Population Estimate, Diurnal Time Budget and Conservation Challenges of Grevy's zebra (*Equus grevyi,* Oustalet 1882) in Hallaydeghe Asebot Proposed National Park, Ethiopia

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This is to certify that the dissertation prepared by Tolera Abirham Negesa, entitled: Population estimate, Diurnal activity time budget and Conservation Challenges of Grevy's zebra (*Equus grevyi,* Oustalet 1882) in Hallaydeghe Asebot Proposed National Park, Ethiopia and submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Biology (Ecological and Systematic Zoology Stream) conforms with the regulation of the University and meets the accepted standard with respect to novelty and quality.

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ABSTRACT

Population estimate, Diurnal Time Budget and Conservation Challenges of Grevy's zebra (*Equus grevyi,* Oustalet 1882) in Hallaydeghe Asebot Proposed National Park

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Grevy's zebra (*Equus grevyi*) is endangerd species and one of the world's most threatened wild equids. The current study investigated the population, seasonal home range, diurnal activity time budget and conservation challenges of Grevy's zebra in Hallaydeghe Asebot Proposed National Park (HAPNP). Data on population estimate, structure and home ranges were gathered during wet (July to September) and dry (January to March) seasons for two years (2021 and 2021) using line transects and ground tracking following minimum convex polygon method. Silent detection methods were applied to minimize disturbance. Diurnal activity data were collected through scan sampling method. Data related to land cover change were collected from Landsat data of 1990, 2006 and 2021. In addition, ground control points and information about the area were gathered from elders and key informants. Data related to conservation challenges, community attitude towards conservation practices were collected using household survey, key informant interview, field observation; focus group discussion and secondary document review. Population data were analyzed using distance software and seasonal home range data were analysed using QGIS 3.44. Diurnal activity time budget data were analysed through SPSS version 26 and across several groups, the mean percentage of time spent on behaviour was compared using analysis of variance (ANOVA). Land use land cover data were analysed using ArcGIS 10.8 and QGIS 3.26.3. Conservation challenge and community attitude data were analysed using SPSS Version 26. A total of 89 and 61 individuals of Grevy's zebra were counted during the wet and dry seasons, respectively. The seasonal home range of Grevy's zebra in HAPNP was 477 km^2 (n=89) during the wet and 711 km^2 (n=61) during the dry season. Grazing (31.26%) was the highest activity followed by resting (30.24%) during the wet season. Similarly, grazing (37.13%) was the

highest activity followed by moving (27.25%) during the dry season. Land use land cover findings revealed 12.21% of grassland cover lost from 1990 to 2021. On the other hand, bushland increased by 26.45% during the same year. The top conservation challenges of Grevy's zebra were habitat degradation; un-integrated development and poor law enforcement. The study result revealed positive attitude and participation of local community depending on the benefit derived from the protected area. More study is required on the possible ways of making the Blen hot spring and the wetlands around it part of the protected area. In addition, action is required to address identified conservation issues and restore grasslands in order to maintain the Grevy's zebra population in HAPNP by developing an adaptive strategy that takes community inclusivity in benefit sharing.

Keywords: Attitude, Conservation challenges, Diurnal activity, Grevy's zebra, land cover change, seasonal home range.

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List of Acronyms

CITES	Convention on International Trade in Endangered Species
DN	Digital Number
EBI	Ethiopian Biodiversity Institute
EWCA	Ethiopian Wildlife Conservation Authority
GLMM	Generalized Linear Mixed Model
GTP	Ground Training Point
HAPNP	Hallaydeghe AsebotProposed National Park
IUCN	International Union for Conservation of Nature and natural resources
KWS	Kenya Wildlife Society
LCC	Land Cover Change
LUCID	Land Use Change Impacts and Dynamics
LULCC	Land Use Land Cover Change
MEFCC	Ministry of Environment, Forest and Climate Change
NDVI	Normalized Difference Vegetation Index
OUP	Oxford University Press
PAs	Protected Areas
TOA	Top of Atmosphere

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1. INTRODUCTION

1.1. Background of the Study

Grevy's zebra (*Equus grevyi*) belong to the family *Equidae* (Moehlman *et al*., 2013). Equidae originated in North America around 10–20 million years ago and radiated across the steppes of Eurasia to Africa with multiple extinction and recolonization events facilitated by movement through the Bering Strait (Kelekna, 2009). Some of the species of zebras were extinct while others survived. Three of the species (*Equus burchelli burchelli*, *E. b. hunippus* and *E. przewalskii*) are extinct (IUCN, 1990). According to Estes (1997), there are three species of zebras that are still in existence: the Mountain zebra (*E. zebra*), Grevy's zebra (*E. grevyi*), and Plains zebra (*E. quagga*).

Grevy's zebra is an endangered species and have declined over the last century, but accelerated during the last decades (IUCN, 2010). The population of Grevy's zebra has continued to drop across the majority of their territory from an estimated 5,800 in the late 1980s to a recent population of roughly 2,680 individuals; there has been morethan 50% decline in population during the previous three decades (Rubenstein *et al*., 2017). The population in Ethiopia declined severely with large subpopulation of Grevy's zebra has <1,000 mature individuals (Rubenstein *et al*., 2017). Habitat deterioration, poaching, competition for key resources from pastoral people and their cattle, invasion by alien species and drought are some of the causes (IUCN, 2002; Brook *et al*., 2008; Dunn *et al*., 2009).

Understanding and comparing activity patterns help to recognize behavioural trade-offs and potential temporal niches (Peral *et al*., 2022), while also aiding in understanding behavioural ecology and conservation (Tian *et al*., 2020). Grevy's zebras show variability in their daily activity patterns that are driven by environmental variation in their habitats (Grier and Burk, 1992). The diurnal activity of Grevy's zebra varies based on the season, age, sex and time of day. Temperature, climate, biological cycle, time of day, interaction, and predation risk may all have an impact on animal's activity pattern in the wild (Kamler *et al*., 2007). Studies showed that the species spend 60-80% of their time searching for food (Nowak, 1991).

Protected Areas (PAs) are shaped by the land use, species, and ecological processes in the surrounding landscape and should not be viewed in isolation (Defries *et al*., 2007). Over the past 40 years, there has been a global decrease in biodiversity, which has been mostly ascribed to habitat fragmentation and land development (Butchart *et al*., 2010). Tropical forests and their animals are threatened by rapid forest conversion and degradation. National Parks and protected areas are often used to preserve natural heritage and biodiversity. However, these areas are still subject to anthropogenic disturbances like road, recreation, and resource extraction (Barrueto *et al*., 2014). The external influences can decrease the effective size of a PA, limiting their ability to protect biodiversity and ecosystem functions (Jones *et al*., 2009). Specifically, there is a link between increases in anthropogenic activities around PAs and species extinction and illegal extraction within PAs and changes in agricultural land use and urbanization may exacerbate these impacts on PAs (Wittemyer *et al*., 2008). Loss of functionality of PAs from surrounding land-use modification is a particularly daunting problem in developing nations. Furthermore, because their livelihoods are frequently more directly dependent on the land, people who live close to PAs in developing countries depend more on the resources in and surrounding PAs (Hartter and Southworth, 2009). Natural disturbances, ecological processes, and human activities cause the landscapes of protected areas like National Parks and watersheds to change over time (Lin, 2018). Protecting areas from these changes requires a suitable political environment, often leading to their conversion to other uses (Chapman and Lambert, 2000). Therefore, to ensure the effectiveness of PAs in the developing world, it is essential to understand modification influenced by the surrounding landscape. Protected areas in the majority of Eastern African countries frequently encountered land use conversion due to growing population of humans and animals (Maitima *et al*., 2009; Pomeroy *et al*., 2013). Concerns about land use and cover change (LULCC) primarily center on the interaction between people and their surroundings (McCusker and Weiner, 2003).

Emperor Zerea Yacob (1434–1468) is credited with starting the long tradition of conservation in Ethiopia (Derera Ketema, 2017). Since then, protected areas have come to be understood as crucial to the conservation of species. Ethiopia is currently one of the world's most promising countries in establishing protected areas to protect the extensive

variety of indigenous species that make up the country's plants and animals (Melaku Tefera, 2011). Until recently, 138 protected areas have been established. Of these, 39 controlled hunting areas, 57 forest priority areas, 24 national parks, 3 open hunting areas, 6 sanctuaries, and 6 wildlife reserves are officially recognized and reported to the international communities (UNEP-WCMC, 2023). However, the majority of Ethiopia's protected areas confront multiple challenges due to a protracted drought, border conflicts, and growing populations. Local access to grazing areas is a persistent and expanding problem especially in pastoral rural populations (Shibru Tedla, 1995; Zelealem Tefera and Leader-Williams, 2005).

The public's interpretation, acceptance, and the effectiveness of conservation measures depend on studies on community attitudes toward conservation (Barlow and Jung, 2012). The human attitude includes thoughts and sentiments that influence how people will act when there is wildlife nearby (Lyamuya *et al*., 2014). Thus, it's essential to comprehend locals' attitudes toward conservation in order to enhance interactions between people and protected places (Mir *et al*., 2015; Ciocănea *et al*., 2016) and directing the future of wildlife conservation (Barua *et al*., 2013; Lyamuya *et al*., 2014). Identifying these views can help in selecting the best technique for effectively involving local communities in protected area conservation. Perceptions and attitudes are important because the bulk of risks to biodiversity are caused by local communities' deforestation, hunting, and agricultural practices, which also result in a significant loss in wildlife populations and natural ecosystems (Bitanyi *et al*., 2012; Mmassy and Røskaft, 2013).

The design of wild equid conservation strategies based on facts and research from science is essential (Moehlman, 2002). However, there is insufficient up-to-date information on the current population status, diurnal activity time budget, conservation challenges, and trends of land cover change and community attitude towards wildlife conservation practices in HAPNP to enable improved conservation of the species. Therefore, the present investigation aimed to ascertain the aformentioned gaps observed in conservation of Grevy’s zebra in HAPNP for their effective conservation and management in natural environments.

1.2.Statement of the Problem

Most recent scientific information on population estimate of wild animal is necessary to comprehend species ecology and practical management strategies for the conservation of biodiversity (Ito *et al*., 2013). Fanuel Kebede *et al*. (2012) described as there were to the minimum 143 Grevy's zebra in Hallaydeghe plain. To establish a sustainable conservation and long-term monitoring of Grevy's zebra, it is essential to comprehend the distribution, abundance, and population status of these species during different periods. Therefore, the objective of the current study was to determine the population size of Grevy's zebra in HAPNP.

Grevy's zebra's range has considerably decreased. Historically, the species range included substantial portions of south-western Somalia, northern Kenya, substantial portions of Ethiopia, northern Djibouti, and southern Eritrea. However, Grevy's zebras at present live in isolated tiny populations in Ethiopia and Kenya (Low, 2009). So far there was no study conducted regarding the seasonal home range of Grevy's zebra in HAPNP. Therefore, the current study was undertaken to examine the seasonal home range of the species during the wet and dry seasons.

Predation, rivalry for water and food supplies with cattle and pastoralists, habitat loss and degradation, and poaching are considered as the conservation challenges for these animals. Additionally, some pastoral cultures employ Grevy's zebra as a source of medicine, promoting hunting (Rowen and Ginsberg, 1992). Numerous IUCN red lists of threatened species, including elephants, Grevy's zebras, and wild ass, are protected in eastern Ethiopia's protected areas. Nevertheless, there are several threatening causes that these protected areas and their wildlife resources are currently facing. Invasive species, heavy grazing, poaching and land degradation are prevalent issues (Young, 2012). Additionally, there is a dearth of evidence regarding the present threats to HAPNP biodiversity. When it comes to addressing the issues of Grevy's zebra conservation and improving the species' survival in protected areas, the lack of such information is having a significant impact on the prioritization of conservation strategies and mitigation initiatives. Therefore, the current study focuses on the indentification and prioritization of Grevy's zebra conservation challenges in HAPNP.

Quantifying the fundamental activity that every species exhibits at a specific time and location during the different seasons is one of the most helpful ways to describe this interaction. However, there was no study conducted yet focusing on diurnal activity time budget of Grevy's zebra in HAPNP. Therefore, the study was conducted to fill the gap shown in this area of study.

Information on land-use and land-cover changes and their causes is crucial for forming the policies and programmes needed for local and national development planning as well as for estimating how these changes will affect the preservation of natural resources and their sustainable management (Palmer *et al*., 2005). But, there was no information recorded regarding land cover changes from HAPNP. Therefore, analyzing land cover change of HAPNP was the objective of this research in order to provide guidance for a more thorough management strategy for zebras in study area.

There is a growing understanding that local communities must be involved in the management of wildlife resources. In order to conserve and obtain additional space for nature conservation, conservation authorities are increasingly becoming conscious of the necessity to involve local populations in resource management. Given the frequent clashes between conservationists and locals, local attitudes toward wildlife and protected areas require improved understanding on the part of conservationists. Mekoya Mamo *et al*. (2018) studied challenges, attitudes, and perceptions of local communities in this area. There is still a great deal to learn about the responsible elements (socio-economic factors, costs, rewards, and conservation awareness) that affect people's attitude as well as participation in conservation. There is also an inadequate amount of knowledge regarding the linkage of conservation attitudes with practical conservation activity. Therefore, the purpose of this study was to address this gap by examining different factors. The following hypotheses were tested:

H1: Local communities who have benefitted from PA will have a positive attitude toward the PA and a positive relationship with PA employees. On the other hand, those who paid costs will have unfavourable attitudes toward the Park and conservation practices.

H2: Sharing benefits from PA with nearby communities can inspire them to engage in conservation efforts and adopt ethical conservation practices. Positive conservation

attitudes will therefore affect local participation in PA conservation and adherence to PA laws.

1.3.Objective of the Study

1.3.1. General objective

The general objective of this study was to assess population, diurnal activity time budget and conservation challenges of Grevy's zebra in Hallaydeghe Asebot Proposed National Park (HAPNP)

1.3.2. Specific objectives

The specific objectives of the study were to

- estimate the current population of Grevy's zebra
- determine seasonal home range of Grevy's zebra
- analysis the diurnal activity time budget of Grevy's zebra
- evaluate land use land cover change in HAPNP during the last 30 years (1990-2021)
- identify conservation challenges of Grevy's zebra in the study area
- assess local community attitude towards conservation practices in HAPNP

1.4.Basic Research Questions

- What is the current population status of Grevy's zebra?
- How Grevy's zebra are distributed in the study area?
- What is the home range of Grevy's zebra during different season of the year?
- What are the major diurnal activities of Grevy's zebra?
- What are the major conservation challenges of Grevy's zebra?
- What influences local people attitudes towards the PA and its staff?
- What determine the participation of local communities in PA conservation?

1.5. Significance of the Study

Grevy's zebra conservation is mostly focused on a thorough understanding of the population size, activity time budget, local community attitude and their participation towards conservation of the species, and conservation threats of Grevy's zebra. *Grevy's zebra* is obviously in a great danger of geographic area reduction which is clear from its restricted range than their former range. If proper action is not taken, Ethiopia may face the threat of losing this endangered species. This study provided updated information regarding the population size of Grevy's zebra and added value to the previous study conducted. Furthermore, the study provided more precise information on diurnal activity time budget of Grevy's zebra and land use land cover change in the study area that is a key for conservation managers to guide their conservation effort. Moreover, this study also provided important information about conservation challenges, community attitude and their participation towards conservation of Grevy's zebra in the study area.

The result of this study provided important information for the Ethiopian Wildlife Conservation Authority (EWCA) to focus on the conservation effort.

Conservation challenges, community participation in conservation and land use land cover change from HAPNP require immediate attention for sustainable conservation of Grevy's zebra in study area. Indeed, the result of this study would be used as focal subject for the initiation of conservation and revisiting of management plans of Grevy's zebra and to portray a road map for continued demanding efforts in the future conservation of species in the southeastern Ethiopia. The goal of this study was to improve the conservation of Grevy's zebra in the southeastern parts of Ethiopia, particularly in the proposed Park of Hallaydeghe Asebot.

1.6. Delimitation of the Study

Although there were a wide range of areas on which research can be conducted, the researcher planned to limit the scope of this study to determine the current population status, diurnal activity time budget and LULCC analysis, conservation challenges of Grevy's zebra and local community attitude and participation in wildlife conservation in Hallaydeghe Asebot Proposed National Park.

2. LITERATURE REVIEW

2.1. Physical description of Grevy's zebra

Grevy's zebra is considered as the biggest of untamed equines. Its head is very long and narrow, while its neck is short and thick. It has large ears and rounded with black markings. Grevy's zebra has small chestnuts (roughened skin patches) on the inner forelegs and the hooves are small, broad, oval and black. Its tail is cross-banded in the middle (Ransom and Kaczensky, 2016) (appendix 1)

Males weigh up to 451 kg and females 350 kg (Churcher, 1993). Both male and female Grevy's zebra have equal body length. Similarly both sexes have equal tail length which is about 55 cm (Ransom and Kaczensky, 2016).

2.2. *Equus* Taxonomy

The only surviving genus in the *Equidae* family, *Equus* includes both living and extinct animals. In the genus *Equus,* there are presently nine species that exist: the African taxa *Equus africanus* (African wild ass), *E. grevyi* (Grevy's zebra), *E. quagga* (Plains zebra), *E. hartmannae* (Hartmann's mountain zebra) and *E. zebra* (Cape mountain zebra); and the Asian taxa *E. ferus* (Wild horse), *E. hemionus* (Asiatic wild ass, dschiggetai), *E. kiang* (Kiang) and *E. khur* (Indian wild Ass, khur) (Schulz and Kaiser, 2012).

2.2.1. Early history and distribution patterns of Equus

According to Lindsay *et al*. (1980), the genus *Equus* was first represented in the fossil record by Equus *simplicidens* (Cope), occurring for the first time in the Hagerman fauna, dated at about 3.3 million years (Kurtén, 1980). The same species was discovered in excavations in Washington's Ringold Formation, which were dated even later at 3.4–3.8 million years (Lindsay *et al*., 1984). A fossil horse that has been found and dated to roughly 4.2 million years ago has been described as an early *Equus* or the direct ancestor of *Equus* (an advanced *Pliohippus*) in the Concha Fauna of New Mexico. However, morphological features such as body size and limb proportion diverged before the earliest events of migration to Eurasia, which are thought to have happened 2.5–3.0 million years ago (Lindsay *et al*., 1980; Azzaroli and Napoleone, 1982).

It was in Africa that they were first discovered at a location in the Omo beds (Ethiopia) approximately 2.0 million years ago (Hooijer, 1976; Eisenmann, 1976). *Equus quagga and Equus grevyi*, or a progenitor of this species, were the two distinct species identified at this location (Eisenmann, 1985).

Grevy's zebra (*E. grevyi*) historically ranged in its distribution from east of the Rift Valley in Kenya to western Somalia, and in Ethiopia from the Alledeghi Plain through the Awash Valley, Ogaden, and northeast of Lake Turkana in Ethiopia to north of Mt. Kenya and southeast down the Tana River in Kenya (Bauer *et al*., 1994).

Grevy's zebra occured well outside of their historical range according to an increasing amount of fossil evidence (Tryon *et al*., 2010). This suggests that Grevy's zebra populations may have already been declining before any historical observations of the species were made. This means that, in addition to the effects of human activity over the past few decades, mechanisms acting on temporal scales outside the scope of human observation may also have a role in the decline of Grevy's zebras, as evidenced by the fossil history of a number of other mammal species (Faith, 2012).

With multiple records in south-central and southwestern Kenya, fossil evidence suggests that Grevy's zebra existed during the middle/late Pleistocene, to the South and West of its historical range. In the fossil record, they never coexisted with domestic species. The primary reason for this segregation is that the majority of Grevy's zebra are Pleistocene in origin, while domestic species are exclusively Holocene (Faith *et al*., 2013).

2.3. Equid Population

2.3.1. Global population of equids

The number of extant wild equids worldwide is as follows: there are 500,000 Plains zebra (King and Moehlman, 2016), 33,265 Mountain zebra (Gosling *et al*., 2019), 2,680 Grevy's zebra (Rubenstein *et al*., 2017), 60,000–70,000 Kiang zebra (Shah *et al*., 2015), 64,000 Asiatic wild ass (Kaczensky *et al*., 2020), 200 African wild ass (Moehlman *et al*., 2015), and 1200 Przewalski's horse (Rademacher *et al*., 2020).

2.3.2. Grevy's zebra population

Of all the African mammals, the grevy's zebra has had one of the greatest declines in range and population size (KWS, 2012). Once distributed through some of the sub-Saharan Africa, they have now been exterminated from most of their range. They historically used to be existed in Djibouti, Eritrea, Somalia, possibly Sudan and currently found only in Ethiopia and Kenya (KWS, 2007; Moehlman *et al*., 2016) (Fig.1).

