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Population Estimation and Habitat þÿ P r e f e r e n c e o f H e u g l i n s g a z e l (Eudorcas tilonura) in Kafta Sheraro National Park, Northwest, Ethiopia

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COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

GRADUATE PROGRAM

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MSc Thesis

By

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Submitted in partial fulfillment of the requirements for the degree of Master of Science (MSc) in Wildlife Conservation and Ecotourism Management

Supervisor: Dr Eshetu Moges

Co-supervisor: Dr Girma Eshete

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THESIS APPROVAL SHEET

As a member of the Board of Examiners of the Master of Sciences (MSc) thesis open defense examination, we have read and evaluated this thesis prepared by Mr. **Tatek Shawul Tefera** entitled "**Population Estimation and Habitat Preference of Heuglin's gazelle (*Eudorcas tilonura*) in KSNP, North West Ethiopia"**. We hereby certify that, the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (MSc) in Wildlife Conservation and Ecotourism Management.

Board of Examiners

Name of External Examiner	Signature	Date
Name of Internal Examiner	Signature	Date
Name of Chair Person	Signature	Date

DECLARATION

This is to certify that, this thesis entitled "**Population Estimation and Habitat Preference of Heuglin's gazelle (*Eudorcas tilonura*) in KSNP, North West Ethiopia**" Submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in "Wildlife Conservation and Ecotourism Management" to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University, the School of Fisheries and Wildlife done by Tatek Shawul (ID. No. BDU1100500) is an authentic work carried out by him under our guidance. The matter embodied in this research work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

Tatek Shawul	_____	_____
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DEDICATION

This work is dedicated to all those who sacrificed their lives in conserving Wildlife Resources of Ethiopia.

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ABBREVIATIONS /ACRONYMS

ANP	Alatash National Park
DNP	Dinder National Park
EWCA	Ethiopian Wildlife Conservation Autority
GEF	Global Environmental Facility
GNP	Godebe National Park
GPS	Geographical Positioning System
IUCN	International Union for Conservation of Nature and Natural Resources
KSNP	Kafta Sheraro National Park
SPSS	Statistical Package for Social Sciences

ABSTRACT

The result of the study on population status and habitat preference of Heuglin's gazelle in KSNP is presented in this thesis. This study was aimed to undertake the current population size and habitat preference of Heuglin's gazelle in KSNP, Northwestern, Ethiopia. Total count method was used to estimate the population size of Heuglin's gazelles in the present study site. The population size estimated, both during wet and dry seasons, using 10 counting blocks (6 - 10 Km^2 area) in four habitat types from June 2019 to April 2020. Habitat preference was assessed based on the abundance of herds and individuals frequently observed in four habitat types during data collection period. Chi-square test, Chi-square goodness of fit, Kruskal Wallis test and Wilcoxon test were used to analyze the data. The mean population size were 220 ± 9.85 (SE) and 189 ± 7.55 (SE) individuals during the wet and dry season, respectively; whereas, mean of individuals within a seasons were 204.5 (≈ 205). There was a decrease in individuals by 31.2% between the 2016 and the present estimates. There was no significant variation in the number of individuals observed during the wet and dry seasons (Z = - 1.604, P = 0.109). The overall density of the species was 2.23 individuals/km^2. Most frequently observed herd sizes were 5 and 2 animals in wet and dry seasons, respectively. However, was no significant variation between the herd size encountered during wet and dry seasons (Z = - 1.342, P = 0.18). Population of the species was characterized by more adult individuals. However, there was no significant difference between the number of individuals in each age category during both wet and dry seasons (χ^2 = 4.6, df = 2, P = 0.11). In case of sex, the population of the species was characterized by more female individuals. Even though, there was no significant difference between the number of individuals in each sex category during wet and dry seasons (χ^2 = 5.56, df = 2, P = 0.063). Age ratio of Juvenile unknown sex to adult was greater in wet season and the sex ratio male to female were also greater during the wet season biasing to females. Higher numbers of individual gazelles were observed in wooded grassland in both seasons; whereas, no one gazelle was recorded in woodland habitat type during the wet season. There was a significant difference in their occurrence in four habitat types regardless of seasons (χ^2 = 7.5, df = 3, P = 0.03). Finally, the studies suggests that, effective conservation measures should be implemented in current study area to halt the declining in number of the species and maintain their habitat; since, the populations of the species are highly decreasing due to natural and anthropogenic factors.

Keywords/Phrases: *habitat preference, herd size, population density, population size*

1. INTRODUCTION

1.1. Background of the Study

Globally, mammalian species are one of the greatest resources found on the earth (Bogonia *et al*., 2017). They are biologically the most successful groups of animals with the possible exception of arthropods (Stanbury, 1972). Mammals are the most diverse group of animals having approximately 5,416 extant species on the globe (Kingdon, 1997; Wilson and Reeder, 2005; Mosissa Geleta and Afework Bekele, 2016), of which 1,150 species of mammals are recorded in Africa (Kingdon, 1997). They are the most important components of terrestrial ecosystems (Bogonia *et al*., 2017). Mammals provide vital ecological functions such as pollination, seed dispersal and predation (Mora *et al*., 1999; Weckel *et al*., 2006; Botelho *et al*., 2012). They are also vital constituents of ecosystems in keeping ecological stability (Boddicker *et al*., 2002; Herrerias *et al*., 2008). They are considered as an important resource for humankind and provide benefits such as consumptive and non-consumptive values (Boesch *et al*., 2017).

Ethiopia is among some African countries with high wild mammal species diversity that are comparable with other countries of east Africa (Yalden *et al*., 1996; Dawit Mamo *et al*., 2012). About 320 species of mammals exist in Ethiopia (EWCA, 2012; Alemneh Amare, 2015; Rabira Gonfa *et al*., 215), of which 55 are endemic (Lavrenchenko and Afework Bekele, 2017). However, populations of large mammals of the country including Heuglin's gazelle are directly persecuted by anthropogenic factors (Atakilt Berihun *et al*., 2016). As a result some of the large sized mammals of Ethiopia are classified as vulnerable, endangered or critically endangered (Gordon, 2009).

The Heuglin's gazelle is a large sized ungulate living in the flat and semi-arid areas of the east of Nile River between the southern part of the Red Sea hills in Sudan, in southwest Eritrea and in northwest Ethiopia (East, 1999; Hans *et al*., 2017; IUCN, 2017a). Numbers of Heuglin's gazelle declined and fragmented due to drought and anthropogenic factors (Hashim, 2013).

Heuglin's gazelle inhabits dry open savannah grasslands and shrub-land habitats (Kingdon, 2004; Estes *et al*., 2006). It is both browser and grazer feeding on different plant parts including palatable leaves, shoots, fallen flowers and fruits (East, 1999). The

species are generally least drought tolerant, but requiring very little water (Kingdon, 1997; East, 1999; IUCN, 2017b). According to Workneh Alemu *et al*. (2016), gazelles meet their water requirements mostly from the plant parts they consumed. When other sympatric herbivores migrate to other areas in search of water and food during the dry season, Heuglin's gazelle remain within their original ranges or move locally within short distances, where there is enough fodder (Estes *et al*., 2006). Heuglin's gazelles exhibit a high degree of spatial overlap, with other ungulates congregating to defend from predators and to satisfy their nutritional requirements in areas where resources are plenty (Hashim, 2013).

Habitat destruction and fragmentation due to human population growth is major factors for species loss (Prugha *et al*., 2008; Yosef Mamo and Afework Bekele, 2011; Mengistu Wale *et al*., 2017). Currently, the highest rate of habitat change in Ethiopia has been recorded in the northwestern part of the country, where a reduction of woodlands has been taken place from 79% in 1985 to 35.1% in 2014 (Worku Zewdie and Csaplovicsa, 2014). Similarly, the highest rate of habitat change in KSNP has been recorded, where the most reduction of woodland from 77.8% of total park coverage in 2003 to 38% in 2015 (Zenebe Arafaine and Addisu Assefa, 2019). This happened mainly due to agricultural expansion, charcoal production, gold mining, fuel wood collection, excessive wood harvest, grazing pressure and bush fire (Worku Zewdie and Csaplovicsa, 2014; Binyam Alemu *et al*., 2015; Mengistu Wale *et al*., 2017).

These factors have seriously affected the formerly abundant Heuglin's gazelles to less remnant populations (Scholte and Hashim, 213). Hence long term survival of this species needs to be carefully examined, because this species is considered as endangered (IUCN, 2017a). Individuals are able to select the most suitable habitats for their most basic activities, food selection, protection against predators and reproduction (Armstrong and Seddon, 2008). Temporal distribution of a species depends on its ecological requirements and responses to environmental characteristics (Elton, 1997). These environmental characteristics affect not only population status, but also the population distribution of the species (Zerihun Girma *et al*., 2015). Both the population status and distributions of the species depend on its habitat requirements (Solomon and Burt, 2014; Zerihun Girma *et al*., 2015).

1.2. Statement of the Problem

At most the available information on the number of Heuglin's gazelle both globally and locally are based on informed guesses. However, accurate information on the population status, habitat preference and other ecological aspects of the species are required in order to be successful in conserving the species and its habitat. According to The recent assessment by IUCN (2017a), Heuglin's gazelle is categorized as "Endangered". Hence, the current study was aimed to assess the present population size and habitat preference of the species in KSNP.

There are a number of reasons why this study was so important. First, population of the species has been dramatically declining in Ethiopia across its ranges, mainly due to modification of their natural habitat by the ever increasing of human population (Berihun Gebremedhin *et al.*, 2011; Atakilt Berihun *et al*., 2016; KSNP, 2016). For example, its population in KSNP has been declining from 376 in 2010 (KSNP, 2010) to 298 individuals in 2016 (KSNP, 2016). Second, the viable population of the species found at present in KSNP, mainly threatened by anthropogenic disturbances (IUCN, 2017c; Zenebe Arafayne and Addisu Assefa, 2019). Finally, there is no sufficient data on population size, density, habitat preference and other ecological aspect of Heuglin's gazelle in Ethiopia.

