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**Population Status, Distribution and Habitat Association of Beisa oryx
(*Oryx beisa beisa*) and Its Interactions with Sympatric Species in
Alledeghi Wildlife Reserve, Ethiopia**

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This is to certify that the thesis prepared by Simeneh Admasu, entitled: Population status, Distribution and Habitat association of Beisa oryx (*Oryx beisa beisa*) in Alledoghi Wildlife Reserve, Ethiopia and submitted in partial fulfillment of the requirements for the Degree of Master of Science (Department of zoological sciences) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Population Status, Distribution and Habitat Association of the Beisa oryx (*Oryx beisa beisa*) and Its Interactions with Sympatric Species in Alledoghi Wildlife Reserve, Ethiopia.

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Addis Ababa University, 2016.

Individual count of Beisa oryx (*Oryx beisa beisa*) was conducted in Alledoghi Wildlife Reserve during September - December, 2015 which covered both wet and dry seasons. Transect count method was used to determine the current population size, group size, demographic composition, seasonal distribution and habitat association of Beisa oryx as well as population status of the two co-occurring wild ungulates (Soemmering's gazelle and Gerenuk). Twelve parallel sampling transects were systematically placed perpendicular to the baseline with a minimum distance of 2 km apart. The total transect length was 167 km, and given that width of 0.6 km on both sides of each transect, about 200 km² area (47.6% of the census zone) was sampled during the study. The density of animals observed per transect was used to calculate mean population density. Mean differences in population structure of the species was compared using Tukey's multiple mean tests. Habitat association and seasonal variation of Beisa oryx and the other two co-occurring ungulates were compared using Chi square test. The population estimate of Beisa oryx was 722. There was a decrease in individuals by 22% compared to the 2009 and 2010 estimates. There was a considerable difference in the number of animals observed during the wet and dry seasons ($\chi^2 = 1252.934$ df = 1 P < 0.001). A total of 101 herds of Beisa oryx were observed (67 and 34 herds during wet and dry seasons, respectively). The difference was statistically significant ($F_{1, 99} = 79.17$, P < 0.001). Age structure was mainly dominated by adults (85%), followed by sub-adults (13%). The sex ratio was dominated by females (55.6%). Mean population density of Beisa oryx and the two co-occurring ungulates observed in different habitat types excluding seasons showed non-significant difference.

Key words: Alledighe Wildlife Reserve, Beisa oryx, Density, Herd size, Habitat, Season.

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DECLARATION

I declare that this dissertation, which I hereby submit for the degree M.Sc. in Zoology at Addis Ababa University is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

SIGNATURE:

DATE

June, 2016

DEDICATION

To all those who sacrificed their lives for conserving wildlife resources in Ethiopia.

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LIST OF ACRONYMS

AWR	Alledoghi Wildlife Reserve
CARE	Cooperative for Assistance Relief Everywhere
CDC	Conservation Development Center
EWCO	Ethiopian Wildlife Conservation Organization
EWCA	Ethiopian Wildlife Conservation Authority
EWNHS	Ethiopian Wildlife and Natural History Society

1. INTRODUCTION

Ethiopia is stratified into a number of ecological units. The associated diversity in climate and the varieties of ecosystems have rendered the country to have a diverse, rare, unique and endemic species (Hillman, 1993; EWNHS, 1996). The Great Ethiopian Rift Valley cuts diagonally across the country from northeast to south creating a vast depression. There is great variation in the altitude ranges from 120 m bsl to 4,620 m asl (Hillman, 1993). These factors strongly influence Ethiopia's extraordinary range of terrestrial and aquatic ecosystems which contributed to a high diversity and rate of endemism (Tesfaye Awas, 2007). So far, 320 species of mammals, more than 860 species of birds, 240 species of reptiles, 71 species of amphibians, 150 species fish, and over 7,000 species of plants are known to exist in Ethiopia (EWCA, 2012; James, 2012; Afework Bekele and Yalden, 2013).

The Alledeghi Wildlife Reserve (AWR) is one of the most important wildlife centers of Ethiopia. This Reserve was established primarily to serve as a buffer zone for the neighboring protected areas such as the Awash National Park (Hillman, 1993) and to conserve the remnant population of Grevy's zebra (*Equus grevyi*) and Wild Ass (*Equus africanus*) and other ungulates that occur in the area (Fanuel Kebede *et al.*, 2012).

This reserve harbors more than 31 mammal and 140 bird species (Appendix. 1) and an excellent landscape of grassland (Hillman, 1993; Fanuel Kebede, 2013). It is one of few places in Ethiopia where a good population of wild ungulates, such as Beisa oryx (*Oryx beisa beisa*) and Soemmering's gazelle (*Gazella soemmeringi*) are observed utilizing the

grassland plains (Fanuel Kebede *et al.*, 2006). It is also home of a number of other important wildlife species including Gerenuk (*Litocranius walleri*), Salt's dikdik (*Madoqua saltiana*), Golden jackal (*Canis aureus*), Spotted hyena (*Crocuta crocuta*) and Aardwolf (*Proteles cristatus*). This Reserve is very unique not only for supporting such substantial populations of wild ungulates, but also harbors the remnant population of the critically endangered equid species Grevy's Zebra (*Equus grevyi*) and Wild Ass (*Equus africanus*) (Fanuel Kebede *et al.*, 2012).

This area is also an important grazing land for the Afar and Issa pastoralist communities (Almaz Tadesse, 2009; Fanuel Kebede *et al.*, 2012). Consequently, overgrazing and bush encroachment are the most prominent impacts rapidly accelerating in this reserve (Almaz Tadesse, 2009). These have created ecological challenges for the reserve particularly for the conservation of the plains dwelling animals. These animals may be at risk of losing their habitats and their chance of survival. Currently, the reserve is proposed to be upgraded to the status of national park together with the nearby "Asebot Gedam" monastery (Kassaye Wami and Arega Mekonnen, 2013).

The availability of accurate data on wildlife resources is essential for conservation of biodiversity, ecosystem stability and also for economic gains (Sinclair and Grimsdell, 1978). Furthermore, it is necessary for management and planning within the context of sustainable development. Regular monitoring reveals updated information about the status of species and their habitats which are vital for remedial measures in the case of major population fluctuations and occasions of major disasters (Inglis, 1976). Inglis (1976) noted that species fluctuations are common and are usually interrelated with the conditions in the

habitat. Therefore, data on population status and trends are essential for the management of wildlife, particularly in conservation areas.

Recent surveys in AWR have revealed the occurrence of populations of Soemmering's gazelle (*Gazella soemmeringi*), Beisa oryx (*Oryx beisa beisa*) and other wild ungulates in this area (Fanuel Kebede, 2013; Kassaye Wami and Arega Mekonnen, 2013). Beisa oryx population in the area was estimated to be about 2,000, which is the highest concentration in Ethiopia (Kassaye Wami and Arega Mekonnen, 2013). However, rapid habitat changes have been occurring in the reserve, as well as in the surrounding pastoral grazing lands, due to the alarming expansion of the exotic woody plant called honey mosquito (*Prosopis junifora*) and bush encroachment (Almaz Tadesse, 2009; Fanuel Kebede *et al.*, 2012). Furthermore, urban development along the road and recent waterhole development inside the reserve are other emerging conservation threats that challenge the long-term ecosystem sustainability of the reserve (Almaz Tadesse, 2009; Fanuel Kebede *et al.*, 2012). According to Fanuel Kebede (2013), over 980 km² (52%) of the total area of the reserve has lost its potential as wildlife habitat for conserving large herbivores. The grassland habitat has suffered from severe encroachment due to the expansion of exotic woody plant species (Fig. 1).



Figure 1. Honey mosquito (*Prosopis junifera*) in the center of the plain.

Accurate information is required on the status of ecosystems and populations of the species in order to attain success in conserving ecosystems as well as specific species. In the absence of more recent data, the Beisa oryx is categorized as ‘Near Threatened’ in the IUCN Red List (Woodfine and Parker, 2011), and here the present study was aimed to assess the present population status and distribution of Beisa oryx in the AWR. There are a number of reasons why this study was required and so important. First, population of the species has been dramatically declining in Ethiopia across most of its historic ranges mainly due to modification of their natural habitat by the ever-increasing human population (Cherie Enawegaw, 2004). For example, its population in the Awash National Park has been declined from 4,020 in 1969 (Robertson, 1970) to below 446 individuals in 2004 (Cherie Enawegaw, 2004). Recently, this has declined to less than 200 individuals (*pers. obser*). Second, the most viable population of the species at present is found in the AWR, which is threatened mainly from anthropogenic

disturbances (Fanuel Kebede, 2013; Kassaye Wami and Arega Mekonnen, 2013). Finally, unlike in most protected areas of Ethiopia where ecological studies have been accumulating since the 1960's, very few such studies have been carried out in the Alledoghi Wildlife Reserve, in general, and on Beisa oryx (*Oryx beisa beisa*) population of AWR in particular. Thus, in order to develop effective conservation measures, it is necessary to gather detailed information about population status and seasonal distribution of the species. Accordingly, the present study focuses on detailed survey to provide information on current population size, habitat preference, seasonal distribution patterns and demographic composition of the species across the habitat types and seasons and habitat use of Beisa oryx (*Oryx beisa beisa*) population in the AWR.