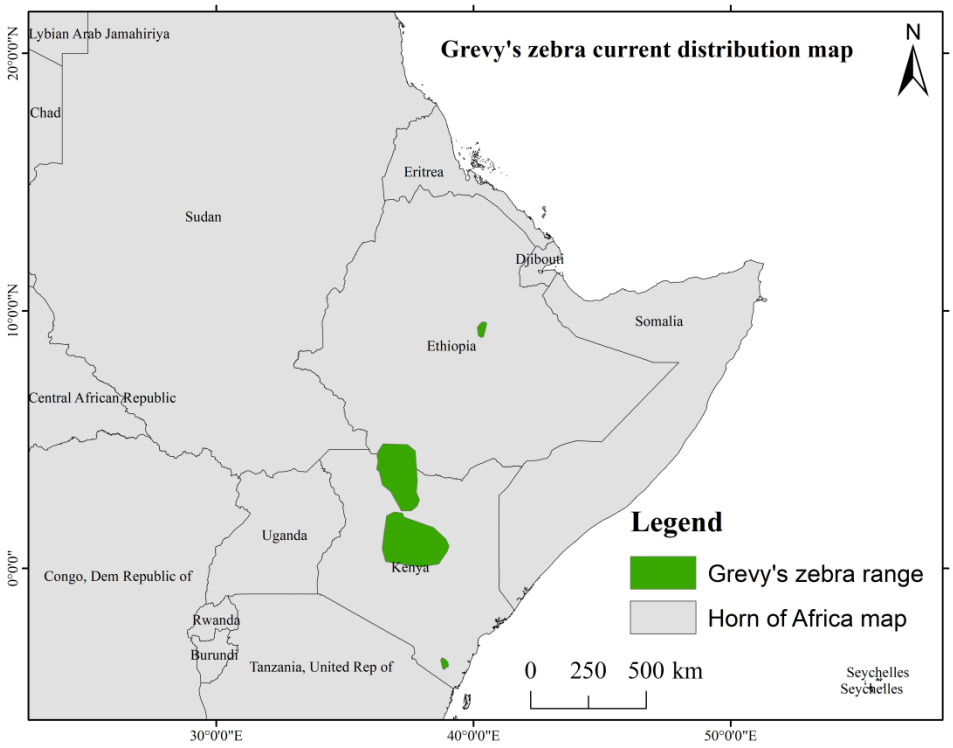

Figure 1. Map shows Grevy's zebra current distribution

Grevy's zebra populations have significantly decreased (Nelson, 2003). Towards the end of the 1970s, the global population of Grevy's zebra was estimated to be approximately 15,000 animals (Grundblatt *et al*., 1996); the recent estimate was 3,318 animals (National Grevy's zebra stakeholders workshop, 2012), that include 491 individuals in captivity in Europe, demonstrating 78% decline in global numbers over the past four decades.

Estimates for Grevy's zebra populations in Ethiopia indicate a minimum of 85% decline throughout the country with an estimated 1,900 animals in 1980 (Klingel, 1980); 577 animals in 1995 (Thouless, 1995 a,b); 110 animals in 2003 (Nelson and Williams, 2003) to 143 animals in 2012, (Fanuel Kebede *et al*., 2012).

Compared to Ethiopia, Kenya has had a slower pace of decline. The 1977 estimate for Grevy's zebra was 13,718 (Dirschl and Wetmore, 1978); in 1988, the estimate was 4,278 (Grunblatt *et al*., 1989); in 2000, the estimate was 2,571 animals (Nelson, 2003); "Guess estimate" numbers of Grevy's zebra in Kenya taken from the 2004 Grevy's zebra workshop (Williams and Low, 2004) ranged between 1,600 and 2,000 animals. In the 2007 National Grevy's Zebra Conservation Strategy Workshop (Mwasi and Mwangi, 2007), these figures were updated by stakeholders with the estimated population ranging between 1,838 and 2,319 animals. A systematic and coordinated aerial census in 2008 yielded 2,407 individuals of Grevy's zebras in Laikipia-Samburu-Isiolo-Marsabit complex.

2.4.Seasonal Home Range of Grevy's zebra

Zebra movement sampling over the course of different seasons of the year assisted for identification of areas which are important throughout years. Williams (2013) reported that non-territorial Grevy's zebras can have home ranges of up to 10,000 km², with bachelors being able to move up to 80 km per day. The distribution of Grevy's zebra covers 437 km^2 during the rainy season and 563 km^2 during the dry season (Fanuel Kebede *et al*., 2012). Letoiye's (2014) reported in Southern Samburu there was no discernible temporal mobility within a year. However, according to Williams (2013), individual dispersal is more noticeable during the dry seasons. Aggregation happens in the dry season as well. Male *E. grevyi* defend areas ranging from 2 to 12 km^2, with the boundaries formed by water courses and other natural features (Kingdon, 1979).

In these areas, conspecific males are tolerated as long as there are no oestrous females present (Kingdon, 1974). High resource availability promotes females to go into oestrus (Williams, 2002).

2.5. Behavioral Ecology of Grevy's zebra

2.5.1. Duirnal activity

For many ungulate species, diurnal time budgets and their variations with respect to season, age, and social status have been thoroughly documented (Zhang, 2000; Colman *et al.,* 2001). Every species' time budget is the consequence of an interplay between internal (biological state, behavioral ontogeny, body mass) and external (group size, daylighting cycle, habitat quality) elements (Owen-Smith, 1998). Animals must optimize their energy intake and modify their behavior in response to differences in the quality and quantity of forage in order to adapt to their surroundings. As a result, the amount of time spent on feeding and sleeping varies on a daily and seasonal basis (Dulphy *et al.,* 1980). Grevy's zebras show variability in their activity patterns, as influenced by environmental fluctuations in their habitat (Stanislaus, 2006). Studies show that they spend 60- 80% of their time searching for food (Nowak,1991). Generally, the activity time budget is assumed to rely upon the resource availability.

2.5.2. Social organization

Studies on the behavior and social structures of *Equus* species have revealed two primary forms of social organization (Stahlbaum and Houpt, 1989). Some of *Equus* species have harem-type social organization, wherein the equines establish enduring, non-territorial family groupings consisting of a stallion and multiple mares along with their young. Other *Equus* species display a territorial form of social structure, where a stallion's domain is temporarily occupied by a number of estrous mares or mares with their foals (Kimura, 2000).

Grevy's zebras prioritize food and water for their females. Based on whether a male creates a harem or territorial group during the reproductive condition (Ginsberg and Rubenstein, 1990). As a result of male territories and an adequate supply of food and water, lactating females form nursing groups, whereas non-lactating females are

exceedingly promiscuous and have very weak association. Bachelor herds do exist, and mixed herds can be formed when they converge with other social groups. Nonetheless, Grevy's zebras have shaky ties, and their gatherings are influenced by environmental factors like drought. Males have enormous territories and only socialize with mares when they reach their zone. The most successful males obtain grassy areas near water, which are very appealing to females, especially breast feeding ones (Williams, 1998). Aggression is minimal, with the exception of territorial males expressing their mating rights. The territories extend up to 12 km^2, the largest among the ungulates (Kingdon, 1979). Other stallions in the vicinity of the residential stallion are tolerated as long as they do not obstruct his mating activities. Local rainfall patterns, which occur largely during the brief and consistent rains of July and August or later in October and November, appear to be driving the peak of territorial and mating activity. Female and male home ranges can typically reach up to 10,000 km^2 (Duncan, 1992).

2.5.3. Habitat

Grevy's zebras inhabit grassland and shrubland areas that are permanently wet and semi-arid (annual rainfall range: 100–650 mm). They are primarily grazers, but during periods of drought, they switch to browsing (Rowen and Ginsberg, 1992). Their spread into more arid parts to the east and north is primarily determined by the absence of free-standing water, whereas competition with other grazers may restrict their distribution into more humid geographical areas. While they associate with giraffe, oryx, eland, plains zebra, impala, and buffalo in their southern range, they occupy a narrow niche between the more water-dependent plains zebra and the more desert-adapted wild ass (Kingdon, 1979; Bauer *et al*., 1994). If there are reliable water sources, they can survive in dry areas (Yalden *et al*., 1986; Nowak, 1999).

2.6. Conservation Threats

Equids were among the most common herbivores on the plains of Africa and Asia thousands of years ago. There are currently very few species left: some are vulnerable others are endangered or critically endangered, and either extinct in the wild (Moehlman, 2002). Hunting, habitat destruction and loss, cattle and pastoralist competition for food and water supplies and predation are all regarded to be key causes to grevy zebra

dramatic decline (IUCN, 2002). Because of a 1976 legal restriction on hunting and trafficking of wildlife trophies, as well as its inclusion in CITES Appendix 1 in 1979, poaching is no longer a severe problem (IUCN, 2002). Nonetheless, in Kenya and Ethiopia, Borana, Somali, and Turkana people kill Grevy's zebras for meat (Williams, 1998; IUCN, 2002). Due to their slowness in fleeing predators and hunters, they are more vulnerable to predators and hunters than other ungulates (Kingdon, 1979). Additionally, certain pastoral cultures use Grevy's zebra as a source of medicine, which stimulates hunting (IUCN, 2002).

The percentage of the Grevy zebra range that is covered by protected areas is less than 0.5%. This implies that the majority of the animals reside in communal areas with no effective protection and human activities to be blamed for habitat deterioration and the subsequent extinction of the Grevy's zebra in these locations (Williams, 1998; Oindo, 2002). Overgrazing, soil compaction, and severe soil erosion all reduce forage production (Bronner, 1990). Improper introduction and dispersal of non-native livestock species exacerbate the problem by altering the composition and communities of the flora (Barker *et al.,* 1990). Soil erosion and vegetation changes result from habitat degradation, with annuals replacing perennials, lowering the food availability (Herlocker,1993). Pastoralists and their cattle, on the other hand, use community water sources, forcing Grevy’s zebras to drink at night, making them more vulnerable to nocturnal predators (O’Brien et al., 2018). This also causes them to make extended journeys in search of water, endangering the foals' survival, which is heavily dependent on the distances travelled by the mother in search of basic resources (Williams, 1998).

Grevy's zebras can withstand drought (IUCN, 2002). This is because they can feed on plant parts that are inedible by other livestock during this critical time.

Nonetheless, in pastoral areas, foal survival is limited because of competition with other animals (Rubeinstein, 1986). Despite their hardness, competition with pastoralists and their cattle forces Grevy's zebra to travel to other high risk areas or abandon their optimal breeding grounds (Olson and Dinerstein, 1998).

2.7. Land Cover Change and its Implication in Conservation

A land use is an indication of the intricate human activities on the land surface. The land's surface is covered in a wide variety of physical and biological features, making it essential to a range of functions (Foley *et al.*, 2005). According to Lambin *et al*. (2003), land cover refers to the characteristics of the land's surface and immediate subsurface, which include soil, biota, topography, surface and groundwater, and human structures. According to Mesfin Anteneh *et al*. (2016), Land Use Land Cover (LULC) is defined as environmental change features that occur on the environment in different places and periods. Global community livelihood and conservation are greatly impacted by changes in land use and land cover (LULC). Approximately, about 40% of the world's once-natural vegetation has been converted to cropland for agriculture (Meiyappan and Jain, 2012). Competing changes in land use and land cover have been expedited by the growing demand for resources to support human existence (Meiyappan *et al*., 2017).

Although the causes of land cover change are different at the local, regional, and global levels (Long *et al*., 2007), they eventually have an effect at all three levels (Cotillon, 2013).

The majority of forest loss happens in developing countries (Sunderlin *et al*., 2005), where substantial changes in vegetation have been brought about by the growth and development of urban and peri-urban areas as well as related socioeconomic activities (Van Asselen and Verburg, 2013). The main factors causing the depletion of natural resources in rural areas are population growth and the high demand for food, charcoal, timber, and poles in urban areas (MacKenzie and Hartter, 2013).

In the future, the impact of changing land cover and land use will pose additional challenges to numerous global protected areas. It jeopardizes protected area efficacy as a tool for conservation (Radeloff et *al*., 2010). This pressure will be particularly intense in areas experiencing intense land-based economic development, rapid socioeconomic change, and rapid population growth (Defries *et al*., 2007). Therefore, rapid and extensive landscape degradation in natural conservation areas and ever-increasing human-induced changes to the areas will impact developing countries' efforts to meet conservation goals (Nagendra and Rocchini, 2008).

Ethiopia's high population growth rate which is more than 2.5% annually is the main cause of the country's rising rates of deforestation and degradation of its forests and woodlands (World Bank, 2021). This increasing population exacerbates the processes of land cover conversion for human settlements, clearing for agriculture, logging, producing charcoal, and gathering firewood (Aberham Megaze *et al.*, 2013). As a result of irregular rainfall and lack, floods, and dwindling yield in agriculture, such LULCC in the nation have in turn caused biodiversity loss, environmental disruption, and socioeconomic crises (Kassa Taka *et al*., 2015).

2.7.1. Protected areas as land use strategies for biodiversity conservation

The establishment of protected areas is one of the most important strategies for achieving conservation (Du *et al*., 2015). Protected areas (PAs) are places where natural ecosystem management and species conservation are practiced. They serve as pillars for the preservation of environmental services and biodiversity conservation for sustainable development. Protected areas cannot be effectively protected without appropriate design and management that considers the requirements of the surrounding community (Ervin *et al.*, 2010).

Protected areas located in densely populated areas and where employment opportunities are low, the reliance of human populations for local resources like food and energy increases and leads to degradation of resources. Protected areas assist in conservation efforts and shield biodiversity from human activity's indiscriminate devastation. When protected areas preserve biodiversity and maintain their ecosystem values, they face undetectable changes (Mathur *et al*., 2015).

The majority of land use change in protected areas begins outside their administrative borders and eventually moves into the core conservation sites (Defries *et al*., 2007). The earth's biodiversity is currently declining quickly and will do so in the future unless immediate action is taken (Ervin *et al*., 2010). Thus, knowledge of land cover changes in different protected areas in the world have been vital to understand the impacts on biodiversity, wildlife and ecosystem services, and is critical to promote conservation efforts in protected areas as well as in policy making (Dejene Sintayehu and Merkebu Kassaw, 2019).

2.7.2. Impact of land use land cover change on biodiversity and ecosystems

Ecosystems are severely harmed by land use and land cover change (LULCC) on a local, regional, and global level. The world's protected areas are rapidly diminishing as a result of global change (Chape *et al.*, 2005). This makes managing and conserving biodiversity and the world's valuable ecosystems more difficult. The impact of land use and cover change is the most significant factor affecting biodiversity conservation in protected areas, despite the fact that there are many other issues as well. These consequences include increased urbanization, fragmentation of natural ecosystems, climate change, and the introduction of invasive species. The increasing pressure on natural resources to satisfy the needs of a growing human population has resulted in environmental deterioration (Ervin *et al*., 2010).

The alteration of natural habitat for various purposes is the most serious threat to biodiversity worldwide. According to estimates of the Earth's terrestrial habitat, 39% of the natural environment has been replaced by farms and residential areas (Dejene Sintayehu and Merkebu Kassaw, 2019). Environmental alterations result from changes in the structure of land cover, which also have an impact on wildlife resources and their habitats (Yirmed Demeke, 2008). This has been shown in a few semi-arid ecosystems in eastern Africa, where land use changes have primarily affected ecosystem services and wildlife conservation in and around protected areas (Dejene Sintayehu and Merkebu Kassaw, 2019). Even though many countries are working to protect and manage the environment, the intensification of inappropriate human land use is isolating protected areas, preventing biological and landscape connectivity, and lowering the quality of habitat in a variety of natural areas (Wilson *et al*., 2014).

There are two types of causes for changes in land use: direct and indirect. Direct causes impact biodiversity in various ecosystems. Direct causes include things like overgrazing, agriculture, logging, and other activities that endanger the conservation of biodiversity within protected areas. However, socioeconomic, demographic, or biophysical variables that result in the loss of forest cover due to human activity and influence are the indirect causes of land use change in conservation or natural areas (Naughton-Treves *et al*., 2005).

2.7.3. Land use land cover change impact on Ethiopian protected areas and their biodiversity

Many studies conducted on LULCC across Ethiopia's protected areas (Aramde Fetene *et al*., 2016; Yenenesh Hailu *et al*., 2018; Temesgen Yadeta *et al*., 2022) evidenced a rapid rate of change in most of the protected areas. Similar to other East African countries, land use change and associated factors pose a growing threat to Ethiopia's protected areas. The main threats to Ethiopia's protected areas and biodiversity are intensive agriculture, commercial farming, overgrazing, conflicting claims from neighbouring communities in various protected areas, deforestation brought on by the country's growing population, and urbanization (Hamare Yohannes *et al*., 2017). In many natural areas of Ethiopia, the conversion of natural habitats to other land use forms is a frequent occurrence (Melakneh Gelet *et al*., 2010). The shift in land use in Ethiopia's protected areas is caused by a variety of factors. Due to socioeconomic and biophysical factors like population growth, agricultural expansion, development activities, climate, and resource accessibility, a significant amount of LULC change has recently been observed (Hailu Shiferaw *et al*., 2019).

2.8. Community Attitude towards Equids and Protected Area Conservation

2.8.1. Community attitude towards equids conservation

Among stakeholder groups, free-roaming equid management is still a very controversial and contentious issue (Scasta *et al*., 2018). According to National Academy of Sciences (2013) report; equids are regarded as highly valued and beloved animals in certain citizen groups. The report further stated that there are organizations that consider free-ranging equids as trespassers, threats to wildlife and agriculture, and disturbances of delicate ecosystems. However, decisions about the management of free roaming equids began to take public opinion into account as early as 1982 (National Research Council, 1982).

Human wildlife conflicts (HWCs) are defined as interactions between humans and wildlife with either real or perceived adverse economic, social or environmental outcomes (Abrahms, 2021). There are several documented types of conflict between humans and wildlife, and these conflicts get worse as human populations increase and natural habitat for wild animals decreases (Butt and Turner, 2012). Lethal techniques including poisoning, trapping, and shooting have historically been used to manage a

significant number of HWCs (Conover and Conover, 2022). However, opposition to culling has grown significantly as a result of worries about human safety in urban environments, the welfare of animals, the environmental effects of toxicants like rodenticides, and the ineffectiveness of lethal control in addressing problems and attaining intended results (Jacoblinnert *et al.,* 2021).

Grevy's zebra is not considered a problem species since it rarely inhabits areas where crop raiding would be a concern and it never attacks people, their livestock, or their property. Although there have not been many documented instances of direct conflict between humans and zebras, Sundaresan *et al*., (2012) noted that locals are still curious about zebras because they have similar needs to livestock in terms of food and water resources. The KWS (2007) claims that local communities that are not aware of species conservation status and not benefitted from conservation consider Grevy's zebras competitors of livestock. Grevy's zebra appears to be seen as a rival for the rangeland resources that livestock keepers with sizable herds of cows and goats, in particular, need for their domestic animals (Sundaresan *et al.,* 2012).

2.8.2. Community attitude towards protected area conservation

Humans inhabit over land which is limited in size and the resource it contains (Guerra *et al*., 2019). There is a gap in supplying available resource to fulfill demands for ever increasing human population from the inhibited land (Schmitz *et al*., 2014). Such scarcity forces humans to expand to the areas of intact natural resource of which wildlife area is the one (Ramachandran *et al*., 2018).

Knowing how the local community and environment interact is essential to developing and implementing effective conservation initiatives. These relationships are particularly crucial for managing protected areas (PAs), as long-standing disagreements over land tenure, local resource use, and conflicts between people and wildlife may make it difficult for communities to accept conservation goals (Whitesell *et al.,* 2002; Balint 2006; Mekbeb Tessema *et al.,* 2010).

2.9. Factors influencing community attitude

According to Kimengsi *et al*. (2019), PAs are "natural resource battlefields" due to the intricate disputes resulting from a variety of interests. The majority of these conflicts originated from the PAs' to invade as well as their contempt for the socioeconomic needs of the local communities and customary rights of the locals (Birner *et al*., 2006). Research on people-protected area relationships typically reveals the involvement of various stakeholders, including local residents, decision-makers, and Park employees. Their varying backgrounds have led to a diversity of perspectives and interests about the protected areas (Røskaft et al., 2007). Studying community attitudes towards protected area includes conservation practices (Ferreira and Freire, 2009), factors that influence (Aung, 2020) and their impacts (Holmern and Røskaft, 2013).

Knowledge of PA goals, actions, rules, and regulations, according to Glikman and Vaske (2012), moderates residents' adherence to the conservation policy. Individuals' engagement in nature and wildlife conservation has been found to be significantly influenced by their knowledge and social norms (Atuo *et al*., 2020).

Understanding conservation views is thought to need an understanding of experience, benefit-sharing and conflict with PAs (Bennett, 2016), given the objective of ensuring conservation policies from people's viewpoints. Similar to this, the most prevalent influential factors in attitudinal studies are socioeconomic characteristics, such as sex, race, level of education, employment, ownership of land, and household income (Bragagnolo *et al*., 2016).

There are many protected areas in Ethiopia, but they are currently in decline and facing a number of difficulties as a result of the country's population growth and settlements, Illegal expansion of agriculture, habitat destruction and damage, grazing, deforestation, deteriorated soil, and inefficiency of natural resources (Getachew Mulualem and Weldemariam Tesfahunegny, 2016).

3. MATERIALS AND METHODS

3.1. Study Site Description

In the Ethiopian Rift Valley, roughly 280 kilometers from Addis Ababa, Hallaydeghe Asebot Proposed National Park lies between latitude 8^{o} 92' and 9^{o} 48' and longitudes 40^{o} 25' and 40^{o} 63'. Formerly, the area was designated as a Wildlife Reserve with a primary objective to preserve, oversee and propagate wildlife within it. The area was deliberately chosen to act as a corridor between Awash National Park and the plains that surround it, allowing unrestricted movement of wildlife to preserve the park's wildlife population (Schloeder and Jacobs 1993). HAPNP has a semi-arid climatic condition. Large alluvial plains dominate the area, and mountains rise along the proposed park's eastern boundary (Kassaye Wami and Arega Mekonnen, 2013). Currently, there are 13 Kebeles belonging to three Woredas, namely Amibara, Meiso and Haruka in that HAPNP is located (Fig.2). The community surrounding this protected area practices pastoral mode of life. The goats, camels and sheep are considered as main sources of income and social rank indication (person.com).

