Abundance, Diversity and Distribution of Medium and Large-sized Mammal Species in Wurna Community Protected Forest, Tanqua Mlash, Tigray, Ethiopia.

By:Tesfay Hadush

Submitted in Partial Fulfilment of the Requirements for the Degree of Masters of Science in Wildlife Ecology and Conservation, Department of Animal, Rangeland and Wildlife Sciences, College of Dray land Agriculture and Natural Resources, Mekelle University, Ethiopia.

Main Advisor: Cherkos Woldegeorgis (PhD)

Co-Advisor: Solomon Abera (PhD)

February, 2025

Mekelle, Ethiopia

Declaration

I, Tesfay Hadush Tafere, here by present for consideration by the Animal, Rangeland and Wildlife Sciences Department within the College of Dry land Agriculture and Natural Resources at Mekelle University, my dissertation in partial fulfilment of the requirement for the Degree of Masters in **Wildlife Ecology and Conservation.** I sincerely declare that this Thesis (Abundance, Diversity and Distribution of Medium and Large -sized Mammal Species in Wurna Community Protected Forest) is the product of my own efforts. No other person has published a similar study which I might have copied and at no stage will this be published without my consent and that of the Animal, Rangeland and Wildlife Sciences Department.

Name of the student Tesfay Hadush Tafere Signature and date _____

Approval

Name of the main adviser Cherkos Weldegeorgis (PhD) Signature and date_____

Name of the co-adviser Solomon Abera (PhD) Signature and date _____

Name of external examiner Kalayou Mesfin (Asst. Prof) Signature and date _____

Name of internal examiner Abadi Berhe (PhD candidate) Signature and date_____

Name of postgraduate coordinator Daniel Kiros (Asst. Prof) Signature and date _____

Name of department head Emuru Tilahun (MSc) Signature and date_____

Table of Contents

List of Abbreviations and Acronyms

CSAE	Central Statistical Authority of Ethiopia
CWP	Conservation of Wildlife Population
HMC	Human Mammal Conflict
HWC	Human Wildlife Conflict
IUCN	International Union for Conservation of Nature
IWPE	Inventory for Wildlife Potential of Ethiopia
KSNP	Kafta Sheraro National Park
KFGAM	Kingdom Field Guide to African Mammals
MDD	Mammal Diversity Database
MLSM	Medium and Large Sized Mammals
MNP	Mago National Park
NP	National Park
RGHPES	Rapidly Growing Human Populations and Expanding of Settlements
RIPG	Rapid Increase of Population Growth
TRS	Tigray Regional State
WWFN	World Wide Fund for Nature

Acknowledgement

First of all I would like to express my deepest appreciation to God for the great role he plays in all my life and learning process. Primarily, thanks go to my advisors: Cherkos Woldegeorgis (PhD) and Solomon Abera(PhD) for their positively response helped towards me in their consistent and stimulating advice. Secondly, I would like to thank Mekelle University for providing services, gave a chance to take a master's of science in a campus and maintaining social wellbeing in the campus. Lastly, but not the least thanks to all Animal Rangeland and Wildlife Sciences Department Staffs (Emuru Tilahun, Esayas Embaye, Berhe Gebremicheal, Gebremedhn Beyene, Mebrahtom Nigus (PhD), Abadi Berhe, Tadele Alemayo, Samiel Syrag, Alem Fsuh, Daniel Kiros, Kidane Hntsa, Gebrekidan Teka, Samrawit Kidanemariam, Dawit Desta, Tesfay Zemicheal, Tesfakiros Kahsu and Daniel Desta), my friends Dejen Kalayu and Aregawi Beyene, all respondents, The woreda leader and all my family that were help to my thesis in technical and financial support.

List of Tables

List of Figures

Abstract

Medium and large-sized mammals are found in most forest and savannah regions of Africa and it is utmost important to protect them for the role they play in the ecosystem and beauty of nature. The study was conducted from July 2023 to March 2024 on species composition, diversity and distribution of medium and large-sized mammals in Wurna Community Protected Forest, Tanqua Mlash Woreda. Data were collected through direct and indirect evidence using both primary and secondary sources. The forest was stratified in to four habitat types, in each habitat type a representative line transects was selected and counting was employed during the early morning and late afternoon. Finally, the collected data was analysed using Excel, SPSS and Past 4.03 software in the form of descriptive and inferential statistics. A total of 128 observations were compiled and nine medium and large-sized mammalian species were recorded in the forest. During the wet and dry seasons of the year, a total of 1,114 and 584 individuals were recorded respectively. The species diversity index and evenness of the area were H' = 1.334 and J = 0.8288, respectively during the wet season. The strongest similarity in species composition, both across and within seasons, was found between woodland and riverine forest. There was a differences in species richness and abundance of the mammal species in the four habitat types between the dry and wet seasons ($p < 0.05$). The findings of the study revealed that Wurna Community Protected Forest supports a considerable number of medium and large-sized mammalian species, including the vulnerable P. pardus. Further investigation should be conducted on cause and effects of human mammal conflict in the study area. The federal and regional governments should legalize it as a wildlife refuge area to conserve mammalian species.

Keywords: Abundance, Diversity, Forest, Habitat, Medium and large-sized mammal species

CHAPTER ONE

1. INTRODUCTION

1.1. Backgrounds and Justifications

Mammals are subphylum of vertebrata, air-breathing animals whose females are characterized by the possession of mammary glands, while both males and females are characterized by sweat glands, true hair and three middle ear bones. Medium and large-sized mammals are found in most national parks and forest areas regions of Africa (Tefera, 2011).

Ethiopia is among the African countries hosting a high diversity and endemism of plant and animal species (Kelbessa and Demissew, 2014; Butler, 2016; Demissew *et al*., 2021). The country is known to contain, 6,500 species of plants (with 600 endemic species), more than 320 species of mammals (55 are endemics) and 918 species of birds (19 endemics) (Amare, 2015; Gonfa, *et al*., 2015; Eden and Girma, 2023). It is one of the endemicity centers of the world owing to its geographic position and topographic characteristics by having high mountains and deep valleys resulting in a home to many medium and large-sized mammalian species indigenous to Africa (Kassahun, 2021). Currently, the country has established 75 protected areas of different categories, including more than 27 National Parks (Afework and Yalden, 2013; Tessema *et al*., 2019).

Tigray has a diverse species of mammals and particularly the western zone is a center of biodiversity and have a remarkable potential of medium and large-sized mammals (Shoshani and Yirmed, 2008; Meheretu *et al*., 2015). Medium-sized mammals are those whose body weight is

between two and seven kg and large-sized mammals are those have over seven kg body weight (Porras *et al*., 2016). Medium and large-sized mammals account for over 60% of the species in their class. In Ethiopia, there are more than 192 medium and large-sized mammal species (Dereje *et al*., 2015).

The country has a diverse medium and large-sized mammal species. The primary factor responsible for such diversity and endemism is the existence of diverse habitats, ecosystems and other environmental variables that created favourable conditions for the evolution and persistence of mammal species (Mekbeb, 2019). However, like the case of many African countries, several key medium and large-sized mammal species have shown declining trends both in population sizes and ranges of distribution due to habitat loss, fragmentation and hunting in Ethiopia (Abune, 2000).

Studies of medium and large-sized mammals are necessary because they are an important ecological constituent of various ecosystems and thus have significant ecosystem functions and provide vital ecosystem services to human beings (Geleta and Bekele, 2016). They serve as food sources and raw materials for production of basic human needs, regulate plant diversity, structure and potential pest species through herbivory, plant dispersion through seeds consumption and predators control other animal populations through predation (Carvalho *et al*., 2014; Cortés Marcial, 2014). Many large-sized mammal species also act as a flagship for public awareness on the conservation values of biodiversity and as umbrella species because of their large area home range requirements which contribute to the conservation of other species (Struhsaker *et al*., 2005; Heinze *et al*., 2011; Sillero Zubiri *et al*., 2011; IUCN, 2020).

The ecological relevance of medium and large-sized mammals, shortage of ecological data and increased human threats make the matter very essential and necessary to evaluate their current

conservation status (Atnafu and Yihune, 2018). Hence, surveys of medium large-sized mammalian diversity of a particular ecosystem are the first step for conservation action and provide information to establish appropriate conservation strategies (Bernardo and Melo, 2013).

The understanding of how medium and large-sized mammalian species persist in different locally available habitats may also indicate the requirements of species and might contribute to their conservation (Heinze *et al*., 2011; Bernardo and Melo, 2013). This is particularly pertinent because, in addition to anthropogenic activities; the presence of a species and its distribution among available habitats in a given area are influenced by several ecological factors, such as habitat quality and suitability (Fetene *et al*., 2011; Mamo *et al*., 2015; Chala and Afework, 2019). Ultimately, the individual and interactive effects of such anthropogenic and ecological factors shape the patterns of species richness and diversity (Stankowich, 2008; Asefa *et al*., 2019).

Human beings began to hunt medium and large-sized mammals for food, hides and skins. The transformation of global landscapes from predominantly wild to predominantly anthropogenic over the last centuries has created competition between humans and medium and large-sized mammals for space and resources (Hanks, 2006; Mamo *et al*., 2015).

Medium and large-sized mammal species of the country are now largely restricted to a few protected areas (Tewodros and Afework, 2008). Rapid increase of population growth**,** investments in forest area, deforestation, wetland draining for cropland areas and using of forest edge for irrigation is more experienced in northern Ethiopia. These pose pressure on land resources and reduce the area of core habitat for medium and large-sized mammals (Quirin, 2005). Wurna Community Protected Forest is one of the natural forest of northern part of Ethiopia that has suffered severe anthropogenic impacts, is poorly monitored by the scientific community and has

no well organised data available about mammals in the Community Protected Forest. Thus, there is a need for data that would contribute to the documentation as well as carry out conservation action in the future in the study area. In addition to this, it is one step in a larger effort to document Ethiopian mammals in less accessible places. Therefore, the current study was initiated to provide baseline information about species abundance, diversity and distribution of medium and large-sized mammals in Wurna Community Protected Forest.

1.2. Statement of the Problem

A basic requirement for determining the status of species is surveying of medium and large-sized mammals (Keeping and Pelletier, 2014). Medium and large-sized mammal species inventories are essential tools to efficiently forward conservation strategies and management practices (Legese *et al*., 2019). There were several previous studies conducted in Ethiopia based on medium and large-sized mammals (Woldegeorgis and Wube, 2012; Geleta and Bekele, 2016; Kasso and Bekele, 2017). However, there was a need to conduct studies in smaller forest area of the country. Even though studies conducted on medium and large-sized mammals, mainly targeted national parks and sanctuaries, but the survey on fragmented forest is scanty (Kasso and Bekele, 2014).

Understanding of medium and large-sized mammal abundance, diversity and their distribution is surprisingly patchy, particularly in developing countries including Ethiopia. Conservation and management of medium and large-sized mammals is poor; as a result of lack of scientifically investigation, lack of awareness and negative perception of local communities towards those mammals (Atnafu and Yihune, 2018).

Worna Community Protected Forest is one of the natural forest of Northern Ethiopia that has suffered severe anthropogenic impacts, poorly monitored by the scientific community and has no well-organised data available about medium and large-sized mammals in the forest. Thus, there is a need for data that would contribute to the documentation as well as carry out conservation action in the future in the study area. In addition to this, it is one step in a larger effort to document Ethiopian mammals in less accessible places. Therefore, the current study was initiated to provide baseline information about abundance, diversity and distribution of medium and large-sized mammal species in Wurna Community Protected Forest.

It was imperative to investigate the abundance, diversity and their distribution of medium and large-sized mammal species. In Wurna Community Protected Forest, there was no research conducted on medium and large-sized mammal abundance, diversity and their distribution before. Therefore, this study was focused on abundance, diversity and distribution of medium and large-sized mammal species in Wurna Community Protected Forest, Tanqua Mlash, Central Tigray.

1.3. Objectives

1.3.1. General Objective

The general objective of this study was to conduct on abundance, diversity and distribution of medium and large-sized mammal species in Wurna Community Protected Forest.

1.3.2. Specific Objectives

The specific objectives of this study were

- To identify and document the medium and large-sized mammal species occurring within the study area.

- To assess species richness of medium and large-sized mammals in the study area**.**
- To analyse the abundance, relative abundance and diversity of medium and large-sized mammals in the study area.
- To analyze the effects of season and habitat type on richness and abundance of medium and large-sized mammal species in the study area.
- To evaluate the spatial distribution of medium and large-sized mammal species across the study area**.**

1.4. Research Questions

The study was proposed to attempt answers to the following questions:

- What type of mammal species do you have recorded in the study area?
- Which mammal type is the abundant species in the study area?
- What is the total abundance of medium and large-sized mammal species in the study area?
- Which habitat type is the most diversified in the study area?
- In which habitat type is the medium and large-sized mammal species evenly distributed in the study area?
- Is there season and habitat type are effect on species richness and abundance of medium and large-sized mammals in the study area?