Relationships between plants, herbivores and predators shape animal communities and proper functioning of a given ecosystem (Rosenzweig, 1996; Yosef Mamo *et al.*, 2015). The cause and consequences of variations in the relative abundance of coexisting animal species both in space and time are important elements to understand the functioning of ecosystems (Rosenzweig, 1996, Addisu Asefa, 2016). Therefore, given the prevailing environmental changes in the AWR, in addition to studying the ecology of Beisa oryx, having similar information (e.g. habitat use and overlap) on ecology of other ungulates co-occurring with the Beisa oryx is also of significant importance to design and implement appropriate conservation plans that would ensure their long-term survival. Thus, this study was aimed to examine habitat use overlap between Beisa oryx and two other co-occurring ungulates; namely, Soemmering's gazelle (*Gazella soemmeringi*) and Gerenuk (*Litocranius walleri*).

1.1. Literature Review

The Order Artiodactyla comprises even toed herbivores. The family Bovidae includes true antelope, sheep, goats, and cattle. The genus *Oryx* belongs to subfamily Hipotraginae. All species of oryx have compact and muscular, and relatively long body, short and slender legs and broad neck (Kingdon, 1997). Kingdon (1997) described the physical appearance of Beisa oryx (*Oryx beisa beisa*) as a large antelope with compact and muscular body, long and pattern ears, thick neck and large face. The horns are long, narrow and virtually parallel ridged on the lower half. Horns occur in both sexes and grow 75–120 cm long.

Grubb (2005) recognized four species of oryx (*Oryx beisa*, *Oryx gazelle*, *Oryx dammah*, and *Oryx leucoryx*). Beisa oryx was previously considered as a sub-species of the Gemsbok (*Oryx gazelle*) but Groves and Grubb (2011) and Groves (2011) split *Oryx beisa* into three distinct sub-species: *Oryx beisa beisa*, *Oryx beisa gallarum* and *Oryx beisa callotis*. This new taxonomy is rooted in the phylogenetic species concept and extensive morphological analyses. It is supported by expanding knowledge and interpretation of mitochondrial and nuclear DNA analyses across many species of ungulates (Groves and Grubb, 2011) and particularly for *Oryx* species (Iyengar *et al.*, 2006).

Different forms of oryx occur from the Arabian Peninsula westward into East Africa across the Sahara and southward into southwestern Africa, which represents a morphocline from primitive species, related to horn length, skull breadth and associated body size (Grubb, 2000; Groves and Grubb, 2011). Historically, the Beisa oryx was widely distributed across bushy and grasslands in northern Kenya, south-east Somalia, Ethiopia, Eritrea, Sudan, Djibouti and in parts of Uganda. It is a species of

arid savanna, open scrub and semi-desert regions. However, currently the species is wiped out from the majority of its former ranges, including Sudan, Djibouti and Eritrea (Kingdon, 1997; Vaughan *et al.*, 2000).

At present, it occupies large parts of its historical range in northern and eastern Kenya with the Tana River separating the Beisa oryx (*Oryx beisa beisa*) and fringe-eared oryx (*Oryx beisa callotis*) races. The 1990's aerial survey revealed that at least 25,000 Beisa oryx were thought to exist throughout their entire range. Of these, the Kenyan population was thought to number ~17,000 individuals (Woodfine and Parker, 2011). The Majority of the populations occur in the rangelands of Marsabit, Laikipia and Isiolo districts, Sibiloi National Park and in Samburu National Reserve (Woodfine and Parker, 2011). In Ethiopia, Beisa oryx used to occur widely along the northeastern, eastern and southern lowlands of Ethiopia from sea level up to 1,700 m altitude (Yalden *et al.*, 1996; East, 1997). Its distribution in the country ranges in the Awash Valley from Awash National Park northwards to the Danakil region, and in the lower Rift Valley from Omo north and west including Mago and Omo National Parks, Murule and Borena controlled hunting areas (Thouless, 1995; Cherie Enawgaw, 1999; EWCO/CARE, 2001/2002; CDC, 2002). It still occurs within most of its former ranges, but with a reduced number because of overhunting and habitat changes (Thouless, 1995; Cherie Enawgaw, 2004). The estimated total population of Beisa oryx in Ethiopia is between 4,000 5,000, with steadily declining population compared to its population size before four decades (East, 1997; Cherie Enawgaw, 2004; Woodfine and Parker, 2011). For instance, the Beisa oryx population in the Awash National Park, where the species was considered as the flagship species of the Park, has declined alarmingly (Cherie Enawgaw, 2004).

Fossil evidence (Gentry, 2000; Bibi *et al.*, 2009) and phylogenetic analyses of behavior and various aspects of morphology and anatomy (Vrba and Schaller, 2000) suggest that the tribes Hippotragini (oryx, roan and sable antelopes), Alcelaphini (hartebeests and wildebeests) and Caprini (sheep, goats and relatives) form a monophyletic clade of bovids, with a common ancestor dating to the middle Miocene, about 15 million years ago. Fossil genera such as *Protoryx*, *Pachytragus*, *Tethytragus*, and *Gentrytragus* may be early offshoots of the common ancestor of the *Hippotragini Alcelaphini Caprini clade* (Bibi *et al.*, 2009). The most recent common ancestor of all *Hippotragini* was found at Toros Menalla, Chad. These fossils had a mix of derived and primitive characters (Bibi *et al.*, 2009) and were dated from the late Miocene, about 7 million years ago (Harris *et al.*, 1988; Geraads *et al.*, 2008; Bibi *et al.*, 2009). Younger fossils, specific to Oryx, were found scattered within 750 m of exposed strata on the northwestern shore of Lake Turkana in the extreme northwestern corner of Kenya, near the Ethiopian border (Harris *et al.*, 1988). Specimens were dated at 1.0 – 3.4 million years old. These fossils were used in cladistic analyses to estimate that the African oryx lineage originated during the early Pleistocene about 2.5 million years ago (Vrba, 1995).

The home range of Beisa oryx ranges from 200 to 300 km² for females and 150 to 200 km² for males (Kingdon, 1997). Rainfall and availability of green vegetation determine the movement of the herds (Wacher, 1988). A herd may travel around 17 km in the same direction in a single day and a male walk as much as 4 km in an hour (Estes, 1991). Like other oryx species, Beisa oryx consumes 80% grasses in its diet. In addition to grasses, Beisa oryx eats large amount of herbaceous vegetation (Field, 1975). Beisa oryx is adapted to survive in arid areas and deserts, and has exceptional ability to withstand overheating

more than 45 °C for 12 hours by raising the body temperature above 45°C (Taylor, 1969; Field, 1975; Vaughan *et al.*, 2000). Thus, rainfall and temperature appear to have no significant influence on the biomass of oryx (East, 1984; Vaughan *et al.*, 2000). Such extreme temperature kills most mammals, but the specialization of circulatory system has enabled the Beisa oryx to survive under such high temperature. They are active in the early morning and late afternoon hours and in moonlight. Water requirement could be satisfied with the intake of fleshy food, which includes grasses and leaves of shrubs (Taylor, 1969; King *et al.*, 1975). Thus, Beisa oryx is a good example of artiodactyls, which has successfully adapted to overcome harsh conditions of intense heat little or no water and dispersed food (East, 1984).

Males mature at 5 years old while females at 1.5–2.0 years (Kingdon, 1997). The estimated gestation period is 8.5–10.0 months. Female Beisa oryx breed and give birth usually to a single offspring throughout the year (Walther, 1978). Calves wean after 105 days and join other young groups to form peer groups and may stay up to one year. Females could be fertile within 18–24 months. The life span is estimated up to 18 years, but it is known to live about 22 years in captivity (Kingdon, 1997). Calves join the herd after 2–6 weeks of birth (Walther, 1978). Typically, Beisa oryx live in mixed herds of 6–40 individuals, but herds as large as several hundred individuals have been observed during the wet season when grasses are abundant. Old bulls are usually solitary. The majority of the individuals (70–90%) in such herds are females and their offspring, and strictly bachelor herds are not common (Wacher, 1988). Sexually receptive females are present in the herd throughout the year. Some males form territories of 5–8 km², but they typically cannot control all females, which give non-territorial males opportunity to breed (Wacher, 1988).