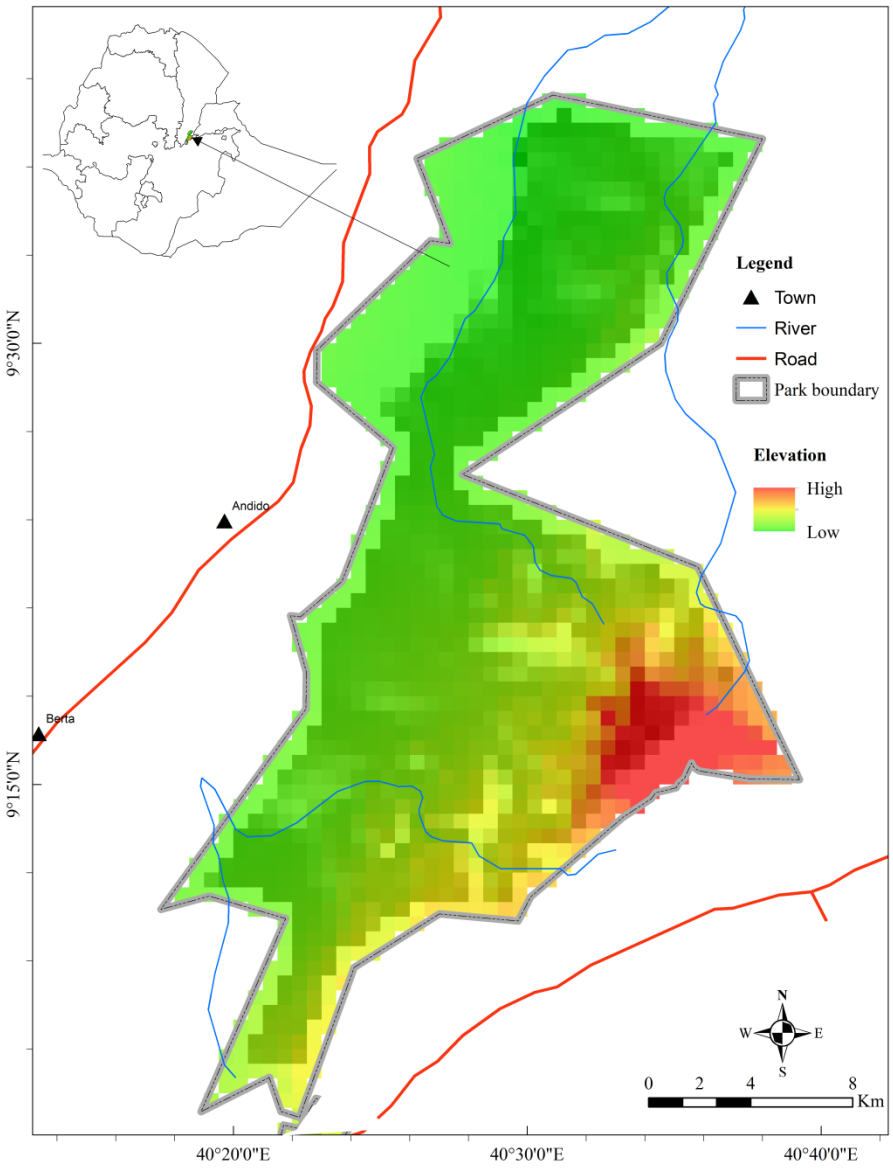

Figure 2. Map of Hallaydeghe Asebot Proposed National Park(HAPNP).

3.1.1. Fauna

Numerous wildlife species can be found in the area, including the Grevy's zebra (*Equus grevyi*), lion (*Panthera leo*), Soemmering's gazelle (*Gazella soemmeringi*), Beisa oryx (*Oryx gazella*), Gerenuk (*Litocranius walleri*), Salt's dikdik (*Madoqua saltiana*), African wolf (*Canis lupaster*), Spotted hyaena (*Crocuta crocuta*), Aardwolf (*Proteles cristatus*) and Ostrich (*Struthio camelus*) (Aschalew Adugna *et al*., 2019).

3.1.2. Flora

Among the predominant plant types found in and near the HAPNP are grassland, bushland, shrubland, wooded grassland, riverine forest and highland forest (Selamnesh Tesfaye, 2015). *Chrysopogon plumulosus* and *Sporobolus iocladus* contribute a relatively substantial percentage of the herbaceous vegetation on the plains (Selamnesh Tesfaye, 2015). The southern, northern, and western edges of the protected area are shrubland, with *Senegalia senegal* being the dominant species. The woody plant species in the plains of this study site include *Prosopis juliflora*, *Senegalia senegal*, *Vachellia tortilis*, *Balanitis aegyptiaca*, *Cadaba* spp. and *Grewia* spp. Some of the highland forests of Mt. Asebot include *Cordia africana*, *Croton macrostachyus*, *Erythrina abyssinica*, *Juniperus procera*, *Olea europaea*, *Podocarpus falcatus* and *Rhus vulgaris* (Almaz Tadesse, 2009; Aschalew Adugna *et al*., 2019).

3.1.3. Climate

Temperature, humidity, and rainfall in the study area vary both temporally and spatially. The area is semi-arid, with 400–700 mm of annual rainfall (Fanuel Kebede, 2008). The area experiences two separate rainy seasons: the heavy rains happen from July to September, while small rains often start in February and stay until the end of April. The mean seasonal temperature is between 25 and 30 degrees Celsius, however in June, the daily maximum temperature may reach 38 degrees, while in December, the lowest daily temperature may fall to 15 degrees (Fanuel Kebede 2008). The separation of the wet and dry seasons was based on the Ethiopian Meteorological season demarcation (Mgalula *et al*., 2023).

3.2.Study Design

3.2.1. Reconnaissance survey

A reconaissance survey was initially carried out in and around the HAPNP to familiarise the researchers with the climate condition of the area, communicating with government bodies about the research, and to identify potential areas where Grevy's zebra could be sighted. This preliminary survey was conducted after discussion was held with proposed national Park staff and local community representatives to ascertain and validate whether zebras are present in their locality or not. Participatory mapping for the probable detection of the Grevy's zebra was prepared during group discussion and identify potential sites of Grevy's in the area. Based on pre-information generated from focus group discussion with community representatives (Appendix 2), extensive surveys of the identified areas were conducted with proposed Park warden and scout (Appendix 3) to confirm the presence/absence of species in the identified areas. It was also done to offer data on landscape, vegetation cover, climate and accessibility.

3.3. Data Collection Methods

3.3.1. General approach

Actual data was collected by splitting the study period into dry and wet seasons after the reconnaissance survey. Data collection took place from July to September to accommodate the wet season and from January to March for the dry seasons during 2021 to 2022 for two consecutive years. Each field trip covered from 5-7 days. Seasonal classifications into dry and wet were based on the change of rainfall pattern and vegetation cover.

3.4. Data Collection Method for Studying Population Status of Grevy's zebra

Based on the vegetation cover of the area, the entire habitat in the HAPNP was stratified into four major vegetation categories: grassland, woodland, bushland and forest. Vegetation descriptions were based on the classification provided by White (1983). A line-transect count method was then employed to assess the current population status of Grevy's zebra (Ratti *et al*., 1983; Brennan and Block, 1986; Fanuel Kebede *et al*., 2012). A total of 15 transect lines of varying lengths were established, and they were

purposefully placed using GPS to reduce double counting and avoid missing data. Each adjacent transect was separated by at least 1500 m. The stip width between transect was 7500 m. The end of each transect was not less than 100 m from the habitat margin. The longest transect was 17 km and the shortest was 5.5 km. About 60% of the transect line was laid in grassland habitat while 40% was laid in different habitats.

During observation, silent detection method was employed to minimize disturbance (Wilson *et al*., 1996). Whenever Grevy's zebra were observed, the observer recorded the time, GPS location, group size, group composition, presence of other large mammal species within 50 m, distance between the animal and the observer, observer-sighted animal angle, transect to animal distance or perpendicular distance, and habitat type where the group was seen. Surveys were conducted once per month. Data collection was generally conducted on foot. However, in open land a vehicle was used to count Grevy's zebra with an average driving speed of 5 km/hr. A team of personnel who were familiar with the area, the researcher and a skilled field assistant conducted the surveys. On each transect, a team of three individuals were assigned. Surveys were conducted from 06:00 to 10:00 h in the morning and 14:00 to 18:00 h in the afternoon. The starting and ending GPS coordinates of transects were determined before starting of each census (Appendex 4). Transects were walked along using GPS (Appendix 5). Censuses were conducted during both the wet and dry seasons.

3.4.1. Group composition

Every Grevy's zebra that was seen during the study period was identified and ascribed to the appropriate age and sex. The individuals in any group were categorized as adults, sub-adults and juveniles. Sex and age category identification was completed in the field for the purposes of sex and age structural analysis. Sex and age were identified by observing the size and external genitalia of the animals, as adopted by Nunez *et al.* (2011). By deploying data collectors in every transect simultaneously, it was possible to prevent counting the same herd or cluster more than once. According to Arcese *et al.* (1995), zebras were categorized as belonging to the same group in this study if they were separated by less than 50 meters.

3.5. Grevy's zebra Seasonal Home Range Data Collection

In the current investigation, home range sizes represented the approximate area covered by a zebra during 2021-2022 for two consecutive years. The seasonal ranges of the Grevy's zebra were studied through intensive ground tracking and recording GPS point. Sizes of the seasonal ranges for both seasons were determined applying the approach of minimum convex polygons (Kie, 1996).

3.6. Grevy's zebra Diurnal Activity

Scan sampling was employed to gather information about the diurnal activities of Grevy's zebra following Altmann (1974). Observations of species diurnal activities were carried out by naked eye and/or binoculars. Field data was collected by the team of three individuals (animal activities observer, stop watch time keeper and data recorder) to make fieldwork easy and minimize missing of data. Activities recorded were grouped as moving (walking, jumping or running), grazing, resting (inactive, either standing or lying down), grooming (using its teeth or tongue to clean its own or another's body), mating (when an individual is engaged in copulatory behaviour) and other activities (chased, bite, grabbed, displaced, threatened another zebra or vocalized in an aggressive context). For comparison with the amount of time dedicated on a particular behaviour and how it varies with sex, age, and season, we collected observational data on Grevy's zebra diurnal behavioural activities. The diurnal activities observed for each individual were coded on dataset and assigned the appropriate behaviour categories to each recorded behaviour event. Additionally, sex, age, and season information for each individual were recorded.

Observation of the species activity was taken for 10 minutes and the 5 minute rest (Appendix 6). Furthermore, the pre-determined 10 minutes were cascaded to 30 seconds to make observation and data recording easy. Accordingly, the activities made in ten minutes was noted and ticked on a data collection sheet.

Using body size metrics such as size and external genitalia as recommended by Nunez (2011), the identification of sex and age category was performed on the field. The amount of time that the field animals were viewed out of sight was noted if they disappeared from the observer's field of view. The out-of-sight period was eliminated from the sample and

the sample period's duration was also removed when it exceeded the length of the common activities. The observation of animal was undertaken by selecting strategic location like being on the tree or vantage point (Appendix 7)

3.7. Land Use Land Cover Change (LULCC)

3.7.1. Data acquisition

Landsat images were retrieved from United States Geological Survey (https://earth explorer.usgs.gov). Multi-sensor and multi-temporal image were utilized to estimate the size and directions of land cover change (Table.1). Landsat satellite imagery covering the area was collected for 1990, 2006, and 2021. Using Landsat images, this study examined into the detection of LULC changes throughout these times. The effects of cloud cover were considered during satellite image selection. Early to mid-April, when the dry season is in full swing, satellite photos with the least amount of cloud cover (less than 10%) were examined. Additionally, ground training points (GTPs) were gathered to verify that the area's existing state complies with requirements and to ensure the accuracy of data gained from satellites and utilized in accuracy assessments. High resolution images available at Google Earth Engine were used as supplementary tool for ground training points.

For 1990 and 2006 LCC map, GTPs were gathered from the false colour composite of 1990 and 2006 satellite image with the help of elder's and knowledgeable people (Lunetta and Lyon, 2004). GTPs were taken by well-trained staffs of the proposed Park. From every major land cover category a minimum of 50 points were received, in accordance with MacLean *et al.* (2012). The land cover of HAPNP was categorized into five major different classes: grassland, woodland, bushland, forest and settlement. White's (1983) classification served as the basis for the description of the vegetation.

Table 1. Definition of land cover category across habitats.

LU/LC types	Description
Forest	A landscape that is mostly composed of trees, dense bamboo, and woodlands covering at least 0.5 hectares of land and growing to a minimum height of 2 meters and a canopy cover of at least 20%, or trees that have the potential to achieve these thresholds and may be man-made or natural (MEFCC, 2016).
Bushland/Shrubland	Areas with a dense cover of shrubby, woody vegetation with a defined crown that grows to a height of less than 7 m and typically grows to a height of more than 0.5 m (MEFCC, 2016).
Woodland/savannah woodland	An area consisting of trees that are branched, *Acacia-Commiphora*, deciduous and range from 8 to 20 m in height, crowns may touch grasses and herbs present (Kindt *et al.*, 2007).
Open land/Grass	Area devoid of woody trees and covered in grasses and other herbs (Pan, 2023)
Settlement	Permanent residential places (mostly urban built-up places), refugee camps, and rural settlements with an area of at least one hectare in the research area that is easily visible and identifiable on satellite images (Im and Jensen, 2005).

3.8. Conservation Challenges

3.8.1. General approach

The list of species conservation challenges was first prepared in English (Appendix 8) by researcher and translated into Afarigna language (Appendix 9) by native language speaker to minimize confusion. Moreover, during data collection, the native language speakers read the developed questions for the respondents and probe them for the response they provided to minimize error made during response provision. The list of Grevy's zebra conservation challenges presented for respondents were: habitat degradation, poaching, drought, disease, predation, roadside killing, weak law enforcement and un-integrated development. Based on the list provided to them, they were asked to rank from top to down. The interview average length time was 90 minutes.

3.8.2. Quantitative data collection

3.8.2.1. Sampling techniques and sample size determination

The preliminary survey was made to estimate the distance of the surrounding Kebeles (smallest administrative units) from headquarter of the Park. Based on the preliminary survey, Kebeles were classified into three domains (less than 5 km, 6–10 km, and >10 km). After stratifying Kebeles into three strata based on their distance and accessibility from headquarter of the Park, one Kebele was selected using random sampling technique from each strata and a total of three Kebeles were considered. Then, household sample sizes were calculated using Israel, (1992) formula as:

$n = N/1\text{-}N\,(e)^2$

Where:

n – Sample size

N – Population size/ sampling frame

e – Error of prediction which was 0.05 (95%)

There were 996 households (N) in the chosen Kebeles. Then, the total respondents were 285.The distribution of sample respondent to each Kebele was made according to the percentage of the chosen Kebele's population. Finally, the study household was selected from each selected Kebeles using systematic random sampling method. The first

household was randomly selected, thereafter, every K^{th} household were taken until the desired sample size is reached (where K=N/n). From family members, individuals that had a better understanding about study issues were purposively selected.

3.8.3. Qualitative Data Collection

Structured and semi-structured questions were used for in-depth interviews. In this way, the in-depth interview participants were purposefully chosen based on their roles, backgrounds, and relevance to the research questions. Accordingly, from nearby Woredas, animal science, plant science, natural resources management experts and Police officers have participated. Chief Warden and senior staffs of HAPNP also participated. The issues discussed were the current conservation challenges of Grevy's zebra and possible solutions for sustainable conservation of the species. The protected area field personnel's interviewed using this method were deemed knowledgeable in view of their involvement in protected area management over time.

Digital camera was used during filed observation to take the photos of conservation challenge effect. Moreover, it was undertaken to augment the reliability of information collected through different sources. To undertake field observation checklist, a walk along the transect line was conducted. Transects were laid North to South direction to minimize the effects of sunlight. The main road that connects Ethiopia with Djibouti crosses the HAPNP. So, the data on impact of road side killing was collected via mix of roadside walk and drive (Shilling *et al.*, 2015; Smith and Van Der Ree, 2015). The length of the road used for such data collection was 23.5 km. Data was collected by driving 4WD vehicles at a speed of 20–30 km/h, once a day. Road kill locations were recorded using a GPS (Garmin GPS72H). Once recorded, road kill was removed to avoid recounts. In addition, desk review was held to make the findings of the study stronger.

3.9. Local Community Attitude

3.9.1. Questionnaire survey

A survey was conducted from 2021 to 2022, applying stratified random sampling based on distance. First, relative distances of each Kebeles found around HAPNP boundary were determined using ArcGIS Version 10.5. Next, all the Kebeles were divided into three distance strata; near (<5 km), intermediate (5–10 km) and far (>10 km) (Sarker and Røskaft, 2011). Therefore, 3 Kebeles were rondamly selected (i.e. one kebele from each strata). According to Israel (1992), the minimum number of participants needed to conduct this study with 95% confidence interval and 5% precision level was 285. The respondent size determination for each Kebele was carried out according to their population size. Only one family member who met the two requirements being over the age of eighteen years old and agreeing to participate in the survey was questioned from each of the chosen households. To determine whether or not the questions were understandable, a pilot survey of a small number of local villagers who were not from the sample villages was carried out. Following that, a few changes were made to increase the data's quality and its clarity. Since the people could understand and speak Afarigna fairly well, all interviews were done using Afarigna language.

3.9.2. Operationalization of Variables

A closed-ended survey questionnaire was developed and contained data on socioeconomic variables, perceptions of costs and benefits, knowledge about the PA's conservation activities, attitudes toward the PA, relationships with PA staff, local communities' involvement in conservation, and compliance with PA regulations.

Socio-economic variables, practices and knowledge of the respondents were used as independent variables. Attitudes of the local people, relationship with HAPNP staff, conservation participation and compliance with conservation policies were the principal response variables. Attitudes of the respondents toward the HAPNP and relationship with the staff were measured on a Likert scale with five points through 1 (strongly disagree) to 5 (strongly agree). Partcipation in conservation and compliance with conservation regulation were measured in dichotomous responses (no=0 or yes=1)

3.9.3. Key informant interviews

Participants who had specialist knowledge and/or extensive experience in the field were considered as key informants. The approach provided data that could be used to verify the accuracy of information obtained from other sources. The key informant interview participants were the management of the proposed National Park, police officers and Kebele administrators of the selected villages.

3.9.4. Observation

Observation was the method by which the researcher observed, noted, recorded, and examined the behaviours of respondents in the field (Creswell, 2009). It is an effective way to obtain understanding of a problem (Kothari, 2012). The effects of community involvement in wildlife conservation and viable community development programs supported by HAPNP were given particular consideration. Photos and a checklist were the tools used to make this approach of data collecting easier.

3.9.5. Document reviews

Secondary data was gathered through reviewing documents (Kothari, 2012). It necessitated perusing through books, research articles, reports, and other written materials that were available. The documents analyzed for this study were from the proposed park offices included reports, manuscripts, and other pertinent office file documents.

3.9.6. Focus group discussions

Additionally, focus group discussions (FGDs) were employed to gather data. Focus Group Discussions (FGDs) are a type of group interview designed to encourage discussion about the study's topic among participants (Bogdan and Biklen, 2007). The purpose of the FGDs was to cross-check the data collected via surveys. There were between six and eight participants in each FGD. Few people should participate in FGDs because managing a big number of respondents in a group is challenging. Every sampled village had three FGD sessions, and a total of nine FGDs. FGD sessions lasted roughly 1.5 hours each. The minimum age for FGD participants was eighteen. To enhance collected data, the FGD technique is quite helpful (Mclafferty, 2004). It did, however, come with a lot of disadvantages. For instance, individuals might have been too embarrassed to disclose significant events they had (Kaswamila, 2009). When there were any questions about the study, the researchers had to ask the participants to clarify their answers. Data on community participation in wildlife conservation, knowledge of PA legislation, and obstacles to community participation in wildlife conservation were gathered.

3.10. Data Analyses

3.10.1. Population data

Using the "DISTANCE" software application, data were analyzed to estimate the Grevy's zebra population (Buckland *et al.,* 2004). Due to the substantial variations, a prudent estimate of the population number was determined by utilizing the lowest limit of the 95% confidence interval. More than 60 sightings are required for a reliable density estimate using DISTANCE analysis (Buckland *et al.,* 2004). The data from forest habitat were excluded from the estimate of population density, nevertheless, due to the very low frequency of Grevy's zebra sighted in forest habitat. Population size was estimated by multiplying the population density with the total area occupied by the Grevy's zebra in the HAPNP (Wilson *et al*. 1996). The population structure data were analysed and compared using the Chi-square test using the computer programme SPSS 26.0.

3.10.2. Seasonal home range

The coordination points collected through field observation and data gained from office of the proposed Park were first entered into excel. Using QGIS, a polygon encompassing the smallest area containing all of the presence points was created for each individual's Minimum Convex Polygon (MCP) data. This was accomplished using the Minimum Bounding Geometry tool within QGIS 3.44 and specifying "Convex Hull" as the geometry type.

3.10.3. Diurnal activity

Once the behaviours and relevant demographic data were coded, data analysis was proceeded. Since the behavioural data recorded was not normally distributed, log transformation was carried out. Analysis of Variance (ANOVA) was used to compare the means of the proportion of time spent on a behaviour across multiple groups (e.g., different age groups, sex and or seasons). The test was done to verify whether there are any differences in proportion of time spent in a behaviour among the three categories of sex (i.e., male, female and unidentified sex) and between seasons (wet and dry) using

two-way ANOVA. One-way ANOVA was also computed to test whether there are any differences in proportion of time spent in behaviour among the three categories of age. Tukey multiple comparisons of means were computed to identify the mean difference in proportion of time spent among the groups with 95% of confidence intervals. Data were analysed using statistical package of R software version 4.1.2. The dependent/response variable was a proportion of Grevy's zebra diurnal activities whereas independent variables were age, sex and season of the year.

3.10.4. Land cover change

To generate land cover change maps, the satellite image for each period was classified using supervised classification. Overall, it involves radiometric normalization, land cover classification, accuracy assessment and post classification analysis using ArcGIS 10.8 and QGIS 3.26.3. In order to perform radiometric correction on satellite images, digital number (DN) values were converted into radiance values using computed calibration factors. Radiometric correction is a method for enhancing the brightness magnitude of a satellite image for well visibility and analysis. Radiometric correction can be used to convert Digital Numbers (DNs) into Top of Atmosphere (TOA) radiance measurements by tweaking the bias and gain levels for each band (Gao and Liu, 2010).