1.5. Hypothesis of the Study

- Habitat type has a significant effect on abundance of medium and large-sized mammal species in the study area.

- Season has no significant impacts on species richness of medium and large-sized mammal species in the study area.
- Season and habitat type has no significant impact on diversity of medium and large-sized mammal species in the study area.

1.6. Significance of the Study

This study is significant, because it provides essential information on the current status of medium and large-sized mammal species population in the forest area, which is critical for informing conservation and management efforts. The findings of this study can be used to identify areas of high conservation value and prioritize conservation efforts, develop sustainable forest management plans that balance human needs with the conservation of forest ecosystem and contribute to the global understanding of mammal diversity and distribution, which is essential for informing conservation efforts and management of ecosystems globally.

It leads to, the local community will a positive contribution on medium and large-sized mammals occurred in and around the forest. Therefore, the finding will expected to assess and document the current population status, abundance, diversity and their distribution of medium and large-sized mammals. Furthermore, the study helps to other researchers, policy makers, extension workers and wildlife conservationists as guidelines for their conservation action and policy makers. And helps to students that review on medium and large-sized mammals, who want further investigate on the forest.

1.7. Limitation of the Study

In this study, there was lack of camera traps for easy collection of data on nocturnal medium and large-sized mammal species in Wurna Community Protected Forest and there was shortage of budget to accomplish the thesis on time.

CHAPTER TWO

2. LITERATURE REVIEWS

2.1. Mammal Diversity

Africa is well endowed with both varieties and abundance of biological organisms. Biodiversity is the total variety of life on earth. It includes all genes, species, populations, ecosystems and ecological processes of which they are part. At ecosystem level, biodiversity underpins the ecological processes which are vital to human life. For example: influencing global climate patterns, mediating carbon cycle, safeguarding watersheds and stabilizing soils to prevent desertification. At species level, components of biodiversity in the form of domesticated and wild animals, plants and microorganisms provide a vast array of goods and services, which are essential for the survival of humanity as well as having of enormous economic value (Feddema *et al*., 2021). Mammal diversity refers to the variety of all living mammals from the little Etruscan shrew or bumblebee bat (*Craseonycteris thonglongyai)* (2g) to Blue whale (*Balaenoptera musculus*) (103-150 tone) that differ at the genetic, species and ecosystem levels throughout the world (Wilson and Reeder, 2005). In Ethiopia, the profound topography variation and diverse climate are the most significant predictors of the high mammalian diversity (Tefera, 2011; Bekele and Yalden, 2013; Bantihun and Bekele, 2015) and endemicity, generating heterogeneous habitats that support different mammal species (Vaughan *et al*., 2000).

The most common mammals of the country are African Elephant *(Loxodonta africana*), Leopard (*Panthera pardus),* African Wild Ass (*Equss africanus*), Lion (*Panthera leo*), Spotted Hyena (*Crocuta crocuta*), Anubis Baboon (*Papio anubis*) and Gelada Baboon (*Theropithecus gelada*).

Table 1: List of some a representative large-sized mammal species occurred in Ethiopia and their IUCN status

Order	Common name	Scientific name	Status
Carnivora	Ethiopian Wolves	*Canis simensis*	Endangered
Primate	Gelada Baboon	*Theropithecus gelada gelada*	Least Concern
Primate	Ethiopian Gelada	*Theropithecus gelada obscurus*	Endangered
Artiodactyla	Walia Ibex	*Capra walie,*	Endangered
Artiodactyla	Mountain Goat	*Capra ibex*	Endangered
Artiodactyla	Nubian Ibex	*Capra nubiana*	Endangered
Artiodactyla	African Wild Ass	*Equus assinus africanus*	Extinct
Artiodactyla	Swaynes Hartebeest	*Alcelaphus buselaphus swaynei,*	Endangered
Artiodactyla	Baxtons Bushbuck	*Tragelaphus baxtoni,*	Least Concern
Artiodactyla	Menelik Bushbuck	*Tragelaphus scriptus meneliki*	Endangered
Proboscidea	African Elephant	*Loxodonta africana*	Endangered
Carnivora	Lion	*Panthera leo*	Extinct

Investigating of mammal diversity is continue to be a central theme of ecological, systematic and evolutionary biology. It is also absolutely critical to the fields of conservation biology and resource management. Monitoring highlights the need of conservation actions, species recovery and restoration of habitats (Campbel *et al*., 2002). Monitoring is also important in order to manage mammal species for conservation and landscape conservation decisions. This requires species-specific knowledge of its biology, ecology, population and habitat status (Baillie *et al*., 2004). Information regarding biological system is also important for mammal abundance, diversity and distribution, for the maintenance of genetic diversity and to identify threats to species. It is also

essential to monitor factors such as habitat destruction, fragmentation and degradation (Baillie *et al*., 2004).

2.2. Mammal Abundance and Distribution

2.2.1. Distributional Pattern of Mammals in Ethiopia

Mammals are one of the most widely distributed organisms in the world (Girma and Worku, 2020; IUCN, 2020). They successfully colonize diverse habitat types, having approximately 6,500 wild extant species worldwide (MDD, 2022). Due to their diverse morphological, physiological and behavioral adaptations, they inhabit various areas from the Antarctic to desert regions (Ceballos and Ehrlich, 2006). Villagra *et al*. (2009) stated that the diversity of mammals in an ecosystem provides essential food, medicine, industrial and household materials for the nation. Almost 40% of the modern drugs in the developed world are derived from plant and animal products (McGeocha *et al*., 2008). Forests provide wildlife habitat, recreational opportunities, prevent soil erosion and help to provide clean air and water (Scholes *et al*., 2006).

According to Mohammed and Afework (2017), one of the most important attributes of mammal diversity, that it is not evenly distributed. Ultimately this is because each species has its own unique range, largely a product of the interaction between existing ecological conditions and the species' evolutionary history. However, many mammal species share broadly similar distribution patterns. The distribution of mammal species is determined by climate, availability of suitable resource and interspecific interaction.

2.2.2. Geographical and Local Distribution of Mammals

Distribution of mammals occurs in two levels namely geographical distribution and the local distribution. The distribution of species represents the sum of many local populations and the

distribution of a particular species or group of populations (Vaughan *et al*., 2000). Plant communities determine the physical structure of environment and have a considerable influence on the distribution and interactions of mammal species (Isla Escudero, 2024). They live on land, water bodies and air (Solomon, 2005).

Mammal species are found on all continents, occurring from the arctic in the north hemisphere to the southern tips of the continents and large islands in the southern hemisphere. Since the first edition of mammalian species of the world was published in 1882, nearly 500 new mammal species have been described and the cumulative number of new mammal species is still on the rise (Gerardo and Paul, 2009; Meheretu *et al*., 2015). Ojeda *et al*. (2000) indicated that mammals are one of the most important components of biodiversity in the world. Functional structures of mammals are determined by the composition of functional traits (Hashim and Mahgoub, 2007; Teklay and Haylegebriel, 2024).

2.2.3. Abundance of Mammals

According to Kristy (2021), one of the most fascinating features of mammals in Africa is the wealth of an ecosystem and diversity of its mammalian fauna. Africa hosts the highest number and diversity of mammalian species in the world. Over 1,150 species of mammals are recorded from Africa, belonging to 14 Orders and 50 Families (Kingdon, 2015). Ethiopia is among the world leader in species richness and endemism of mammalian species. Inventory of the wildlife potential of Ethiopia indicates that there are over 320 species and sub-species, 144 genera, 43 families and 14 order of mammals in Ethiopia (Afework and Yalden, 2013; EWCA, 2020). Of which are more than 55 species are endemic to the country. Out of this, 3 of them are endemic medium-sized and 12 of them are endemic large-sized mammal species (Lavrenchenko and Bekele, 2019; IUCN, 2021; Tamirat, 2023). Tigray is one of an area of biodiversity and a remarkable potential of medium

and large-seize mammals in the country. KSNP is occurred in the western zone of Tigray and harbors with 42 species of mammals (Shoshani and Yirmed, 2008).

The body mass of medium-sized mammals measured between 2 kg and 7 kg, while the body mass of large-sized mammals is above 7kg (Porras *et al*., 2016). Medium and large-sized mammals account for over 60% of the species in their class (Dereje *et al*., 2015). Medium and large-sized mammal species have long been recognized as animals that interact in particularly complex and powerful fashions with their habitat (Teklay and Haylegebriel, 2024). They are also fundamental elements in many ecosystems. Large carnivores frequently shape the number, distribution and behavior of prey animals (Berger *et al*., 2001). Large herbivores function as ecological engineers by changing the structure and species composition of the surrounding vegetation (Berger *et al*., 2001; Dinerstein, 2003). Large mammals perform important ecological functions and are good indicators of the habitat value because they do not typically rely on specific single habitat as many medium-sized mammals do (NLFC, 2005).

According to Kingdon (2015), large mammals, particularly those in well-protected National Parks are generally easy to observe. Medium-sized mammals are important components of biological diversity (Hashim and Mahgoub, 2007). They are known to have economical, ecological, social and cultural values (Martin, 2003). They also have an important role in natural communities to play and provide the main supply of live-food for many species. Medium-sized mammals consume invertebrates, vegetation, fruits and seeds and also they are considered to be good bio-indicators of habitats (Frey *et al*., 2017).

2.3. Values of Medium and Large-sized Mammals

2.3.1. Ecological Values of Medium and Large-sized Mammals

Most of the mammals are important for the local community as well as the country. Medium and large-sized mammals play key roles throughout many of the world's ecosystems. These mammals are important for the proper functioning of an ecosystem. They play a fundamental role in nutrient cycling, pollination and seed dispersal. Such as large-sized mammals has the ability to modify and alter woody structure, increase habitat complexity by modifying the woody structure (Sianga *et al*., 2017).

The extinction of medium and large-sized mammals in protected areas may affect ecosystem processes in ways that was do not yet comprehend. Therefore, it is imperative to document and monitor mammalian species in and around protected areas to plan on their future conservation and management activities (Nichols and Williams, 2006). The presence or absence of medium and large-sized mammals, abundance and their distribution in different areas can be affected the ecosystem (Boddicker *et al*., 2002; Burton *et al*., 2015). It is also used to know the excellence of the ecology and activity patterns of mammals (Frey *et al*., 2017).

2.3.1. 1. Seed Dispersal and Germination of Tree Seeds

In forest area, seeds are dispersed by many medium and large-sized species of mammals such as *L. africana.* Mature bulls can transport seeds to a maximum distance of 65 km away from their source (Bunney *et al*., 2017). Concurrently, the acid treatments in their digestive system of mammals promote the germination of seeds. From these increasing of diversity of plant species as well as environmental utilization such as balance food chain, control climate change and increase soil fertilizer (Cochrane, 2003; Owen-Smith, 2006).

2.3.1.2. Ecosystem Engineers

Medium and large-sized mammals are important as an ecosystem modification in different ways, such as habitat modification, creating corridors through woodlands and digging deep holes in the dry river beds (Valeix *et al*., 2009). The *L. africana* is one of an ecosystem engineer mammal in KSNP. They alter the structure of vegetation directly through consumption and indirectly through processes such as nutrient mediation. All these habitat modifications also implement changes in insect communities (Kerley *et al*., 2008; Shannon *et al*., 2008). Hence, landscapes used had altered vegetation structure, which leads to a higher diversity of ants, reptiles and frogs through the creation of micro- habitats. This sustains grazing animals such as antelopes. Corridors prevent the spread of wildfires and deep holes collect water for other animals (Barua, 2011; Mograbi *et al*., 2017).

2.3.2. Economic and Cultural Values of Medium and Large-sized Mammals

Medium and large-sized mammals are important in terms of economic and cultural values in the world. They are also important in fulfilling the needs of humans such as cloth, food and spiritual values (Boesch *et al*., 2017). It provides important human benefits such as recreation and income generating to the country (Bekele and Yalden, 2014). However, mammals are severely affected by habitat loss; overexploitation, invasive species and climate change.

2.4. Threats of Medium and Large-sized Mammals

Major threats of medium and large-sized mammals of many forest areas are anthropogenic and natural forces that affects it.

2.4.1. Anthropogenic Factors

Human activities such as agricultural practice, deforestation, grazing, charcoal production, poaching and Conflict in and around forest areas affects mammal species. Human wildlife conflict is defined as any interaction between humans and wildlife that results in negative impacts on social, economic, cultural life, on the conservation of wildlife population and on the environment.