1.2. Research Questions

1. What is the current population status of the Beisa oryx in AWR?
2. Is the distribution of Beisa oryx population influenced by variations in seasons and habitat types?
3. Is the demographic composition of Beisa oryx population influenced by variation in seasons and habitat types?
4. Is there habitat use overlap between Beisa oryx and other wild ungulates of AWR?

1.3 Objectives of the Study

1.3.1. General objective

The major objective of the present study was to examine the current population size, habitat preference, and seasonal distribution patterns of Beisa oryx in AWR.

1.3.2 Specific objectives

- To determine current population size and herd size of Beisa oryx in AWR.
- To estimate herd demographic composition of Beisa oryx population across habitat type and season.
- To examine habitat use of Beisa oryx population and its habitat use overlap with Soemmering's gazelle and Gerenuk.

2. THE STUDY AREA AND METHODS

2.1. The study Area

Alledoghi Wildlife Reserve was established in the 1960's covering an area of 1,832 km² (Hillman, 1993). It is located in the Great Ethiopian Rift Valley along the northeastern region of the country between longitude 39⁰ 30' to 40⁰ 30' E and latitude 8⁰ 30' to 9⁰ 30' N, about 280 km east of Addis Ababa (Fig. 2). The altitude of the area ranges between 800 m to 2,400 m asl. The landscape is dominated by a large alluvial plain with mountains rising along the eastern border (Almaz Tadesse, 2009). This reserve occurs in the Afar and Oromia Regional States of Ethiopia. However, populations of the major wildlife are largely concentrated in the Halaidege plain, which occurs within the Amibara district administration of the Afar Region. The southern and southeastern parts lie in the Mieso district of the Oromia Region. The Afdem Gewane Controlled Hunting Area occurs to the northeast and the Blen Hartele Controlled Hunting Area to the northwest. Awash National Park is also found to the southwestern side and in between these two protected areas the Garagumbi Open Hunting Area is situated (Almaz Tadesse, 2009; Kassaye Wami and Arega Meknnen, 2013).

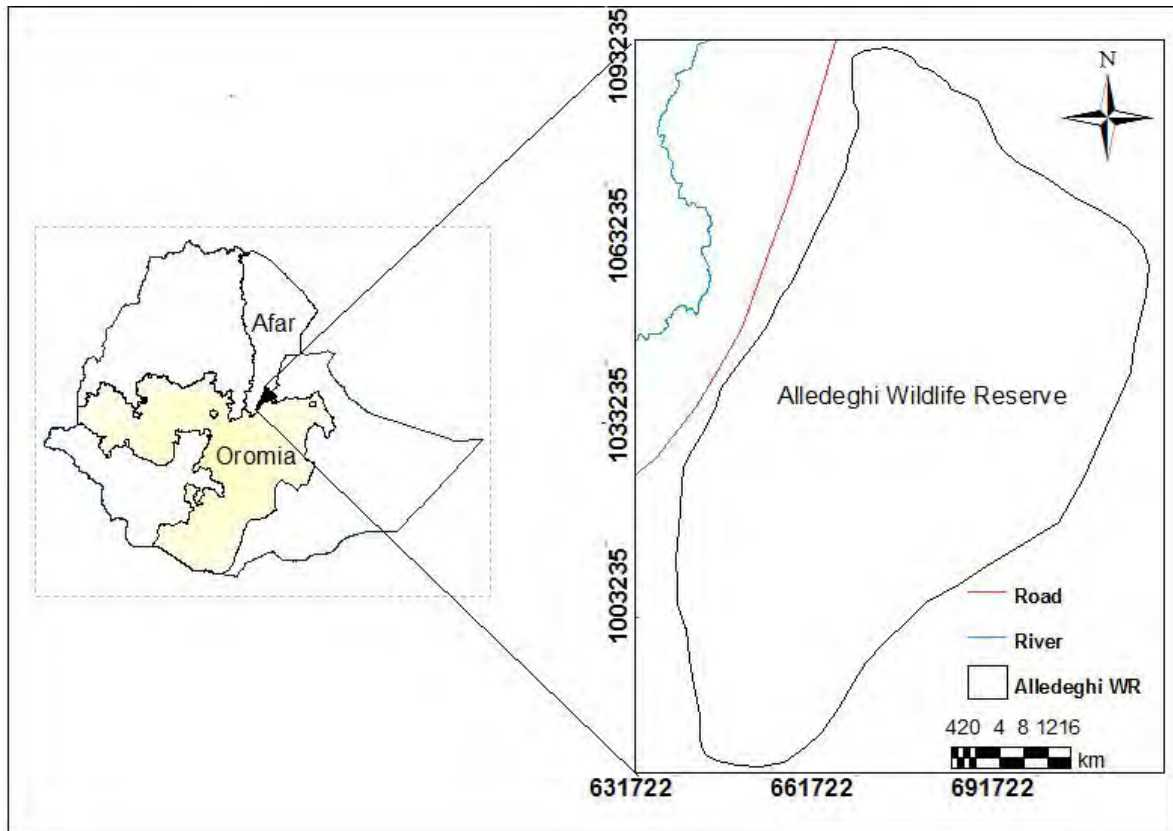


Figure 2. Location map of the study area (EWCA, 2012).

Alledeghi Wildlife Reserve is characterized by a semi-arid ecosystem with annual rainfall ranging between 400 and 700 mm. The rainfall pattern is bimodal with two distinct seasons. The short rainy season occurs during March and April, while the long rainy season occurs during July and September (Almaz Tadesse, 2009). According to Daniel Gemechu (1977) this semi arid zone in general receives an annual rainfall of 400 700 mm. The mean seasonal temperature ranges from 25 °C to 30 °C. The coolest temperatures prevail from October to January while the warmest temperature prevails during May and June. The maximum and minimum temperature ranges from 40 °C in June to 15.5 °C in January (Almaz Tadesse, 2009; Fanuel Kebede, 2013).

Reports of soil study in the Halaidege plain indicate that, the area is characterized by two major soil types: Vertic Cambisols and Calcic Cambisol (The Werer Agricultural Research Center, 2003). The chemical analysis showed that the PH of the soil is alkaline and ranges from 8.1 to 9.1. The organic matter content is low and ranges from 0.5 to 1.9% (Werer Agricultural Research Center, 2003).

Although detailed studies on flora of the reserve have been lacking, the major vegetation types in and around the reserve include grasslands, bushland, shrubland, wooded grassland, shrub grassland, gallery /riverine forest and highland forest (Almaz Tadesse, 2009). *Chrysopogon plumulosus* and *Sporobolus iocladius* comprise relatively high percentage of herbaceous vegetation on the plains. The southern, northern and western edges of the reserve are bushy grasslands or shrublands, with *Acacia senegal* being the dominant species. The woody plant species in the plains include *Acacia senegal*, *Acacia tortilis*, *Acacia mellifera*, *Balanitis aegyptiaca*, *Cadaba species* and *Grewia species*. The highland forest of Mount Asebot includes *Cordia africana*, *Croton macrostachyus*, *Erythrina abyssinica*, *Juniperus procera*, *Olea europaea*, *Podocarpus falcatus*, *Pouteria altissima* and *Rhus vulgaris* (Almaz Tadesse, 2009; Fanuel Kebede, 2013).

So far, more than 31 species of mammals and over 140 avian species have been recorded from the area (Hilliman, 1993; Fanuel Kebede, 2013). The most common wild animals inhabiting the reserve include the Beisa oryx (*Oryx beisa beisa*), Gerenuk (*Litocranius walleri*), Grevy zebra (*Equus grevyi*), Lesser kudu (*Tragelaphus imberbis*) and Soemmering's gazelle (*Gazella soemmering*) (Hilliman, 1993; Fanuel Kebede, 2013).

2.2. Methods

Field data collection was conducted in September 2015, representing wet season, and in December 2015, representing dry season (for detail on seasonality of the area, see Fanuel Kebede, 2013). Fanuel Kebede (2013) identified optimum suitable habitat for large herbivores, including for Beisa oryx, in the Alledoghi Wildlife Reserve using maximum entropy model (maxent). Based on his study, a census zone was demarcated for the present study to survey the Beisa oryx population and the other two co-occurring species (Soemmering's gazelle and Gerenuk) in the study area (Fig. 3).

Line transect counting method was used to collect data on Beisa oryx (Norton-Griffiths, 1978; Buckland *et al.*, 1993; Sutherland, 1996; Wilson *et al.*, 1996; Fanuel Kebede, 2013). The longer side of the census zone, lying south-north direction and measuring ~36 km, was used as a baseline to lay sampling transects along. Twelve parallel sampling transects were systematically placed perpendicular to the baseline with a minimum distance of 2 km apart in an east-west orientation. Nearly 3 km distance was skipped at both ends of the baseline transects to avoid edge effects (Sutherland, 1996; Wilson *et al.*, 1996). Each transect covered the three major habitat types (grassland, tree scattered grassland and bushland) found in the census zone. To avoid the effect of double counting of same individuals on the results due to the relatively more proximity of adjacent transects, a transect width of 0.6 km was used in the present study. The total transect length was 167 km, and given that width of 0.6 km on both sides of each transect, about 200 km² area (47.6% of the census zone) was sampled during the study.