The post-classification change detection technique was used to identify changes in land cover after the supervised classifying of the images (Yang *et al.,* 2002; Yuan *et al.,* 2005). This post-classification method is used to compute and produce a map of land cover changes over time, and it offers statistical evidence on how land cover has evolved. According to Han *et al.* (2009), Image overlay, principal component analysis, change vector analysis, image rationing, and the normalized difference vegetation index (NDVI) are the most often used techniques for detecting land change. Land cover statistics were classified and compared for this study. Each land cover type covered areas over time was compared. Afterwards, it was decided which way every classification of land cover was changing (positive or negative).

$$Percentage\ of\ land\ use/land\ cover\ change = \frac{Area\ of final\ year - Area\ of\ initial\ year}{Area\ initial\ year} x100$$

By comparing the 1990, 2006, and 2021 classification results to the ground observations, a confusion matrix was used to evaluate the accuracy of the land cover classification. A contingency matrix was produced for each land cover class, and the producer and user accuracy, the Kappa statistic, and the overall accuracy were computed for each class (Congalton, 2009). The computation of overall accuracy produced by dividing the entire number of pixels included in the evaluation process by the number of correctly categorized elements, which can be defined as the sum of the diagonal elements in an error matrix. An alternate way to calculate classification accuracy is to use the Kappa statistic, which measures how much better a given classification is than a random classification after deducting the influence of random accuracy.

$$User's\ accuracy = \frac{Number\ of\ Correctly\ Classified\ Pixels\ in\ each\ Category}{Total\ Number\ of\ Reference\ Pixels\ in\ that\ Category\ (The\ Row\ Total)} x100$$

$$Producer\ accuracy = \frac{Number\ of\ Correctly\ Classified\ Pixels\ in\ each\ Category}{Total\ Number\ of\ Reference\ Pixels\ in\ that\ Category\ (The\ Column\ Total)} x100$$

$$Total\ (overall)\ accuracy = \frac{Total\ Number\ of\ Correctly\ Classified\ Pixels\ (Diagonal)}{Total\ Number\ of\ Reference\ Pixels} x100$$

$$Kappa\ Coefficient\ (T) = \frac{(TSxTCS) - \sum(Column\ Total\ x\ Row\ Total)}{TS^2 - \sum(Column\ Total - Row\ Total)}.$$

3.10.5. Conservation challenges

The data was analyzed using SPSS version 26.0, a statistical tool. Descriptive statistics like percentages, frequencies, and means were used to present quantitative data. To determine whether there was a significant relationship between the dependent and independent variables, the chi square test was performed.

3.10.6. Local community attitude

Descriptive statistics were used to understand the nature of collected data and to analyze the frequency distribution of different variables. Chi-square analyses were performed to test the significant differences between conservation attitudes and relationships with Park staff including different categories of independent variables (H1).

To identify the main determinants of conservation involvement and compliance with the rules and regulations of the HAPNP (H2), Generalized Linear Mixed Model (GLMMs) fitting was performed with an information theoretic approach. As the response variables have binary outcomes, all models assumed binomial distribution error and logit link function. In order to ensure multicollinearity among the possible predictors, correlations were examined at ($r<0.7$) (Harrison *et al*., 2018). The significant level of all statistical analyses was set at $P< 0.05$.

4. RESULTS

4.1.Population Structure

4.1.1. Population estimate

The average Grevy's zebra populations estimated were 89 (SD±25) and 61 (SD±13) during the wet and dry seasons, respectively. On average, the estimated population size was 75 individuals with SD±14. During the wet season, 12 groups were noted with a maximum of 26 group members whereas, during the dry season, 21 groups were observed with a maximum of 14 individuals per group.

4.1.2. Age Structure

During the wet season, 62 adult and 20 sub-adult Grevy's zebras were counted, while during the dry season, 44 adults and 11 sub-adults were tallied. During the wet season, the adult to sub-adult age ratio was 3.1:1.0, the adult to juvenile ratio was 9:1 and the sub-adult to juvenile ratio was 2.9:1.0. During the dry season, the adult to sub-adult age ratio was 4:1, the adult to juvenile ratio was 7:1 and the sub-adult to juvenile ratio was 1.8:1.0 (Table 2).

Table 2. Age ratio of Grevy's zebra population in Hallaydeghe Asebot Proposed National Park

Seasons	Age category	Ratio
Wet season	Adult to sub-adult	3.1:1
	Adult to juvenile	9:1
	Sub-adult to juvenile	2.9 :1
Dry season	Adult to sub-adult	4:1
	Adult to juvenile	7:1
	Sub-adult to juvenile	1.8:1

4.1.3. Sex Structure

The sex structure of the Grevy's zebra population during the wet season favoured females, with 75.28% females and 14.6% males (sexes of the remaining individuals could not be determined). Similarly, during the dry season, 72.13% were females. During the wet season, the sex ratio of adult female to adult male was 5:1 while during the dry season, it was 4:1. The Chi-square test (χ^2 = 42.35, df = 2, p < 0.781) showed no significant difference in the sex of Grevy's zebra individuals recorded during the wet and dry seasons. Similarly, the age groups of the Grevy's zebra individuals recorded during the field surveys did not differ significantly between the seasons (χ^2 = 67.5, df = 1, p < 0.852) (Table 3).

Table 3. Sex and age group of the individuals recorded during the wet and dry seasons.

	Group	Dry	Wet	SD	Mean	Chi-Square	Sig.
Sex	Female	43	67	±24	55	0.495	0.781
	Male	11	13	±2	12		
	Unidentified	7	9	±2	8		
Age group	Adult	44	62	±18	53	0.321	0.852
	Juvenile	6	7	±1	7		
	Sub-adult	11	20	±9	16		

4.1.4. Distribution

During the wet season, the Grevy's zebra distribution across different habitats was 85.4%, 12.4% and 2.2% in the grassland, shrubland and woodland, respectively. Whereas during the dry season, the distribution was 45.9%, 29.5%, 16.4% and 8.2% in the shrubland, grassland, woodland and forest habitats, respectively (Fig.3). It was investigated how habitat affected Grevy's zebra distribution in both seasons. Significant differences were observed in the grassland (χ^2 = 51.69, df = 3, p < 0.001) and forest (χ^2 = 47.43, df = 3, p < 0.021) habitats when compared with distributions in other habitats. Substantial numbers of Grevy's zebras were observed in the grassland habitat during the wet season (76 individuals) compared to the dry season (18 individuals). Only five

individual Grevy's zebras were counted in the forest habitat during the dry season, while there were no individuals observed in this habitat during the wet season (Table 4).

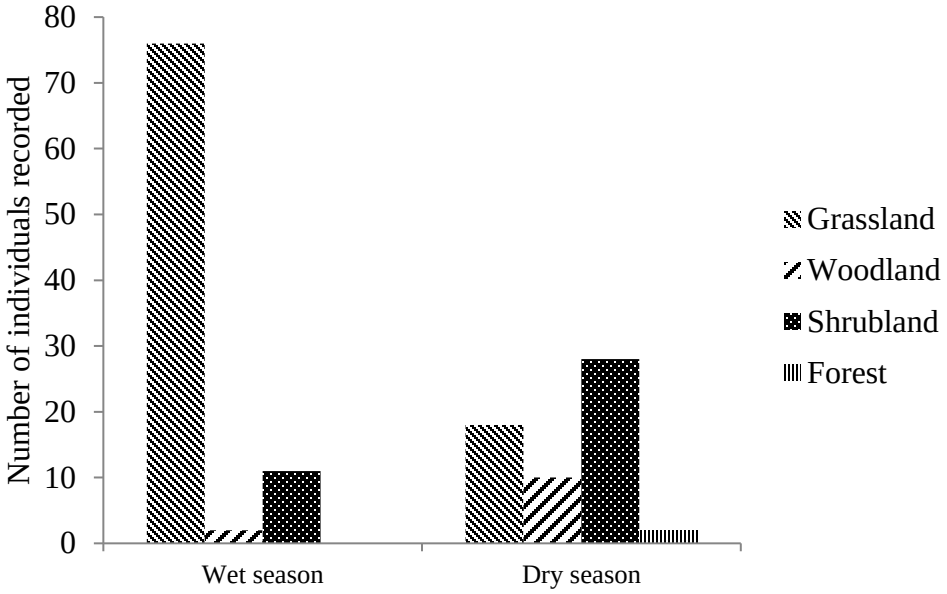

Figure 3. Number of individual Grevy's zebra counted in different habitats at HAPNP.

Table 4. Grevy's zebra distribution across different habitats during the wet and dry seasons in HAPNP.

		Dry (n)	Wet (n)	mean±SD	Chi-Square	*P*
Habitat	Grassland	18	76	47±29	3.494	0.001*
	Shrubland	28	11	20±9	4.224	0.650
	Woodland	10	2	6±4	6.424	0.072
	Forestland	5	0	3±3	5.549	0.021*

4.2.Seasonal Home Range

The seasonal home range of Grevy's zebra in the HAPNP was 711 km^2 (n = 61) during the dry season (Fig. 4) and 477 km^2 (n = 89) during the wet season (Fig. 5), and covered areas outside the current boundary of the protected area. During the dry season, this species moves beyond the boundary of the protected area in search of water and sufficient food.

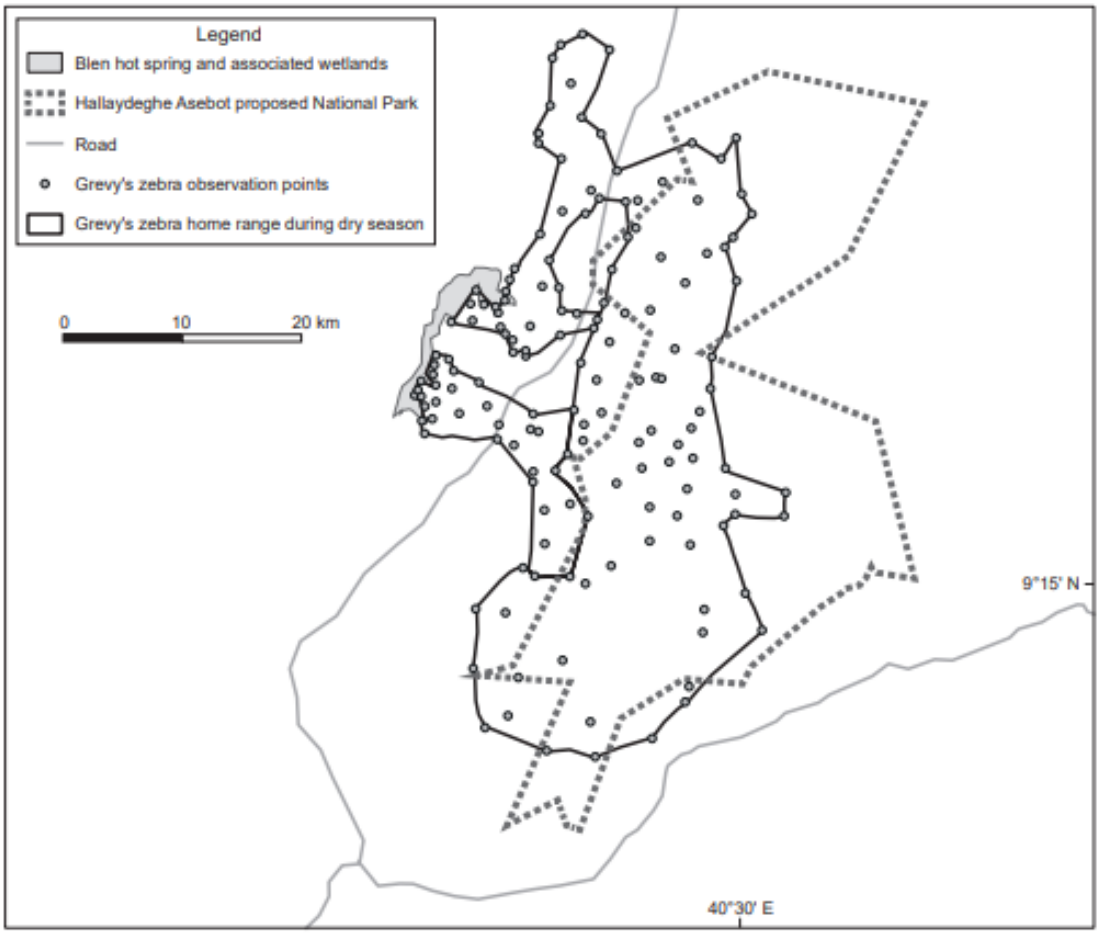

Figure 4. Grevy's zebra home range during the dry season at HAPNP.

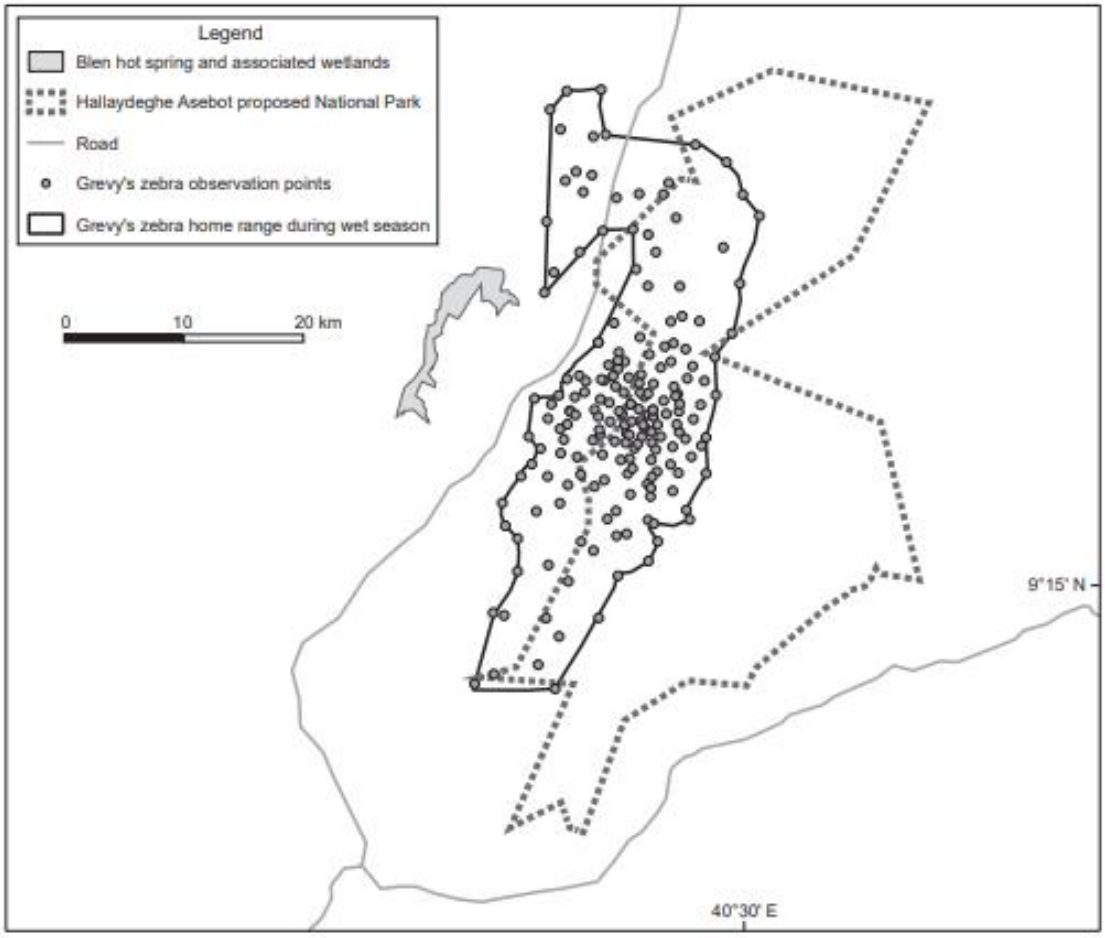

Figure 5. Grevy's zebra home range during the wet season at HAPNP.

4.3. Diurnal Activity

4.3.1. General description

A total of 2016 observations were carried out during 504 hrs of the study period and 11,223 individual diurnal activities of Grevy's zebra were recorded. Grazing (37.13%) and moving (27.25%) activities were the highest during the dry season, while grazing (31.26%) and resting (30.24%) were the highest during the wet season (Fig.6)

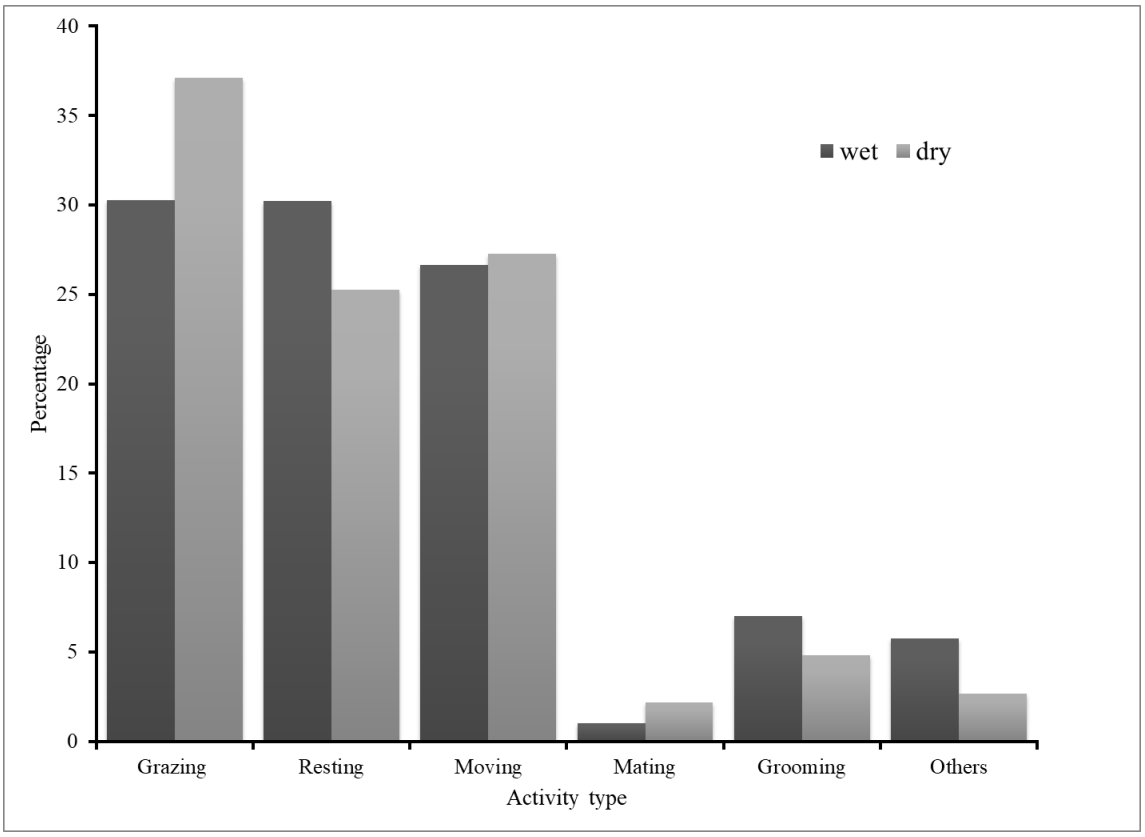

Figure 6. Percentage of diurnal activities performed by Grevy's zebra during the wet and dry seasons at HAPNP

During the wet season, morning 07:00-08:00 (52.29%), 08:00-09:00 (50.63%) and afternoon 16:00-17:00 (42.29%) were the optimal grazing time for the species. The mid-day time, 12:00-13:00(6.7%) was the lowest time allocated for grazing activity during the season. Optimal resting time of the species was 13:00-14:00 (65.67%), 12:00-13:00 (63.5%) and 14:00-15:00 (56.88%), respectively. The time from 11:00-12:00 (47.3%),

10:00-11:00 (39.38%) and afternoon 15:00-16:00 (37.5%) was the peak time for the species moving activity. Least time was allocated for moving 07:00-08:00 (13.72%). Grooming was the highest 15:00-16:00 (18.31%) (Fig.7).

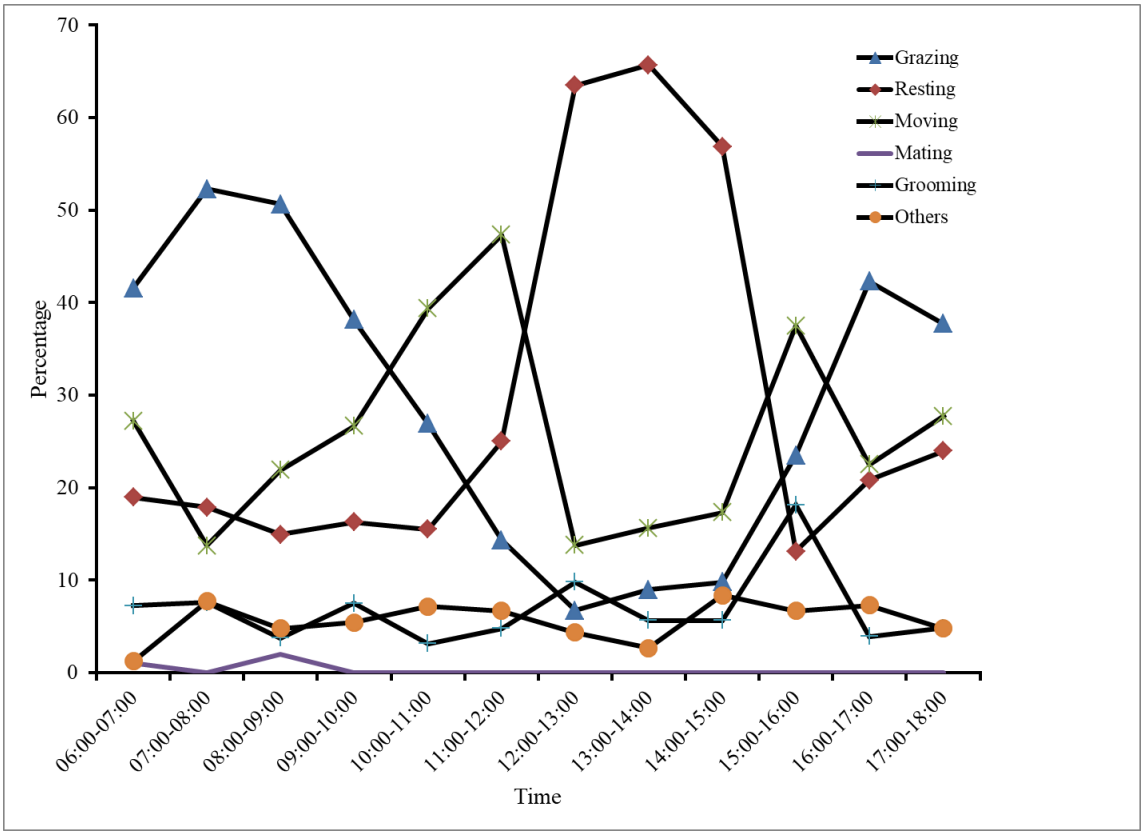

Figure 7. Diurnal activity time budget of Grevy's zebra during the wet season at HAPNP.