Human wildlife conflict is rapidly becoming one of the most important threats to the survival of many mammal species and is an increasingly significant obstacle to the conservation of wildlife (Madden, 2008). It is a serious issue in Africa and other developing areas of the world where rapidly growing human populations and expanding settlements are reducing the areas left for mammal habitat and increasing the interaction between humans and mammals (Blair, 2008; (Dickman, 2010).

Medium and large-sized mammal species are respond to anthropogenic activities that range from behavioral to distributional changes. These changes may depend on the type, intensity and frequency of anthropogenic activities (Gaynor *et al*., 2018). Anthropogenic activities are the main cause of the disturbance of medium and large-sized mammals. As a result, many species of mammals showed a strong fear response to anthropogenic activities (Clinchy *et al*., 2016; Smith *et al*., 2017). Human recreation can negatively affect mammal species, particularly on weekends when human activity is highest. Moreover, the local people commonly collect resources from protected areas during the dry season due to poor agricultural activity, which may confine mammalian activity to their local community. Such temporal change in human mammal interactions can cause changes in mammal behavior, such as increased stress, missing foraging opportunities, lower reproductive success, avoidance of certain areas and higher mortality (Longshore *et al*., 2013).

Mitigating the negative impacts of anthropogenic activities on mammals becomes a challenging task to conserve wildlife in protected areas. Understanding wildlife movements and habitat use are critical for species conservation and management on a landscape scale (Allen and Singh, 2016).

2.4.2. Natural Factors

Natural factors are becoming one of the most threats to the survival of many mammal species and is an increasingly significant obstacle to the conservation of medium and large-sized mammals ((Dickman, 2010). It is a serious issue in Africa and other developing areas of the world where rapidly change the areas, it results naturally (Blair, 2008; Dickman, 2010).

2.5. Human Mammal Conflict (HMC)

Human mammal conflict (HWC) occurs when the needs and behaviour of mammals impact negatively on humans or when humans negatively affect the needs of mammals. These conflicts may result when medium and large-sized mammals damage crops, threaten, kill or injure people and domestic animals. These are as critical problems created by the growing rural population in and around mammal habitats. Human mammal conflict incidents are widespread but not evenly distribute because they are dependent on the proximity of mammals. In addition, different species cause different types of damage at different times of the year. The damage caused has variable effects on the livelihood of households depending on their level of livelihood security at the time of the incident (Mulonga *et al*., 2003).

2.5.1. Cause of Human Mammal Conflict (HMC)

2.5.1.1. Human Population

One major cause of human mammal conflict is increasing human population adjacent to mammal habitats and protected areas (Treves *et al.,* 2003). As human population increases and the demand for resources grow, the frequency and intensity of such conflicts increases. This can be manifested by increasing encroachment to habitats of medium and large-sized mammals. As a result, the populations of those species which are unable to adapt to altered habitats may invade the marginal habitats or decline in number. Human mammal conflicts undermine human welfare, health, safety and have economic and social cost (Mulonga *et al*., 2003).

Naturally, organisms live together in an ecosystem for a long period of time. Then, through time, it show high degree of intrinsic stability and resilience to climate and other environmental factors in the given ecosystem. Because of their habitats are increasingly altered by humans. Certain individual mammal species may cause a significant problem to humans, crop and livestock production. Much of the current mammal diversity crises arise as a result of increasing competition with humans for space and resources. Crop raiders including African elephants and many primate mammals can diminish the farmers' food and cash crops (Anonymous, 2002). But those species that were able to adapt a changing ecology and survive in agricultural system become involved in a direct competition with humans (Vos, 2000; Deresse, 2003).

2.5.1.2. Habitat Loss

Habitat loss is the greatest and most serious of all threats to all mammals. It is caused by both human and natural forces. Due to high level of it, medium and large-sized mammals are reduced, lost and migrating from the place. Habitat loss due to the expansion of human activities, including

urbanization and the increase in cultivated land surfaces, is identified as a main threat to all mammal species described in the IUCN Red List (IUCN, 2020).

2.5.1.3. Agricultural Practice

Agricultural practice is another major threat of mammals. Due to agricultural practice around the forest area, conflict was raised between wild mammals and human. African elephant was hunted by local communities for the collection of ivory. Fertilizers, pest control chemicals, tillage and even crop rotation had an impact on the biodiversity of agricultural ecosystems. Due to increasing human and livestock population was a common experience in protected areas of most Ethiopia. Such a conversion of natural vegetation cover to other use types such as farmlands, grazing lands, human settlements and urban center has shown for the cause of deforestation, land degradation and loss of medium and large sized mammals, (Vos, 2000).

2.5.1.4. Invasive Plant Species

Invasive species is common problems. The introduction of non-native species and genetic stock was a major threat to mammal diversity. There are thousands of new and foreign genes introduced with trees, shrubs, herbs, microbes and higher and lower animals each year. Many of these new species survive and adapt, after many years of adaptation, become invasive. It has failed to protect the continuous decline of both faunal and floral communities (Young, 2012).

CHAPTER THREE

3. Materials and Methods

3.1. Study Areas

The present study was conducted on the Northern part of Ethiopia, Central Zone of Tigray, in Tanqua Mlash Woreda, Wurna Community Protected Forest (Map 3.1).

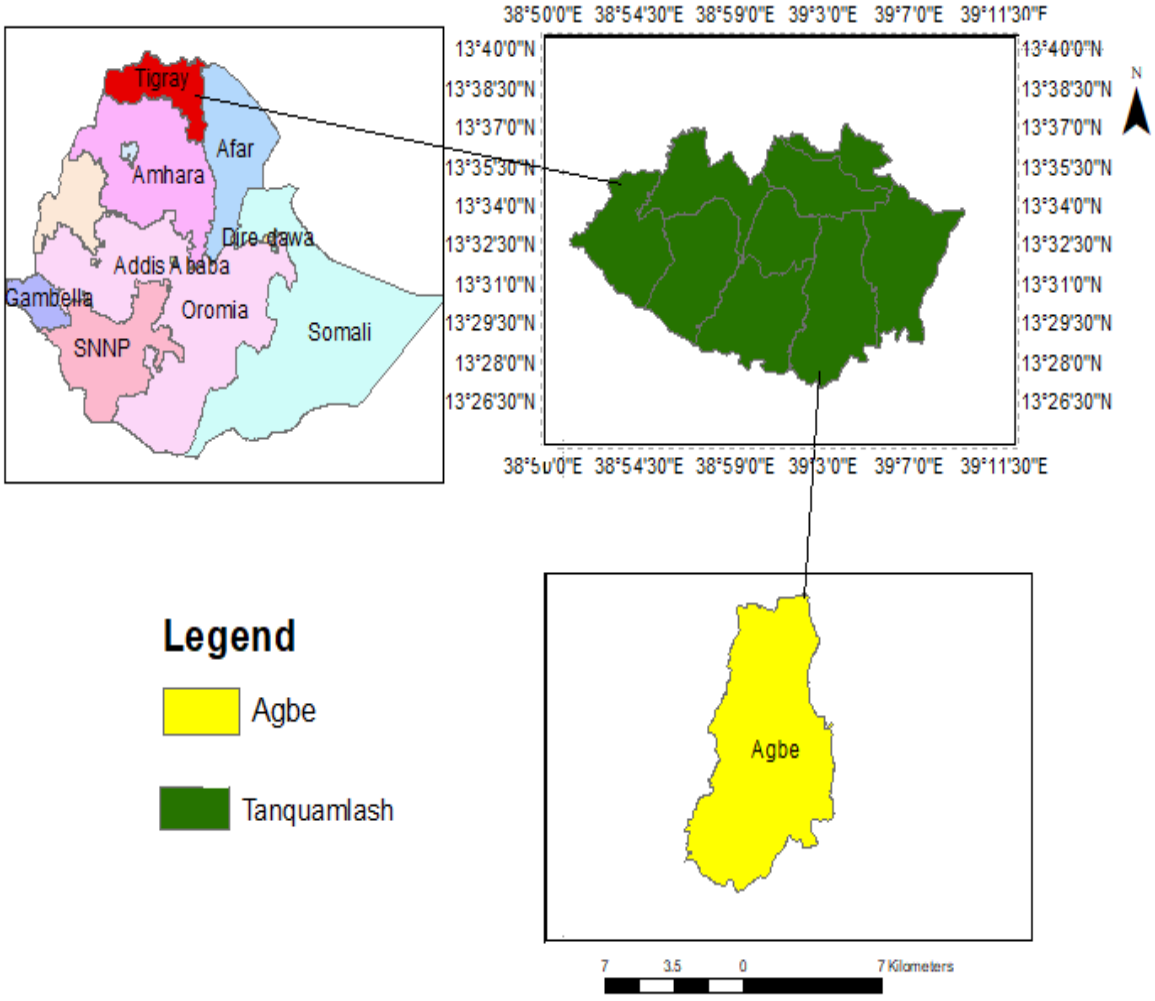

Figure 1: Map of the study area (Tanqua Mlash); (by Tesfay Hadush)

3.1.1. Location

Agbe is found in Tanqua Mlash Woreda, Central Zone of the Tigray, in the Northern part of Ethiopia. In Tabia Agbe there are four Kushets: namely Agbe, Aqalazba, Zikuli and Seyemtiruba. Woreda Tanqua Mlash was created from parts of the Tanqua Abergelle and Degua Tembien in 2020 and also geographically located between $13^0 26' 30'' N - 13^0 40' 00'' N / 38^0 50' 00'' E - 39^0 11' 30'' E$ latitude and longitude. Agbe is geographically located between$13^0 33' 00'' N / 39^0 30' 00'' E$ latitude and longitude and 20 km far from Tembien Abyi Addi and the altitude of the area lies between 1,350 - 1,678 m.a.s.l (Igziabher and Taddesse, 1972). The forest covers an area of 710 hectares, bounded by Aqalazba in the north, Zikuli in the east, Seyemtiruba in the south and Daserawat in the west. The forest area was designated by the Woreda's Natural Resource Department as a Community Protected Forest in 2009.

3.1.2. Rainfall and Temperature

The main rainy season of the area is from June to September with a short rainy season from February to April, with mean annual rainfall ranging from 450 - 500 mm (Jacob and colleagues, 2013). Most rains fall during the main rainy season, which typically extends from June to September. Mean temperature in the Woreda is 25.4 °C, oscillating between average daily minimum of 14.6 °C and daily maximum of 35.6 °C. The contrasts between day and night air temperatures are much larger than seasonal contrasts (Central Statistical Authority of Ethiopia, 2009; Nyssen, 2019).

3.1.3. Soil Type and Vegetation

The forest has a sandy and clay soil type. It is important for nature conservation and for human well-being of the local community. The forest support different mammals, birds, reptiles and vegetation. In this forest area, there are different vegetation types like: Ethiopian acacia (*Acacia*

abyssinica), Red acacia *(Acacia seyal),* Etbaic acacia *(Acacia etbaica),* Wild fig *(Ficus vasta),* Rock fig *(Ficus gluimosa),* Bark cloth tree *(Maytenus senegalensis),* Narrow leaved hopbush *(Dodonea angustifolia),* Cordia *(Cordia africana)* and Doggrass *(Cyndon spp)*.

3.1.4. Water Source and Economy

There is one permanent river and springs which are important for the local people. The main springs in the tabia are May Hitsare; located in Agbe and Gerebgiba river located in Seyemtiruba, where construction works for a soft drinks factory and irrigation have been started respectively. The main other populated places are Agbe, Kalazba, Zikuli and Seyemtiruba. The population lives essentially from crop farming and irrigation, supplemented with off-season work in nearby towns. The farmers have adapted their economy using cropping system and irrigation to the spatio-temporal variability in rainfall and rivers. In a certain way, there is irrigation of various fruits and peppers in Sheka irrigation with water from both sources of May Hitsare and Endaba Tomas. May Selele, May Ayini, May Zegaru and Endagabr are the water sources of springs in Zikuli. These water springs are used for irrigation.

3.2. Materials

Materials used during this study were field binoculars (7x 50mm), meter tape and different stationary materials like note book, guide book, pen, flash, paper and mobile.

3.3. Methods and Data Sources

Preliminary Survey

Reconnaissance was made in the first weeks of July 2023 for five days to get basic information on accessibility, vegetation type and topography of the area. The dominant habitat types were

transverse on foot and visual estimation of the area of each habitat type was made. Totally, 16 Key Informant Interview (KII) of the local community were asked about the availability of the forest.