Likewise, little is known about the population size and habitat preference of Heuglin's gazelle in KSNP. As a result, it is difficult to design effective conservation and management by developing monitoring plans and protocols to the targeted species without updating the information on this regard. Therefore, this study can provide initial and vital information related to the population status and habitat preference of the species in the study area. Furthermore, it will also add new information for assessing their population growth pattern in the future and to develop conservation plans of Heuglin's gazelle in the country. Generally, this study will attempt to fill information gaps about the population size, habitat preference, population density, herd size and composition of Heuglin's gazelle across habitat types and seasons.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of this study was to assess population status and habitat preference of Heuglin's gazelle in KSNP, Northwest Ethiopia.

1.3.2. Specific Objectives

The specific objectives of the study were:

- To estimate the current population size of Heuglin's gazelle in KSNP.
- To estimate the density of Heuglin's gazelle in the study area.
- To determine herd size of Heuglin's gazelle between wet and dry seasons in the current study area.
- To identify age and sex structure of Heuglin's gazelles population in KSNP.
- To identify habitat preference of Heuglin's gazelle in KSNP.

1.4. Research Questions

- What is the current population size of Heuglin's gazelle in KSNP?
- What is the density of Heuglin's gazelle in the study area?
- Is there a variation in herd size of Heuglin's gazelle between wet and dry seasons in the current study area?
- What is the age and sex structure of Heuglin's gazelle population in current study site?
- Is there a variation in habitat use of Heuglin's gazelle in the study area?

2. LITERATURE REVIEW

2.1. Taxonomy and distribution of Heuglin's gazelle

Heuglin's gazelle (*Eudorcas tilonura*) is named after a German explorer and ornithologist Theodor von Heuglin who first describe it in 1863. He made his description based on a specimen from the plains close to Ain-Saba in Bogos land in Abyssinia (the Ethiopian Empire). Authors such as Gentry (1972), Kingdon (1997) and East (1999) considered Heuglin's gazelle as a member of the genus *Gazella* within subgenus *Eudorcas* before *Eudorcas* was elevated to generic status. It was treated as conspecific with related forms of *Eudorcas thomsoni* and *Eudorcas albonotata* (Kingdon, 1997; East, 1999). *Eudorcas tilonura* considered as a sub-species of *Eudorcas rufifrons* (Grubb, 2005). However, Heuglin's gazelle is a distinct and independent species (Groves, 2013). It belongs to the Bovidae family, subfamily Antilopinae and genus *Eudorcas* (IUCN, 2017a). Earlier, in KSNP it was wrongly listed as a red fronted gazelle in (Zenebe Arafayne and Addisu Assefa, 2019).

Heuglin's gazelle ranges east of the Nile River between the southern part of the Red Sea Hills in Sudan, in southwestern Eritrea and northwestern Ethiopia (East, 1999; Hashim 2013; IUCN, 2017a). Currently it is believed to remain present in much of its historical range but in localized patches (Hashim, 2013). It is a poorly studied species and very few recent survey data are available (IUCN, 2017a). The former sites of Heuglin's gazelle were severely fragmented and depleted by anthropogenic factors. The species still present in DNP of eastern Sudan and in the Gash-Setit wildlife in the southwestern Eritrea (Hashim, 2013; Mallon, 2014). Locally, it is found in KSNP, and possibly in ANP and GNP of north western Ethiopia (IUCN, 2017a). Heuglin's gazelle extended north western Ethiopia, at altitudinal ranges between 500 and 1400 masl (Yalden *et al*., 1996; IUCN, 2017a).

2.2. Identification and Physical description of Heuglin's gazelle

Heuglin's gazelle is the large sized member of the Bovidae family with slender and well adapted to living in semi-arid, open grasslands, wooded savannas and shrubby steppes, but not in arid areas (Kingdon, 1997; IUCN, 2017b). Both sexes of the species are horned with slight s-shape over their length and diverging towards the tip. The females have thinner,

smooth or slightly ringed horns towards the base, growing shorter than the male whereas, the male horns are thicker than the female with strongly ringed almost to the tips, growing (Plate 1). The horns measure 22 - 35 cm in males and 15 - 25 cm in females, and turn inward at the tips (Groves, 1969; Castello, 2016). Heuglin's gazelle is a light reddish color gazelle, with uniformly tan colored upper coat and white underside and rump (Plate 1). Characteristically, it has narrow distinct thin 2 - 4 cm high black band that runs from the elbow to the hind leg (Plate 1). Band of rufous stripe separates the dark stripe from the white belly under parts and the upper tan colored coat (Plate 1). The tan center of the face is bordered by a pair of white stripes that run from the eye to the corner of the mouth, which are echoed by a dark stripe beneath (Plate 1). It has large and black eyes with a faint white ring. The length of its head and body reaches 55 - 120 cm and the shoulder height is nearly 67 cm (Groves, 2013). The tail measures 15 - 27 cm and is rufous at the base, turning black towards the end (East, 1999; Groves and Grubb, 2011; Castello, 2016). It is smaller and more rufous than the red-fronted gazelle, the nose is unmarked. Males weigh between 20 - 35 kg while the weight of females varies from 15 - 25 kg (Groves and Grubb, 2011; Castello, 2016).

2.3. Behavior and Adaptation

The global population of Heuglin's gazelle is only found in Africa (Scholte and Hashim, 2013). They are solitary in pairs or groups, which exhibit momentary male to female pairing during the breeding season (Hashim, 2013). Territorial Heuglin's gazelle males aggressively defend females against younger males, which employ a non-territorial (sneaky) mating tactic. Another form of association includes that of a female and it's young. Heuglin's gazelle exhibit a high degree of spatial overlap, with other ungulates congregating to defend from predators and to satisfy their nutritional requirements in areas where resources are enough (Scholte and Hashim, 2013). When alarmed, this species produces a series of short wheezy snorts while pinching the nostrils forward (East, 1999).

They are the least drought adapted gazelles, unable to inhabit in the Saharan regions, but successfully adapt semi-arid areas with open grasslands, wooded savannas and shrubby steppes (Kingdon, 1997; IUCN, 2017b). Predominantly, it is diurnal and activities start early in the morning and continues until sunset. During the daylight when the sun becomes strong they tend to remain under the cover of thicket, especially thorny brush and trees for

shade. Heuglin’s gazelle sometimes appears in open sunny spots in both mornings and afternoons (Hashim, 2013). Heuglin’s gazelle seem to be able to tolerate semi-arid temperatures, which occurred in their habitat for most times of the year. They are primarily active at dawn and dusk of the day (Kingdon, 1997).

2.4. Habitat preference

Heuglin's gazelle inhabits dry grassland and thorn bush land up to 1,400 masl (Yalden *et al*., 1996). Grassland, shrub lands and fallow land are the main habitat types used by Heuglin’s gazelle throughout the range (Kingdon, 1997; IUCN, 2017a). Hashim (2013) previously stated that, semi-arid, flat areas of little vegetation cover with enough shelter are the preferred habitats. But, it shun large areas of dunes and drought. It is able to move locally according to the season in order to benefit from small areas with rich forage and high level of moisture (East, 1999).

According to Hashim (2013), Heuglin’s gazelle had no seasonal habitat preference in Sudan. Evidence of Heuglin’s gazelle, as indicated by the presence of tracks, was related to exploratory activity, with more tracks being found on the forest clearing/fallow areas rather than in the other habitats such as densely wooded land and highly grassy woodland areas (Scholte and Hashim, 2013). Their findings suggest that, in an area where food and water are available, the structure of the habitat is the most significant factor in the Heuglin’s gazelle choice of habitat. A further consideration that may influence habitat choice by the Heuglin’s gazelle is their modes of communication. Gazelles use visible rump patch patterns for communication in different situations and this is easier in open areas (Abaigar *et al*., 2013).

The Heuglin’s gazelle are mixed feeder, predominantly grazer preferring grasses during the wet season and occasionally browser preferring fallen leafs from trees and shrubs during the dry season (East, 1999). Some previous studies suggest that palatable grass and Acacia species such as *Acacia mellifera*, *Acacia tortilis*, *Balanites aegyptiaca* and *Boscia senegalensis* are the principal foods for the gazelles including Heuglin’s gazelle (East, 1999; Scholte and Hashim, 2013). Other gazelles in east and central Africa increased their intake of shrubs and forbs over grasses during the dry season, even though these made up only 26% of the available vegetation (Loggers, 1992). They suggested that, this was

because dicotyledonous plants contain higher levels of protein than grasses during the dry season. In DNP protection of Heuglin's gazelle was ineffective as the open habitats preferred by the species were utilized intensively in the dry season by camel herders who cut down the shade trees to feed their livestock (East, 1999). In regions devoid of water, Heuglin's gazelle obtain most of their moisture requirements from their food (Hashim, 2013). The Heuglin's gazelles use shorter trees to browse on leafy vegetation from close to the ground to the top. Likewise, that of other gazelles it browse on shrubs and forbs when available (East, 1999). According (IUCN, 2017c), the species in KSNP eat more shrubs and forbs than grasses during the dry season.

Herds most gazelles cannot range over large areas in searching of food and sometimes they tend to congregate in areas where rainfall has led to fresh plant growth (Baharav, 1980). Gazelles including the target species contribute to the correct functioning of ecosystems through its role as a major disperser of seeds. East (1999) and Hashim (2013) found that, charcoal production from Acacia trees has a negative impact on gazelle populations because it reduced the availability of food and refuges. Furthermore, the social behavior of the species may be affected by the loss of plant species that gazelles feed from. Attum *et al*. (2006), Wronski and Plath (2010) reported that, all species of gazelles prefer Acacia species of plants. This may be because Acacia plant species are more conspicuous and so advertise their presence more effectively. According to Attum *et al*. (2006) noted that, protecting of Acacia population has a great contribution in protection of Heuglin's gazelle. With regard to water requirements, different authors, including Tear *et al*. (1997), Ostrowski and Williams (2006), have reported that certain Heuglin's gazelle populations can survive without access to drinking water provided they are able to find vegetation with adequate moisture. However, Heuglin's gazelles are more water dependent than other species of gazelles in the same region (Hashim, 2013).