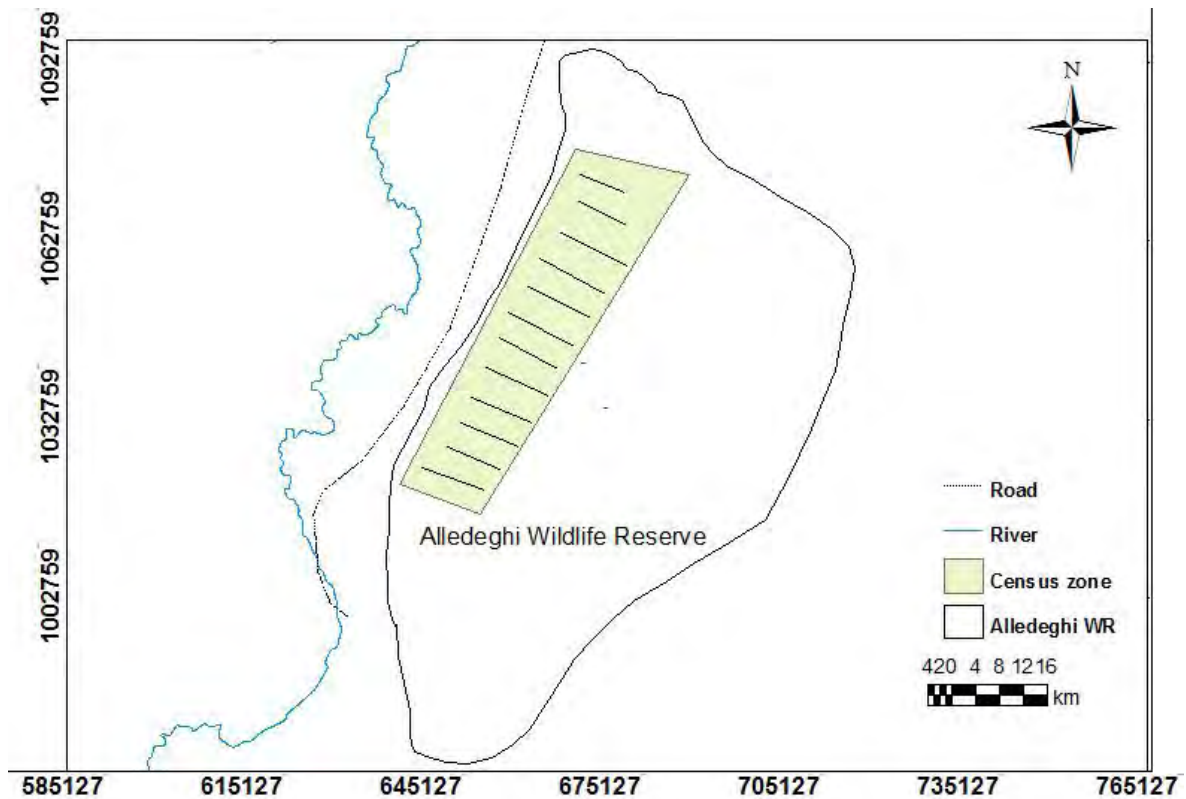


Figure 3. The Alledoghi Wildlife Reserve study area and transect lines used for 2015 survey.

The Alledoghi Wildlife Reserve is flat and open plain and hence off road driving along transect lines was the most efficient method for conducting surveys (Fanuel Kebede, 2013). Following Sutherland (1996) for counting medium-/large-sized animals in such open habitats, surveys of Beisa oryx population was undertaken using four-wheel vehicle while driving slowly at an average speed of 20 km per hour. The exception was that some portions of transects were found to be difficult to access by vehicle during wet season, in which case, survey was undertaken on foot for recording animals.

Whenever a herd or individual of Beisa oryx was encountered, date and time of observation, kilometer traveled, estimated perpendicular distance from the sight of

observation to the animal, total number of individuals in the group, sex and age categories and habitat type (grassland, tree scattered grassland and bushland) where they were observed were recorded on standard census datasheet prepared for this study (Appendix 2). Similar procedures were used to collect data on populations of the other co-occurring species also. Age and sex composition of each herd was classified into four broad categories, following Lewis and Wilson (1979) as adult male and female, sub-adult male and female, calves and unidentified sex. To categorize individual animals into these categories, the methods of Lewis and Wilson (1979) were followed. Relative body size, horn size, pelage, external genitalia and shape, fur color, the presence of scrotum in males or udder in females and other physical features were used as a clue to determine the sex and age of the individuals (Lewis and Wilson, 1979; Kingdon, 1997).

Each transect was surveyed twice in each season (wet and dry seasons), totaling four surveys in the course of the study period. Observations were made early in the morning (06:30 h - 10:30 h) and late in the afternoon (03:30 h - 06:30 h) with the help of experienced wildlife experts and game rangers of the reserve. On the average, 4 - 5 transects were covered on a single day. Care was taken to minimize the risk of double counting by noticing the movement of animals between the effective counting widths of adjacent transects. The start and end of geographical coordinates of each transects were saved in Garmin® GPS unit to ensure same transects were repeated during each counting session. Pairs of Navigator® binoculars 7 x 50 were used for counting the animals and for proper sex and age identification, while Sony® digital camera, with 20.1 mega pixels, was used to take pictures of unusual features encountered in the study area.

2.3. Data Analysis

The average number of animals observed along each transect in each season was computed and used for analysis. The density estimate of the species was computed using Jolly's method 2 (Norton-Griffiths, 1978) for unequal sized sample unit using the formula.

$$DT_i = \frac{n}{2LT_i} * \frac{1}{WT_i}$$

Where DT_i : Population density (D) along transect T_i

n: numbers of sighting

T_i : Transect

LT_i : length of Transect i

WT_i : width of Transect i

The density of animals observed per transects was used to calculate mean population density. Population size of Beisa oryx was estimated by multiplying mean population density (DT_i) with total extent of the census zone (420 km²) using the following formula (Burnhan *et al.*, 1980).

$N = (DT_i/n) \times A$, Where N= Population size estimates

D = Mean population density (individual per km²)

n = number of transects

A = Total extent of the census zone (km²).

Based on age/sex composition of each observation, the following four different group types were identified. Male herd (a herd containing only adult and sub-adult males), female herd (only adult and sub-adult females), male and female (a herd without calves) and all mixed herd type (containing all age/sex categories). Differences in herd size of overall herd and each herd type between dry and wet seasons and the three habitat type were determined using one way ANOVA.

Demographic characteristic of Beisa oryx was determined by calculating the ratio of age and sex category. Ratios were calculated by dividing number of individuals of animals of each respective pair (e.g. adult male vs adult female) of age and sex categories. Accordingly, ratios were computed between male vs female, adult vs sub-adult, adult vs calf and sub-adult vs calf.

The habitat selection of Beisa oryx, in each season and across seasons was determined by comparing the observed abundance values in each habitat type with theoretically expected even distribution in each habitat type (Yosef Mamo *et al.*, 2015). The significance was tested using Chi-square analysis in IBM SPSS statistics version 20. In addition, mean differences in population abundance of overall and each age/ sex categories of the species among habitats and between seasons were compared using Tukey's multiple mean test. As abundance values of some age/ sex herd (e.g. sub-adult male and calves) were found to be very small for statistical test, abundance values of adult and sub-adult males were lumped and those values for adult and sub-adult female and calves were pooled together. Similar method was also followed to determine habitat association and seasonal variation in

abundance of the other two co-occurring ungulate species. Chi-square test was used to examine habitat use overlap of Beisa oryx with each of the other two ungulates.

3. RESULTS

3.1. Population Estimate, Herd Size and Trends of Beisa oryx

A total of 732 and 92 individuals were recorded during wet and dry seasons, respectively. The population was more abundant during the wet season than during the dry season. The mean population size (SE), was 61 (4.85) and 7.67 (0.97) individuals during wet and dry seasons, respectively. There was a significant difference in the number of animals observed during the wet and the dry seasons ($\chi^2 = 1252.934$ df = 1 P <0.001). The present mean population estimate with standard error of Beisa oryx was 722 ± 119 in the reserve. The wet and dry season estimation was $1,252 \pm 104$ and 191 ± 23 respectively (Table 1).

Table 1. Mean population estimate of Beisa oryx in Alledoghi Wildlife Reserve in the present survey.