During the dry season, the peak grazing time of the species was morning 07:00-08:00 (58.69%),08:00-09:00 (58.21%) and 09:00-10:00 (55.63%). In the afternoon, 17:00-18:00 (47.5%) and 16:00-17:00 (45.83%) time was budgeted for grazing. The lowest time was budgeted for grazing during the period 13:00-14:00 (10.33%). The species highest resting time during the dry season was 12:00-13:00 (71%), 13:00-14:00 (68.21%) and 14:00-15:00 (61.64%). Grevy's zebra moving activity was peak between 11:00-12:00 (40.08%), 06:00-07:00 (35.63%) in the morning and afternoon 16:00-17:00 (34.35%) and 17:00-18:00 (33.54%).

The highest time was budgeted for mating and grooming activities by species during the period of 15:00-16:00 (5.63%) and 11.66%. The animal peak time for other activity was between 08:00-09:00 (3.75%) and 15:00-16:00 (3.34%) (Fig.8).

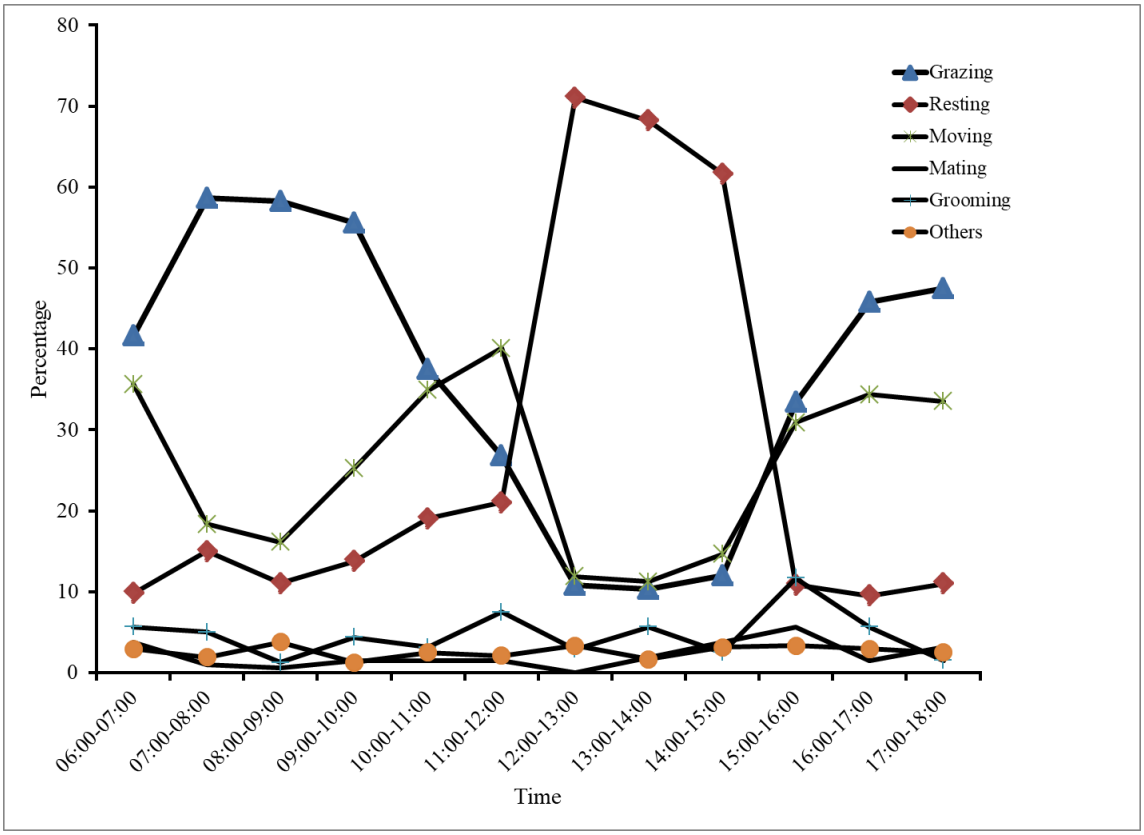

Figure 8. Diurnal activity time budget of Grevy's zebra during the dry season at HAPNP.

4.3.2. Comparison of activities based on seasons

During the wet season, the most frequent activities of adult female Grevy's zebra were grazing (35.63±2.7), resting (27.09±3.7) and moving (25.34±2.9) whereas, during the dry season, the top three activities of the species were grazing (43.7±5.4), moving (37.00±3.2) followed by resting (22.21±10.5). The time devoted for grazing and moving during the dry season was much greater for adult females than the wet season. However, the species spent more time on resting during the wet season than the dry season. Adult male Grevy's zebra highest activities during wet season were grazing (32.45±3.9), resting

(31.39±8.4) and moving (26.14±2.7). While during the dry season, grazing (40.23±1.7), moving (25.76±4.2) and resting (23.68±10.8) were the highest activities for the species . The highest activities for sub-adult Grevy's zebra during the wet season included grazing (32.43±4.6), resting (31.39±8.4) and moving (24.55±7.5). On the other hand, during the dry season, grazing (46.03±2.5), moving (38. 23±2.7) and resting (21.95±11.5) were top activities for the species (Table 5).

The three activities of juveniles during the wet season were resting (45.02±3.6), moving (21.03±4.1) and grazing (20.15±3.9). During the dry season, the top three activities of the species were resting (39.72±5.9), moving (25.39±3.8) and grazing (26.73±3.3). Generally, energy conserving activities, like resting showed a strong inverse correlation with grazing and moving activities (Table 5). The time when the species spent over grazing (df=1, F=27.15, p=0.000132), Grooming (df=1, F=24.082, p=0.000231), mating (df=1, F=24.850, p=0.0002) and moving (df=1, F=5.550, p=0.0336) activities during dry and wet seasons were significantly different. However, the time the species spent over resting (df=1, F= 57.02, p= 0.06) and other activities (df=1, F= 80.140, p= 0.07) during both seasons was not significant. During the dry season, since there is scarcity of food availability compared to the wet season, the species spent much time on grazing activity.

Table 5. Grevy's zebra activities during both seasons.

Activities	Adult Female		Adult Male		Sub-adult		Juvenile	
	Wet (%)	Dry (%)	Wet (%)	Dry (%)	Wet (%)	Dry (%)	Wet (%)	Dry (%)
Grazing	35.63±2.7	4.7±5.4	32.45±3.9	40.23±1.7	32.43±4.6	46.03±2.5	20.15±3.9	26.73±3.3
Grooming	1.00±8.4	1.30±11.1	4.59±4.8	4.27±5.4	1.45±5.8	0.47±0.00	5.50±4.2	4.44±5.2
Mating	1.17±0.00	2.00±6.7	2.57±3.7	4.50±5.4	0	0.32±8.1	0	0
Moving	25.34±2.9	37.00±3.2	26.14±2.7	25.76±4.2	24.55±7.5	38. 23±2.7	21.03±4.1	25.39±3.8
Others	5.78±2.8	2.11±5.1	3.57±5.6	7.26±4.7	4.11±4.1	2.57±5.6	9.03±5.3	8.03±4.3
Resting	27.09±3.7	22.21±10.5	30.35±6.0	23.68±10.8	31.39±8.4	21.95±11.5	45.02±3.6	39.72±5.9

4.3.3. Comparison of activities based on sex structure

Statistical test was made to know if there were significant differences on activity of Grevy's zebra based on sex. The result evidenced that there are statistically significant differences on time devoted to grazing (df=2, F= 9.34, p= 0.002), mating (df=2, F= 6.216, p= 0.01), moving (df=2, F= 5.604, p= 0.01) and other (df=2, F= 5.006, p= 0.02) activities based on sex of the species. However, there is no statistical difference on resting activity based on the sex of species (df=2, F= 44.18, p= 0.07).

The time female Grevy's allotted for grazing was greater and statistically different than other groups of Grevy's zebras (df=2, F=35.88, p=0.032). Male and juveniles devoted more time to grooming and this was statistically different compared to other groups of Grevy's zebra (df=2, F=21.01, p=0.02). Compared to other categories of Grevy's zebra, males spend highest time to mating and statistically different (df=2, F=58.25, p=0.012). Male zebras spent less time to moving when compared with others and statistically there are significant differences (df=2, F=22.33, p=0.004).

4.3.4. Comparison of activities based on age structure

The impact of age on Grevy's zebra activity was tested and there is no significant difference on activities of the species based on age structure (df=3, F=13.73, p=0.359). Specifically, grazing (df=3,F=23.63, p=0.259), grooming (df=3,F=1.134, p=0.651),

mating (df=3 , F=2.75, p=0.0697), moving (df=3, F=54.07, p= 0.094) andother activities (df=3, F=1.43, p=0.264) and (df=3,F=17.29,p=0.063).

4.4. Trends of LULCC and Conservation Challenges

4.4.1. Trends of LULCC

4.4.1.1. LULCC of HAPNP between 1990-2006

The major LULCC categories identified for Hallaydeghe Asebot Proposed National Park are given in Table 6. Five major LULC types were identified for this study: namely, forest, open land (grassland), woodland (savanna woodland), bush (shrub) land and settlement. The pattern of LULCC between 1990 and 2006 has exhibited different geographical features in the HAPNP. Accordingly, grassland covered 59,824.42 ha (32.66 %) of the proposed Park during 1990. However, it showed a declining pattern by -9,320.73 (4.09 %) in the last 15 years reduced to 50,503.69 ha by 2006. In contrast, bushland coverage showed an increasing pattern from 40,779.91 ha (22.30%) during 1990 to 54,078.64 ha (29.52 %) during 2006. That means Bushland showed an increment pattern of +13,298.73 (7.22%) in fifteen years 1990-2006 (Table 6) and (Fig.9), respectively.

Table 6. Area and proportion of LULC in HAPNP between 1990 and 2006.

LULC Type	1990		2006		Difference (1990-2006)
	Ha	%	Ha	%	Ha. (%)
Forest	13,527.34	7.34	18,659.36	10.19	+5,132.02 (2.85%)
Open land/Grassland	59,824.42	32.66	50,503.69	28.57	-9,320.73 (4.09 %)
Settlement	187.99	0.11	175.38	0.10	-7.25 (0.01%)
Bushland / Shrubland	40,779.91	22.30	54,078.64	29.52	+13,298.73 (7.22%)
Woodland/savannah woodland	68,880.79	37.59	59,782.93	32.64	-5,311.09 (4.95%)
Grand Total	183,200.00	100.00	183,200.00	100.00	-

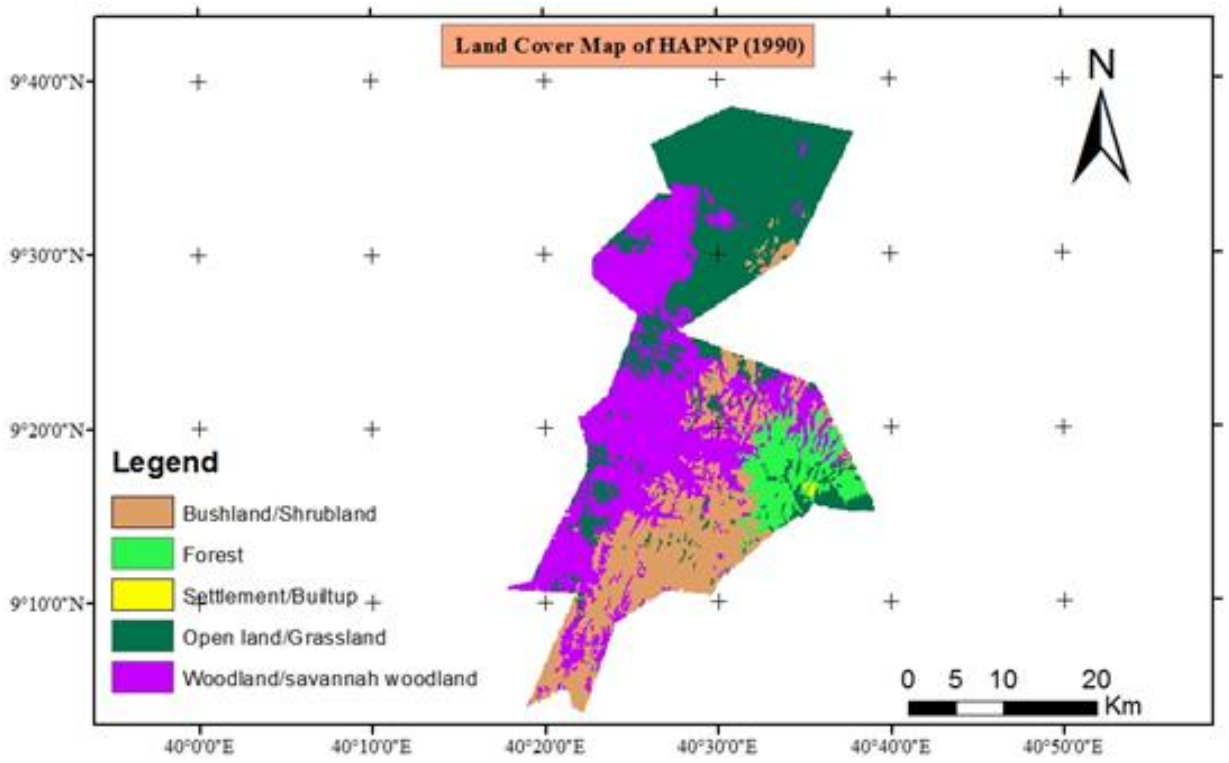

Figure 9. Land Use Land Cover Map of HAPNP during 1990.

During the last 15 years (2006-2021), major land cover change was observed on bushland. During 2006 the bushland area coverage was 54,078.64 ha and in 2021, it increased to 89,307.96 ha with an area increment of +35,229.32 (19.23%). In contrast open land/ grassland area decreased. During, the area coverage of open land/grassland was 50,503.69 ha and in 2021 was reduced to 37,458.72 ha with significant area decrement of -13,044.97 (8.12%) in HAPNP. Similarly during the stated period, the woodland (savanna woodland) area decreased from 59,782.93ha to 48,149.44 ha with a decrease coverage area of 11,633.49ha (6.36%) in the study area (Table 7 and Fig. 10).

Table 7. The land cover change of HAPNP between the years of 2006-2021.

LULC Type	2006		2021		Difference (2006-2021)
	Hectare	%	Hectare	%	Hect. (%)
Forest	18,659.36	10.19	7,534.61	4.11	-11,124.75 (6.08%)
Open land/Grassland	50,503.69	28.57	37,458.72	20.45	-13,044.97 (8.12%)
Settlement	175.38	0.10	749.23	0.41	+573.85 (0.31%)
Bush land / Shrub land	54,078.64	29.52	89,307.96	48.75	+35,229.32 (19.23%)
Woodland/savannahwoodland	59,782.93	32.64	48,149.44	26.28	-11,633.49 (6.36%)
Grand Total	183,200.00	100.00	183,200.00	100	-

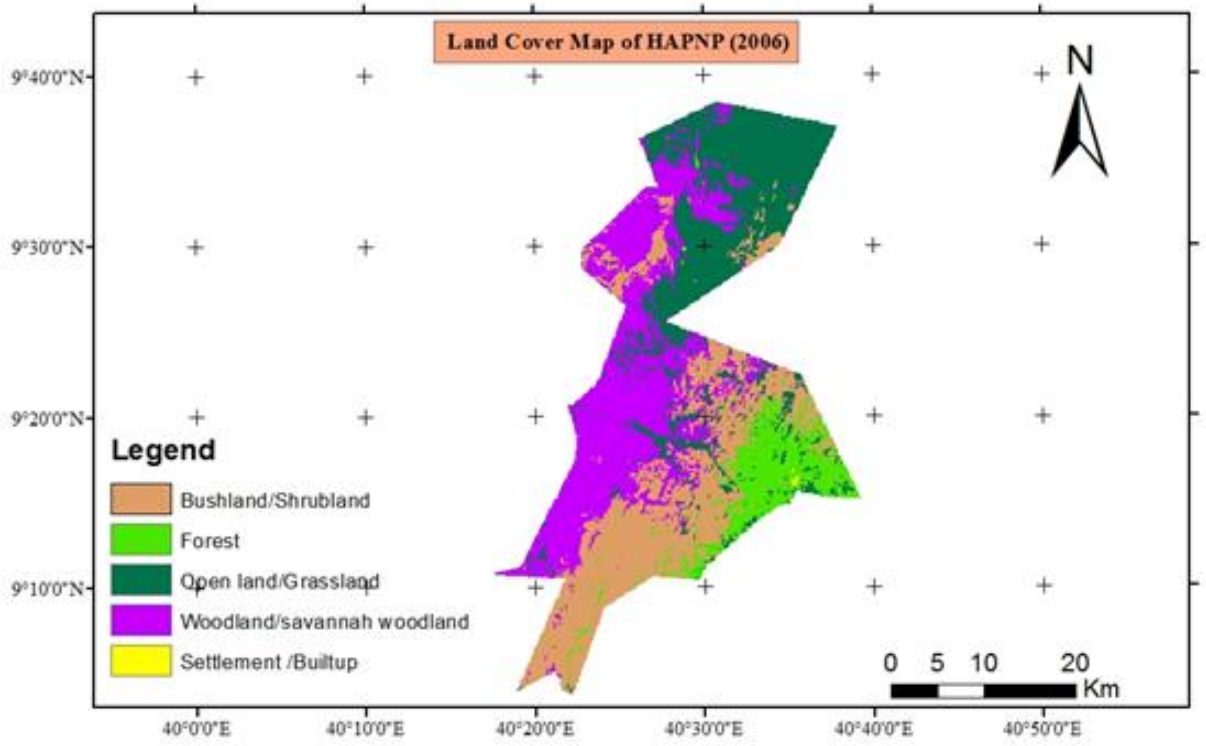

Figure 10. Land Use Land Cover Map of HAPNP during 2006.

4.4.1.2. LULCC of HAPNP during 2021

Currently, five major land use and land cover types are available in HAPNP. These are forest 7,534.61ha, Shrubland 89,307.96 ha, grassland 37,458.72 ha, Woodland 48,149.44 ha and Settlement 749.23 ha (Fig. 11).

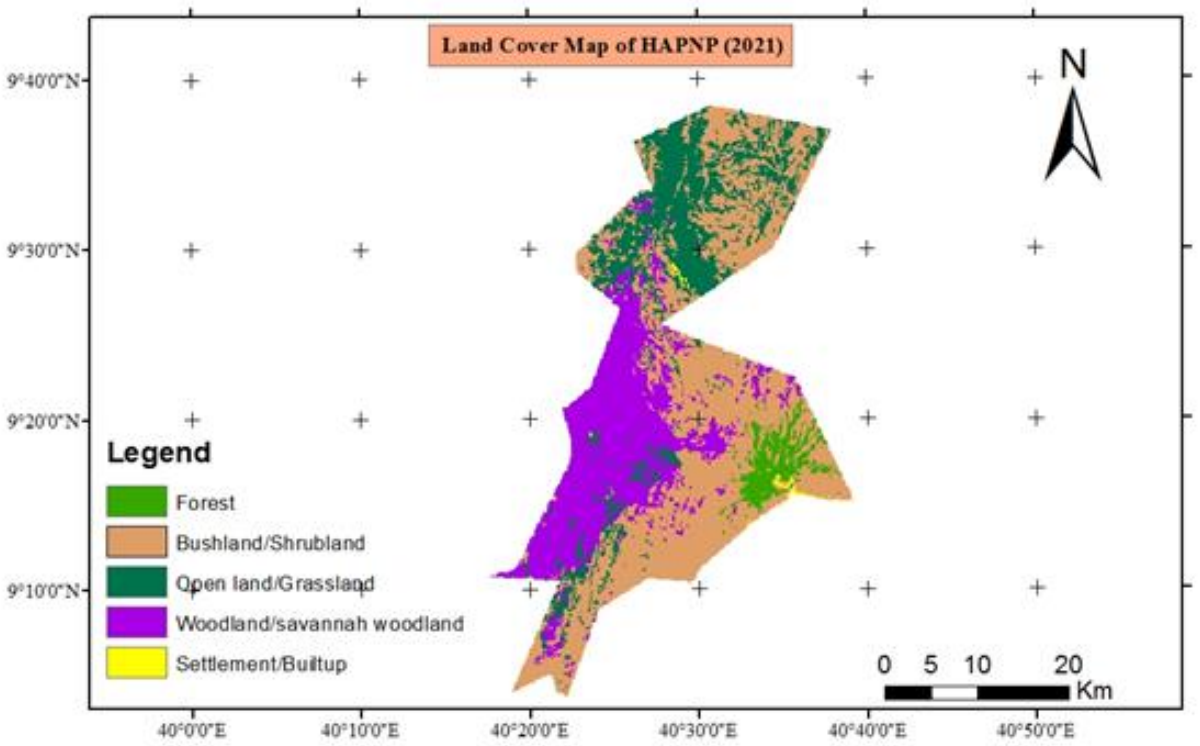

Figure 11. Land Use Land Cover Map of HAPNP during 2021

4.4.1.3. LULCC pattern in HAPNP (1990-2021)

The major land cover change observed during the first fifteen years 1990-2006 was converted from woodland to shrubland was 9213.31 ha. During the same period, the second major land cover change was from open land to woodland, that was 8525.09 ha. The smallest change was made settlement to open land 0.43 ha and woodland to settlement 0.5 ha.