2.5. Reproduction

Heuglin's gazelles reproduce throughout the year (Scholte and Hashim, 2013). However, births usually skewed towards the wet season and early dry season (Hashim, 2013). During mating, the dominant male of Heuglin's gazelle chases off all the other males of Heuglin's gazelle from the herd. After, even the dominant male Heuglin's gazelle chased off by pregnant females. As a result, herds of the same sex are a common occurrence

(Castello, 2016). Copulation lasts a few seconds; the male stands upright on the hind feet and mounts the female. Gestation lasts 184 to 189 days, after which probably a single calf is born (Dittrich, 1972). The period when the female is on heat is very short, only a half to two days. A single young is born, which remains hidden (Workneh Alemu *et al*., 2016). Fawns weaned at about 2 to 3 months age and reach maturity at about nine months of age (Castello, 2016). The aggressive behavior in male Heuglin's gazelles should be more frequent during peak reproductive periods (Hashim, 2013). A strong mother young relationship is apparent, however, this is only stable until the next birth (East, 1999).

Fawns are visibly smaller than any other age group of the species and their horns cannot be consistently seen from distance. Even when they are nearly 12 months old, their horns are about as long as their ears (Castello, 2016). Fawns are weaned after about 3 months. Loggers (1992) reported that, gazelles in the most African country live in groups of adult females and their fawns, juvenile females and males which are less than about 18 months old. Although, females group ranged over territories of more than one male and they are frequently found within the territory of a single male. Males live either as lone territorial males or as bachelors. Bachelors were found singly or in herds of up to ten individual Heuglin's gazelles. Adult males tend to defend territorial areas in which they keep groups of females. Territorial males also advertise their presence by keeping at a distance from females and standing or lying lonely for long period of time. Females do not mark or display signs of territoriality.

2.6. Group Size and Composition

Heuglin's gazelle form a groups of 5 - 12 adult females and young, territorial males and bachelor groups of 2 - 5 males (East, 1999). Heuglin's gazelle lives at most and for most of the year in small herds containing 2 to 8 individuals (Hashim, 2013). In current study area herds of 2 to 10 individuals of Heuglin's gazelle seen in the park (KSNP, 2016). Occasionally, herds of up 12 individuals seen in the study area during the wet season in the south western part of the park (*personal observation*). The greatest coming together of the species occurs at the beginning of the wet season, when herds comprise adult males and females as well as sub-adult males and females (East, 1999). If herds are unable to congregate in the breeding season, the adults do not receive the stimulation as necessary to commence the pre mating rituals (Castello, 2016).

2.7. Competition and Predation

In most cases Heuglin's gazelle share their habitat with livestock and humans (East, 1999; Hashim, 2013). According to Hashim (2013), Heuglin's gazelle were likely to experience competition in the form of exploitation by humans such as, interference from competing livestock, clearance of scrub, cutting of shade trees and encroachment of agriculturalist. Heuglin's gazelles regard humans as predators and they avoid large trees frequented by farmers and their livestock's and avoid areas extensive of human activity (East, 1999; Castello, 2016). Distribution of Heuglin's gazelle in Eritrea, a country which neighbors to Ethiopia was more affected by human activities than habitat features, particularly the intensity of land transformation for agriculture (Mallon 2014). They also found that Heuglin's gazelle tend to inhabit the same areas as camels, which could be due to the fact that both species use agriculture free land for grazing (Hashim, 2013).

The natural predators of Heuglin's gazelle are Lion (*Panthera leo*), Leopard (*Panthera pardus*), Cheetah (*Acinonyx jubatus*), Wild dog (*Lycaon pictus*), Striped hyena (*Hyaena hyaena*), Common Jackal (*Canis aureus*), and Caracal (*Felis caracal*) (Frost, 2014; Hashim, 2013; Castello, 2016). Of these, the known wild predator which exists in KSNP are leopard (*Panthera pardus*), Caracal (*Felis caracal*), Stripped Hayna (*Hyaena hyaena*), Spotted Hayna (*Crocuta crocuta*) and Black backed Jackal (*Canis mesomelas*) (Mekbeb Eshetu *et al*., 2002; KSNP, 2016). In the study area Jackals are particularly adept at taking the newly born Heuglin's gazelle and they are often found close to the herds during the birthing season.

2.8. Status of Heuglin's gazelle

2.8.1. Global status of Heuglin's gazelle

According to the IUCN, the numbers might have fallen by as much as 20% in roughly nine years after 2008, and still nowadays decreasing throughout its ranges, mainly due to anthropogenic factors. East (1999) produced a rough estimate of 3,500 - 4,000 Heuglin's gazelle globally. He also noted that, the number of the species is in a declining trend in Eritrea and Ethiopia, and unknown in Sudan. According to Hashim (2013), the Heuglin's gazelle has been reduced to small fragmented populations throughout its range and declining in Sudan. Hashim (2013) noted that, Heuglin's gazelle was under pressure for a

long period of time across its range with number now being significantly lower and the populations more fragmented than was a few decades ago.

East (1999) said that, a fair numbers' of Heuglin's gazelle were found in Gash Setit Wildlife Reserve of Eritrea. However, he was not indicating how they came to that figure. Castello (2016) indicated that, the numbers of the species are rapidly fragmented to scattered remnants and depleted throughout most of its ranges. This resulted from anthropogenic factors, repeated droughts and predation by feral dogs. In other way, Heuglin's gazelle was listed as endangered under criterion C1 version 3.1 (IUCN, 2017a). This is because of the estimated global population of the species ranges between 2,500 - 3,500 gazelle with less than 2,450 mature individuals (IUCN, 2017a). The criterion taken into consideration to level this species as endangered was based on the IUCN international rules. That means, if the total number of the species with < 2,500 mature individuals and its decline continue by 20% in 5 years (2 generations) it is listed as endangered under criteria C1 (IUCN, 2019).

Fewer than 25% of the remaining populations of the species are live in protected areas (Lerp *et al*., 2011). If present trends continue throughout its ranges, the numbers of the species will probably decline further until its status becomes critically endangered (Dupuy, 1984). According to East (1999), formerly Heuglin's gazelle was widespread towards the east of Nile River. But, now survive in small fragmented populations due to the loss of much of their habitats (Scholte and Hashim, 2013). Hunting and habitat degradation due to overgrazing, clearance of scrub, cutting of shade trees, drought, and agricultural encroachment are the main threats for decline of population of this species (East 1999, Hashim 2013). In DNP the density of Heuglin's gazelle was estimated around 1 animal/km^2 (Hashim, 1998).

2.8.2. Status of Heuglin's gazelle in Ethiopia

In Ethiopia, particularly in KSNP, specific up to date information is sparse. However, the decline is exacerbated by the encroachment of agriculturalist, increasing of illegal miners and the encroachment of livestock in the study area (Berihun Gebremedhin *et al*., 2011; IUCN, 2017c). This is resulted from limited awareness of the value of the Heuglin's gazelles (IUCN, 2017a). According to assessment by KSNP (2010 and 2016), the

estimated populations of Heuglin's gazelle in the study area were 376 and 298 individuals respectively. When we compare together the assessment by KSNP, the numbers of Heuglin's gazelle declined rapidly in the study area (20.7% decline) between 2010 and 2016.

3. MATERIALS AND METHODS

3.1. Materials

Over the period of field study different materials such as Binocular (Nikon 10*50), Garmin® GPS 72H, Pen, Note book and Tecno Camon CX Air 13 mega pixel camera phone were used during data collection.

3.2. Description of the study area

3.2.1. Location and Topography

The present study was conducted in KSNP, which is located in Tip of Northwestern, Ethiopia. It is about 1,015 km from Addis Ababa to the Northwest, Ethiopia. Geographically it is located between 13°50’0’’ and 14° 30’0’’N latitude and 36° 40’0’’ and 37°40’0’’ E longitude (Fig 1).