3.3.1. Sampling Technique

To effectively survey the abundance, species diversity and distribution of medium and large-sized mammals, two standardized survey techniques were used, direct (line transect; sighting/hearing) and indirect (plots; scat, foot print, vocal, food remaining and spines) census were followed. Both the transect lines and field plots were laid/set lengthwise, following the slope of the ground and oriented perpendicular to ecological or density gradients. From random sampling techniques, purposive and stratified random sampling technique was used. In this study, 16 KII were purposively selected and the forest was stratified in to four habitat types. Direct field observation was used to identify mammal type, species richness and abundance of medium and large-sized mammals in the forest.

3.3. 2. Research Design

Surveys were conducted during the wet and dry seasons in August and September 2023, March and April 2024 of the year respectively. The forest was divided into four habitat types based on their geographical location, area coverage and vegetation type: a total of 10 transect lines were used. In each habitat type, a representative transect lines was used. Four habitat types were determined namely wood land (3 transect lines), farmland (2 transect lines), shrub land (3 transect lines) and riverine (2 transect lines). In the study area, woodland habitat type is located between shrub land and farmland and covered above 50% by woody plant species, farmland habitat type is located centre of the forest and covered above 50% by farm activities, shrub land habitat type is located eastern part of the forest and covered above 50% by shruby plant species and riverine

habitat type is located western part of the forest and covered above 50% by river and spring water. In four habitat types, a representative line transect was selected and the width and length of each transect line depends on vegetation type and geographical areas. In woodland and shrub land, the width among transect line was 100 m and 1500 m length. In farm land and riverine, the width among transect line was 150 m and 1000 m length.

Counting was starting during the early morning from 6:00 to 10:00 am and late afternoon from 4:00 to 7:00 pm. When counting the mammals, one researcher and two filed assistants were walking on foot along the pre-established line transect in order to count all the individuals sighted and record indirect evidence of the mammal presence in the area.

Observation of individual and categories with their respective species was done using unaided eyes and binocular. To minimize disturbance during counting, silent movement followed by 3 to 5 minutes waiting period was allowed. Each encountered species of medium and large-sized mammals was identified in the field using Kingdom Field Guide to African Mammals (Kingdon, 2015). Mammals weighting between 2 and 7 kg were considered as a medium-sized while, weighing above 7 kg were considered as large-sized mammals as applied by (Sutherland, 2006).

The conservation status of medium and large-sized mammals in the study area was addressed through key informant interview and field observation. A total of 16 people (four from each village) were selected (old age people, scouts and herbs) for interview based on their long years lived adjacent to the area and their extensive knowledge of the local fauna. Interviews were mainly focused on mammal species existing in the forest.

3.4. Data Collection Method

Data was collected using both primary and secondary sources. The present study was carried out by means of field observation/direct and indirect methods of data collection using transect line methods in both seasons within four months and data were collected 16 days per month (Maddox, 2003). In this study, secondary sources of data was also used: such as published research articles, books and textbooks (for identification of mammal type, scientific name and status). These sources provide a wealth of knowledge on specific topics and can be used to support existing research literature.

3.4.1. Direct Observation and Total Count

Direct field observation was used to identify medium and large-sized mammal type and their abundance in the forest. The species identification was carried out using keys and guide books. Furthermore, total counting and identification of medium and large-sized mammals was conducted on foot traveling. Abundance was counted by direct observation along the established transect lines, during morning hours (6: 00 to 10: 00 am) and late afternoon (4: 00 to 7: 00 pm). Each line transect by gently walking at a constant speed of ~1 km/h. During the study periods, the silent detection method (suitable clothing for camouflage, moving opposite wind direction (from south to north), and avoiding loud voices) was practiced minimizing disturbance. Observations was made with naked eyes and binocular. Body weight was the parameter used to categorize mammals as medium and large-sized.

3.4.2. Indirect Observation and Key Informant Interview

Due to the elusive nature of the medium and large-sized mammals, difficult topography and relatively dense vegetation cover, indirect survey and key informant interview were also employed to assess the presence of nocturnal medium and large-sized mammal species in the forest and used in the preliminary survey period respectively.

3.5. Data Analysis

The data was analyzed using descriptive and inferential statistics like percentage, mean, range, tabulate and charts. Data were organized into different topics following the objectives of the study and coded according to the topics already described. The collected data was analyzed using the Microsoft excel, Statistical Package for Social Sciences (SPSS) Computer software program version 26 and Past 4. 03 software. To examine species diversity over the study period, the Shannon-Weaver index of diversity (H′) was calculated for each. Species evenness was also computed on a habitat type basis using the evenness index, J. Evenness index provides a measure of how evenly the different species was represented in the forest area. The formula for species diversity:

$H' = -\sum pilnpi$----------Eq. 1

Where, H' is Shannon-Weaver index of diversity, S is the number of species and pi is the proportion of the total number of individuals represented by the i^{th} species. Species evenness was calculated by using the evenness index formula:

J=H'/H max----------Eq. 2

Where, H' is Shannon-Weaver index of diversity and H max is maximum diversity Index.

H max=lnS----------Eq. 3

The Shannon-Weaver index value typically ranges from 0 to 3.5, with a few unusual occurrences surpassing 4.5 (Kent, 2011). The range values for J is 0 to 1, with a greater value indicating a more evenly distributed species. With the help of the Sorensen similarity index, which was calculated using the formula:

$$SI = 4c/4c + w + s+f+r \quad \text{Eq. 4}$$

Where SI is Sorensen's coefficient (index), c is the number of species shared between habitats, w is the number of species found in woodland, s is the number of species found in shrub land, f is the number of species found in farm land and r is the number of species found in riverine only, the similarity of the mammalian species composition was evaluated.

The abundance of observed mammals were categorized as “common” if they were seen during all of the surveys “uncommon” if they were seen in more than half of the surveys, and “rare” if they were seen in less than half of the survey periods following (Legese *et al*.,2019).

To calculate a relative abundance, the total number of individual species in an area was divided by the total sum of all populations of species in an area, then multiplied by 100. The following formula was used to calculate the relative abundance of species in an area.

$$RA = TS / TP * 100 \quad \text{Eq. 5}$$

Where RA is the relative abundance of species (%), TS is the total number of individual species in an area, TP is the total populations of all individual species in the area. Finally, data were analyzed using diversity index, regression and chi square test for species diversity, quantitative and qualitative data. Effects of season and habitat type on abundance of medium and large-sized mammal species was analyzed by chi square test and multiple linear regression has used to analysis effects of season, month and habitat type on the total abundance of medium and large-sized mammal species.

CHAPTER FOUR

4. Result

4.1. Species Composition

Within a total of 128 observations, 9 species of medium and large-sized mammals were recorded in the study area. Those mammals are belonging to six orders and nine families. Those species were directly recorded using total count with the help of indirect evidence of mammal species in the forest. In addition to direct sighting: through indications of body parts, vocalization and evidences obtained from key informant interview of local peoples in the forest: three large-sized carnivore mammal species were recorded. During wet and dry seasons, the same number of total species were recorded in the forest, which belongs to five medium and four large-sized mammal species.

Order carnivora was the highest number of species (4 species) recorded in the forest, but the remaining all orders were represented by a single species in each. However, at family level, all families were represented by a single species each in the study area (Table 2). From a carnivore medium-sized mammal species, *I. albicauda* was recorded in the forest. However, all the remaining order carnivores are large-sized mammal type. Most of the medium-sized mammals were recorded in farmland habitat. In this forest, *H. cristata* was recorded in all habitat types.

Table 2: Lists of medium and large-sized mammal species in Wurna Community Protected Forest

Common name	Local name	Scientific name	Order	Family	Genes	Species
Leopard	ኑብሪ	*Panthera pardus*	Carnivora	Felidae	Panthera	Pardus
Porcupine	ቅንፈዝ	*Hystrix cristata*	Rodentia	Hystricidae	Hystrix	Cristata
Rock Hyrax	ጊሐ	*Procavia capnesis*	Hyracoidea	Procavidae	Procavia	Capenesis
Vervet Monkey	ወዓግ	*Chlorocebus pygerythrus*	Primate	Cercopithecinae	Chlorocebus	Pygerythrus
Spotted Hyena	ዝብኢ	*Crocuta crocuta*	Carnivora	Hyaenidae	Crocuta	Crocuta
Common Jackal	ብኽርያ	*Canis aureus*	Carnivora	Canidae	Canis	Aureus
Cape Hare	ማንትለ	*Lepus capnesis*	Lagomorpha	Leporidae	Lepus	Capnesis
Klipspringer	ሚዳቕ	*Oreotragus oreotragus*	Artiodactyla	Bovidae	Oreotragus	Oreotragus
White-tailed Mongoose	ፂሐራ	*Ichneumia albicauda*	Carnivora	Herpestidae	Ichneumia	Albicauda

C. crocuta, H. cristata and *I. albicauda* were exclusively identified from direct evidences. During the filed survey, direct and indirect evidences of *P. pardus* was observed in the woodland habitat type. As the result indicated, all medium and large-sized mammal species were recorded by the help of direct and indirect evidence. However, indirect evidence was used as identification of medium and large-sized mammal species in the forest: where the mammals were their home range and daily activities'. Total individual abundance of medium and large-sized mammal species were not analysed using indirect evidence (Table 3).

Table 3: Mode of recording, mammal type and status of MLSM species in Wurna forest

Scientific name	Mammal type	Order	Mood of recording	Local status	IUCN Red List
P. pardus	Large	Carnivora	*,?, £	Rare	Vulnerable
H. cristata	Medium	Rodentia	*, £, ?, ¥	Rare	Least concern
P. capnesis	Medium	Hyracoidea	*, £, ?, ¥	Rare	Least concern
C.pygerythrus	Medium	Primate	*, £, ?, ¥	Rare	Least concern
C. crocuta	Large	Carnivora	*, £, ?, ¥	Rare	Least concern
C. aureus	Large	Carnivora	*, £, ?, ¥	Rare	Least concern
L. capnesis	Medium	Lagomorpha	*, £, ?, ¥	Rare	Least concern
O. oreotragus	Large	Artiodactyla	*, £, ?,	Rare	Least concern
I. albicauda	Medium	Carnivora	*, ?, £,	Rare	Least concern

Key: * = visual/direct sighting, ¥ = sound/vocalization, ? = personal communication (Interview), £ = foot print, food remaining, scat/spines.

4.2. Species Richness of Medium and Large-sized Mammals

The distributional patterns of medium and large-sized mammal species were varied across the study habitats. High number of species richness was occurred in the farmland (6 species) in both seasons. In this habitat type, there was no significant difference in species richness of medium and large-sized mammals in the forest in relation to season. Whereas, in shrub land and woodland there were five species of medium and large-sized mammal species recorded during the wet season. However, in riverine habitat type of the forest, only four species were recorded during wet and dry seasons. Therefore, season has no significant effect on species richness in the forest (chi square =

0.661, df = 2 and p = 0.717). However, habitat type has a significant impact on species richness (chi square = 13.333, df = 6 and p = 0.038). In both seasons, there was evenly distribution of medium and large-sized mammal species in shrub land habitat type (J=0.8288). But in farmland and riverine, there was less evenly distribution of medium and large-sized mammal species during wet and dry seasons, respectively (Table 5).

4.3. Abundance of Medium and Large-sized Mammals

Among the 9 species of mammals, Vervet Monkey and Porcupine were the least dominant mammalian species followed by Cape Hare and Rock Hyrax.

Table 4: Abundance of MLSM species in Wurna forest in wet and dry seasons

	Wet Season					**Dry Season**				
Species Name	Woodland	Farmland	Shrub land	Riverine	Total (N)	Woodland	Farmland	Shrub land	Riverine	Total (N)
P. pardus	5	0	0	0	5	1	0	0	0	1
H.cristata	10	14	9	8	41	5	2	4	5	16
P.capnesis	0	0	38	554	592	0	0	20	281	301
C.pygerythrus	45	151	0	182	378	54	62	0	87	203
C.crocuta	23	6	5	0	34	8	2	1	0	11
C.aureus	6	0	7	0	13	5	0	8	0	13
L.capnesis	0	14	25	4	43	2	5	18	1	26
O.oreotragus	0	3	0	0	3	0	6	0	0	6
I.albicauda	0	5	0	0	5	0	7	0	0	7
Total (N)	89	193	84	748	1114	75	84	51	374	584
Relative Abundance	0.081	0.173	0.075	0.671	1	0.128	0.144	0.087	0.641	1

P. pardus, and *O. oreotragus* and *I. albicauda* species were occurred only on woodland and farmland habitat type in both seasons respectively.

At the wet season, 1,114 medium and large-sized mammal species were recorded in Wurna forest (Table 4) and from a total abundance of medium and large-sized mammal species, 1,059 species were medium-sized mammal species. In the survey of the dry season, 584 individuals of medium and large-sized mammal species were recorded. From the total individuals of medium and large-sized mammals recorded in the dry season, 31 individuals are large-sized. From those mammals, 14 individuals were recorded in woodland habitat type.