During the second period of 2006-2021, significant land cover change was seen from open to shrubland with 14324.37 ha. In the same years the second major land cover change was observed from woodland to shrubland, 8032.10 ha. In contrast smallest change was observed from woodland to forest 1.34 ha and settlement to open land 6.92 ha.

Generally, during the last thirty years (1990-2021) the significant land cover change was observed from open land to bushland with 16790.32 ha followed by woodland to bushland 11,852.51ha. During the same year, the smallest change was observed from forest to open land 0.94 ha.

Using high resolution photos from Google Earth Engine as a supplemental tool and GTPs acquired on transect walks with the assistance of knowledgeable individuals, the accuracy of the land use/cover maps from 1990, 2006, and 2021 was evaluated. Aerial photos obtained in 2020 and a thorough ground survey carried out in 2021–2022 served as the basis for the land use/cover map of 2021. Overall, land use/cover classification accuracy levels for the three dates ranged from 85 to 90 percent with Kappa statistics falling between 0.79-0.88 (Table 8). These accuracies were adequate for the analysis of the study area because they meet the minimum accuracy stipulated by others for satellite-derived land use/cover maps.

Table 8. Summary of LULC classification accuracies for 1990, 2006 and 2021.

LU/LC types	1990		2006		2021	
	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy
Forest			0.95	0.914	0.98	0.91
Woodland			0.890	0.958	0.94	0.99
Grassland			0.92	0.953	0.88	0.92
Settlement			0.84	1.000	0.83	0.89
Bushland			0.94	0.953	0.95	0.95
Overall Accuracy			89	-	94	-
Kappa Statistics			84	-	91	-

94.19% overall classification accuracy and 0.915686 overall Kappa statistics

4.4.2. Conservation challenges

4.4.2.1. Socio-demographic information of respondents

Most (90%) of the research participants were men. About 69% of the respondents lack formal education and are illiterate, while the remaining respondents had formal education and are literate. Nearly half (41.3 %) of the total respondents were between the age category of 40-50 indicating that the majority of them are of productive age.

4.4.2.2. Identified conservation challenges

The major conservation challenges of Grevy's zebra were; habitat degradation (94.7%) unintegrated development (92.4%) and poor law enforcement (90.7%), respectively (Table 9).

Table 9. Response rate of target respondents towards Grevy's zebra conservation challenges.

List of conservation threats	Respondents		Rank
	Frequency	Percentage	
Habitat degradation	274	96.14	1st
Poaching	80	28.07	8th
Drought	236	82.8	6th
Disease	93	32.63	7th
Predation	251	88.07	4th
Roadside killing	247	86.67	5th
Weak Law enforcement	258	90.52	3rd
Unintegrated development	270	94.74	2nd

Habitat degradation stands as a top conservation challenge compared to other factors. Habitat degradation was mainly caused by invasive plant species expansion (*Prosopis juliflora*), overgrazing, human-induced fire, and harvesting of grass by local people for different purposes. Practice of grass burning to control tick was another pressing problem (Fig. 12 c and d). In 2020, human induced fire was practiced many times (person.com). In a day, more than ten thousand of domestic livestock were grazing over the plain of Hallaydeghe (Fig. 12b).

a)  b) 

c)  d) 

Figure 12a Local woman harvesting of grass from HAPNP plain, (b) Herds of domestic livestock heading to Hallaydeghe plain for grazing, and c,d human induced fire damaging the Park (photo taken by the researcher on September, 2021)

Poor law enforcement was the third challenge for conservation of Grevy's zebra. Due to shortage of man power, especially in areas of law enforcement, the protected area faces a serious problem. Inadequate manpower and lack of fund to enforce the law were the main causes. Currently, unintegrated development has been initiated around HAPNP that includes establishing new zonal town and opening new offices within 1 km distance from the Park. Due to expansion of newly established zonal town and Kebeles, the corridors that wildlife use to drink water is going to be closed. Since the corridors are busy by human activity during the day, wildlife is forced to use night time to go to water point to drink water (person. com). This may expose wildlife to predator attack. A conflict of interest exists between the conservation and development initiatives. The local

communities believe that the foot of Grevy's zebra is used to heal from epilepsy disease. Although actual data were not gained, there was a probability of hunting the species for medicinal purpose. Further study is needed on this particular issue.

4.4.2.3. Conservation challenges and their causes

Below is the summary of the conservation challenges along their causes (Table 10). The causes for the conservation challenges were identified through field observation, FGDs and KIIs.

Table 10. Summary of conservation threats and their causes in HAPNP.

Conservation threats	**Causes**
Habitat degradation	Invasive plant species expansion, overgrazing, human induced fire and harvesting of grass
Illegal hunting/poaching	For medicinal purposes
Drought	Shortage of enough rainfall and climate change
Disease	No regular vaccination of domestic livestock
Predation	Presence of large carnivore like lion and hyena, movement of wild animal at night for water point search
Road side killing	Speedy driving, no speed breaker, no enough sign post, lack of awareness, movements and road crossing
Poor government attention	The government uses the site for military training, not enough workforce assigned and budget shortage
Weak law enforcement	Severe shortage of manpower, lack of integration between wildlife stakeholders and limited awareness made for local communities
Practices of Disintegrated development	Investment and settlement

4.5. Community Attitude

4.5.1. Profile of respondents

Among the 285 respondents, 90% were males and 10% were females. About 69% of the respondents were illiterate. Nearly half of them were within age group of 40-50 years old. The primary source of income was livestock (88%) and followed by other occupation (9%) (Table 11).

Table 11. Summary description and coding of variables.

Variables	Response N= 285	%
Socio-economic variables		
Distance from PA	<5 km	40
	5-10 km	35
	>10 km	25
Age (years)	18-29	20
	30-39	23
	40-49	47
	>50	10
Gender	Male	90
	Female	10
Education	Illiterate	69
	Certificate	21
	Diploma and above	10
Income from PA	No	37
	Yes	63
Perception		
Benefit	No	84
	Yes	16
Cost	No	23
	Yes	77
Knowledge		
	No	63

Conservation awareness	Yes	27
Attitude		
Attitude towards HAPNP	Negative	62
	Neutral	21
	Positive	17
Relationship		
Relationship with PA staff	Bad	7
	Neutral	24
	Good	69
Participation		
Participation in conservation	No	65
	Yes	35
Compliance		
Compliance with HAPNP regulation	No	53
	Yes	47

4.5.2. Community Knowledge, Perceived Benefits and Costs from the HAPNP

Among the respondents (27%) were aware of HAPNP conservation activities and knew that the main objective was to conserve different wildlife species found in the area. The recorded key species that they knew the PA aimed to conserve included Grevy's zebra (85%), Beisa Oryx (50.7%) and other wildlife species. About 16% of the respondents acknowledged the benefits of the HAPNP for the provision of exploitable goods (timber, fuelwood, food benefits (Fig.13) and non-exploitable ecosystem services (climate regulation, flood control, cultural and esthetic values). 77% of the respondents claimed that the costs of having this PA in their vicinity restricted resource access, land conflict and livestock damage (Table 12).

Figure 13. HAPNP delivering support services for the people in need of support (Photo by Ahmed Endris, 2021).

4.5.3. Attitudes towards HAPNP and its Management

4.5.3.1. Attitudes towards HAPNP

Overall, 62% of the respondents had negative attitude toward the presence of the HAPNP while 21% were neutral, and 17% were showed positive attitude (Table 12). Respondents attitudes toward the HAPNP differed significantly with the distance they lived from the HAPNP (χ^2=88.01, df=2, P<0.001, Table 12). People who live near the PA were more positive than those living at an intermediate distance and far away. People who received benefits from the PA showed more positive attitudes than those who did not receive benefits (χ^2=29, df=1, P<0.001). Communities with reduced benefit due to the presence of HAPNP displayed more negative attitudes than those who did not (χ^2=11.2,df=1, P<0.05). People who possess conservation awareness are more positive than people who did not get conservation awareness (χ^2=8.61,df=1, P<0.05).

Table 12. Chi-square analyses for attitudes toward the PA and attitude towards PA staff against independent variables.

Variables	Attitude towards PA		Attitude towards PA staffs	
	Df	χ^2	Df	χ^2
Distance	2	88.01***	2	72***
Age	3	3.83	3	7.4
Gender	1	1.24	1	1.07
Education	2	3.2*	2	5.86
Income from PA	1	18.18***	1	23.26***
Percieved benefit	1	29***	1	14.52***
Perceived cost	1	11.2*	1	33.58***
Conservation awarness	1	8.61*	1	9.05*

**P≤0.05; **P≤0.01; ***P≤0.001. Significant effects are denoted by asterisks*

4.5.3.2. Community attitude towards *protected area staffs*

Regarding local community's attitude towards HAPNP staff, 69% had a good attitude, while 24% were neutral, and 7% had negative attitude. Communitie's attitude towards HAPNP staff were more desirable in the Kebeles closer to the PA than those who were in the intermediate and far away Kebeles (χ^2=72,df=2, P<0.001). Respondents who benefitted from the HAPNP indicated better attitude towards PA staff than those who did not receive benefits from the HAPNP (χ^2=14.52,df=1, P<0.001). In contrast, individuals who suffered due to the presence of HAPNP depicted worse attitude with Park staff than those who did not suffer any costs from the P (χ^2=33.58, df=1, P<0.001). People who received conservation awareness have better attitude towards HAPNP staffs when compared with people who did not receive conservation awareness (χ^2=9.05,df=1, P<0.05).

4.5.4. Local Community participation in the Conservation of the HAPNP

A total of 35% of the respondents were involved in the conservation activities of HAPNP which were invasive plant expansion control, road preparation, waste management and fire break preparation (Fig. 14). Local communities living in the near Kebeles were more engaged in conservation than those living in the intermediate and far away Kebeles (χ^2=26.05,df=2, P<0.001). Local support for conservation differed significantly depending on whether they were receiving benefits from the HAPNP or not (χ^2=37,df=1, P<0.001), whether they had developed conservation awareness or not (χ^2=26,df=1, P<0.05), whether they were having positive attitudes toward the PA or not (χ^2=13.05,df=2, P<0.05) and whether they had a good relationship with the PA staff or not (χ^2=11.26,df=2, P<0.05).

Figure 14. Local community and Park staff undertaking fire break preparation (Photo Ahmed Endris).

4.5.5. Compliance with the Rules and Regulations of HAPNP

When the respondents were asked “Are you allowed collecting the resources that your household mainly depends on from HAPNP? About 37% of the respondents replied “No”while 63% “Yes”. The communities who were economically dependent on HAPNP (χ^2=51.22, df=1, P<0.001) confirm that they were not allowed to collect resources from inside HAPNP. Furthermore, positive attitudes toward the area (χ^2=61,df=2, P<0.05), good relationships with HAPNP staff (χ^2=11.26,df=2, P<0.01), getting benefits from the HAPNP (χ^2=7,df=1, P<0.001), neutral in obtaining benefits from the HAPNP (χ^2=5.87,df=1, P<0.05) and living far from HAPNP (χ^2=23.5, df=2, P<0.05) follow compliance with HAPNP rules and regulations.

5. DISCUSSION

Estimating the population and distribution of Grevy's zebra within the research area is crucial for the proper management of the population and the implementation of conservation measures. The current findings revealed average of 75 individual Grevy's zebra in the HAPNP. Fanuel Kebede *et al*., (2012) reported the estimated population of Grevy's zebra in the same study site was 143, suggesting that our current findings demonstrate a population reduction. During the dry season, the population is divided into many small groups to avoid competition over sparse food and water. Although the current female-biased sex ratio is promising for a healthy population in the HAPNP, the low proportion of juveniles is of concern. The current study's results supported the notion that a population build-up occurs during the wet season. The two seasons' counts differed significantly from one another. This could be due to several ecological factors, such as the amount of food, breeding sites, predator protection, heat stress, and amount of open space that the habitat offers. The number of Grevy's zebra counted in the open grassland, shrubland, bushland and forest habitats showed significant differences. The number of zebra counted in the 15 transects varied, and this was most likely due to individual preferences for habitats with abundant food sources. More zebra were counted during the wet season when food was abundant. This supports the findings of Dankwa-Wiredu and Euler (2002) and Reta Regassa and Solomon Yirga (2014) who confirmed that habitat utilisation is often determined by the availability of cover, food and rich plant growth.

This study demonstrates the abundance of Grevy's zebra in open grassland habitats. During the wet season, the Grevy's zebra appeared to prefer in the open grassland the most and the shrubland to a lesser extent, with the fewest individuals observed in the bushland. In contrast, they were observed mostly in the shrubland during the dry season because of the availability of relatively green resources, wet pastures and relatively comfortable ambient weather conditions. This accords with the findings of Reta Regassa and Solomon Yirga (2014) and indicated that the availability of food and water determine the distribution of zebra population

Understanding the age distribution and sex ratio of individual mammals is crucial for evaluating the survivability of a species, as these variables impact the composition and behavior of a population (Wilson *et al*., 1996). A population's age and sex composition at

any given time can also provide information about its health (Reta Regassa and Solomon Yirga, 2014). A healthy population is indicated by the high percentage of females and the relatively high percentage of juvenile zebras (Yisehak Doku *et al*., 2007). Foals recorded during both seasons suggest that there is year-round breeding in the HAPNP.

In the various habitat types during both seasons, group-size distribution followed a distinct pattern. Yet, a highly significant difference between those in the open grassland and those in the dense and intermediate habitats was observed. Group size varies in response to different external conditions, including environmental disturbance resulting from heavy grazing, fire and other factors. In the study area, water is also a limiting factor for the group-size distribution of Grevy's zebra, as they need water to survive the dry season. This study demonstrates that the seasonal home range size of Grevy's zebra is strongly associated with the presence of water and edible grass. The study finding is consistent with (Maria *et al.,* 2020) in that both biotic and abiotic factors were considerd as the detereminant factor for the wild animal population distribution.

The species belongs to equidea have different size of home range. Forinstance, the home range sizes for burchell's zebra equus burchelli antiquorum from the Kruger National Park sizes varied from 49 to 566 km^2 (Smuts, 1975). Plain zabra have the home range size of 80-250 km^2 in the Ngorongoro Crater, Tanzania (Klingel, 1969). In a similar vein, variations within a single species should be expected based on its environment. The core range of Grevy's zebra on Kasigau Corridor ranches, southeast Kenya, was estimated to be 400 km^2 (Githiru, 2017), much smaller than the home range of Grevy's zebra in the present study. This may be associated with factors including resource availability, human induced factors and climatic conditions.

In essence, a home range is an area that is productive enough to meet the energy needs of the individual or group who uses it (Fryxell, 2014). The knowledge of measures such as the usual density at which the animal lives and biomass or standing crop, which affects the number of animals a given habitat can support, should help to elucidate variations in the home range size of particular species (Viana *et al.,* 2018). In addition, possible long-term effects associated with abrupt variations in the climate, changes in the availability of water and food, fire and predation could also affect the size of an individual's home

range. Another long-term factor that is important in regulating the size of a particular home range is the general acceptability of the habitat with respect to the species concerned, i.e., whether the habitat is optimal or marginal (PA, 1966).

The Grevy's zebra's activity time budget varied at different times of the day and in both seasons. The current research revealed that Grevy's zebras in HAPNP spend most of their time on grazing, resting and moving. The time devoted to grazing was greater during the dry season compared to the wet season due to the variation in feeding resources. The results are consistent with those of (Lamidi and Ologbose, 2014) in that ruminant in Nigeria spent more time on grazing during dry season. Several African grazers have reported experiencing an increase in grazing time during the dry season, accompanied by a decrease in food availability (Owen-Smith, 1982; Rubeinstein *et al.*, 2004; Kivai, 2006; Reta Regassa and Solomon Yirga, 2014). The animal most preferred time for grazing activity is variable. The time was preferred by species due to different factors including avoiding competition that may occur over resources with livestock and human induced impacts since livestock and human movement in the area is limited during this time. Moreover, the weather of the day during this time is very encouraging for energy consuming activities since mid-day is known by hot temperature in the area. This finding was in line with Reta Regassa and Solomon Yirga (2014) on Burchell zebra spending more than 50% of their time on grazing in Yabello wildlife sanctuary and most of their activities were in the morning and afternoon with resting during day time.

Moving activity was higher during the dry season. During the dry season in search of water points and to overcome shortage of resources, the species devotes higher time to moving than the wet season when resources are relatively abundant. The inference that a severe climate and the availability of resources appear to be the main factors influencing the behaviours of Grevy's zebra may result from the variation in the allocation of time budgets between the wet and dry seasons. In addition human activities also influence the diurnal activities of Grevy's zebra. Numerous factors influence the activity patterns of animals. Optimal daily and seasonal activity patterns may be influenced by biotic ambient elements including light and temperature (Nielsen, 1984; Patterson *et al.*, 1999).

The LULCC classification's output had respectable accuracy and was mostly consistent with earlier research on the classification of Landsat images (Kpienbaareh *et al.,* 2022). We identified various land-cover patterns in HAPNP after analyzing the change in land cover between 1990 and 2021. These patterns are likely to affect how well the protected area functions. In 1990, when the area was a wildlife reserve, the land cover of grass land area was wide. Through time, grassland declined while bushland increased. The decline of grassland area in and around protected area goes in line with the findings of Temesgen Yadeta *et al. (*2022). This decline of grassland cover but increasing bushland coverage seen was attributed by the effects of intensity of livestock grazing. Reduced grass biomass results from increased grazing intensity (Sankaran *et al.,* 2005; Wragg *et al.,* 2018; Zhang *et al.,* 2018; Gomes *et al.,* 2020). This in turn lessens the intensity of fire, which helps woody plants to regenerate and speeds up the transition from grassland to bushland. The result complies with the earlier research reports by Sankaran *et al. (*2004) and HasanYusuf *et al.* (2011).

Grazing land scarcity has come from the conversion of grazing areas to cultivation areas beyond the HAPNP, in addition to increases in human and cattle populations. As a result, people may be compelled to cross park boundaries in order to exploit resources such as cattle pasture.

Our result confirms with the previous study of Kpienbaareh *et al.* (2022) that LCC from forest to shrubs conversion was the main form of land cover transition observed in Kasungu National Park, Malawi. In contrast to the current findings, the study conducted by Solomon Belay *et al.,* (2014) in Awash National Park, grassland expanded by 14.2% between 1972 and 1986 as well as by 10.5% of the study area during the entire study period (1972-2006). The current study identified the contribution of invasive and exotic plant species expansion may play a key role in land cover change of HAPNP. The finding confirms with the study of Cole and Landres (1996) that because of their direct and indirect effects on native species as well as their effects on larger-scale ecological patterns and processes that contribute to habitat degradation, non-native or alien species pose a serious threat to protected areas.

Habitat degradation in HAPNP has become the top conservation challenges for Grevy's zebra. One of the main reasons for habitat degradation in the area is livestock

overgrazing, which led to decreased high-density pasture volume and increased low-density pasture in this area. These findings have also been confirmed with previous studies as overgrazing was reported as the most important reason for habitat degradation (Zhao *et al*., 2005; Zhang, 2012). Furthermore, this study goes in line with the findings of the study of Kenya's Grevy's zebra Technical Committee assessed and ranked habitat degradation first rank as conservation challenges (Low *et al.* 2009; Rubenstein, 2010). Another conservation challenge for the species is the uncontrolled movements of local community for harvesting grasses, fire wood collection and keep livestock in this area. Furthermore, there is continual expansion of temporary and permanent settlements in and around the Park for the need of animal fodder and water sources. Insufficient monitoring is one main reason for the uncontrolled entry of nomads and livestock into the area resulting in many negative impacts on habitat degradation. This finding is also inline with Haghverdi *et al.* (2018).

The other conservation challenge of the species in HAPNP is the practices of un-integrated development around the proposed Park. Accordingly, in HAPNP, many causes have contributed to the severe destruction of the plain of the study area and its surrounds, most notably the meddling of various institutions with the management of the PA through the development of economic and physical activity. The surrounding areas of this PA have been given to different groups or investors for financial exploitation due to overwhelming influence, and this could swiftly ruin the local ecosystem and habitats. Moreover, another important issue increasing the conservation challenges for the species in this area is the growing of human activities by the name of development, particularly urban development and road. The inability of the protected area to monitor and manage the area due to staff shortage, limited skill to utilize modern technology to track Grevy's zebra ecological trait and severe financial shortage along with the influence of some governmental stakeholders, have led to extensive human activities in the area. These findings go in line with the previous studied by Xu and Melick (2007).

Moreover, lack of collaboration among different organizations and protected area staff in protecting this area has caused extensive conservation challenge. Our studies have also confirmed with the findings of Sadegh *et al.* (2019) and Danehkar (2017).