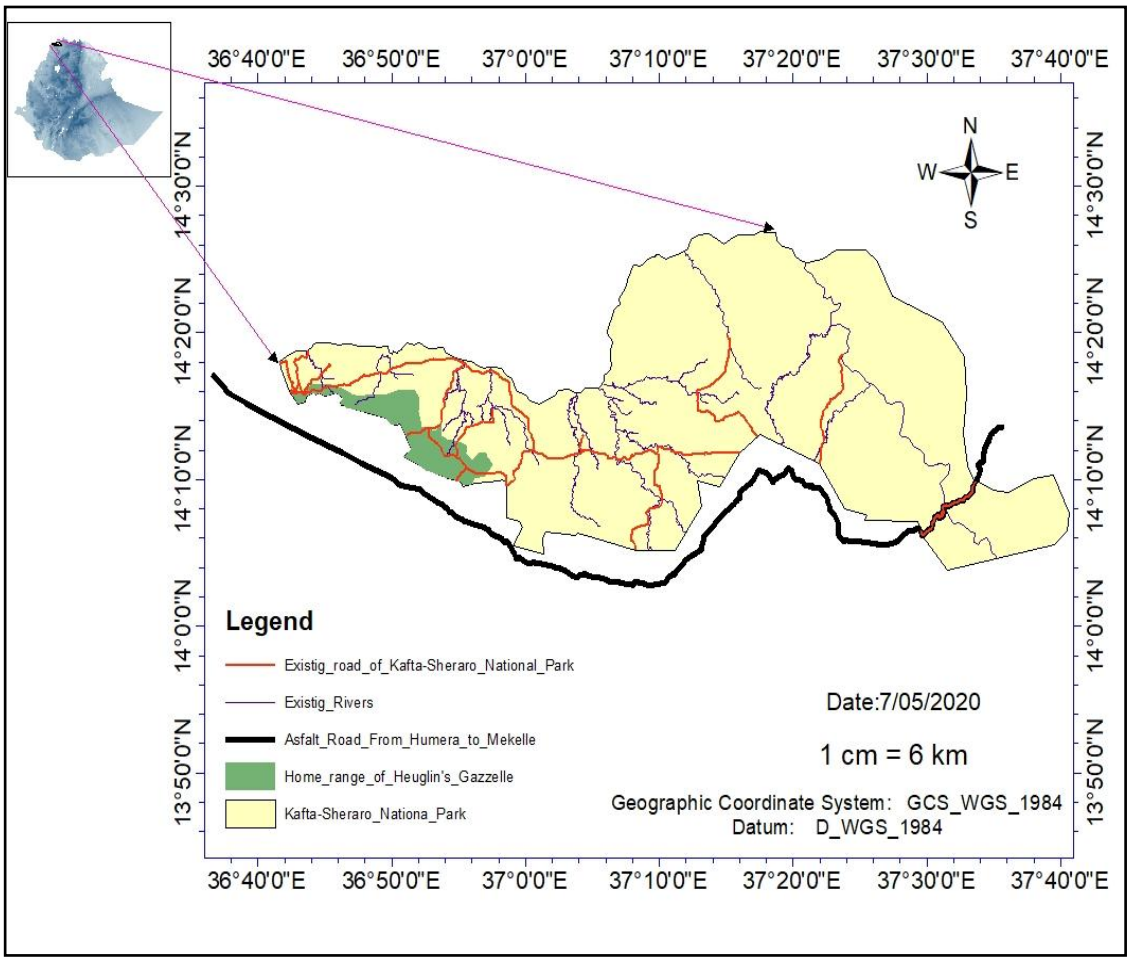

Figure 1: Map of study area

Kafta Sheraro National Park is a lowland area with an elevation ranging between 568 and 1163 masl (KSNP, 2016; Alembrhan Assefa and Chelmala, 2019). The low and high elevation values are found in the western and eastern parts of the study area, respectively. Topographically, it consists of extended up and down terrain, flat plain and cliffs. They cover an estimated about 70%, 25% and 5% of the total areas of the park, respectively. The park has an area of 2176.43 Km^2 and it was established legally as a national park in 2007 (KSNP, 2016; Zenebe Arafayne and Addisu Assefa, 2019).

3.2.2. Climate

The climate of KSNP is characterized by extremes wet and dry hot seasons. Agro ecologically, the study area characterized by semi-arid climatic zone (Alembrhan Assefa and Chelmala, 2019; Teklay Girmay *et al*., 2020). It is characterized by mono modal type of rainfall regime, occurring from April to October with highest rainfall from June to September, and August is the peak rainy month (Fig 2).

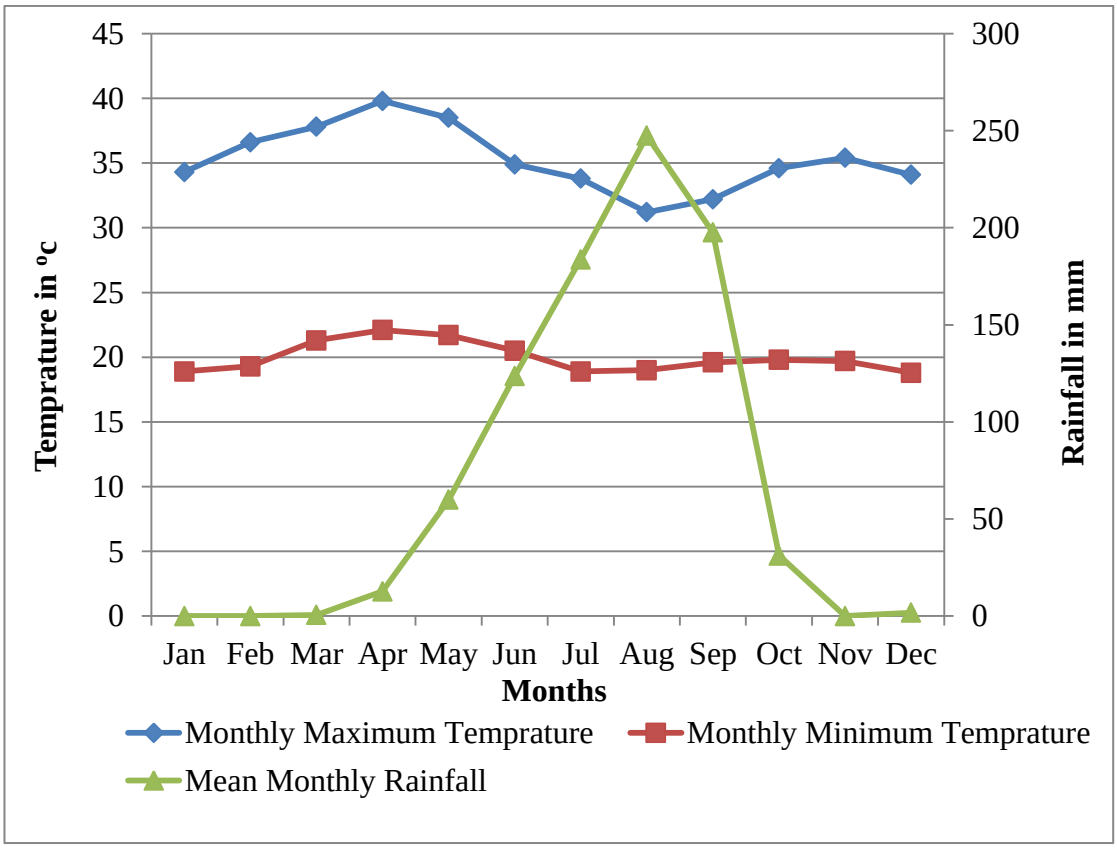

Figure 2: Mean monthly maximum and minimum temperatures and rainfall distribution of the study area (2013-2019). Data Source: Ethiopian National Meteorological Agency Mekele Branch.

The mean monthly rainfall range extends from 0 mm in dry season months to a 271.7 mm in August. In the present study period in 2019 the rainfall may extend from about 1.7 mm in April to a maximum rainfall record of 275 mm in August. The total annual rainfall ranges between 554.8 mm and 959.1 mm, and the mean annual rainfall is 738.1 mm. The mean monthly minimum temperature ranged between 18.8^{o}C in December and 22.1^{o}C in April, and the mean monthly maximum temperature ranged between 31.2^{o}C in the heavy rainy month (August) and in fourth rainy month (September) of the study area, and 39.8^{o}C in dry hottest month (April). The relative humidity also showed variation among months (Fig 3). The lowest relative humidity was recorded in April, while the highest humidity was scored in August. Thus, the cold wettest and hot driest months of the area were August and April, respectively.

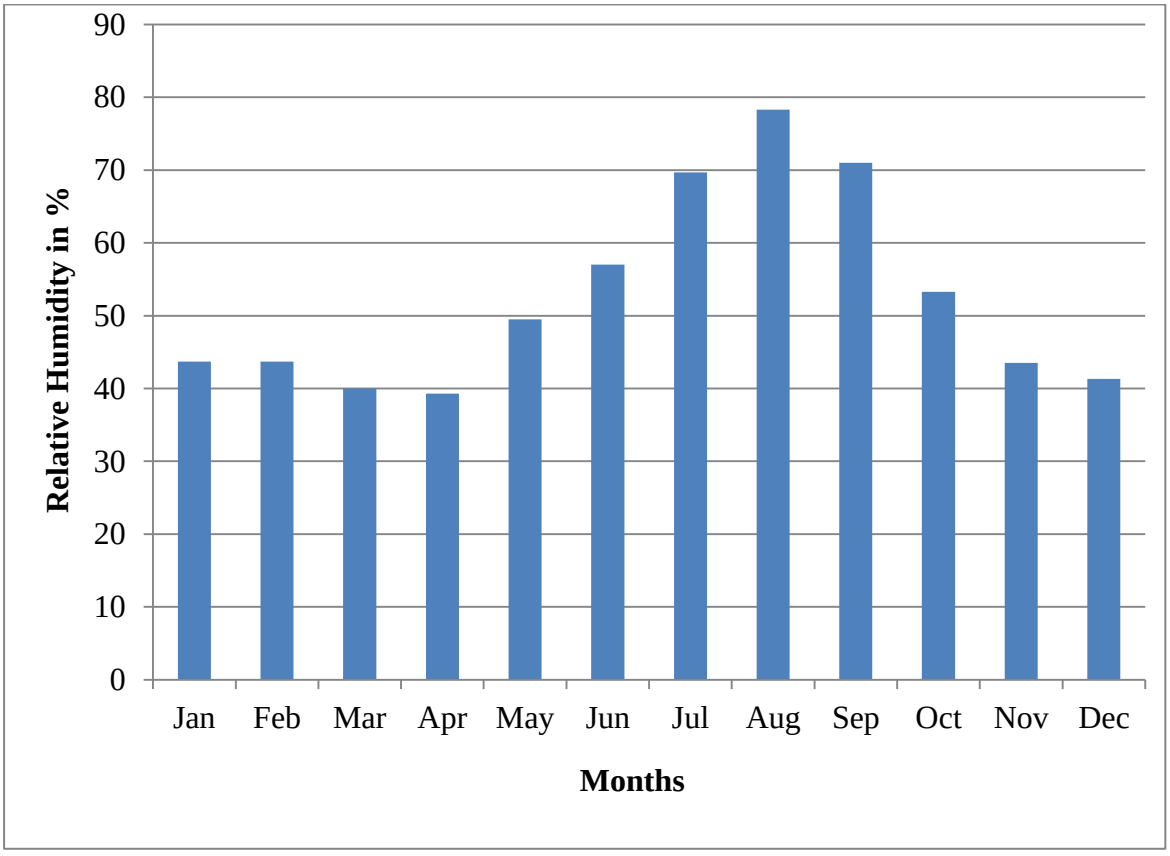

Figure 3: Mean monthly relative humidity of the study area. Source: Ethiopian National Meteorological Agency, Mekele Branch.

3.2.3. Soil and Water Source

The dominant soil types of KSNP are vertisols, lentisols and alluvial deposits. Vertisols are described as the dark heavy cracking clays of the plains occur scattered throughout the

park's plains, but is more dominant in the northwestern and southern part of the park. The soil of the flat plain mainly consists of heavy, dark cracking vertisols broken by streams, sandy loam and sandy lentisols. The black cotton soil usually cracks deeply during the early dry season. The entisols dominate the western and central limits of the park. This soil type occurs in patches of loam and sandy loam. Entisols occur in patches of sandy loam and sandy clay in scrub land. Alluvial deposits are dominant in the central flood plains along Tekeze and Deguagum Rivers. Cone-shaped low lying hills and rocky out crops are scattered throughout the park and the escarpment ranging towards the south eastern limits.