Year	Species	Mean population estimate (SE)	Season	
			Wet	Dry
2015	Beisa oryx	722 ± 119	$1,252 \pm 104$	191 ± 23

A total of 101 herds of Beisa oryx were observed, 67 herds during the wet season and 34 herds during the dry season in AWR. The wet season total number of Beisa oryx herds observed was higher. The maximum herd size consisted of 30 and 4 individuals during wet and dry seasons, respectively. The most frequently observed herd size was 7 animals during the wet season and 2 animals during the dry season.

Mean herd size with standard error was 9.73 (4.71) during wet season and 2.48 (1.29) during the dry season. The difference was statistically significant ($F_{1, 99} = 79.17$, $P < 0.001$). Large herd sizes of Beisa oryx were aggregated during the wet season, while during the dry season, they were distributed in a wider area forming smaller herds and solitary individuals. Results of one-way ANOVA showed that there was a significant difference in mean herd size of Beisa oryx among the three different vegetation types ($F = 7.67$, $df = 2$, $P < 0.001$). Tukey's multiple mean comparison showed that mean herd size of Beisa oryx in the grassland was 8.5 (SD = 4.61, N = 56) and the shrubby grassland habitat was 8.39 (SD = 5.95, N = 33) and these were significantly greater than the observations in the bushland habitat type (4.17, SD = 3.3, N = 12). The present population estimate of Beisa oryx in the reserve revealed that its population has declined by 22 % within the last five years.

3.2. Population Structure

The population structure and the proportion of various age and sex categories of Beisa oryx in AWR are provided in Figures 4 and 5. A total of 824 individuals were sighted during the present study period. Of these, adults comprised 703 (84.6% of the total), sub-adults 104 (14.2%) and calves 17 (1.2%) individuals. The sex ratios (male: female) of adults and sub-adults were 1.0:1.8 and 1.0:1.9, respectively. Regardless of sex category, the age ratios of sub-adults to adults and calves to adults were 1.0:6.0 and 1.0:36.8, respectively. That of calves: sub-adults was 1.0:5.2 (Table, 2).

Table 2. Demographic ratios of (age and sex) composition of Beisa oryx population in Alledghi Wildlife Reserve during wet and dry seasons.

Categories	Ratios of demographic composition		
	Wet season	Dry season	Mean
Male: Female	1.0 : 1.8	1.0 : 1.7	1.0 : 1.75
Sub-adult: Adult	1.0 : 7.0	1.0: 5.1	1.0 : 6.0
Calf: Adult	1.0 : 36.8	0	1.0 : 36.8
Calf: Sub-adult	1.0 : 5.2	0	1.0 : 5.2

Adults accounted for 85.5% and 82.6% during the wet and dry seasons, respectively, while sub-adults and calves accounted for 12.15% and 16.3% during the wet and 2.32 % and 0% during the dry season, respectively (Fig. 4). The mean population size was 52.17 ± 4.04 for adults, 7.42 ± 0.8 for sub-adults and 1.42 ± 0.38 for calves during the wet season. During the dry season, the mean population size was 6.33 ± 0.67 for adults and 1.25 ± 0.38 for sub-adults (Fig. 4). Calves were not recorded during the dry season. Analysis of age structure revealed that there was no significant difference in age distribution during the wet and dry seasons ($\chi^2 = 8.000$, $df = 5$, $P = 0.238$).

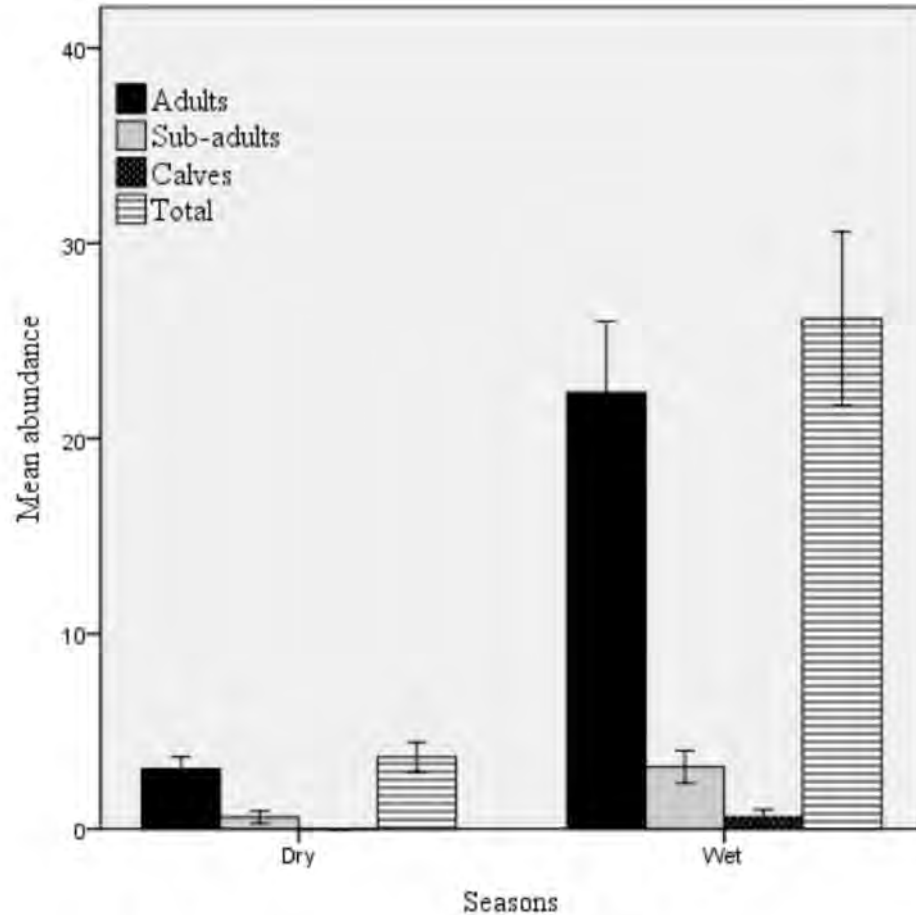


Figure 4. Age composition of Beisa oryx during wet and dry seasons.

Out of the total 824 individuals observed during the present study, 254 (30.8%) were males and 458 (55.6%) were females. The mean population size was 18.5 ± 1.64 and 33.58 ± 2.81 males and females during the wet seasons, respectively. The dry season mean population size was 2.67 ± 0.55 and 4.58 ± 0.41 males and females, respectively (Fig. 5). Analysis of sex composition revealed that there was insignificant difference in sex composition during the wet and dry seasons ($\chi^2 = 63.75$, $df = 3$, $P > 0.05$).

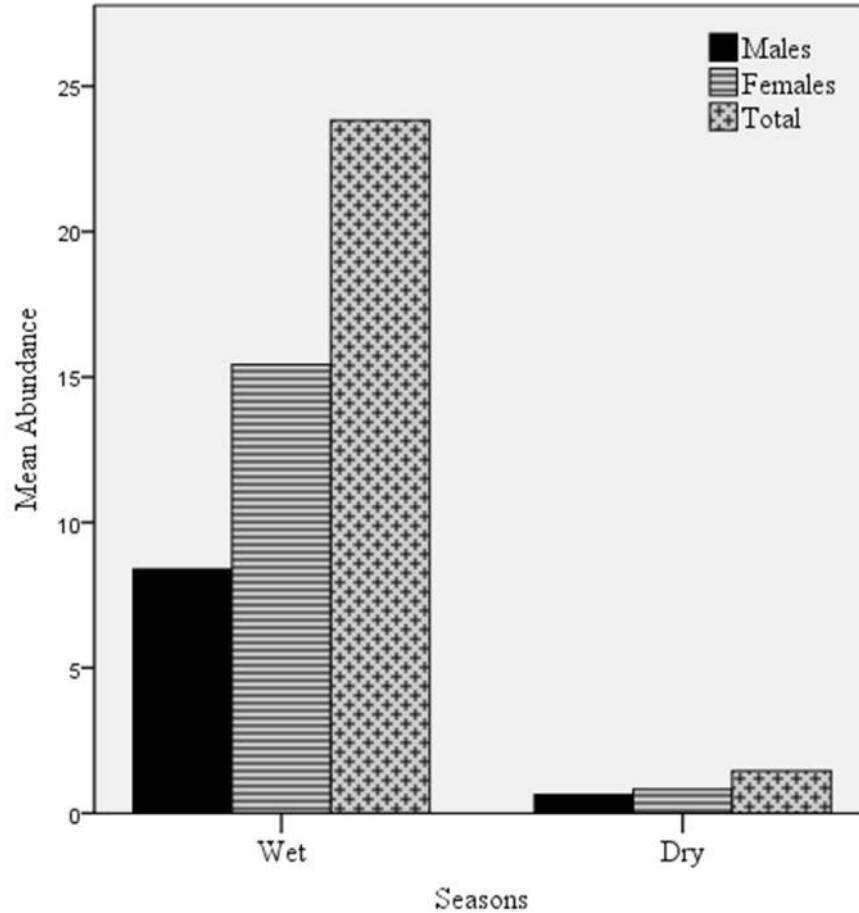


Figure 5. Sex composition of Beisa oryx during wet and dry seasons.