According to the current study report, there is no significant evidence of predation on Grevy's zebra in Hallaydeghe Asebot Proposed National Park. Possibly the presence of numerous large and medium sized mammals in the proposed Park might have reduced the rate of predation over Grevy zebra. The findings of this study differ from the study conducted in Kenya that revealed predation as a potential limiting factor in the growth of the population of Grevy's zebra within their range (Rubenstein, 2010). In Lewa wildlife conservancy of Kenya, lions and possibly hyaenas are a major conservation challenges for the growth of the Grevy's population (Mwololo, 2006). The complex and multifaceted nature of conservation attitude is influenced by a wide range of social, cultural, political, and economic issues in addition to individual experiences with conservation programs (Guerbois *et al.,* 2013).

In numerous researches on how humans view wildlife, attitudes play a crucial role in providing an exhaustive overview of communities' opinions towards wildlife and their conservation. Attitude surveys are common in the conservation field and are essential tools for assessing societal impacts. The attitudes of people determine whether conservation aims are attained (Richards, 1996). The long-term fates of protected areas (PAs) are determined by the conservation attitudes of people living nearby. It is imperative that managers of protected areas investigate factors that impact attitudes towards conservation (Ite, 1996). Many respondents of the remote villages around the HAPNP were not visited by Park staffs and with some villages even unaware of the creation of the Park, let alone included in conservation of protected areas. This finding was inline with Peters (1999) in that remote villages complained for being forgotten by Park managment staffs in Madagascar. Communities adjacent to HAPNP get more benefit (e.g. employement opportunity like scout and free vehicle services during emergency) compared to communities that reside at distance. They also have more partcipation in conservation of HAPNP. The benefit, services and participation they receive from the Park led the adjacent community to have positive attitude and the forgotten distant communities resulting in negative attitude for HAPNP. This finding was dissimilar with the findings of Sarker and Røskaft (2011) in that the community adjacent to protected areas is more compliant to protected areas.

From social impact side, distant residents noted existence of limited awareness of conservation and improvement in basic infrastructure (e.g., roads, drinking water,

transportation to a nearby town, and schools) as the primary benefits that can be received due to the existence of the Park were overlooked. This finding goes in line with previous study conducted by Shahi *et al*. (2022) in that communities develop negative attitude on protected area when tangible benefits were not practiced.

Age can also influence local community attitudes towards conservation of wildlife. In the current, older generations have demonstrated more positive or protectionist attitude (i.e., supportive of conserving species) compared to younger generations. Younger generations have no positive attitude for the conservation practices of HAPNP because they are not driving adequate benefit from this protected area. Coservation alone has no benefit for them if it could not provide them different benefits including employment opportunity for local people (Pathak and Ashish, 1998).

Furthermore, perceived benefits from the Park were more skewed toward less educated people with low social status. Relatively more educated people from HAPNP expect to obtain the neccessary benefit (tourism activity benefit, employment opportunity and others). This finding was different from the findings of Shahi *et al*. (2022) in that the benefit focuses towards well educated and higher social class.

Males and females living in and around protected areas have different attitudes, and it is critical to recognize and take these variations into account in order to effectively participate in the protection and sustainable use of natural resources. Typically, men are more involved in the commercial exploitation of natural resources than women. This will happen because women spend more time on household tasks like cooking, gathering fuel and water, taking care of children, etc (Sass, 2002).

Less opportunity has existed for women to be involved in environmental decision-making. Because of this, when policies are being developed, their opinions and interests are occasionally disregarded or left out (Sass, 2002). Lack of opportunity is frequently caused by cultural constraints, women's low self-esteem, and lack of education, while other situations may also be the result of logistical issues. Projects that have implemented gender parity and encouraged women's participation have been more successful and well-rounded from the perspective of conservation (Biermayr-Jenzano, 2003).

6. Conclusion and reccomendations

Conclusion

The estimated population during current study show reduction compared to previous study. Although Grevy's zebra populations have declined markedly throughout their range, it is not too late to prevent them from extinction. With adequate protection and management, there is no reason why these populations should not endure.

Greater population of Grevy's zebra was counted during the wet season. This might imply that during the dry season the Grevy's zebras may travel long distance out of protected area. Fewer individuals of Grevy's zebras with more groups were counted during the dry season. This might be a copyingstrategy adopted by Grevy's zebra to overcome the shortage of resources during a season.

Grevy's zebra is investing most of its time on energy consuming activities. This has bad implication to have healthy population of Grevy's zebra in HAPNP.

Grazing habitat of Grevy's zebra is diminishing in size due to land conversion. This will affect the future conservation fate of Grevy's zebra in the area.

Conservation of Grevy's zebra is challenged by many threats in HAPNP. If attention is not given the continual survival of the species in the area will encounter severe problems. This study showed that the benefit from HAPNP is the main determinant factor of conservation participation.

Recommendations

The researcher forwarded the following recommendations to the concerned bodies based on the findings of the study:

- Heavy grazing by domestic animals and wildlife populations may encourage bush encroachment, hence decreasing the area that zebras can graze on effectively. As a result, planned grazing of livestock should be required in HAPNP for conservation of the population of Grevy's zebra in the Halladghe plains in view of expecting disease transmission and competition for food, space and cover.
- Although further study is required on strategies regarding how to utilize part of protected area, the Park can be expanded to the Blen hot spring and associated wetlands to include potential ranges of Grevy's zebra population.
- Participation of different stakeholders through community based conservation activities is expected in HAPNP for the Grevy's zebra populations sustainable survival.
- The current study employed ground tracking of Grevy's zebra to determine seasonal home range and diurnal activities time budget. Ground tracking was expensive and requires extra labour. Because of these limitations of ground tracking surveys, it would be ideal to combine with other survey tools such as telemetry surveys and direct observations in the future.
- Grassland habitat restoration activities should be initiated to increase the grazing land for Grevy's zebras and other grazers found in the protected area.
- Government sectors, NGOs and conservationists operating in and around the protected area need to develop integrated development plan to save the Park and its resources from destrucion.
- Government should give special emphasis to the area to solve the problem observed in areas of law enforcement (capacitating staffs through capacity building training delivery, availing modern monitoring equipment and hire sufficient staffs or scouts).

- The current study did not investigate the impact of LULCC in HAPNP. Therefore, future study can be conducted to analyse the impact of landuse land cover change on wildlife.
- Local support for conservation should be ehanced through the provision of benefits from systematic resource utilization in the respective zones of the HAPNP or community support programmes.
- HAPNP conservation programmes should not concentrate to only nearby Kebeles but should be spread out to include more areas.

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Appendix

Appendix 1 Photos of Grevy's zebra, adult male (a) and adult female (b) and juvenile (c) (Photo by: Tolera Abirham, 2022).

a)  b)  c) 

Appendix 2. Focus Group Discusion with local community representatives.

Appendix 3. Grevy's zebra presence and absence observation with Park staffs

Appendix 4. Geographic coordinates of transects.

Transect ID	Start point		End point	
	X	Y	X	Y
T1	649212	1026199	652737	1023472
T2	654269	1024049	650819	1026679
T3	651431	1028274	655118	1026809
T4	656090	1028084	650316	1030948
T5	638017	1012993	645707	1016402
T6	646078	1018003	642778	1017717
T7	641708	1018998	644708	1023160
T8	650882	1032326	656413	1030388
T9	657091	1031992	651986	1034856
T10	653301	1036187	657680	1032950
T11	658697	1033923	654758	1038422

T12	653683	1053811	659457	1056969
T13	660421	1057549	662367	1055527
T14	661664	1054702	657804	1048998
T15	649213	1014417	650419	1015880

Appendix 5. Sample transect walk undertaken during counting of Grevy's zebra.

Appendix 6. Activity time budget recording datasheet format.

Site name_____group ID_____group size_____ member: Adult Male_____

Adult Fmale_____Subadult_____Juvenile_____Weather_____

date _____

TIME INTERVAL (a day)	DURATION (minutes)	Start Time Min	How many minutes or seconds of 10 minutes used for each activity budget											
			Moving		Grazing		Resting		Grooming		Mating		Other activities	
			ST	ET	ST	ET	ST	ET	ST	ET	ST	ET	ST	ET
00:00-00:1:00	10	0												
		1												
		2												
		3												
		4												
		5												
		6												
		7												
		8												
		9												
		10												
00:10-00:15		Resting time for researchers												
00:15-00:25	10													
00:25-00:30	5	Resting time for researchers												
00:30-00:40	10													
00:40-00:45	5	Resting time for researchers												
00:45-00:55	10													
00:55-01:00	5	Resting time for researchers												

ST- Start Time ET-End Time

Appendix 7. Researcher observing the activity of Grevy's zebra on a hill.

Appendix 8. Survey tool used in English language

Informed Consent form

Name of researcher: Tolera Abirham

Name of main advisor: Professor Afework Bekele

Name of co-advisor: Mesele Yihune (Dr)

I am Tolera Abirham PhD student at Addis Ababa University. I am doing research on population status of Grevy's zebra, diurnal activity time budget of Grevy's zebra, and local community attitude towards HAPNP and its management. Furthermore, we are collecting data on Trends of land cover change of HAPNP and conservation threats of Grevy's zebra/Equus grevyi / in HAPNP, Ethiopia.

I am going to give you information and invite you to be part of this research. You do not have to decide immediately whether or not you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research. This consent form may contain words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain.

Grevy zebra is an endangered animal that is found only in Ethiopia and Kenya. Its number is minimal in Ethiopia. This animal is threatened by different factors however these factors are not well studied and there is no update information about the threats in your area. I want to identify the threats and ways to stop from happening. Conservation of Grevy's zebra without the local community participation is unthinkable. So the purpose of the study is to know the level of local community participation in conservation of wildlife in the HAPNP and propose the ways forward for concerned body.

This research will involve your participation in a group discussion that will take about one and a half hour, and a one hour interview. You are being invited to take part in this research because we feel that your experience as wildlife stakeholders (responsible citizens) can contribute much to our understanding and knowledge of local practices.

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. If you choose not to participate all the services you receive at this Centre will continue and nothing will change. The choice that you make will have no bearing on your job or on any work related evaluations or reports. You may change your mind later and stop participating even if you agreed earlier.

There will be no direct benefit to you, but your participation is likely to help us find out more about how to prevent the declining of Grevy's zebra and promote sustainable conservation of wildlife in HAPNP.

We will not be sharing information about you to anyone outside of the research team. The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and I will lock that information up with a lock and key. It will not be shared with or given to anyone.

I have been invited to participate in research about assessment of population status of Grevy's zebra, diurnal activity time budget of Grevy's zebra, and local community attitude towards HAPNP and its management. Furthermore, Trends of land cover change of HAPNP and conservation threats of Grevy's zebra/Equus grevyi / in HAPNP, Ethiopia.

I have read (I have witnessed the accurate reading) the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study

Name of participant _____ date_____ signature _____

Start time _____end time _____ date_____location _____

Part 1: Socio- demographic Background of Participant

1.1.Woreda name _____

1.2.Kebele name _____

1.3.Age _____

1.4.sex_____

1.5.Education status _____

1.6.Job _____

1.7.Family size _____, male _____female_____

1.8.Means of income _____,_____,_____,_____

1.9.Livestock type and number _____,_____,_____,_____

1.10. Position _____

1.11. Distance from head quarter of the park

Part 2: Conservation Threats

You are asked to rank the conservation threat from 1-5. 1 indicates the factor is not as such hindering the impact on conservation of Grevy's zebra and you are also expected to rank it for other wild animal found in the park too. 5 indicate the factor has severe impact on conservation of Grevy's zebra and other wild animals found in the park too. Accordingly,

1- strongly disagree
2- disagree
3- neutral
4- agree
5- strongly disagree

Conservation threats	Grevy's zebra	Other wild animals
Habitat degradation		
Poaching		
Drought		
Disease		
Hybridization		
Predation		
Roadside killing		
Poor attention given from government		
Shortage of budget		
Poor low enforcement		
Un-integrated development practices		

Part 3: Explore ways of local community participation

3.1.Do communities in this area participate in wildlife conservation activities that were under taken in this area?

- ✓ Yes
- ✓ no ,
- ✓ if yes how do they participate_____ ,
- ✓ if no why,_____

3.2.Do communities get any benefit due to participation in conservation of wildlife?

- ✓ yes
- ✓ no,

- ✓ if yes what benefit you get ,
- ✓ if no what should be done?_____

3.1. What benefit local communities are getting from Alledeghi plain currently?

_____
_____
_____

3.2. In what ways local communities are participating in the conservation of Grevy's zebra and other wildlife found in this area?

_____
_____
_____
_____

3.3. In what ways local community need to participate in conservation of wildlife in this area to the future case?

_____
_____
_____

3.4. What bylaws/local taboos/ are there in these areas that support the conservation of grevy zebra and others in the protected areas

_____
_____
_____
_____

3.5. List the wild animal species that you know and observed in Alledeghi AsebotProposed National Park

_____
_____
_____

3.6. What do you think the role of local community, government and other NGOs to promote the local community participation in conservation?

_____
_____
_____
_____

3.7.What wildlife species do you know in HAPNP?

_____

3.8.If you were participating in conservation activities that were implemented in HAPNP, please mention in which activities you were participated.

_____

3.9.If you were paying cost due to presence of HAPNP, please mention types of cost you were paying.

_____

3.10. If you drive benefit from HAPNP, Please mention them.

_____

3.11. What factors influenced you to have positive or negative attitude for the HAPNP?

_____

3.12. What factors influence you to have positive or negative attitude for the staffs of HAPNP?

_____

Part 4. Grevy's zebra focused questions

4.1. What is the recent time you observed Grevy's zebra?

_____

_____

4.2. How many individual do you observed?

Total_____ male_____female_____, unidentified _____

In terms of age structure adult_____sub adult _____juvenile _____unidentified _____

4.3. When you compare the Grevy's zebra population about 10 years ago with current one do you think it is increasing, decreasing or stable?

_____

_____

_____

_____

4.4. If the population of Grevy's zebra is decreasing what do you think the factors behind?

_____

_____

_____

4.5. If the population of Grevy's zebra is increasing what the suitable condition is there that favor the population existence?

_____

_____

_____

4.8. Do Grevy's zebra make composition with other wild animal species during feeding? If yes, with which species it form composition most of the time

_____

_____

_____

4.9. What behavior Grevy's zebra shows in the existence of cattle, human being and on road movement of people and car?

_____

_____

_____

4.10. What do should be done to promote sustainable conservation of Grevy's zebra in this protected area?

_____
_____
_____

Binomial question

a. Do you drive benefit from HAPNP? ☐ Yes ☐ No
b. Have you paid any cost due presence of HAPNP? ☐ Yes ☐ No
c. Do you have any experience of conflict from wildlife found in HAPNP? ☐ Yes ☐ No
d. Do you participate in conservation activities of HAPNP? ☐ Yes ☐ No
e. Do you have compliance with regulation of HAPNP? ☐ Yes ☐ No
f. Have you received conservation awareness so far from HAPNP? ☐ Yes ☐ No

Lickert scale questions

Items	**1 SD**	**2 D**	**3 N**	**4 Ag**	**5 SA**
Wildlife are important and should be protected					
People and wildlife can live together in way of harmony(coexist)					
Local people have positive attitude for the HAPNP					
Local people have positive attitude for the staffs of HAPNP					
Local people have good relationship with HAPNP staffs					

SD: Strongly Disagree, D: disagree, N: Neutral, Ag: Agree, SA: Strongly agree

Appendix 9.Survey tool translated to afarigna language

Dariifah ayyuntaa kee maftacah tan xaagoyso yacee marih mablâ-garayat gaba tassagalleh tani xaagoysol rakitak aban sittingey cibta.

Barteeni migaq:- Toleera Abraha

Maytanî kassaloyse:- Porofesser Afworki Bakkale

Qokol kassaloyse:- Massale Yihune (D.r)

Yoo toleera Abrahaam Axxis Ababah jaamiqatak xoktireet barteena kinniyo. Alaydagi asaboot hangit haak Itiyoppiyak Agat parkil baaxô dananaay, lawlî caalataay, dariifah ayyuntih gaba aglee kee dacayri bohoyittel kusaq abak geytima.

Takusaq wagittaamal xaagoyso koh aceem faxaamih sabbatah, ta kusaaqat gaba tassagalluh koo aqzume. Fokkaaqot gaba tasgallem kee assagallewaytamih margaqa beytam asaaku hinna. Ta margaqa beytak naharat kusaq wagittaamal faxe num lih agaaraddam xiqtah. Ta idnissô cibti atu afhime wayta qangor yanim xiqqimtaamih sabbtah ta koh baxxaqimewayteemik addâ fakoot abuh too aracal yoo soolisak esserittam xiqtah.

Gireev zebra Itiyoppiyaa kee keeniyal dibuk geytimtah tan samad kak bayak geytimah yan dubaala. Itiyoppiyah addal kak geytimtam kaxxam dagoomu. Ta dubaali baxaabaxsa le sababittek ugutak bohoy gubat culeh geytima. Takkay ikkah ta caagiida nagay kusaaqiseweenim kee sin dariifal yanih yan bohoyittek wuli qaynatih qasri xaagoyso/qusba xaagoyso/ matan. Takkeh tan calwayittee kee elle takke gititte meexam faxa. Dariifâ marih gabat agle maliinoh baaxô danan wadaanam takkem hinna. Tonna kinnuuk, fokkaaqok hadaf Alaydagi Agat Parki hangit haak kay addal garbô dubaalih dacayril dariifah ayyuntih gabat agleh caddo yaaxigeenim kee wagsiisah yan dagar foocâ fan edde gexah yan gita fiirisaanama.

Ta kusaq inki, saaqat kee garab beyah yan hortâ walal kee inki saaqatih mablâ-garayat ku gabat agle edde tan. Ta kusaaqat gabat tassagalluh koo naqzume. Toh akah kinnim, inki garbô dubaalih maglableela (akah esserimah yan dagar) abak raag dariifâ gexsitil tû-cubbus kee ixxigal rakittaanam fayya le doori leh tanim naabbeemih sabbata.

Ta fokkaaqoh addal taalluwaytah tan gabat agle inki gabuuk sinni labbatak abataama. Gaba edde tassagallem kee assagallewaytam ku dooriti. Ta fanteenal geytah tan ayfaafayitte inkih akket gaba assagallewaytaamah taggiriqem hinnaay, tassagalleemih taggiriqqem hinna. Tu elle gexak sugteh tan gurral gexak raqtaah, milaagimtam mali. Beyteh tan doorit taamaa kee taamat axaw le caagiidal wuli qaynatih taqabiy kataysa mali. Tonnah, naharal oggolteh qembissaamah kot gexewaytam tenek, gabat agle targiqem/soolissam duuddaamih gar lito.

Ta kusaaqat gabat agle haysittaamah, wuli qaynatih tuxxiq kee tû-xagootuy saanih akak geytah tani matan. Takkay immay, ku gabat agle greev baaxô danan samad mannal wadaanam xiqaanam kee Alaydagi asaboot poroposed Agat Parkih addal maytanî dacayri akah abaanah yanin garbô dubaala mannal yaynabeenim naaxaguh yayse gurral nee cattu xiqta.

Ayyunti addal gexsitah yan kusaq hangi hirigu xiqaamih sabbatah, ayyunti dagortiy kok kalah tanih tani atu gabat agle edde haysittek esseroora ugusaanam xiqan. Ku xaagoyso ta xaagoysoh hortak iroh wuli maral matabataay, edde miyaaban. Ta fokkaaqoh cugaysok gaabosnah nan xaagoyso sirri le gital daccarsimele. Koo wagisissah tan xaagoyso ku migaq hinnay, tohih aftok nibro edde anele. Ta nibro maca kinnim kee ku nibro kinnim taaaxigem dibuk fokkaaqo abeyniiti. Ta xaagoysot faxximtah tan

xaagoyso abak maftacat haanam akkele. Tah yaanam wuli marat matabsaanaay wonna hinnay, miyacaan.

Ta fokkaaqoh ukummo Axxis Abaabah Jaamiqatak IRB abaluk faaticime. Ta makaado fokkaqot gabat agle haysittah tan maritte calwayak ken catoonuh saffos taama abatah tan makaado. IRB wagittaamal ossotinah esseroora teellek wonna hinnay, geytam faxxek sugmenta keenik Axxis gambiik geytu xiqta.

Itiyoppiyak, Alaydagi Asaboot poroposed Agat Parki, Giriivi baaxô danan qadadaay, makmok maaqaboh caalataay, daariifah ayyuntih gabat aglee kee griiv baaxô danan/eqhuus griiv dacayrî bohoyitte wagittaamal yakkeh yan kusaaqat gaba assagalluh yoo yuqzumen.

Dagal tan xaagoyso ikriyeeh, (massah tanim kak ismiteeh) wonna hinnay, yoh kawsimteh. Tah wagittaamal essero esseraamih saami geeh, faxe qaynatih esseroy yoo essereenih yaniini ruffa yoo hayte. Ta kusaaqat/fokkaaqot gaba assagalluh inni labbataak edde bice.

Gabat agle edde haa numih migaaqa_____Ayro_____Sumaqta

Edde qembise uddur_____Gaba edde kale uddur _____ Ayro_____Arac _____ Amôladi tû-mabul_____

1haytoh Exxa: Gaba tassagallok numtin amô xaagoyso

1.1. Daqar migaq _____
1.2. Awdâ migaq_____
1.3. Karmá _____
1.4. Nado____
1.5. Barittô caalat_____
1.6. Taamá_____
1.7. Buxâmarih qadad _____,Labha _____Sayyo_____
1.8. Culenti raceenaani_____, _____,_____,_____
1.9. _Saqi qaynat kee ixxima_____,_____,_____,____
1.10. Arac_____

2 haytoh exxa:- Dacayrî bohoyitte

Dacayrî bohoyitteh 1-5 fan tan caddo tacoonu sin essera. 1 wagsiisah yanim sabab kak griiv baaxô danan dacayril tanih tan taqbitte gexe kalit akke sinnim kee atu kaadu parki addal geytimtah tan gersi dubaalittek caddo akah tabbixeh tan innal daccayrimta. 5. Sabab kak Parki addl geytimtah tan baaxô danan kee gersi dubaalitteh dacayril kaxxa taqabi yanim tambulle. Tahak ugutak caddo kah yaceenim aba.