As shown in (Fig 1) Tekeze is drained by different rivers, which include Deguagum, Zerbabit, Mayweyni, Mitsats, Agaf-Urgo and their tributaries. These rivers flow to the northwest of the Park and finally after they mixed to Tekeze River, they flow to the west of the park. All of these rivers hold a large volume of water in the wet season, especially Tekeze, Deguagum and Agaf - Urgo. Tekeze and Deguagum are prominent rivers in the Park with many tributaries and seasonal floods from the surrounding upper highland areas. But, except Tekeze, all the others do not flow throughout the year.

Plate 1: Tekeze River

The core hydrologic function of the study area is influenced by Tekeze River (Plate 2). Its major tributaries rise from the highlands on the eastern side of the Simien Mountains including Zarima, Tserare, Geba and Wori. There are also sub-tributaries that originate from the highlands of Welkayit those runs through the park. River beds of these rivers are mostly sandy soils, which have the capacity to carry water below the surface of the river course. As a result most water sources including the rivers, dry up during the hot dry season from December to mid-June. However, some water pool patches may remain along the rocky bed of the river courses and hold water throughout the year (Plate 3).

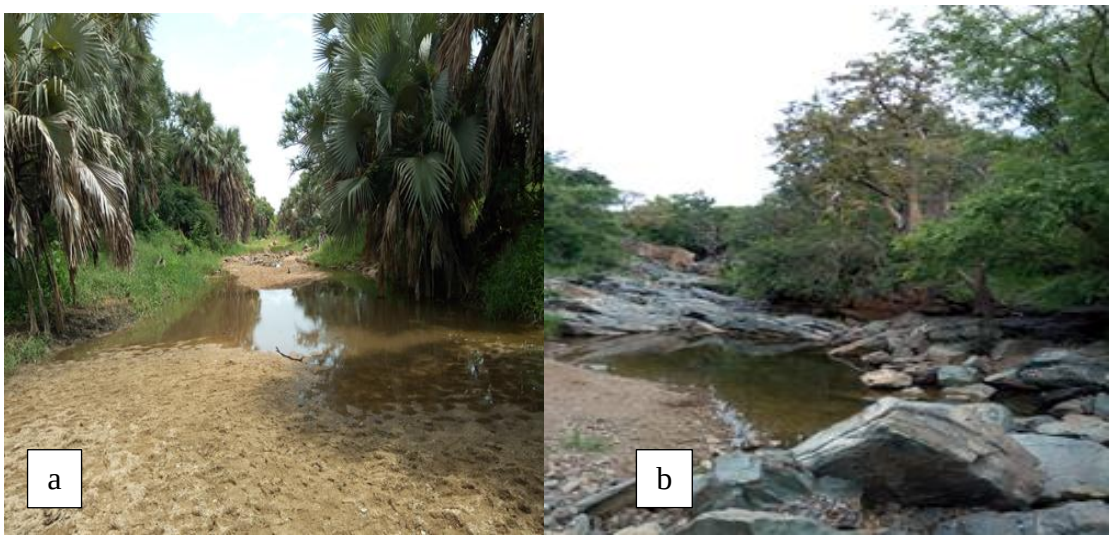

Plate 2: Water pools remain on the rivers bed of Tebeko (a) and Deguagum (b), River

3.2.4. Vegetation and Habitat Types

In KSNP there are about 53 species of plants and the dominant vegetation are *Acacia commiphora* and *Combretum terminalia* woodlands that contain several economically important tree species, such as *Boswellia papyrifera* that provide the widely known and traded frankincense gum (Atakilt Berihun *et al*., 2016; Zenebe Arafaine and Addisu Asefa, 2019; Teklay Girmay *et al.*, 2020). The most common trees species are *Anogeissus leiocarpus*, *Terminalia spp*., *Boswellia papyrifera*, *Sclerocarya birrea*, *Zizyphus spp*., *Dalbergia melanoxylon*, *Boscia angustifolia*, *Sterculia africana*, *Adansonia digitata*, *Balanites aegyptica*, *Dichrostachys cineria*, *Acacia seyal*, *Acacia mellifera*, *Hyphaene thebica*, *Diospyros mespiliformis* and *Combretum spp*. The ecosystem of the study site, classified in to four major habitat communities, such as wooded grassland, open grassland, shrub land, woodland habitats (Fig 4).

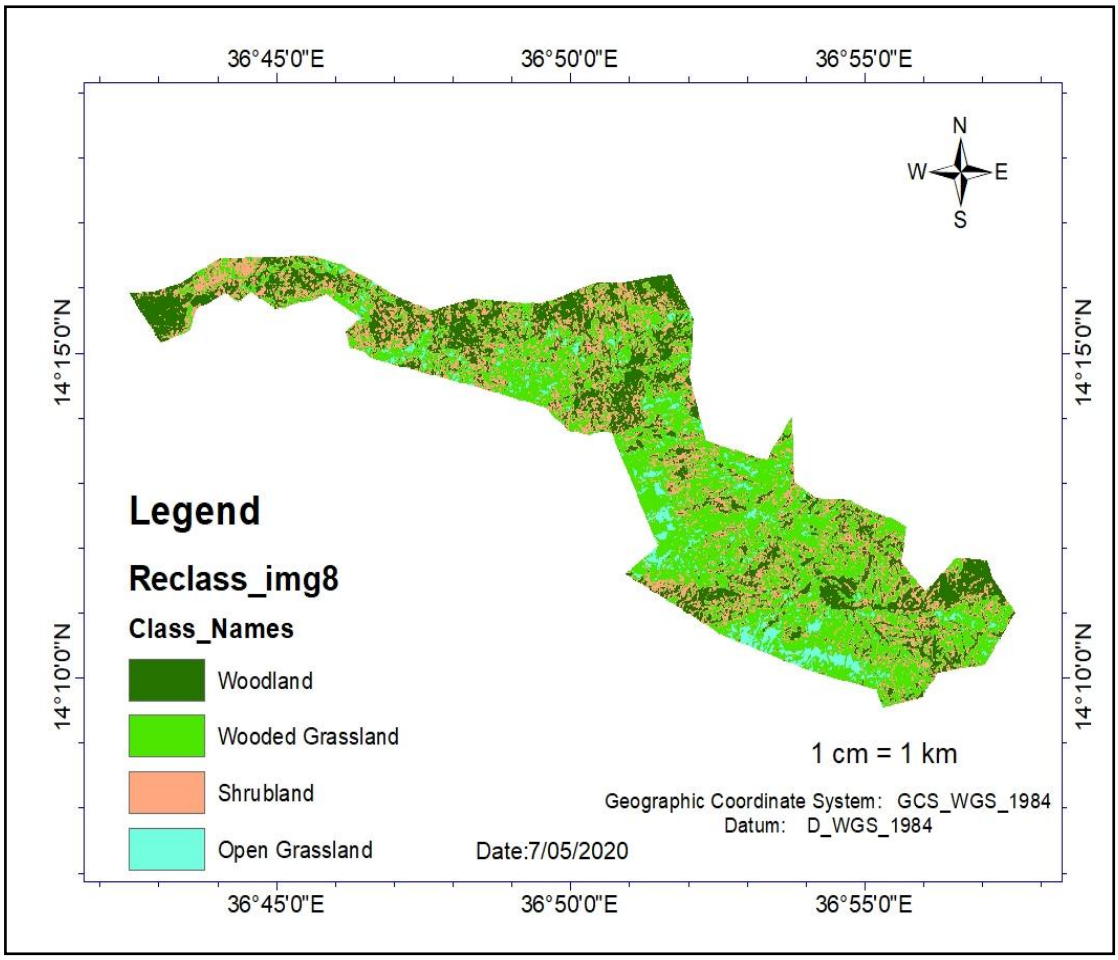

Figure 4: Map of study site shows habitat categorization

3.2.4.1. Wooded Grassland Ecosystem

According to (Pye, 1985), the wooded grassland habitat is mixed of trees and grasses with less than 35% of tree cover. Grasses with scattered trees dominate the ground covers and it is the first wide spread habitat in the study area and site (Plate 4). This habitat is found in shallow soils of sandy to dark cracking clay soils. Variation in the vegetation and soil types resulted in mixed and pure stands of grasses. This habitat is represented by small to tall trees of different species such as *Acacia seyal*, *Balanites aegyptica*, and *Comberetum spp* scattered in patches of open grasslands. This ecosystem is highly threatened by fire and shortages of water in the dry season. It is a feeding area for most wild herbivores including Heuglin's gazelle as they can run and are not easy to hunt by carnivores. This habitat covers 44.4% of the study site of the park (Fig 4 and Appendix 6).

Plate 3: Wooded grassland habitat

3.2.4.2. Woodland Ecosystem

This habitat is the second largest habitat in the study site. It is rich in different size mixed vegetation composition (Plate 5). Moderately sized deciduous mixed trees with at least 40% canopy cover dominate this habitat, but their crowns are not densely interlocked. Tree species of the genus such as *Terminalia spp.*, *Combretum spp.*, *Acacia spp.*, *Pterocarpus* and *Lannea* with understory grass coverage dominated the ecosystem. This habitat covers 25.16% of the study site (Fig 4 and Appendix 6).

Plate 4: Woodland habitat

3.2.4.3. Shrub Land Ecosystem

Shrub land habitat is the third wide spread habitat of study site. It is a mixed of shrubs, grasses and herbs, but plant community dominated by shrubs (Plate 6). Shrub land of the study area occurs naturally and by the result of human activities. It includes both mature and immature vegetation type remains stable over the time or transitional community that occurs temporarily as a result of disturbance such as fire and agriculture. It is much branched woody plants with not more than three meters high and usually with many steams. This habitat covers 25.06% of the study site (Fig 4 and Appendix 6).