P. capnesis was the abundant mammal species in the forest during both seasons followed by *C. pygerythrus*. In wet season, *P. capnesis* was higher total individuals (N = 592) than the dry season (N = 301) and also abundant in riverine habitat type (N = 554, N = 281). However, *O. oreotragus* and *I. albicauda* mammals were higher number of individuals during the dry season than the wet season (Table 4). Even though, most of the mammal species recorded in the forest, during the wet season was higher than the dry season, but *C. aureus* (N = 13) has equal in both seasons (Figure 2). Therefore, habitat type has a significant effect on the abundance of medium and large-sized mammal species in the forest, (df = 117 and p = 0.001), but season has less significantly impact on abundance of medium and large-sized mammal species (df = 39, p = 0.323).

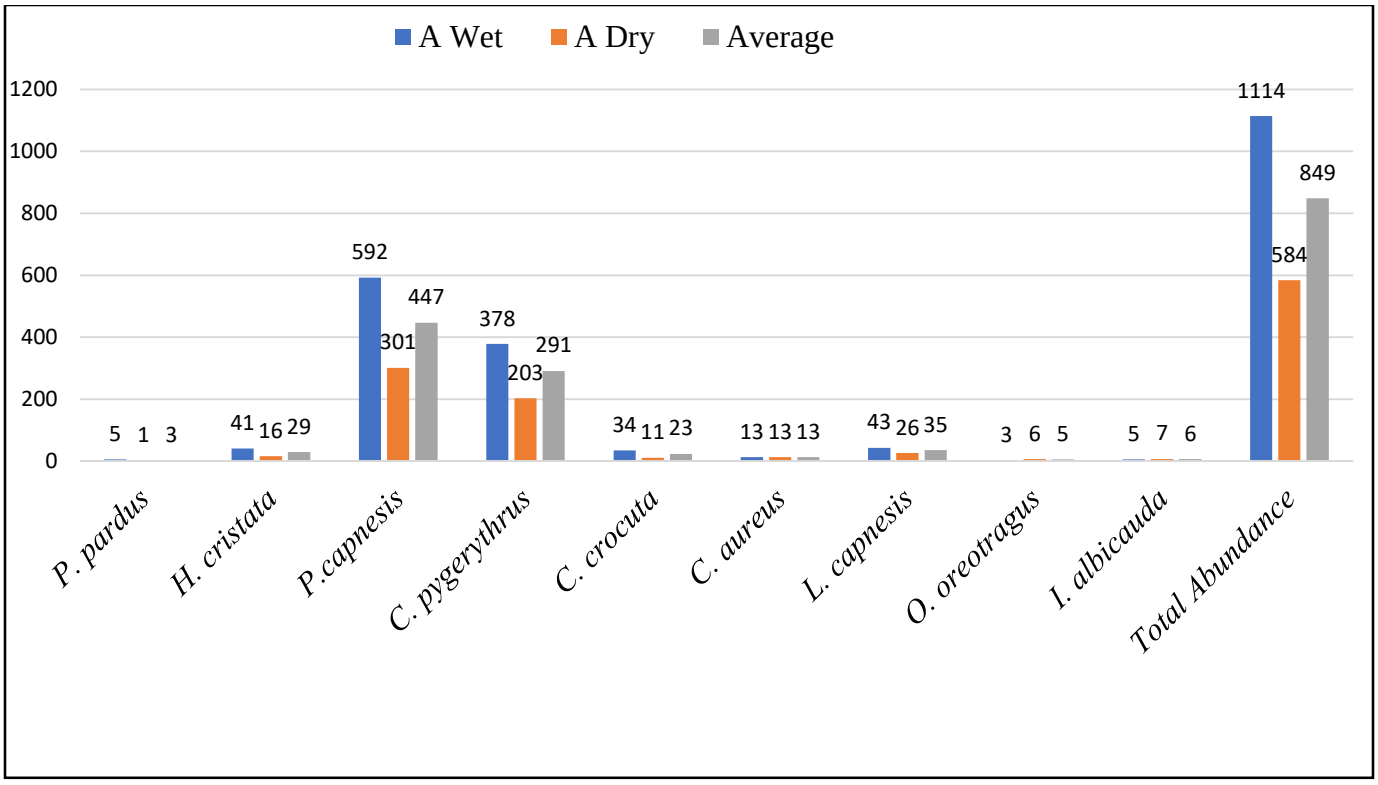

Figure 2: Abundance (A) of MLSM species in Wurna forest

In Wurna Community Protected Forest, the relative abundance of medium and large-sized mammal species was higher in riverine habitat type in both seasons (Figure 3). In woodland habitat type, the relative abundance of mammals were higher in the dry season than the wet season (Figure 3). Shrub land has less relative abundance (Ra = 8% and Ra = 9%) during wet and dry seasons respectively. Season has a significant impact on the relative abundance of medium and large-sized mammal species. As the result indicated, 94.9% (N = 1,612) of mammals in the forest are medium-sized mammal species. From a total individuals of large-sized mammals, 89.5% are belongs to carnivore.

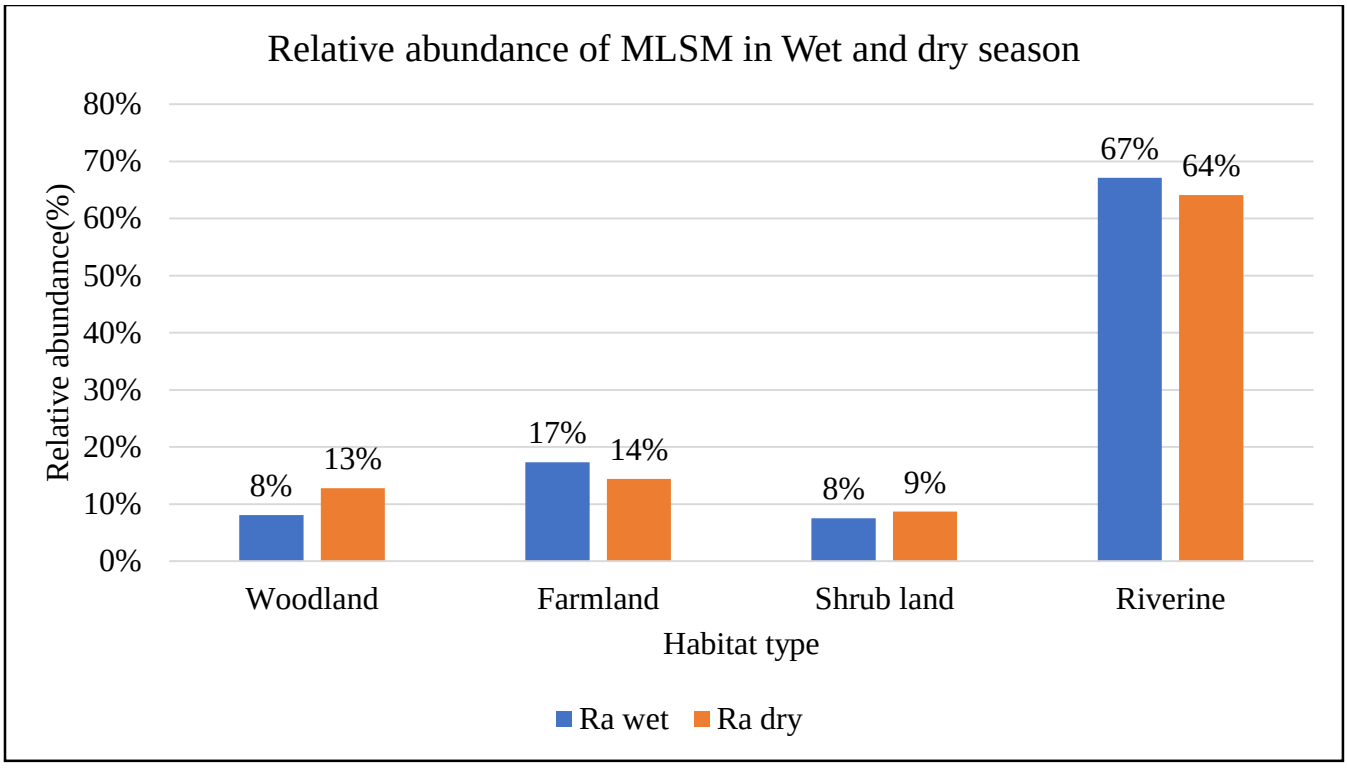

Figure 3: Relative abundance (Ra) of MLSM in Wurna forest during Wet and dry seasons

Regarding to the occurrence of mammals based on their frequency of observation through the study interval, all the observed mammals were rare species. According to the results of the study area, *C.pygerythrus* was frequently (*No* = 53) observed. However, *P. capnesis* was the maximum individual numbers recorded in the forest (Table 5). And also, 893 individuals of *P. capnesis* were recorded in both seasons.

Table 5: Frequency and total abundance of MLSM species in both seasons

	P. pardus	*H.cristata*	*P.capnesis*	*C.pygerythrus*	*C.crocuta*	*C.aureus*	*L.capnesis*	*O.oreotragus*	*I. albicauda*
Frequency (No)	6	40	43	53	29	21	38	8	7
Range	0	2	49	22	4	1	2	1	2
Minimum	1	1	1	3	1	1	1	1	1
Maximum	1	3	50	25	5	2	3	2	3
Sum	6	57	893	581	45	26	69	9	12

4.3. Species Diversity and Evenness Recorded During Wet Season

In different habitat types of the forest, diversity of mammals are vary in both seasons. During in the wet season, the highest species diversity of mammals was recorded from shrub land habitat type (H' =1.334) followed by woodland (H' =1.284), farmland (H' =0.8399) and riverine (H' =0.6428). In contrast to farmland habitat type, shrub land has lower species richness and total individuals. And also shrub land has highest evenly distribution of species in the forest (J = 0.8288) followed by woodland (J = 0.7976) and farmland (J = 0.4688). Similarly, lowest species dominant was recorded in shrub land habitat type (D =0.3152) whereas, the highest one was in riverine habitat type (D =0.6079). However, there were richness and abundant of medium and large-sized mammal species in farmland and riverine (n = 6, N = 748) respectively (Table 4).

4.4. Species Diversity and Evenness Recorded During Dry Season

The highest species richness of mammals was recorded from woodland and farmland habitat type (n= 6), followed by shrub land (n= 5) and riverine (n = 4). In the study area, the highest evenness of mammal species in the forest was recorded in shrub land (J = 0.809) followed by woodland (J = 0.5528) and farmland (J = 0.5389). Mammals occurred in shrub land has evenly distribution in the forest. Similarly, the highest species diversity was recorded in shrub land habitat type (H' = 1.302) whereas, the lowest one was recorded in riverine (H' = 0.6276). Woodland was the second diversified (H' = 0.9905) habitat in the forest. However, in riverine, there were highest individual abundance of species (N = 374) in the forest (Table 4). Therefore, riverine was dominated by some species (D = 0.6188).

Table 6: Diversity index of medium and large-sized mammalian species

	Wet Season				**Dry Season**			
	Habitat Type				Habitat Type			
	Woodland	Farmland	Shrub land	Riverine	Woodland	Farmland	Shrub land	Riverine
Species richness (n)	5	6	5	4	6	6	5	4
Abundance (N)	89	193	84	748	75	84	51	374
Dominance_D	0.3428	0.6245	0.3152	0.6079	0.5396	0.5615	0.3095	0.6188
Shannon_H′	1.284	0.8399	1.334	0.6428	0.9905	0.9656	1.302	0.6276
Evenness_e^H/S	0.722	0.386	0.7591	0.4754	0.4488	0.4377	0.7353	0.4683
Equitability_J	0.7976	0.4688	0.8288	0.4637	0.5528	0.5389	0.809	0.4527

The Sorensen species similarity index of medium and large-sized mammal species was varied between and among habitat. In both seasons, similarity of medium and large sized mammalian species in the forest were high between woodland and shrub land (SI = 0.73) followed by woodland and farmland, shrub land and riverine (SI = 0.67). However, shrub land and riverine has highest

species similarity (SI = 0.67) during wet season. The species similarity among woodland, farmland and riverine (SI = 0.563) was slightly higher than among woodland, shrub land and riverine (SI = 0.4) during dry season. Among the four habitat types, similarity of mammal species was (SI = 0.38) during the dry season, which is higher than during the wet season. Therefore, season has significant effects (P = 0.027) on the Sorensen's coefficient similarity index of medium and large-sized mammalian species between and among the four habitat types in the forest (Table 7).