3.3. Distribution and Habitat Association of Beisa oryx

The mean population density was 2.66 individuals/km² and 0.1 individuals/km² in the grassland, 3.79 individuals/km² and 0.4 individuals/km² in the shrub grassland and 2.47 individuals/km² and 0.86 individuals/km² in the bushland habitats during the wet and dry seasons, respectively (Fig. 6). Results of Chi square test showed that there was a significant difference in the occurrence of Beisa oryx in each vegetation type during the wet season (September), Beisa oryx population was observed in shrub grassland and grassland habitats, whereas, during the dry season (December), the species was observed more in

shrub grassland and bushland habitats. Results of Chi square test showed that there was a significant difference in their occurrence in various habitat types regardless of seasons ($\chi^2 = 50.37$, $df = 2$, $P < 0.05$) (Table 3).

Table 3. Habitat association of Beisa Oryx in Alledoghi Wildlife Reserve and its variation within and across season.

Treatment	Habitat/season	df	Chi square	P
Within habitat between seasons	Bushland	1	20.09	$P < 0.001$
	Grassland	1	3463.28	$P < 0.001$
	Shrubby grassland	1	571.70	$P < 0.001$
Overall (between seasons)		2	50.37	$P < 0.05$
Within season among habitats	Dry	5	86.9	$P < 0.01$
	Wet	5	262.64	$P < 0.01$

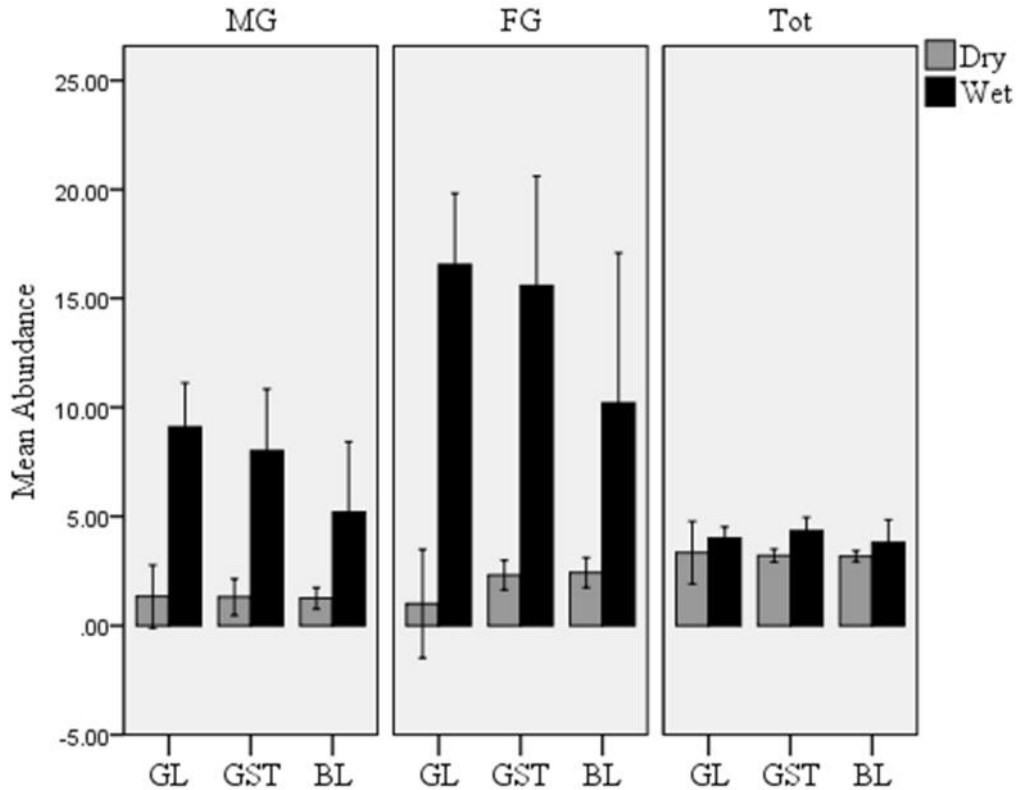


Figure 6. Sex composition of Beisa oryx in different habitat types during wet and dry seasons.

Where GL= Grassland GST= Grassland with scattered trees and BL= Bushland MG= Male herd FG= Females herd Tot= Total).

3.4. Estimate of Population Size and Density of Co-occurring Species

Soemmering's gazelle (*Gazella soemmeringi*) was observed in all transects both during wet and dry seasons. The present survey revealed that the mean population size was 77.75 (SE= 5.75) and 17.75 (SE= 2.2) individuals during the wet and dry seasons, respectively. The average population size was 47.75 (SE= 3.975). The mean population estimates was 1,197 \pm 291(SE) (Table 4).

Gerenuk (*Litocranius walleri*) was encountered in several transects during the present study. The mean population size with standard error was 8.5 (1.34) and 2.5 (0.48) during the dry and the wet season respectively. The average population size was 5.5 ± 0.91 . The mean population estimates with standard error of the species in the study area was 126 ± 63 (Table 4).

Table 4. Mean population estimate of three major wild animals of in Alledeghi Wildlife Reserve.

Year	Common name	Mean population estimate
2015	Beisa oryx	722 ± 119
	Soemmering's gazelle	$1,197 \pm 291$
	Gerenuk	126 ± 63

Of all species encountered in the present survey Soemmering's gazelle had the highest density both during the wet ($3.82/\text{km}^2$) and dry ($1.88/\text{km}^2$) seasons. Beisa oryx had higher density than Gerenuk during the wet season ($2.98/\text{km}^2$ for Beisa oryx and $0.14/\text{km}^2$ for Gerenuk). However, the dry season density of Gerenuk was higher than that of the Beisa oryx ($0.47/\text{km}^2$ for Gerenuk and $0.45/\text{km}^2$ for Beisa oryx).

3.5. Habitat Use Overlap of Beisa oryx with Other Co-occurring Herbivores

Wet season mean population sizes of Soemmering's gazelle and Gerenuk were significantly different from the dry season ($F_{1, 22} = 50.36$, $P < 0.05$ for Soemmering's gazelle and $F_{1, 22} = 34.8$, $P < 0.05$) (Fig.7).

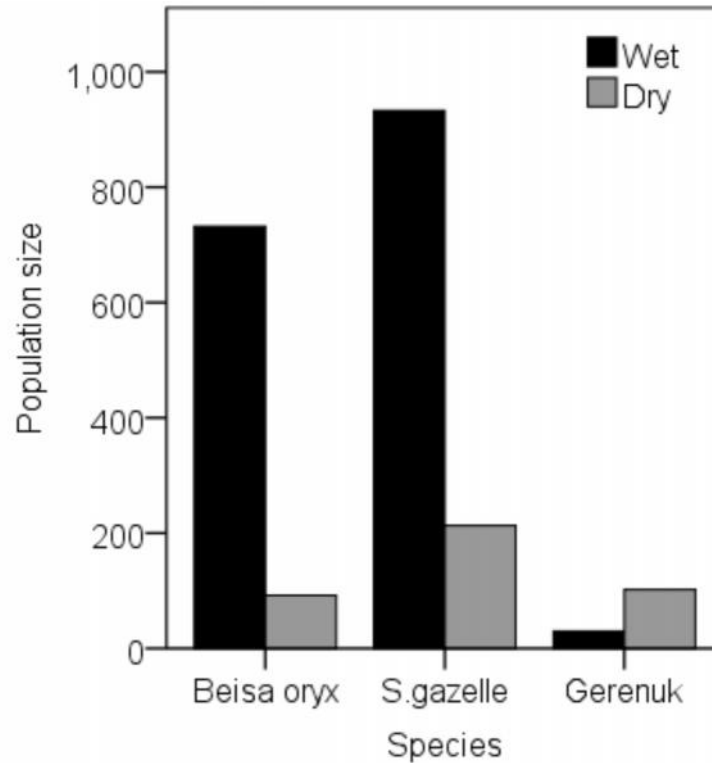


Figure 7. Population size of other co-occurring herbivores during wet and dry seasons.

Comparisons of mean population density of these animals in different habitats of AWR between the two seasons showed significant differences (Fig 8). Chi-square test comparing the occurrence of Beisa oryx and the two co-occurring ungulates showed non-significant difference between seasons for each vegetation type ($\chi^2 = 1.86$, $df = 5$, $P = 86.7$ in open grassland, $\chi^2 = 0.99$, $df = 5$, $P = 96.2$ in shrubby grassland and $\chi^2 = 2.2$, $df = 5$, $P = 82$ in bushland) (Fig. 8).