1 - Inkinnah moggola
2 - Moggola
3 - Tut maana/tu maxca
4 - Oggolah
5 – **Inkinnah moggola**

Admó
Qabaara
Biyaaka
Samad asgolla
Admo abeeniti
Giti qaxih qidimi/ raba./
Doolat gambik keenih yeceen hangi kaxxa boola leemi.
Miizaaniyyat dagna
Qaku le abnisso
Koobaahime wayte daaddos abtoota

3 haytoh Exxa:- Dariifah ayyuntih gabat agleh gorantoh gititte.

3.1. Ta dariifal yanih yan ayyunti , ta dariifal takkeh tan dubaali dacayrih taamat gabat agle loonuu?

- ✓ Yeey
- ✓ Bale
- ✓ Yeey tekkek, mannal gabat agle haysitaanaa?_____
- ✓ Akkewaytek macahaay?_____

3.2. Dubaali dacayrit gaba yassagalleenim ayyuntah tuxxiq lee?

- ✓ Yeey
- ✓ Bale
- ✓ Yeey tekkek macâ tuxxiq kak geyaanaa?_____
- ✓ Akkewaytek maca abaanam faxximtaa?_____

3.3. Dariifah ayyunti Alaydagi booxak macâ tuxxiq geyaanaa?

_____

_____

__

3.4. Dariifah ayyunti ta dariifal geytimtah tan Griiv baaxô danan kee gersi dubaali dacayrit gaba elle yassagalleenim magitaay?

_____

_____

_____

3.5. Fooca fanah dariifah ayyunti ta dariifah dubaalih dacayrot gabat agle elle haysitam faxximtam magititteey?

_____

_____

3.6. Ta dariifal griiv baaxô danan kee gersi dubaalitteh dacayri qokolah yan maqaynatih edde xinti madqooqi maay tan?

_____

_____

_____

3.7. Alaydagi asaboot poroposix Agat Parkih addat taaxigeenim kee tableenih tanin dubaala roorisa

_____
_____
_____
3.8. Dariifah ayyunti doolat kee doolat akke sinni massoynaani dariifah ayyunti dacayrî gabat agle fayya hayoonuh macâ doori loonum siinit celtaa?
4 haytoh Exxa:- Griiv baaxô danan wagitta esseroora
4.1. Griivi baaxô danan xayi udduurah addat teetik tubleenim magide takkee?
_____
_____
4.2 **Maanxulle mari yublee?**
Sittat _____Labha ____Sayyo_____, Amixxigewaytaama_____
Karmâ caddo: Furraynu____ Cataytu _____ Qunxaaneyta_____Matamixxiga _____
4.3. Tabna sanatak fal sugteh tan baaxô danan qadad away yan qadadalluk qalalisnah nan waqdi, ossimeh innaa yunkusem siinit celtaa?
_____
_____
_____
_____
4.4. Griivi baaxô danan qadad ankasuk gexaa kaa tekkek darret macâ sabab kak yanim siinit celtaa?
_____
_____
_____
4.5. Griivi baaxô danan qadad ossimak gexaa kaa tekkek, tah qokolah yan meqe caalat macaay?
_____
_____
_____
4.6. Griivi baaxô danan kak iyyan dubaala taaxigee?
Macayakmee_____
_____
4.7. Mango adda tublen kaa tekkek griivi baaxô danan uddur elle tatrussam maqaynatih abtooy?
_____
_____
_____
4.8. Griivi baaxô danan qayso yakmen waqdi, gersi dubaalalih yangalee?

Yeey tekkek, maqaynatih dubaala lih xayyoowaanaa?

_____
_____

4.9. Sehdayti baxaay, laa kee makiina gital Giriivi baaxô danan taybulleeh yan yan caalat maca ceelaa?

_____
_____
_____

4.10. Ta gasoh addal griiv baaxô dananah maytanî dacayri baarisoonuh maca abaanam faxximtaa?

_____
_____
_____

Appendix 10. Grevy's zebra diurnal activity time budget data analysed

>grazing<-read.csv("Grazing_season.csv", header = T)

```
> str(grazing)
'data.frame':         18 obs. of  3 variables:
 $ Season    : chr  "Wet" "Wet" "Wet" "Wet" ...
 $ Sex       : chr  "Female" "Male" "IND" "Female" ...
 $ Proportion: num  2.23 2.2 2.09 2.21 2.23 ...
> graz.aov<-aov(Proportion~Season+Sex, data=grazing)
> summary(graz.aov)
             Df   Sum Sq   Mean Sq  F value   Pr(>F)
Season       1    0.05123 0.05123    27.147    0.000132 ***
Sex          2    0.03523 0.01762     9.336    0.002653 **
Residuals   14  0.02642 0.00189
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> TukeyHSD(graz.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Season + Sex, data = grazing)
$Season
                diff            lwr         upr               p adj
Wet-Dry  -0.1066955 -0.1506164 -0.06277471 0.0001321
$Sex
                     diff             lwr                upr           p adj
IND-Female  -0.094910209 -0.16055230 -0.02926812 0.0053449
Male-Female -0.002147659 -0.06778975  0.06349443 0.9959666
Male-IND     0.092762550   0.02712046  0.15840464 0.0063088
```

>graz.lm<-lm(Proportion~Season+Sex, data=grazing)

```
> anova(graz.lm)
Analysis of Variance Table
Response: Proportion
            Df   Sum Sq    Mean Sq   F value    Pr(>F)
Season      1    0.051228 0.051228 27.1469 0.0001321 ***
Sex         2    0.035235 0.017617  9.3359 0.0026526 **
Residuals 14  0.026419 0.001887
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

> grooming<-read.csv("Grooming_season.csv", header = T)

```
> grom.aov<-aov(Proportion~Season+Sex, data=grooming)
> summary(grom.aov)
             Df    Sum Sq  Mean Sq  F value   Pr(>F)
Season       1     0.6769   0.6769     24.082   0.000231 ***
Sex          2     0.0653   0.0327     1.162     0.341393
Residuals  14   0.3935   0.0281
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> TukeyHSD(grom.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Season + Sex, data = grooming)
$Season
              diff            lwr           upr            p adj
Wet-dry    0.3878417   0.2183337  0.5573498  0.0002311
$Sex
                    diff                lwr         upr            p adj
```

```
IND-Female    0.05663156 -0.1967075 0.3099706  0.8302103
Male-Female  -0.08966630 -0.3430054 0.1636728  0.6332046
Male-IND     -0.14629786 -0.3996369 0.1070412  0.3155940
> grom.lm<-lm(Proportion~Season+Sex, data=grooming)
> anova(grom.lm)
Analysis of Variance Table

Response: Proportion
           Df    Sum Sq  Mean Sq   F value    Pr(>F)
Season     1   0.67690  0.67690    24.0822   0.0002311 ***
Sex        2   0.06530  0.03265    1.1616     0.3413928
Residuals 14  0.39351  0.02811
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

>mating<-read.csv("Mating_season.csv", header = T)

```
> mat.aov<-aov(Proportion~Season+Sex, data=mating)
> summary(mat.aov)
             Df   Sum Sq    Mean Sq   F value   Pr(>F)
Season       1    1.3699     1.3699      24.850    0.0002 ***
Sex          2    0.6854     0.3427      6.216      0.0117 *
Residuals   14    0.7718     0.0551
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> TukeyHSD(mat.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Season + Sex, data = mating)
$Season
               diff            lwr            upr          p adj
Wet-dry  -0.5517413 -0.7891282 -0.3143545 2e-04
$Sex
                   diff               lwr               upr          p adj
IND-Female  -0.41975232 -0.77453995 -0.0649647 0.0202100
Male-Female -0.01189265 -0.36668028  0.3428950 0.9957668
Male-IND     0.40785967    0.05307205   0.7626473 0.0239085
> mat.lm<-lm(Proportion~Season+Sex, data=mating)
> anova(mat.lm)
Analysis of Variance Table
Response: Proportion
           Df  Sum Sq   Mean Sq  F value   Pr(>F)
Season     1   1.36988   1.36988   24.8500  0.00020 ***
Sex        2    0.68537   0.34268  6.2163    0.01169 *
Residuals 14  0.77177   0.05513
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

>moving<-read.csv("Moving_season.csv", header = T)

```
> mov.aov<-aov(Proportion~Season+Sex, data=moving)
> summary(mov.aov)
             Df      Sum Sq   Mean Sq    F value Pr(>F)
Season       1    0.01733     0.017326   5.550    0.0336 *
Sex          2    0.03499     0.017494   5.604    0.0163 *
Residuals   14  0.04371     0.003122
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> TukeyHSD(mov.aov)
```

```
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Season + Sex, data = moving)
$Season
                diff        lwr              upr            p adj
Wet-dry -0.06204953 -0.1185408 -0.005558215 0.0335891
$Sex
                    diff                 lwr               upr                 p adj
IND-Female  -0.0936902535 -0.178119605 -0.009260902 0.0291719
Male-Female -0.0003285845 -0.084757936  0.084100767 0.9999428
Male-IND     0.0933616690  0.008932317  0.177791021 0.0297415
>mov.lm<-lm(Proportion~Season+Sex, data=moving)
> anova(mov.lm)
Analysis of Variance Table
Response: Proportion
            Df   Sum Sq    Mean Sq      F value   Pr(>F)
Season     1      0.017326  0.0173256  5.5499   0.03359 *
Sex         2      0.034989  0.0174944  5.6039   0.01630 *
Residuals 14    0.043705 0.0031218
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

>other<-read.csv("Other_season.csv", header = T)

```
> oth.aov<-aov(Proportion~Season+Sex, data=other)
> summary(oth.aov)
             Df    Sum Sq    Mean Sq   F value   Pr(>F)
Season       1     0.5938     0.5938      80.140    3.61e-07 ***
Sex          2     0.0742     0.0371      5.006      0.0229 *
Residuals   14   0.1037     0.0074
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> TukeyHSD(oth.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Season + Sex, data = other)
$Season
            diff          lwr           upr            p adj
Wet-dry 0.3632558 0.2762251 0.4502865 4e-07
$Sex
                   diff                lwr               upr                p adj
IND-Female   0.133583149  0.003511003  0.263655295 0.0438491
Male-Female -0.005069489 -0.135141635  0.125002657 0.9942821
Male-IND     -0.138652639  -0.268724784  -0.008580493 0.0362195
> oth.lm<-lm(Proportion~Season+Sex, data=other)
> anova(oth.lm)
Analysis of Variance Table
Response: Proportion
            Df     Sum Sq   Mean Sq   F value    Pr(>F)
Season     1      0.59380   0.59380   80.1398   3.614e-07 ***
Sex         2      0.07419   0.03709  5.0064    0.0229 *
Residuals 14     0.10373   0.00741
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

>resting<-read.csv("Resting_season.csv", header = T)

```
> rest.aov<-aov(Proportion~Season+Sex, data=resting)
> summary(rest.aov)
```

```
              Df     Sum Sq    Mean Sq   F value   Pr(>F)
Season        1      0.03729   0.03729   57.02     2.66e-06 ***
Sex           2      0.05777   0.02889   44.18     8.96e-07 ***
Residuals     14     0.00915   0.00065
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> TukeyHSD(rest.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Season + Sex, data = resting)
$Season
              diff            lwr              upr          p adj
Wet-dry  0.09102547  0.06517152  0.1168794  2.7e-06
$Sex
                diff        lwr        upr     p adj
IND-Female   0.12800556  0.08936541  0.16664570 0.0000015
Male-Female  0.01759007 -0.02105007  0.05623022 0.4772179
Male-IND    -0.11041549 -0.14905563 -0.07177534 0.0000084
> rest.lm<-lm(Proportion~Season+Sex, data=resting)
> anova(rest.lm)
Analysis of Variance Table
Response: Proportion
              Df   Sum Sq     Mean Sq    F value    Pr(>F)
Season        1     0.037285  0.037285  57.022    2.664e-06 ***
Sex           2     0.057773  0.028886  44.177    8.957e-07 ***
Residuals 14     0.009154  0.000654
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Age versa diurnal activity

```
> grazing<-read.csv("Grazing_age.csv", header = T)
> str(gra)
'data.frame':         24 obs. of  2 variables:
 $ Age       : chr  "AF" "AM" "SA" "JU" ...
 $ Proportion: num  2.23 2.2 2.21 1.92 2.21 ...
> gra$Age<-factor(gra$Age)
> grazing.aov<-aov(Proportion~Age, data = gra)
> summary(grazing.aov)
              Df    Sum Sq    Mean Sq    F value      Pr(>F)
Age           3     0.2638      0.08794     13.73        4.3e-05 ***
Residuals 20    0.1280      0.00640
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> TukeyHSD(grazing.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Age, data = gra)
$Age
               diff                 lwr           upr               p adj
AM-AF  -0.002147659  -0.1314478  0.1271525   0.9999626
JU-AF    -0.248745321  -0.3780454  -0.1194452  0.0001559
SA-AF   -0.019626410  -0.1489265   0.1096737   0.9735525
JU-AM  -0.246597662  -0.3758978   -0.1172975  0.0001730
SA-AM  -0.017478751  -0.1467789   0.1118214   0.9810228
```

```
SA-JU     0.229118911    0.0998188   0.3584190   0.0004061
>grazing.lm<-lm(Proportion~Age, data = gra)
> anova(grazing.lm)
Analysis of Variance Table
Response: Proportion
           Df  Sum Sq     Mean Sq    F value     Pr(>F)
Age         3     0.26381    0.087938   13.735    4.305e-05 ***
Residuals  20   0.12804   0.006402
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> par(mfrow = c(1, 1)) # This code put two plots in the same window
> hist(grazing.aov$residuals)
> plot(grazing.aov, which = 2)
> plot(grazing.aov, which = 1)
> boxplot(Proportion~Age, data = gra, ylab = "Proportion of time spent on grazing", xlab = "Age")
```

> grooming<-read.csv("Grooming_age.csv", header = T)

```
> gro$Age<-factor(gro$Age)
> grooming.aov<-aov(Proportion~Age, data = gro)
> summary(grooming.aov)
           Df    Sum Sq   Mean Sq    F value   Pr(>F)
Age         3     0.716      0.2386      1.134       0.359
Residuals   20    4.207      0.2104
> TukeyHSD(grooming.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Age, data = gro)
$Age
             diff                lwr             upr              p adj
AM-AF    -0.089666297  -0.8308140  0.6514814   0.9862306
JU-AF     -0.448980942  -1.1901286  0.2921667   0.3518822
SA-AF     -0.087404162  -0.8285518   0.6537435   0.9872157
JU-AM    -0.359314645  -1.1004623   0.3818330   0.5393343
SA-AM    0.002262135   -0.7388855   0.7434098   0.9999998
SA-JU      0.361576780  -0.3795709     1.1027245   0.5342432
> grooming.lm<-lm(Proportion~Age, data = gro)
> anova(grooming.lm)
Analysis of Variance Table
Response: Proportion
           Df            Sum Sq     Mean Sq     F value    Pr(>F)
Age         3             0.7157       0.23856     1.1341     0.3592
Residuals  20 4.2070  0.21035
> par(mfrow = c(1, 1)) # This code put two plots in the same window
> hist(grooming.aov$residuals)
> plot(grooming.aov, which = 2)
> plot(grooming.aov, which = 1)
> boxplot(Proportion~Age, data = gro, ylab = "Proportion of time spent on grooming", xlab = "Age")
```

> mating<-read.csv("Mating_age.csv", header = T)

```
> mat$Age<-factor(mat$Age)
> mating.aov<-aov(Proportion~Age, data = mat)
> summary(mating.aov)
           Df    Sum Sq    Mean Sq    F value  Pr(>F)
Age         3     0.9146      0.3049       2.75     0.0697 .
Residuals   20 2.2172  0.1109
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
> TukeyHSD(mating.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Age, data = mat)
$Age
             diff           lwr               upr         p adj
AM-AF -0.01189265 -0.5499349 0.5261496   0.9999120
JU-AF   -0.41975232 -0.9577946 0.1182899   0.1620036
SA-AF  -0.36958066 -0.9076229 0.1684616    0.2505032
JU-AM  -0.40785967 -0.9459019 0.1301826    0.1803509
SA-AM  -0.35768801 -0.8957303 0.1803543    0.2758769
SA-JU     0.05017167 -0.4878706 0.5882139     0.9935690
> mating.lm<-lm(Proportion~Age, data = mat)
> anova(mating.lm)
Analysis of Variance Table
Response: Proportion
           Df   Sum Sq    Mean Sq  F value  Pr(>F)
Age        3    0.9146     0.30486     2.75     0.06965 .
Residuals 20   2.2172     0.11086
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> par(mfrow = c(1, 1)) # This code put two plots in the same window
> hist(mating.aov$residuals)
> plot(mating.aov, which = 2)
> plot(mating.aov, which = 1)
> boxplot(Proportion~Age, data = mat, ylab = "Proportion of time spent on mating", xlab = "Age")
```

> moving<-read.csv("Moving_age.csv", header = T)

```
> mov$Age<-factor(mov$Age)
> moving.aov<-aov(Proportion~Age, data = mov)
> summary(moving.aov)
              Df     Sum Sq    Mean Sq    F value    Pr(>F)
Age           3      0.6103    0.20342      54.07    8.91e-10 ***
Residuals   20     0.0752     0.00376
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> TukeyHSD(moving.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Age, data = mov)
$Age
               diff                 lwr              upr              p adj
AM-AF   -0.0003285845  -0.09944598   0.09878882  0.9999997
JU-AF    -0.3616363668  -0.46075377  -0.26251897  0.0000000
SA-AF     0.0188882400  -0.08022916    0.11800564  0.9498906
JU-AM    -0.3613077823  -0.46042518   -0.26219038  0.0000000
SA-AM     0.0192168245  -0.07990058   0.11833422    0.9474476
SA-JU       0.3805246068   0.28140721   0.47964201     0.0000000
> moving.lm<-lm(Proportion~Age, data = mov)
> anova(moving.lm)
Analysis of Variance Table
Response: Proportion
              Df    Sum Sq   Mean Sq      F value    Pr(>F)
Age           3     0.61027   0.203425    54.072     8.91e-10 ***
Residuals  20     0.07524    0.003762
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
> par(mfrow = c(1, 1)) # This code put two plots in the same window
> hist(moving.aov$residuals)
> plot(moving.aov, which = 2)
> plot(moving.aov, which = 1)
> boxplot(Proportion~Age, data = mov, ylab = "Proportion of time spent on moving", xlab = "Age")
```

> other<-read.csv("Other_age.csv", header = T)

```
> oth$Age<-factor(oth$Age)
> other.aov<-aov(Proportion~Age, data = oth)
> summary(other.aov)
             Df  Sum Sq  Mean Sq  F value  Pr(>F)
Age           3  0.2004  0.06681     1.43   0.264
Residuals    20  0.9342  0.04671
> TukeyHSD(other.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Age, data = oth)
$Age
              diff         lwr        upr     p adj
AM-AF  -0.005069489 -0.3543180  0.3441790 0.9999750
JU-AF   0.210802291 -0.1384462  0.5600508 0.3549453
SA-AF   0.004823271 -0.3444253  0.3540718 0.9999785
JU-AM   0.215871780 -0.1333767  0.5651203 0.3350543
SA-AM   0.009892761 -0.3393558  0.3591413 0.9998149
SA-JU  -0.205979019 -0.5552275  0.1432695 0.3744944
> moving.lm<-lm(Proportion~Age, data = mov)
> anova(moving.lm)
Analysis of Variance Table
Response: Proportion
          Df  Sum Sq  Mean Sq F value   Pr(>F)
Age        3 0.61027 0.203425  54.072 8.91e-10 ***
Residuals 20 0.07524 0.003762
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> par(mfrow = c(1, 1)) # This code put two plots in the same window
> hist(other.aov$residuals)
> plot(other.aov, which = 2)
> plot(other.aov, which = 1)
> boxplot(Proportion~Age, data = oth, ylab = "Proportion of time spent on other", xlab = "Age")
```

> resting<-read.csv("Resting_age.csv", header = T)

```
> res$Age<-factor(res$Age)
> resting.aov<-aov(Proportion~Age, data = res)
> summary(resting.aov)
             Df  Sum Sq   Mean Sq  F value    Pr(>F)
Age           3  0.20100  0.06700    17.29  8.91e-06 ***
Residuals    20  0.07751  0.00388
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> TukeyHSD(resting.aov)
  Tukey multiple comparisons of means
    95% family-wise confidence level
Fit: aov(formula = Proportion ~ Age, data = res)
$Age
              diff         lwr         upr     p adj
AM-AF   0.017590071 -0.08300651  0.11818665 0.9605569
JU-AF   0.219757391  0.11916081  0.32035397 0.0000313
```

```
SA-AF    0.009112854   -0.09148372   0.10970943   0.9940943
JU-AM   0.202167320    0.10157074    0.30276390   0.0000913
SA-AM  -0.008477217   -0.10907380   0.09211936   0.9952282
SA-JU  -0.210644537    -0.31124112  -0.11004796   0.0000543
> resting.lm<-lm(Proportion~Age, data = mov)
> anova(resting.lm)
Analysis of Variance Table
Response: Proportion
             Df   Sum Sq   Mean Sq   F value   Pr(>F)
Age           3   0.61027   0.203425    54.072   8.91e-10 ***
Residuals   20   0.07524   0.003762
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> par(mfrow = c(1, 1)) # This code put two plots in the same window
> hist(resting.aov$residuals)
> plot(resting.aov, which = 2)
> plot(resting.aov, which = 1)
> boxplot(Proportion~Age, data = res, ylab = "Proportion of time spent on resting", xlab = "Age")
>
```