Table 7: Sorensen's coefficient of similarity index in Wurna forest

	WFSR	WFS	WFR	WSR	FSR	WF	WS	WR	FS	FR	SR
SI of wet season	0.2	0.375	0.4	0.214	0.4	0.55	0.4	0.44	0.55	0.6	0.67
SI of dry season	0.38	0.53	0.563	0.4	0.4	0.67	0.73	0.6	0.55	0.6	0.67

Key: SI = Sorensen's coefficient of similarity index, W = woodland, F = farmland, S = shrub land, R = riverine.

4.5. Distribution of Medium and Large-sized Mammals

Mammals are evenly and unevenly distributed in different habitat types and forest areas. In the study area, most of medium and large-sized mammals were evenly distributed in the four habitat types during both seasons. During the wet season, mammals recorded in shrub land habitat type were highest evenness index (J = 0.8288) than others. In shrub land, woodland and riverine habitat, the evenness index is higher in the wet season than the dry season. However, in farmland habitat, in the dry season is higher evenness than in the wet season (Table 5).

Leopard

Mammals may prefer their habitat type, due to the availability of the habitat. In the study area, *P. pardus* has preferred woodland area over other habitat types. *P. pardus* was recorded in August, September and February in both seasons. The maximum number of *P. pardus* recorded in Wurna forest was one and, was seen frequently in woodland habitat during the wet season than in the dry season. Totally, 6 individuals of *P. pardus* were recorded in both seasons in Wurna forest.

Porcupine

H. cristata was evenly distributed in all habitat types of the forest and has feed on mostly roots, bulbs, insects and crops. It travels long distance looking for food. In this forest area, 41 individuals of *H. cristata* were recorded. Season has significant effect on the abundance of *H. cristata*. *H. cristata* its home range were in the riverine and farmland habitat types. *H. cristata* was abundant in farmland habitat type (N = 14) during wet season (Table 4).

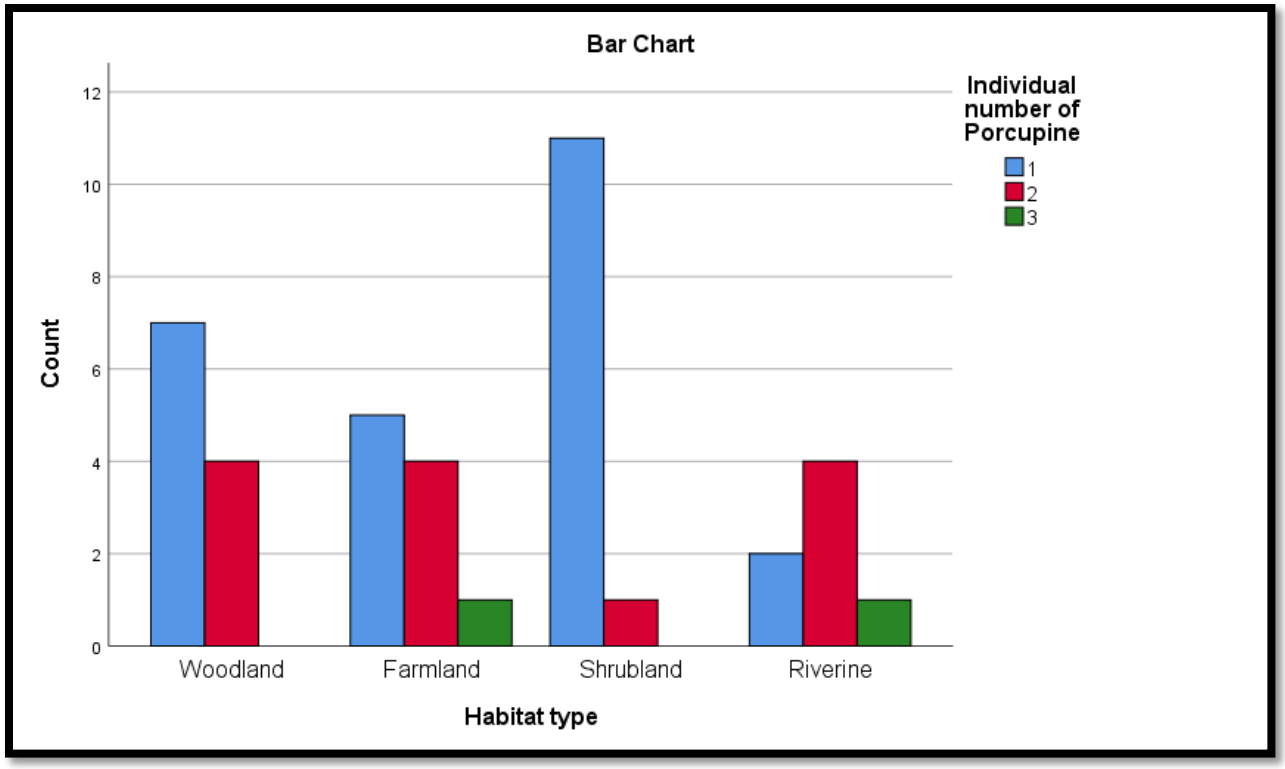

Figure 4: Frequency of *H. cristata* in Wurna forest

Rock Hyrax

P. capnesis is a medium-sized mammal species found in shrub land and riverine habitat. *P. capnesis* was dominated in riverine habitat type than the other medium and large-sized mammal species in the forest. In riverine habitat, 554 individuals of *P. capnesis* were recorded during wet season and feed on insects, grass and *Giesho.* In both seasons, totally 893 individuals of *P. capnesis* were recorded in the forest (Table 4).

Figure 5: Rock Hyrax (*P. capnesis*); (Photo by Tesfay Hadush, 2024)

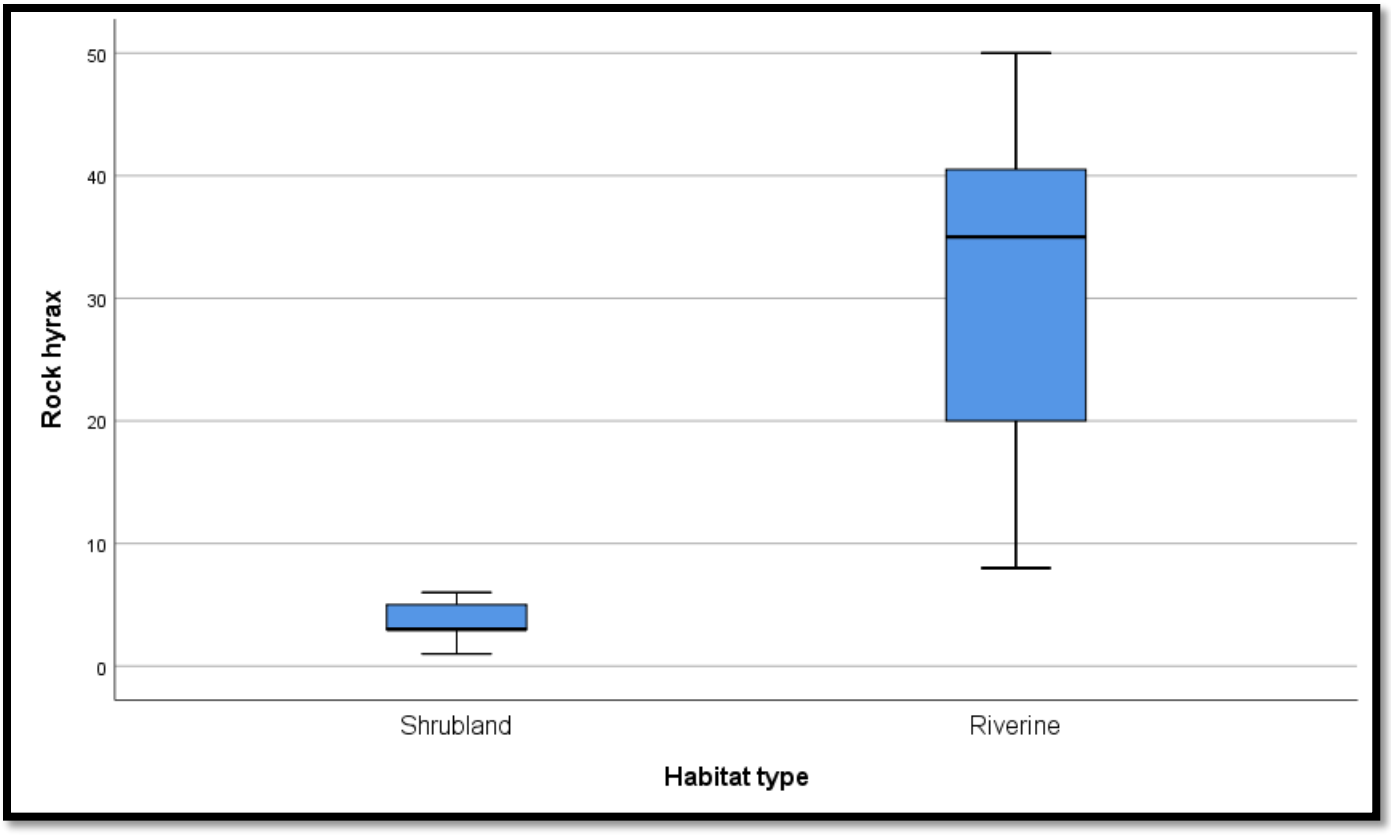

Figure 6: Minimum and maximum number of *P. capnesis* recorded in shrub land and riverine habitat

Vervet Monkey

Except in shrub land, *C. pygerythrus* was evenly distributed in all habitat types of the forest and abundant (N = 581) next to *P. capnesis* in both seasons. In farmland, 62 individuals of *C. pygerythrus* were recorded during the dry season (Table 4). However, *C. pygerythrus* was recorded higher individuals in wet season. *C. pygerythrus* is a medium-sized mammal type, that was preferred three habitat types in the forest.

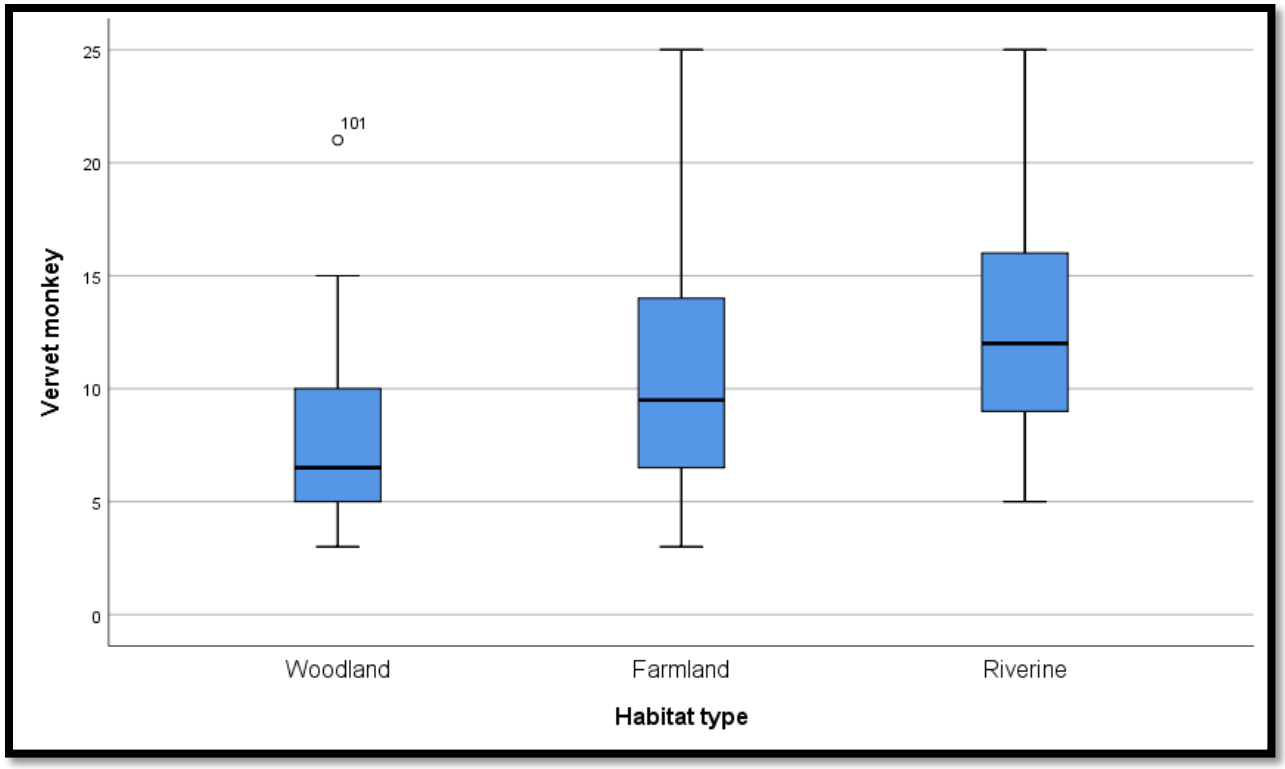

Figure 7: Minimum and maximum number of *C. pygerythrus* recorded in three habitat types

Spotted Hyena

C. crocuta is a large-sized carnivore mammal species mostly occurred in woodland, farmland and shrub land habitat. Except in riverine habitat, *C. crocuta* was evenly distributed in all habitat types of the forest and abundant (N = 11) next to *C. aureus* in dry season. In farmland, 2 individuals of *C. crocuta* were recorded during the dry season (Table 4). During in the wet season, higher individuals of *C. crocuta* were recorded in woodland habitat type. In those habitat types, *C. crocuta* was evenly distributed in both seasons.