Plate 5: Shrub land habitat

3.2.4.4. Open Grassland Ecosystem

Open grassland is area which the vegetation is continuous cover of free grasses (Plate 7). This grass land cover occurs in environment to help the growth of this plant cover, but not to that of taller plant types, particularly trees and scrubs. Open grassland is one of the least spread of all the major vegetation types of the park. Open grassland habitat is grasses that support high densities of grazing animals in most national parks of Africa in general and in Ethiopia in particular. But a case of KSNP, this habitat does not frequented by animals as other habitat types, especially by Heuglin's gazelle. Almost grassland ecosystem of KSNP is fragile because water is scarce. Grasslands in the study area are often dependent on regular time of fire for renewal. They are also prime targets for population development,

which can have devastating consequences. This habitat covers 5.39% of the study site (Fig 4 and Appendix 6).

Plate 6: Open grassland habitat

3.2.5. Fauna of Kafta Sheraro National Park

The Tekeze River valley had been known to be historically rich in wildlife. The park is home to many ungulates, predators and other wild animal species (Atakilt Berihun *et al*., 2016). It harbors 42 mammalian species including the endangered and rare species like African elephant (*Loxodonta africana*), Leopard (*Panthera pardus*) and also the low risk but, conservation dependent Greater Kudu (*Tragelaphus strepsiceros*) (Mekbeb Eshetu *et al*., 2002; Teklay Girmay *et al.,* 2020). Of which 15 of them are observed during the current study time (Appendix 5). It is also anticipated as a potential site shelter of Roan antelope (*Hippotrags equins*) which has a historic bio-geographic distribution range in north eastern Sudan, northwestern Ethiopia and southwestern Eritrea (Heckel *et al*., 2007). Kafta Sheraro National Park is also potential site shelter of the endangered Heuglin's gazelle (*Eudorcas tilonura*) which has a historic bio-geographic distribution range in northwestern Ethiopia, east of Nile River between the southern part of the Red Sea hills in Sudan and southwestern Eritrea. In addition to the presence of mammalian species, 167 species of birds, 9 species of reptiles and unidentified fish, reptiles and amphibian species

have been so far recorded (Atakilt Berihun *et al*., 2016; Zenebe Arafaine and Addisu Asefa, 2019). As KSNP is a Trans boundary Park which is adjoined with the Gash Setit Wildlife Reserve of Eritrea, it has huge potential to conserve rich wildlife resources. KSNP serves as a migratory route for African elephant, which traverse from Gash Setit Wildlife Reserve in Eritrea (Shoshani and Yirmed Demeke, 2006).

3.3. Methods of data collection and analysis

3.3.1. Data Collection

Before the actual data collection, a reconnaissance survey was carried out in KSNP from 01-10 June 2019. During this survey period, relevant information on KSNP vegetation types and distribution of Heuglin's gazelle were observed and identified. Most flat area of the park dominated by wooded grassland, woodland, shrub land and open grassland were selected for the present investigation. The major consideration for site selection was the distribution and abundance of Heuglin's gazelle observed in different habitat types during the reconnaissance survey. After the reconnaissance survey, the selected site was assigned into 10 counting blocks (6 - 10 Km^2 area) that covered the four habitat types wooded grassland (40.75 Km^2), woodland (23.1 Km^2), shrub land (23 Km^2) and open grassland (4.95 Km^2) area in order to generate the required data about population status of the species (Figure 4 and Appendix 6).

Intensive field work for data collection were carried out for three consecutive months in each seasons from 16 June to 16 September 2019 for wet season and from 01 January to 01 April 2020 for dry season. Each block was surveyed once per month and three times in each season (wet and dry seasons), totaling six surveys in the course of the study period, using 20 observers, who are familiar with the study area. These 20 observers were deployed for the established blocks (n = 10). Each block was having 2 observers to collect the required data in all blocks at the same time of the day to avoid double counting during the movement of animals from one block to the other. The ten counting blocks were designed based on natural and artificial boundaries, which act as barriers.

Total count method was applied throughout the study period to estimate the population size of the Heuglin's gazelle based on silent detection as adopted by Sutherland (1996) and Wilson *et al*. (1996). Whenever a herd or individual of Heuglin's gazelle was

encountered, date and time of observation, total number of individuals in the herd, sex and age categories, block and habitat type (wooded grassland, woodland, shrub land and open grassland) where they were observed were recorded on standard census datasheet prepared for this study (Appendix 1). Data collection was carried out when the Heuglin's gazelle were most active early in the morning 07:00 am to 10:00 am and late in the afternoon from 03:00 pm to 06:00 pm (Sutherland, 1996).

Age and sex composition of each herd was classified into five broad categories; such as adult male, adult female, sub-adult male, sub-adult female and juvenile unidentified sex. To categorize individual of Heuglin's gazelle into these categories, the methods of Lewis and Wilson (1979) and Kingdon (1997) were followed.

Census was carried out on foot using unaided eyes and a pair of binoculars to detect Heuglin's gazelle at a distance. In other ways double counting of the same individuals or herd was avoided using easily recognizable features of individual gazelle, herd size and group composition. Group composition of Heuglin's gazelle over the study period was recorded using age and sex categories. This distinction was made based on body size, horn size and shape (Lewis and Wilson, 1979; Kingdon, 1997). Operational definition of herd used in this study was any number of animals of the species found together at any point and time, within a distance of less than 50 m between them and apparently in sensory contact with one another (Hillman, 1987; Workneh Alemu *et al*., 2016).

3.3.2. Data analysis

The average number of gazelles observed in each blocks and habitats in wet and dry seasons was computed and used for analysis. Density of the species in the study area was estimated as a summation of the mean count of Heuglin's gazelle in each blocks divided by the total area of the selected study site (i.e. 91.8 Km2) (Sutherland, 1996). The total population of Heuglin's gazelle in the whole selected study site of the study area was estimated as a summation of the mean count of Heuglin's gazelle in the ten blocks. Likewise, estimates of total population in each block, in each season were obtained by multiplying mean density of the species in each block by total area of each respective block.

The variations of gazelle herd size and individual number encountered during the wet and dry seasons were analyzed using Wilcoxon test. The habitat preference of Heuglin's gazelle, in each season was determined by comparing the observed abundance values in each habitat type with theoretically expected even distribution in each habitat type. The significance was tested using Chi-square test. The density of Heuglin's gazelle across ten different blocks was compared using Kruskal Wallis test.

Demographic characteristic of Heuglin's gazelle 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 of age and sex categories. Accordingly, ratios were computed between male vs female, sub-adult vs adult, juvenile vs adult and juvenile vs sub-adult. Furthermore, to test variation in age and sex category across season (Male, Female, Adult, Sub-adult and Juvenile) Chi-square goodness of fit test was used.

4. RESULTS

4.1. Population Size of Heuglin's gazelle

The mean population size of 220 ± 9.85 (SE) and 189 ± 7.55 (SE) individuals of Heuglin's gazelle were recorded during wet and dry seasons, respectively (Table 1). The population was more abundant during the wet season than the dry season. However, Wilcoxon test showed that, there was no significant variation in the number of individuals gazelles observed during the wet and dry seasons (Z = - 1.604, P = 0.109). The mean count population size for the blocks was 22 ± 4.072 (SE) and 18.9 ± 3.157 (SE) individuals during wet and dry seasons, respectively. Thus the average number of 204.5 (≈ 205) individual gazelles was recorded in current study site within seasons (Table 1).

Table 1: Mean number of herds (ni), mean herd size (si) and mean of individual gazelles counted (xi) in each of the blocks during wet and dry seasons.

Blocks	Numbers of gazelle observed						Mean		
	Wet Season			Dry Season					
	ni	si	xi	ni	si	xi	ni	si	xi
B1	14	3.4	48	16	2.4	38	15	2.9	43
B2	10	3.7	37	11	2.5	27	10.5	3.1	32
B3	7	4.1	29	8	3.5	28	7.5	3.8	28.5
B4	11	2.5	27	11	2.3	25	11	2.4	26
B5	6	2.7	16	6	2.3	14	6	2.5	15
B6	5	2.8	14	3	4.3	13	4	3.55	13.5
B7	7	2.3	16	5	2.8	14	6	2.55	15
B8	6	2.3	14	4	3.5	14	5	2.9	14
B9	5	2.2	11	5	1.8	9	5	2	10
B10	5	1.6	8	4	1.8	7	4.5	1.7	7.5
Total	76	2.76	220	73	2.72	189	74.5	2.74	204.5

B1 = Block one, B2 = Block two, B3 = Block three, B4 = Block four, B5 = Block five, B6 = Block six, B7 = Block seven, B8 = Block eight, B9 = Block nine, B10 = Block ten

Across a block varied numbers of Heuglin's gazelles were observed during wet and dry seasons (Table 1). During the wet season, the highest recorded herds and individual gazelles were 14 and 48 in B1, respectively, and the lowest numbers of herds and

individual gazelles were recorded 5 and 8 in B10, respectively (Table 1). Likewise, during the dry season, the highest recorded herds and individual gazelles were 16 and 38 in B1, respectively whereas, the lowest recorded herds was 3 in B6 and 7 individuals in B10 (Table 1).

4.2. Population density of Heuglin's gazelle

Density of the animal was varied throughout the ten blocks (Table 2). About 4.7 and 4 individuals/Km^2 were recorded in B3 and B1, respectively; whereas, the lowest density (0.8) was recorded in B10 (Table 2). Large numbers of Heuglin's gazelles were recorded in block one compared to other blocks in both wet and dry seasons. There was significant difference in density of gazelle in ten different blocks ($\chi^2 = 2.66$, df = 9, P= 0.026). The overall density of the species is 2.23 individuals/km^2 (Table 2).