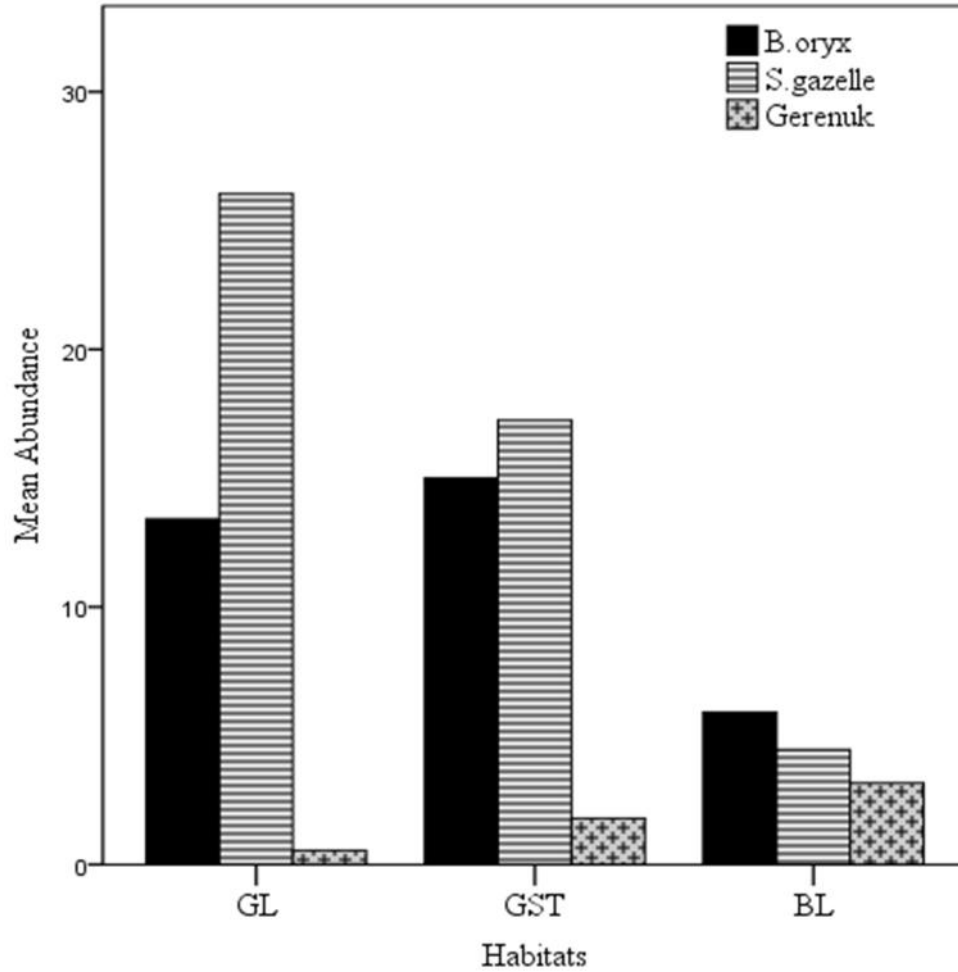


Figure 8. Habitat use of herbivores during the wet and dry seasons.

(Where GL= Grassland, GST = Grassland with scattered trees, BL= Bushland).

Regardless of habitat type, the overall co-occurrence of all the three ungulates between seasons was not significantly different. There was high habitat use overlap between Beisa oryx and Soemmering's gazelle ($P = 0.934$). Their association with Gerenuk was also more or less similar ($P = 0.649$ with Beisa oryx and $P = 0.637$ with Soemmering's gazelle) (Table 5).

Table 5. Habitat use overlap among the three co-occurring wild ungulates of AWR.

Common name	P	df	Chi square
Beisa oryx vs Soemmering's gazelle	0.934096	6	1.836605
Beisa oryx vs Gerenuk	0.649895	6	4.19805
Soemmering's gazelle vs Gerenuk	0.637074	6	4.293127

4. DISCUSSION

4.1. Beisa Oryx Population Estimate and Trend

The present study revealed that the population status of Beisa oryx in AWR is decreasing compared to its population in the past. As a result of the prevailing drought for two successive years in the area, the current population estimates was lower than the estimation carried out by previous workers (22% decline). Drought causes the animals to shift to less productive and more drought tolerant plant species (Grime *et al.*, 2008). This change, affects both the occurrence and behavior of species that feed on such vegetation, leading to population collapse in wild animals. Gandiwa and Zisadza (2010) have reported similar findings from Gonarezhou National Park, Zimbabwe, where 1,500 African elephants (*Loxodonta africana*) died after severe drought in 1991–1992.

It is unsurprising that the population size was found to be lower during dry season compared to the wet season, which accords well with the findings of Fanuel Kebede (2013) on ungulates in AWR. More specifically, Cherie Enawgaw (2004) also reported that Beisa oryx population abundance vary between seasons in Awash National Park; higher during wet season than during the dry season. There are a number of reasons for such seasonal difference in ungulate populations. Rainfall is one of the important factors that determine the population dynamics of species, especially in African savannahs, due to changes in vegetation structure and composition in response to the limited rainfall (Ogutu *et al.*, 2008). Reproduction, survival and movements of wild ungulates are highly responsive to rainfall fluctuations, leading to population fluctuations between seasons. Furthermore, drought dramatically increases rates of breakdown in arid land and vegetation leading to further

desertification, soil erosion and dust storms, posing negative impacts on wild animals such ecosystems (Omar and Roy, 2010). The prevailing drought for two successive years in and around the present study area had killed thousands of livestock and wild animals in the Alledeghi Wildlife Reserve (Fig. 9). However, the effect on wild ungulates seems to be minimal compared to domestic animals. This is because domestic animals drink water on daily basis and they are incapable of adapting to drought compared to drought-tolerant wild animals, such as Beisa oryx and Soemmerring's gazelle. The population size of the species in the study area was higher during the wet season than the dry season. The variation observed was caused by the change in the resource requirements of the species in different habitat types. The availability of resource during the wet season probably made the Beisa oryx to form large herds and spend more time on feeding in the open grassland and shrubby grassland habitat and conversely spent less time in bushland habitat type.

Ungulates form large herds during the wet season and small herds during the dry season (Durant *et al.*, 1986). This was also observed from the results of the present study. Beisa oryx formed larger herds up to 30 individuals during wet season, while they disperse during the dry season. The largest herd observed had only four individuals during the dry season. Large herd size of Beisa oryx was aggregated during the wet season, while during the dry season, they were distributed in a wider area forming smaller herds and solitary individuals.



Figure 9. The skeleton of Beisa oryx in AWR.

4.2. Population Structure

All unidentified individuals of Beisa oryx were adults; as sex identification was not possible as a result of the difficulty in spotting their genital organs. They were commonly observed ranging from large herds (composed of several males, females and sub-adults) to solitary individuals during the study period. Age and sex composition may be influenced by a variety of environmental factors. Unequal sex ratio can occur favoring either males or females in a population. In the present study, females have high proportion in the population. Estes (1974) explained that the possible reasons for an unequal sex ratio may be an increased predation pressure on males, due to greater boldness or the emigration of subordinate males to less favorable habitats. This reason might also be the cause for uneven sex ratio of Beisa oryx in Alledoghi Wildlife Reserve. The large number of breeding females indicates that the species has high potential to increase its population, if better

conservation measures are implemented. However, there was no calf observed during the dry season. This is certainly due to the drought condition in the area limiting the food resources.

4.3. Distribution and Habitat Association of Beisa oryx

Beisa oryx is distributed mainly in the open grassland habitat of the plains during the wet season. Its distribution was extended to the shrubby grassland and bushland habitats during the dry season. The present distribution pattern was in the open grassland habitat and shrubby grassland during the wet season and relatively similar pattern was observed during the dry season. A comparison of the seasonal changes in habitat association showed Beisa oryx has high preference to the grassland and shrub grassland habitat during the wet season while preferring the shrub grassland and bushland habitat during the dry season. Ungulates form large population size during the wet season and decline throughout the dry season (Durant *et al.*, 1986). This was also observed from the results of the present study. Data on habitat association of the species revealed that there was a significant difference in the distribution of Beisa oryx among habitat types (open grassland, shrubby grassland and bushland) both during the wet and dry seasons. Beisa oryx was observed in open grassland and shrubby grassland habitat forming large herds. They also spent most of the wet season grazing together with less water requirement. However, during the dry season, the majority of the individuals disappear from the reserve. Only few solitary individuals and small herds were observed mainly in the bushland and shrubby grassland habitats of the reserve. Significant population of Beisa oryx moves to the area where critical resources are located outside the reserve. Thus, the seasonal local movement of the species depends on the

availability of critical resources (water and pasture) condition of the area. The seasonal water sources persist only for a few months during and after rainy seasons. The permanent water sources are the Awash River and Blen hot springs located outside the reserve. During the dry season, a considerable number of the species was observed in the Blen control hunting area adjacent to the reserve (Personal observation, 2016). This situation may expose the species to the pressure of hunting. During the present study, the bore holes were not functional and herds of Beisa oryx were observed crossing the Addis Ababa- Djibouti highway in order to reach the Blen hot springs. This exposes the animal to collision with heavy trucks and makes the calves vulnerable to predators (Fig 10).