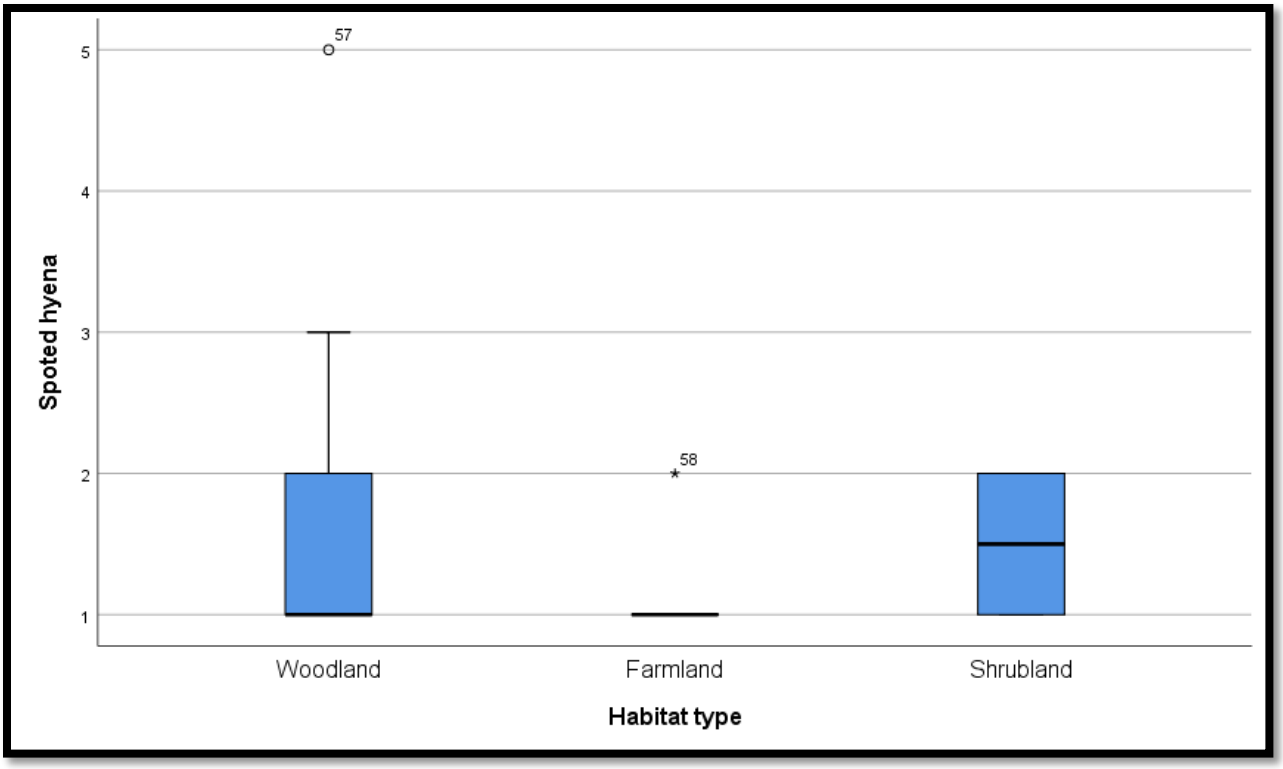

Figure 8: Minimum and maximum number of *C. crocuta* in three habitat types

Common Jackal

C. aureus is a large-sized carnivore mammal species occurred only in woodland and shrub land habitat types. Equal number of individuals of *C. aureus* (N = 13) were recorded during both seasons (Table 4). In woodland and shrub land habitat types, *C. aureus* was evenly distributed in both seasons.

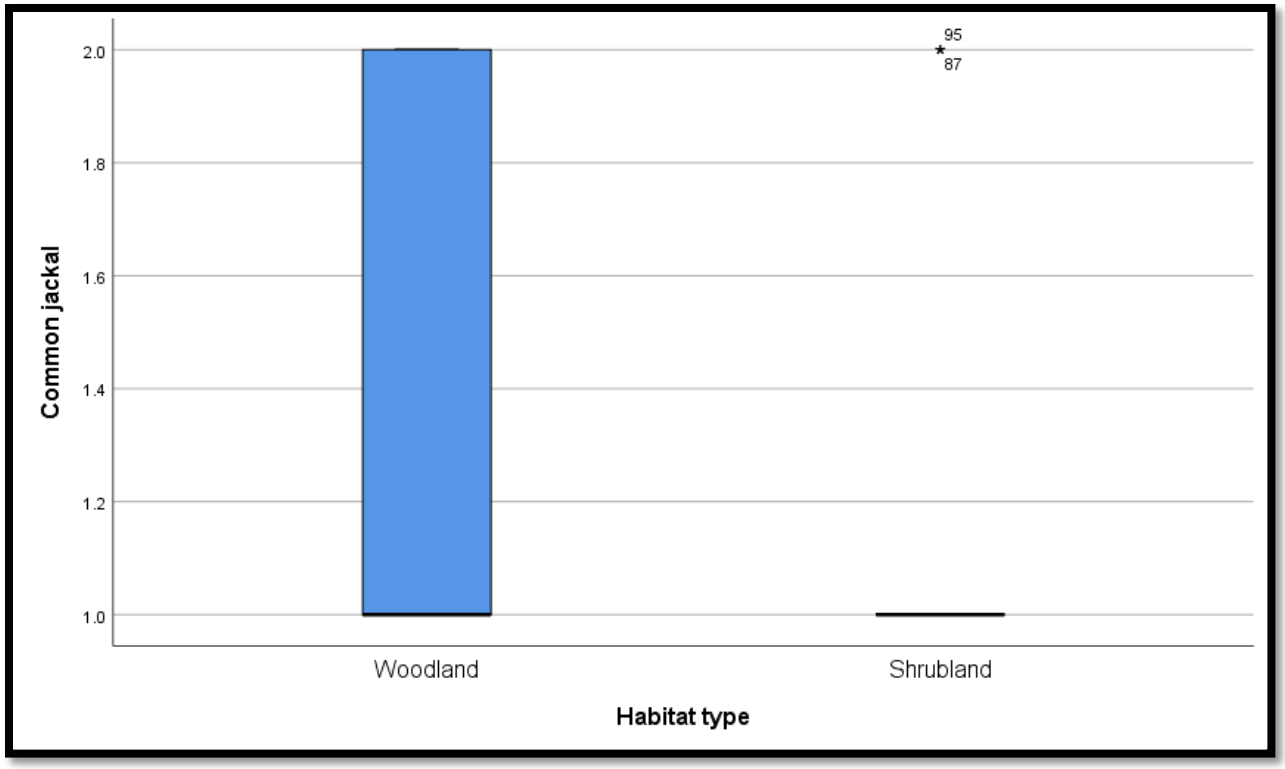

Figure 9: Minimum and maximum number of *C. aureus* in two habitat types

Cape Hare

L. capnesis is a medium-sized leporidae species found in woodland, farmland, shrub land and riverine habitat types in the study area. *L. capnesis* was the abundant mammals in shrub land habitat types next to *P. capnesis* than the other mammal species in the forest. In farmland, 14 individuals of *L. capnesis* were recorded during the wet season. In the study area, higher total individuals of *L. capnesis* were recorded in the wet season than in the dry season (Table 4).

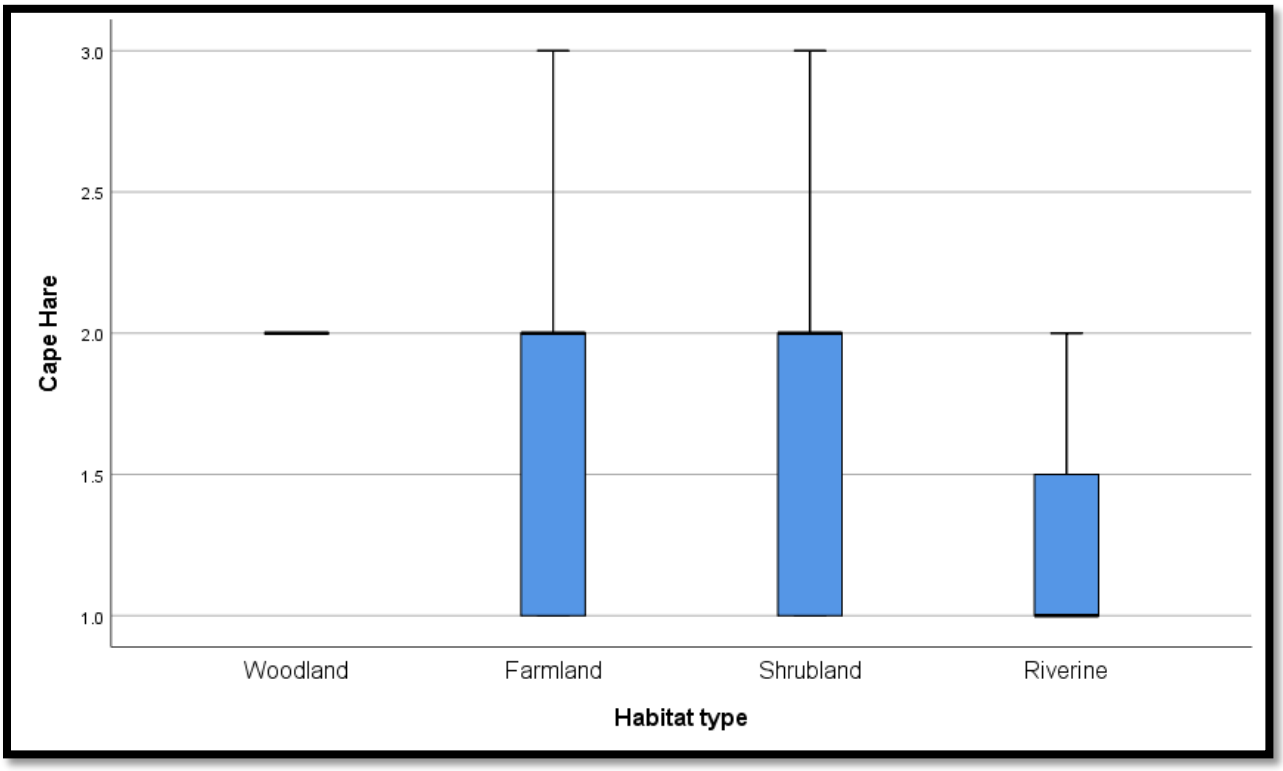

Figure 10: Minimum and maximum of *L. capnesis* recorded in four habitat types

Klipspringer and White-tailed Mongoose

In the study area, *O. oreotragus* and *I. albicauda* were only recorded in farmland habitat type and unevenly distributed in the forest. In the study area, totally 9 individuals of *O. oreotragus* were recorded. In farmland, 3 individuals of *O. oreotragus* were recorded during in the wet season. *I. albicauda* was abundant (N = 7) during in the dry season than in the wet season (Table 4). *O. oreotragus* and *I. albicauda* are a medium and large-sized mammal type respectively.

During the wet and dry seasons, there is highly correlate with the total abundance of mammal species and number of species (species richness) in the study area. Therefore habitat type has a significant impact on total number of individual abundance of mammal species in the study area,

at the confidence interval of 95%, significant P value (P = 0.001) according the multiple linear regression (Table 8).

Table 8: Relationship among abundance and richness of MLSM species

Pearson Correlation		Abundance	Richness	
	Abundance	1.000	0.210	
	Richness	0.210	1.000	
Model Summary	R	R Square	Adjusted R Square	Std. Error of the Estimate
	0.835	0.442	0.422	13.483
ANOVA	Df	Mean Square	F	P value
Regression	4	3892.574	21.413	0.001
Chi-Square Tests	Value	Df	P value	
Pearson Chi-Square	9.64	117	0.001	

CHAPTER FIVE

5. Discussion

A survey of mammals in fragmented forest areas is one step in a larger effort to document Ethiopian mammals in less accessible places as well as carry out conservation action for the future. In this study, an assessment of medium and large-sized mammals confirmed the presence of 9 species, including eight least concern and the vulnerable: *P. pardus* (IUCN, 2021).