Table 2: Density of Heuglin's gazelles in ten different census blocks of the study site

Census Blocks	Average Mean Count	Block Area in Km^2	Density of individuals/Km^2
B1	43	9.7	4
B2	32	9.9	3
B3	28.5	6	4.7
B4	26	9.7	2.7
B5	15	8.9	1.7
B6	13.5	10	1.4
B7	15	9.6	1.5
B8	14	8.9	1.5
B9	10	9.5	1
B10	7.5	9.6	0.8
Total	204.5 (≈205)	91.8	2.23

B1 = Block one, B2 = Block two, B3 = Block three, B4 = Block four, B5 = Block five, B6 = Block six, B7 = Block seven, B8 = Block eight, B9 = Block nine, B10 = Block ten

4.3. Herd Size of Heuglin's gazelle

A total of 76 and 73 herds Heuglin's gazelle were observed during the wet season and dry seasons, respectively (Table 1). This shows that, the observed number of herds was higher

in wet season than the dry season. The maximum herd size consisted of 9 and 4 individuals during wet and dry seasons, respectively. The most frequently observed herd size was 5 animals during wet season and 2 animals during the dry season. However, Wilcoxon test showed that, there was no significant variation in the number of individuals gazelles observed during the wet and dry seasons (Z = - 1.342, P = 0.18). Mean herd size was 2.76 ± 0.968 (SE) during wet season and 2.72 ± 1.317 (SE) during the dry season within blocks (Table 1). The average number of herd size in both wet and dry season was 2.74 ± 1.14 (SE), within blocks (Table 1). Large herd sizes of Heuglin's gazelle aggregated during the wet season, while during the dry season, they were distributed in a wider area forming smaller herds and solitary individuals. The average number of 74.5 (≈ 75) herds of Heuglin's gazelle was recorded within seasons (Table 1).

Table 3: Number of herds (ni) and individual gazelles (xi) observed in each habitats during wet and dry seasons.

Seasons	Habitats							
	WGL		SL		OG		WL	
	ni	xi	ni	xi	ni	xi	ni	xi
Wet	41	134	26	69	9	17	0	0
Dry	42	105	19	48	5	17	7	19
Mean	41.5	119.5	22.5	58.5	7	17	3.5	9.5

WGL = Wooded grassland, SL = Shrub-land, OG = Open grassland, WL = Woodland.

Different herds of gazelle were recorded during the study period across habitats and seasons. In wet season, 54%, 34% and 12% herds of Heuglin's gazelle were recorded in wooded grassland, shrub land and open grassland habitats, respectively whereas, during the dry season, 57.5%, 26%, 6.9% and 9.6% herds of Heuglin's gazelle were recorded in wooded grassland, shrub land, open grassland and woodland habitats, respectively (Table 3). The distribution of Heuglin's gazelle in KSNP extends in south western part of the park from Militsay to Helegen site which is 91.8 Km^2 of the total area (Fig 1).

4.4. Age and Sex Composition of Heuglin's gazelle

Adults comprised 89%, sub-adults 9.5% and juvenile unknown sex 1.5% individuals within seasons (Table 4). Across a season adults accounted for 89.1% and 88.9% during the wet and dry seasons, respectively, while sub adults and juvenile unknown sex

accounted for 21 9.55% and 1.4% during the wet and 9.5 % and 1.6% during the dry season, respectively. During the study period more adult individuals were counted than sub adult and juvenile (Table 4). Even though the population was characterized by more adult individuals, there was no significant difference between the number of individuals in each age category during both wet and dry seasons ($\chi^2 = 4.6$, df = 2, P = 0.11).

Table 4: Number of individuals in age and sex categories in both seasons

Seasons	Age and Sex Categories				
	AM	AF	SAM	SAF	JU
Wet	91	105	11	10	3
Dry	79	89	12	6	3
Mean	85	97	11.5	8	3

AM = Adult Male, AF = Adult Female, SAM =Sub-Adult Male, SAF = Sub-Adult Female, JU – Juvenile Unknown Sex.

From the total individuals observed during the present study were, 47.2% males, 51.3% females and 1.5% juvenile unknown were recorded, respectively (Table 4). During this study period more female individuals were recorded than male and unknown sexes (Table 4). However, Chi-square goodness of fit test revealed that there was no significant difference between the number of individual in sex categories during both wet and dry seasons ($\chi^2 = 5.56$, df = 2, P = 0.063).

The sex ratio of male to female was 1.0: 1.08. Regardless of sex category, the age ratios of sub-adults to adults and juvenile to adults were 1.0: 9.3 and 1.0: 60.65, respectively whereas, that of juvenile: sub-adult was 1.0: 6.5 (Table 5).

Table 5: Age and Sex ratio of Heuglin's gazelle during wet and dry seasons

Categories	Age and Sex ratio		
	Wet season	Dry season	Mean
Male : Female	1.0:1.12	1.0:1.04	1.0:1.08
Sub-adult: Adult	1.0:9.3	1.0:9.3	1.0:9.3
Juvenile unknown sex: Adult	1.0:65.3	1.0:56	1.0:60.65
Juvenile unknown sex: Sub-adult	1.0:7.0	1.0:6.0	1.0:6.5

4.5. Habitat preference of Heuglin's gazelle

Heuglin's gazelle was distributed in the four habitat types those are wooded grassland, shrub land, open grassland and woodland. The number of Heuglin's gazelle counted varied per habitat type (Table 3 and Fig 5). In the current study site, the highest number of individuals (134) was recorded in wooded grassland, while the lowest count was (0) in woodland habitat in wet season. During the dry season, the highest count was 105 individuals in wooded grassland whereas; the lowest was 17 individuals in open grassland (Table 3 and Fig 5). In wet season, 60.9%, 31.4% and 7.7% of individual gazelles were recorded in wooded grassland, shrub land and open grassland habitats, respectively whereas, in dry season, 55.6%, 25.4%, 9% and 10% individual gazelles were recorded in wooded grassland, shrub land, open grassland and woodland habitat types, respectively (Table 3 and Fig 5). Results of Chi square test showed that there was a significant difference in their occurrence in four habitat types regardless seasons (χ^2 = 7.5, df = 3, P = 0.03).

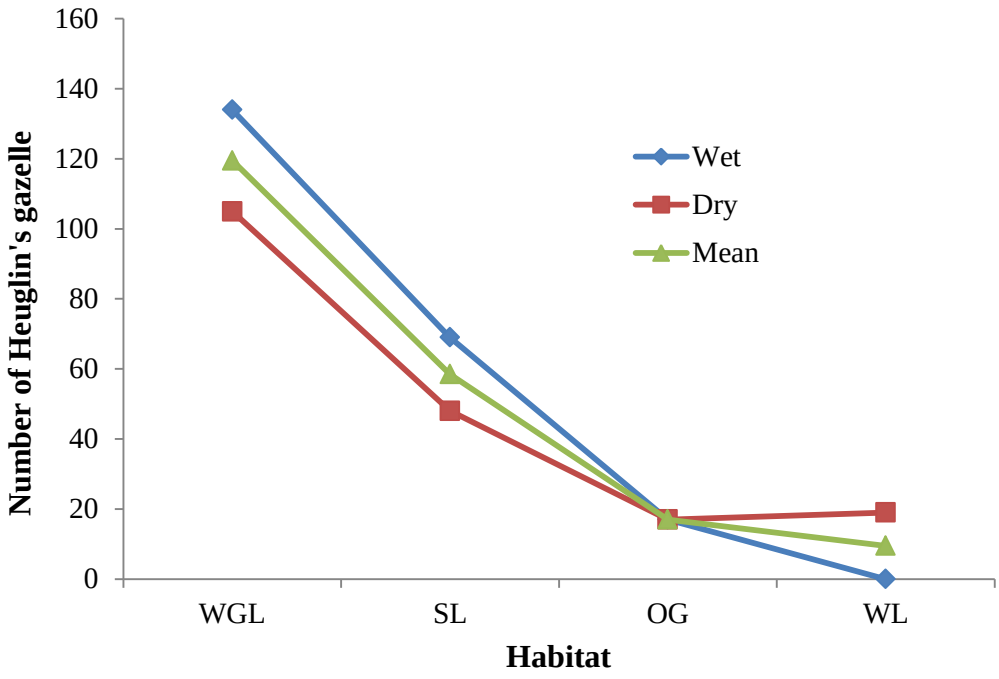

Figure 5: Distribution of Heuglin's gazelle across habitats and seasons

5. DISCUSSIONS

5.1. Population Size and Trends of Heuglin's gazelle

The present study revealed that the population status of Heuglin's gazelle in KSNP is decreasing compared to its population in the past. As a result of natural predators and anthropogenic factors (hunting, habitat degradation and intensive fire) in the area, the current population estimates was lower than the estimation carried out in 2016 by KSNP (31.2% decline). According to East (1999), the protection of the species was ineffective as the habitat preferred by the species was intensively utilized by herdsman that cut down the shed trees to feed their cattle. It is unsurprising that the population size was lower during the dry season compared to the wet season, which accords well with the findings of Fanuel Kebede (2013) on ungulates in Alledeghi Wildlife Reserve. Workneh Alemu *et al*. (2016) also reported that, Grant gazelle population abundance vary between seasons in Nechisar National Park; higher during wet season than during the dry season. However, there no significant variation in population of the species between seasons.

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 the species. Survival and movements of wild ungulates are highly responsive to rainfall fluctuations, leading to population fluctuations between seasons. Furthermore, the variation in population estimation during the wet and dry seasons could be a result of changes in the abundance of resources required in different habitat types. The possible reason, in wet season Heuglin's gazelle gets enough water and food in the study site whereas, in dry season some of the species move locally away from the study area to search water and palatable food since water pools and grasses in the park becomes dry up and productivity drops.

The other possible reason for the less sighting of Heuglin's gazelle in dry season might be due the hotness of the area that made them less active which reduce the probability of observation during the census time, thereby affecting the population estimates. According to Kupika *et al*. (2014), a combination of ecological factors including fire and livestock grazing also act as factors for the population of the species to be lower in the study area

during the dry season. Henley *et al*. (2007), during the dry season gazelle move to the surrounding area to get enough food from di-cotyledons that grow outside their original ranges. The wet season is the most favorable time for gazelle population because; the plain of the study site also possess high fodder quality and moderate atmospheric temperature for Heuglin's gazelles to forage.

