0.01	0.45±0.01	0.65±0.01	0.6±0.03
Solanaceae	*W. somnifera*	0.85±0.03	0	0.7±0.03	0
Malvaceae	*S. collina*	0.6±0.06	0	0.6±0.06	0
Malvaceae	*S. ovate*	2.3±0.4	0	2.4±0.34	0
	Graminoid =1	**1.76%**	**2.36%**	**1.52**	**2.1**
Poaceae	*C. plumulosus*	1.76±0.18	2.36±0.27	1.52±0.3	2.1±0.5
		100%	100%	100%	100%