Figure 10. A road kill of Beisa oryx in the study area.

4.4. Habitat Use, Population Estimate and Density of Other Herbivores

Habitat use, population estimate and density of the three major wild animals were carried out since only three species were commonly observed along the transect lines. Thus, no habitat use, population estimate and density were done for rarely observed wild animals along transect lines. Monitoring trends in animal populations is a key aspect in the management of wildlife. Acevedo *et al.*, (2008) explained that monitoring schemes must

generate reliable estimates of abundance to allow assessment of population trends. Ecological theory emphasizes the logic of spatially extensive movements across a heterogeneous environment so that wildlife can make best use of spatially separated key resources (Burnsilver *et al.*, 2003). Herbivores should be able to locate themselves in areas where they can maximize their energy gains (Bailey *et al.*, 1996) within the natural constraints imposed by abiotic factors such as slope and distance to water.

Apart from season, Beisa oryx and Soemmering gazelle occur in open grassland and shrubby grassland. There was high habitat use overlap between the two species. This observed habitat overlap might be attributable to the degree of similarities in their feeding ecology. However, Gerenuk is mainly browsers and spent more time in the bushland habitat. So, there was only low habitat overlap observed in the case of Gerenuk with Beisa oryx and Soemmering gazelle regardless of season.

The present population estimate and density of Beisa oryx and Soemmering gazelle was low compared to the earlier studies (Fanuel kebede, 2013). This shows that the population of wild herbivores in the reserve is declining from time to time. Drought has an important effect on herbivores in savannah species. Species living in the Mara Serengeti ecosystem have declined by 58% in the last 20 years due to drought related effects on vegetation (Ottichilo *et al.*, 2000). The 2009 drought in the Amboseli ecosystem has reduced the wildebeest (*Connochaetes taurinus*) and zebra (*Equus quagga*) populations by 70 – 95 % (KWS *et al.*, 2010).

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Large concentrations of wild mammals in Africa now occur only in national parks and other types of protected areas, which cover only about seven percent of the African landmass (Happold, 1995). The Beisa oryx population had wider distribution in East Africa, but with a reduced population. The Awash Valley including Alledighe Wildlife Reserve harbors a good population of this species in Ethiopia. The present population estimate in the reserve revealed that its population has declined by 22% within the last five years. The expansion of invasive species and bush encroachment, unsystematic development activities, high level of displacement due to intensive livestock grazing and settlements are the major factors for the decline. More than 50% of the reserve has lost the potential to harbor large wild herbivores due to high modification by humans and encroachment of indigenous and exotic shrubs and herbs. In addition to this, the population suffers from vehicle collision, disturbance and depredation. The infrequent conflict between the two ethnic herds Afar and Issa and the adjacent hunting areas are the major causes of disturbances.

Due to the devastating drought during for two successive years, the majority of the Beisa oryx population is forced to depart from the reserve during the dry season. They locally migrate separately to the north of the reserve around the plain area where critical resources (water and pasture) occur while very few individuals stay in the surrounding Blen hot springs area.

In order to maintain the Beisa oryx and other wild herbivores, urgent conservation strategy is required that can benefit both the wildlife and the communities adjoining the reserve.

5.2. Recommendations

The main recommendations are the following.

1. The population status of Beisa oryx and other wild ungulates have declined alarmingly in Alledighe Wildlife Reserve, mainly due to adverse human activities. Thus, there is an urgent need to take immediate measures against those threats to halt the depletion.
2. The problems of bush encroachment and invasive species (*Prosopis junifora*) are becoming a serious threat particularly for plain dwelling animals in the reserve. Thus, conservation efforts should focus on reducing the threats to ensure the longterm survival of key wild ungulates in the reserve.
3. Beisa oryx distribution depends on the availability of water and pasture. The species suffers from depredation, truck collision and hunting disturbance mainly as they move to Blen hot springs in search of water during the dry season. Thus, establishment of artificial waterholes and making the established borewells functional is relevant to secure the survival of the species. In addition, speed break and crossing bridges should be established depending on the behavior of the animal in selected crossing points on the highway.
4. There is only less data on population and ecology of most of the wild ungulates in Alledighe Wildlife Reserve. Constant and longterm investigations on the ecology and population assessment of key wild animals are essential to identify ecological problems and to maintain their habitats sustainably.

5. The Alledighe Wildlife Reserve is one of the major wildlife centers in Ethiopia with high tourism potential due to its spectacular landscape. Therefore, it is very essential to promote ecotourism in order to generate income for the local community at large.

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7. APPENDIX

Appendix 1. Mammals reported from Alledoghi Wildlife Reserve.

Scientific name	Common name
<i>Equus grevyi</i>	Grevy's zebra
<i>Oryx beisa beisa</i>	Beisa oryx
<i>Gazella soemmerringi</i>	Soemmerring's gazelle
<i>Litocranius walleri</i>	Gerenuk
<i>Madoqua saltiana</i>	Salt's dikdik
<i>Phacochoerus africanus</i>	Warthog
<i>Tragelaphus imberbis</i>	Lesser kudu
<i>Panthera leo</i>	Lion
<i>Panthera pardus</i>	Leopard
<i>Acinonyx jubatus</i>	Cheetah
<i>Orycteropus afer</i>	Aardvark
<i>Felis serval</i>	Serval cat
<i>Felis libyca</i>	Wild cat
<i>Hystrix cristata</i>	Crested porcupine
<i>Crocuta crocuta</i>	Spotted hyena
<i>Hyaena hyaena</i>	Stripped hyena
<i>Proteles cristatus</i>	Aardwolf
<i>Canis aureus</i>	Common jackal
<i>Canis mesomelas</i>	Black backed jackal
<i>Otocyon megalotis</i>	Bat eared fox

<i>Heterohyrax brucei</i>	Rock hyrax
<i>Xerus erythropus</i>	East African ground squirrel
<i>Herpestes ichneumon</i>	Egyptian mongoose
<i>Papio Anubis</i>	Anubis baboon
<i>Herpestes sanguine</i>	Slender mongoose
<i>Civetsctis civeta</i>	African civet
<i>Felis caracal</i>	Caracal
<i>Lepus habessinicus</i>	Abyssinian hare
<i>Ceropithecus aethiopsis</i>	Vervet monkey
<i>Genetta abyssinica</i>	Abyssinian genet
<i>Thryonomys spp.</i>	Cane rats

Appendix 2. Wildlife census summary sheet

Name of Conservation area -----Transect Number ----- Observation----- Starting time -----Stop time -----

Weather Condition -----Starting km-----GPS reading-----Stop km----- GPS reading -----

Observers: 1. -----2. -----3. -----4-----

Km	Time	Species	Ts	Sds	MA	FA	SAM	SAF	Cf	Un	Habitat type

Note: Ts= Total seen, Sds = Sighting distance, MA= male adult, FA= Female adult, SAM = Sub adult male SAF = Sub adult female Cf = Calf, Un = Unknown,

Appendix 3. Wild animals observed during the study period.

Common name	Scientific name
Grevy's Zebra	<i>Equus grevyi</i>
Beisa oryx	<i>Oryx gazelle</i>
Soemmerring's gazelle	<i>Gazella soemmerinig</i>
Gerenuk	<i>Litocranius walleri</i>
Salt's dikdik	<i>Madoqua saltiana</i>
Warthog	<i>Phacochoerus africanus</i>
Spotted hyena	<i>Crocuta crocuta</i>
Common jackal	<i>Canis aureus</i>
Black backed jackal	<i>Canis mesomelas</i>

Appendix 4. Population density of three major wild animals of Alledoghi Wildlife Reserve between 2001 and 2010 survey and the present survey (N/A: Not available).

Years	Sampled area (in km ²)	Beisa oryx Per km ²	Sommering gazelle Per km ²	Gerenuk Per km ²
2001	184.2	0.41	1.53	N/A
2002	123.8	0.66	1.15	N/A
2003	132.2	0.88	0.39	N/A
2004	111.8	4.73	4.43	N/A
2005	111.4	2.13	3.34	N/A
2006	131	0.31	1.18	N/A
2008	110	2.36	2.02	N/A
2009	218	1.28	2.47	N/A
2010	218	1.52	2.33	N/A
2015	200	1.72	2.85	0.3

Source: The 2001-2010 density estimate data for Beisa oryx and Sommering gazelle were taken from Fanuel Kebede (2013).