5.2. Population density of Heuglin's gazelle

Currently, the distribution of Heuglin's gazelle in KSNP is within an area of 91.8 Km^2 which is around 4.2% of the total area of the park. This distribution extends from Miltsay to Helegen site of the current study area. In current study area the result of the study shows that, the overall density of Heuglin's gazelle is 2.23 animals/Km^2. However, previous study by Hashim (1998) indicated that, the density of Heuglin's gazelle in DNP was 1 animal/Km^2. During the current study period the density of the species was higher in block three (4.7 individuals/Km^2), than the other census blocks. And the least density was recorded in block ten (0.8 individuals/Km^2). This variation might be due to the presence and absence of quality food and water across a block. Enough shelter is also another possible reason for population of the species was higher in B3 than the other and vice versa.

5.3. Herd Size of Heuglin's gazelle

Most ungulates form large herd size during the wet season and small herd size during the dry season (Durant *et al*., 1986). This was also observed from the results of the present study. Large herd size of Heuglin's gazelle was aggregated during the wet season, while they disperse during the dry season. The maximum herd size and most frequently observed herd size were greater in wet season than the dry season. However, there was no significant variation in herd size between wet and dry seasons. The food availability drops in the plains of the study site of wooded grassland during the dry season. Therefore, the species disperse into smaller family units and at the same time number of herds increase and herd size decreased in wooded grassland habitat (Table 3). This might help the populations to compensate food shortage during the dry season. The herd size is influenced by a variety of environmental factors, in addition to the special features of social organizations of the species concerned (Mattiello *et al*., 2004).

5.4. Age and Sex Composition of Heuglin's gazelle

Adult individuals were the first largest proportion in terms of their number and sub adults were the second largest proportion. Juvenile of unknown sexes showed the least proportion in terms of their numbers counted in both seasons. In the present study, age structure of the total population was dominated by more adults. However, the number of sub adults and young individuals counted during both seasons varies slightly. Age and Sex composition may be influenced by different environmental factors. Even though, there was no significantly difference regarding to age between seasons. In present study unequal sex ratio was occurred biasing in females with a high proportion in population (Table 5). But, there was no significantly difference regarding to sex between seasons. Estes (1974) explains that, the possible reasons for unequal sex ratio may be due to an increased predation pressure on males, because of boldness and the emigration of subordinate males to other less favorable habitats. Competition of males could also force the bachelor males to migrate to less suitable habitats that are poor in food quality, and exposing them to predators and hunters (Workneh Alemu *et al*., 2016). This reason might be also the cause for an uneven sex ratio of Heuglin's gazelle in KSNP. According to the result of this study, a large number of breeding females indicates that the species has high potential to increase its population, if better conservation measures are well implemented. Surprisingly, equal number of juvenile unknown sexes observed during the present study period in both wet and dry seasons. Comparatively lower proportion of the juvenile individuals was encountered during the present study. Juvenile gazelles are usually hidden inside dense and tall grasses and shrubs of the plains during the wet season and in the surrounding bushes during the dry season, until they are strong enough to run fast and escape from predators (Workneh Alemu *et al*., 2016). This might have influenced lower proportion of the young ones in the study area. In other way predators including Jackals and caracal might be adept at taking the newly born Heuglin's gazelle in current study site.

5.5. Habitat preference of Heuglin's gazelle

Heuglin's gazelle is distributed into four habitat types and varied numbers were counted per habitat type. Larger numbers of the species was recorded in wooded grassland in both wet and dry seasons. There was significantly difference in habitat preference of the species regardless seasons. The large number of any species can also be an indication of the

quality of the habitat where they live (Mattiello *et al*., 2004). Habitat use of animals reflects strategies that enhance their survivorship and successful reproduction (Grignolio *et al*., 2003). The result of this study was parallel with that of Berihun and Solomon (2005), who reported the presence of Soemmerring's gazelle only in the wooded grassland habitat both in dry and wet seasons. This study also supports the finding of Scholte and Hashim (2013), which observed that, the numbers of gazelles were varied per habitat. According to the result of this study, in KSNP Heuglin's gazelle more prefer wooded grassland habitat type and it is the dominant habitat types in the study area with an area of 40.75 Km^2 (Appendix 6). Thus, the stronger preference of Heuglin's gazelle for wooded grassland habitat might be due to quality and better availability of resources in this habitat type in both seasons. Also this study is in line with that of Cooke *et al*., (2016), the species preferred grassland habitat with vegetation cover for shelter. Similarly, the habitat utilization is often determined by the availability of cover and food rich plant growth (Dankwa and Euler, 2002). During the wet season no one Heuglin's gazelle recorded in woodland habitat type. In other way in current study area, woodland habitat is avoided by the target species. This influence may be due to that of their mode of communication. Abaigar *et al.* (2013), gazelles use visible rump patch patterns for communication in different situations and this is no easier in dense woodland habitat types. Woodland habitat might be exposing them for predators, because they never easily detect their predator from a distance.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The global populations of Heuglin's gazelles had distributed only in Africa, with a reduced population. The KSNP harbors a viable population of the target species in Ethiopia. However, the present population estimate in the park revealed that its population has declined by 31.2% within the last four years. Relatively, more individuals observed during the wet season than the dry season. More females as compared to males observed in the KSNP and it indicate that, the species have a potential to increase in their number if better conservation measures are implemented. Except in open grassland and woodland habitat types the density of the species was higher in wet season than the dry season. However, in open grassland the species has equal density during wet and dry seasons. Regarding to the census blocks, the largest and the lowest density of Heuglin's gazelle was observed in B3 and block B10 respectively. Heuglin's gazelle more prefer wooded grassland than all other habitat types in both seasons and avoided woodland habitat type during the dry season. The sex ratio of male to female is greater in wet season biasing to females. Generally, in order to maintain the Heuglin's gazelle population urgent conservation strategy is required that can benefit both the species and the communities adjoining the park.

6.2. Recommendations

Based on the results of the present study, the following points are recommended for effective conservation of the Heuglin's gazelle in the Kafta Sheraro National Park.

- There are only less data on population and ecology of Heuglin's gazelle in Kafta Sheraro National Park. Constant and long-term investigations on the ecology and population assessment of Heuglin's gazelle are essential to identify ecological problems and to maintain their habitats sustainably.
- The status of the Heuglin's gazelle in Ethiopia was characterized by a rapid and inexorable decline due to natural predators and adverse human activities. So, it is too important to take a better and serious conservation measures to mitigate the problems.

- There are no data on feeding ecology of Heuglin's gazelle in Kafta Sheraro National Park. So, investigating the feeding ecology of Heuglin's gazelle is essential to identify ecological problems and to maintain their habitats sustainably.
- The Kafta Sheraro National Park 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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8. APPENDICES

Appendix 1: Basic information of Heuglin's gazelle survey data sheet

Block: _____ Date: _____ Month: _____ Year: _____ Season: _____Count Term: _____ Start Location: East /X/_____ Northing /Y/_____Finish (end) Location: Easting /X/_____ Northing /Y/_____Start Time: 07:00 am morning End time: 10:00 am morning. Start Time: 03:00 pm afternoon end Time: 06:00 pm afternoon. Total Time: _____

Heard	Group Size	Age/Sex Structure					Habitat Categories				GPS reading			Explanation
		AM	AF	SM	SF	JU	WGL	SL	OGL	WL	Easting /X/	Northing /Y/	Altitude /Z/	

NOTE: For Age/Sex Structure: AM= Adult Male, AF= Adult Female, SAM= Sub-Adult Male, SAF= Sub-Adult Female, JU= Juvenile Unknown Sex. For habitat: WGL= Wooded grassland, SL= shrub land, OGL = Open Grassland, WL= woodland.

Appendix 2: Pictures of Heuglin's gazelle captured during a period of field data collection

Appendix 3: Partial view of Heuglin's gazelles during a period of data collection

Appendix 4: Members of field data collectors

Appendix 5: Wild animals observed during the study period

Common Name	Scientific Name
African Elephant	*Loxodonta Africana*
Greater Kudu	*Tragelaphus strepsiceros*
Roan Antelope	*Hippotrags equins*
Water Buck	*Kobus ellipsiprymnus*
Heuglin's gazelle	*Eudorcas tilonura*
Warthog	*Phacochoerus africanus*
Anubis Baboon	*Papio Anubis*
Abyssinian genet	*Genetta abyssinica*
Serval Cat	*Felis serval*
African Wildcat	*Felis libyca*
Caracal	*Felis caracal*
Black Bucked Jackal	*Canis mesomelas*
Striped Hyena	*Hyaena hyaena*
Spotted Hyena	*Crocuta crocuta*
East African ground squirrel	*Xerus erythropus*

Appendix 6: GIS analysis of the sample study area coverage (ha) in the four habitat types

Land Cover Classification	Count Pixel	One Pixel Size	Area of Pixels	Area in hectare	Area in Km^2	Area in Percentage
Woodland	25657	900	23091300	2309.13	23.1	25.16
Shrub land	25566	900	23009400	2300.94	23.00	25.05
W. Grassland	45282	900	40753800	4075.38	40.75	44.4
O. Grassland	5495	900	4945500	494.55	4.95	5.39
Total Area	102,000	900	91,800,000	9,180	91.8	100

AUTHOR'S BIBLIOGRAPHY

The author of this thesis was born in August 1992 in Kerreyu Harzuna Kebele of Tena District East Arsi Zone of Oromia Regional State, Ethiopia. He attended his primary education (1-8) at Elele Walena Primary school from 2001 to 2008 and his secondary and Preparatory education (9-12) at Didea Robe comprehensive Secondary School from 2009 to 2010 and Preparatory School from 2011 to 2012. Then, he joined Hawassa University, Wondo Genet Collage of Forestry and Natural Resource in October 2013 in Ecotourism and Cultural Heritage Management, and he was graduated in June 27, 2015. Then, he works as Tourism and community Service Expert for Kafta Sheraro National Park under Ethiopian Wildlife Conservation Authority Since the end of December 2015. After that, the author joined the School of Graduate Students of Bahir Dar University, Collage of Agriculture and Environmental Science Regular Program in 2018 to study his Master of Science degree in Wildlife Conservation and Ecotourism Management.