Using direct and indirect evidence, a total of nine species of medium and large-sized mammals were identified in the current study area. From a total species recorded in the study area, *H. cristata*, *P. capnesis*, *C. pygerythrus*, *L. capnesis* and *I. albicauda* are medium-sized mammals (55.56%). Farmland was the richest habitat type in the forest. In this habitat type, 6 species of mammals were recorded during both seasons. In this study area, all (except *P. capnesis)* medium-sized mammals were recorded in farmland habitat type. The other 3 medium and large-sized mammas were recorded from riverine, shrub land and woodland habitat types in the forest.

In general, the number of species recorded in Wurna Community Protected Forest is comparable with other results on medium and large-sized mammals in different protected areas in Ethiopia. On the other hand, at the Baroye Controlled Hunting Area in South Western Ethiopia a large number of mammal species (23 species) were discovered (Dereje *et al*., 2015). The findings by (Geleta and Bekele, 2016; Teklay and Haylegebriel, 2024) in species richness (15 species) were higher than this study. In the other hand, in Wurna Community Protected Forest, there were high species richness discovered than the findings in Humbo Community-Based Forest Area, Southern Ethiopia (8 species) (Lemma and Tekalign, 2020).

The variation in the number of medium and large-sized mammal species in Wurna Community Protected Forest from mammal species recorded in another area might be due to environmental factors. The distribution of species and biodiversity is determined by a large number of abiotic and biotic factors (Elith and Leathwick, 2009). The variation might also be due to the difference in sample sites, sampling effort spent, season considered and variation in vegetation (Qufa and Bekele, 2019). The reason for recording lower number of mammal species in the current study area may also be due to the impact of anthropogenic factors observed in and around the forest. The presence of human activities around the habitat of mammals influences the dispersal of the species (Reale *et al*., 2014; Alvarenga *et al*., 2018). Lower number of medium and large-sized mammals in the Wurna Community Protected Forest might also be related to climatic conditions and Tigray post war in 2020. Climate change poses a long-term threat to mammal species. Mammal species severely affected by drought in different parts of the Tigray region (Matthew et al., 2017).

Overall 1,698 individuals of medium and large-sized mammals were recorded during the study area in both seasons in Wurna Community Protected Forest, from which 1,114 were observed during the wet season and 584 individuals in the dry season. In the forest, there were higher individuals of medium-sized mammals. From a medium-sized mammal species, *P. capnesis* was the abundant species in both seasons. As the result indicated, 748 individuals of medium and large-sized mammals were discovered in riverine habitat during the wet season. As compare to both seasons, interims of individual species, in the wet season there were highest individuals of medium and large-sized mammals.

As compare to this study, studies at different parts of the country reported both lower and higher individuals. In this study, there were higher individual numbers of medium and large-sized

mammal species (1,698) than the findings on other studies: such as 227 individuals in Geremba Mountain Fragments, Southern Ethiopia (Girma and Worku, 2020), 647 individuals are found in Michole Community Protected Forest, Southern Ethiopia (Agebo and Tekalign, 2022), 899 individuals in Woyde Woshe Community Reserve Forest (Tamirat, 2023) and 920 individuals in Nensebo Forest, Southern Ethiopia (Girma and Worku, 2020). However, the findings by other studies, are higher than this study: like 3,648 individuals are found in Humbo Community-Based Forest Area, Southern Ethiopia (Lemma and Tekalign, 2020) and 7,168 individuals were recorded in the Wondo Genet Forest Patches (Girma *et al*., 2012).

Season, habitat types, sample design, species types, month and seasonal data collection interval might contribute to such variation of reported results. This difference could be owing to the study area's modest size. Furthermore, during the study period, agricultural land expansion, illegal logging for fuel wood, overgrazing and illegal hunting were all regular occurrences. Typically, these activities has a significant negative impact on the richness and abundance of medium and large-sized mammal species in the forest. Research area size and habitat changes caused by diverse anthropogenic pressures may have a major impact on species' existence, abundance and distribution in the study area, similar to the findings by (Legese *et al*., 2019; Qufa and Bekele, 2019; Eden and Girma, 2024). Similar to other mammalian studies, (Gonfa et al., 2015; Qufa and Bekele, 2019), the current study found that medium and large-sized mammals choose one habitat over another based on resource availability and quality. In the current investigation, larger number of the species were discovered in farmland habitat type.

The highest species diversity of the study area was recorded in shrub land (H' =1.334) during the wet season of the year. In contrast to the findings by (Eden and Girma, 2023) the highest species

diversity index was in woodland habitat type during the wet season in Mago National Park (MNP), Southern Ethiopia. Shrub land habitat has the highest species diversity index in both seasons in this study. As the result indicated, higher species diversity index was in the wet season, similar to the findings by (Eden and Girma, 2023). While species diversity were comparatively low in the riverine habitat during both seasons. This is probably related to the fact that seasonal variations in the level of human disturbances and habitat preferable of mammals in the forest. And also similar to this study, the findings by (Teklay and Haylegebriel, 2024) in Asimba forest, indicated that high species diversity was recorded during the wet season. Woodland was the second diversified habitat type next to shrub land in both seasons in this study area. However, the findings by (Bobo *et al*., 2014; Qufa and Bekele, 2019; Tilahun and Merewa, 2020) indicated that high species diversity of mammals was recorded either in woodlands and/or forest habitats. In shrub land, there were lower local community activities than in woodland. Not only the activities of the local communities but also the availability of habitat types chosen by those mammals, season, habitat types, species richness and individual abundance were affects mammal species diversity.

The most common species seen were Vervet Monkeys and Rock Hyrax, followed by Porcupine. The topographic features of the current research area were ideal for primate populations. Primates were the most abundant order in various study areas, according to several studies (Geleta and Bekele, 2016; Legese *et al*., 2019). However in this study area, primate was the second abundant order next to order hyracoidea in both seasons. Beyond their abundance in varied places, it was argued those primates' has high reproductive success, diversified feeding habits and adaptable nature of habitats (Bobo *et al*., 2014).

The evenness index (J) shows, the distributional patterns of each species along with habitats between seasons. In shrub land habitat, there was evenly distribution of mammals (J = 0.8288) than the other habitat types in the study area during the wet season. The distribution of mammals could be based on their requirements for survival and reproduction in conjunction with the presence of preferred food and better-quality habitat in the forest. Distribution of individual mammal species in the area could be based on habitat selection in relation to the availability and abundance of green forage and water in different habitat types, as well as individual adaptability to human activities. Thus, the better conditioned the habitat, the better the distribution and survival of the mammals. According to the (Wolf and Ripple, 2016) report, mammal distribution is often determined by the availability of food in a given area. Likewise, studies carried out in different parts of Ethiopia have also indicated that the distribution of mammals is often related mainly to the better availability of water, foraging opportunities and protection (Mohammed *et al*., 2011; Tariku *et al*., 2011).

Order artiodactyla was the smallest distribution and abundance in the Wurna Community Protected Forest. In this order, only one species (*O. oreotragus)* and (nine individuals) was observed in both seasons. The findings by (Tamirat, 2023) in Woyde Woshe Community Reserve Forest were higher individuals of *O. oreotragus* (N = 30) than of this study. In other studies, artiodactyla was placed second in terms of distribution and abundance after the order primate reported (Legese *et al*., 2019). Nonetheless, this result contradicts to findings (Geleta and Bekele, 2016; Qufa and Bekele, 2019). This difference could be a result of the change in the availability of resource in each study area.

Hyracoidea species was the abundant medium-sized mammals in Wurna forest. In contradict to this study, lower individuals of *P. capensis* were discovered by (Teklay and Haylegebriel, 2024). Mammals like *P. capensis* thrives in the presence of rocks and caves. Carnivores were few in the research area, both in terms of distribution and individuals in comparison to hyracoidean and primate. Totally, 45 individuals of C. crocuta were recorded in Wurna forest. Individuals recorded in this area is higher than individuals recorded by (Tamirat, 2023, N = 37; Teklay and Haylegebriel, 2024, N = 42). However, higher individuals (N = 59) were recorded by (Eden and Girma, 2024) in MNP. In different study areas, there are variable number of individuals of *C. crocuta.* This variable, indicates the researcher has used different techniques of individual counting. Not only the techniques, but also the study areas modest size and duration of time were affected individuals of mammal species. The existence of unlawful hunting due to large depredations of livestock by carnivores (particularly, Spotted Hyena and Leopard) in and around the research area and its surroundings greatly reduces their number. Their presence could not be easily documented due to human intervention in their nocturnal and cryptic activities, according to (Gonfa, et al., 2015; Teklay and Haylegebriel, 2024), similar to the findings in this research. The Spotted Hyena (*C. crocuta*) distributed throughout the country except extreme Northeast margins. It lives in the forest and dense woodland (Kasso and Bekele, 2017).

Only *L. capnesis* was represented in lagomorpha and 43 individuals of this species were recorded during the wet season. Higher individuals of *L. capnesis* were recorded in Wurna Community Protected Forest (N = 69) than individuals recorded in Asimba Forest Priority Area, Semiarid Highlands of Northern Ethiopia (N = 28) (Teklay and Haylegebriel, 2024). Because, it is a common crop raider, it was usually hunted. As a result of the struggle, its population began to dwindle over time. In and around the Wurna forest, human-mammal conflicts are typical

occurrence similar to the finding (Bobo, *et al*., 2014). Similarly, order rodentia was recorded only one species (*H. cristata)* in the study area. *H. cristata,* almost the entire body is covered with bristles and has evenly distributed in all habitat type of the forest and has feed on mostly roots, bulbs, insects and crops. It travels long distance looking for food. In this forest area, 41 individuals of *H. cristata* were recorded. Similar to (Tamirat, 2023) findings, in the dry season, 16 individuals of *H. cristata* were recorded. In this study, higher individuals were recorded in the wet season than the dry season. Season has effect on the abundance of *H. cristata* in this study.

Order lagomorpha, hyracoidean and rodentia were each represented by a single species in the study area. This research finding was similar to (Geleta *et al*., 2016) discovered in Wacha Protected Forest, Western Ethiopia.

In this study, *P. pardus* has preferred woodland habitat type. In contrast to other studies, the individual numbers of *P. pardus* recorded in this study were lower than that of in MNP (Eden and Girma, 2023) and in Yechilay, Tanqua Abergele, Northern Ethiopia (N = 7) (Matthew et al., 2017). This difference is due to the area modest size and material (Camera Trap) used during the study. However, the findings of (Tamirat, 2023) in Woyde Woshe Community Reserve Forest (N = 5) is lower than that of this study. *P. pardus,* is an adaptable mammal species across most of sub Saharan Africa, occurs in woodland, grassland, shrubland and mountain habitat type and, is classified as a vulnerable species (Stein *et al*., 2016). Mammals may prefer their habitat type due to their availability of resources in the habitat. *P. pardus* was seen frequently in wet season. Distribution and abundance of Leopards are poorly known in Ethiopia (Yirga *et al*., 2012). The most suitable habitat for Leopards appears to be largely determined by primary productivity and

vegetation type. Thicket vegetation and drainage lines attract prey species seeking both forage and water. And also, dry streambeds may provide relatively low-cost pathways to Leopard.

The *I. albicauda* is distributed throughout the country, except in extreme East parts of the country (Bekele and Yalden, 2013). It lives habitat in forest margin and woodland habitats (Merga, 2020).

The shrub land and riverine shared the most species similarities during both seasons. This is most likely owing to the fact that these habitats are located near rivers and mountain ranges, which allows them to hide from potential enemies. In this study, the species evenness among the habitats is mostly determined by the proximity of different habitats to one another, differences in sampling attempts and animal utilization of habitats. It is similar to the findings of (Bobo *et al*., 2014; Legese *et al*., 2019; Teklay and Haylegebriel, 2024).

Most mammals were under local threat, especially *O. oreotragus.* During a field survey, bovidae was being illegally hunted for meat. The common conservation concerns in the research area, included land degradation, agricultural land expansion, illegal logging for fuel wood and illegal hunting. In and around the research area, human wildlife conflict was claimed to be a common concern, similar reports as discussed by (Tilahun and Merewa, 2020). The main problems in Wurna forest were substantial habitat fragmentation, deforestation, expansion of agriculture, human settlements and illegal hunting of mammal species. This finding was similar to (Legese *et al*., 2019; Teklay and Haylegebriel, 2024) results in Asimba protected forest. Other studies, such as (Qufa and Bekele, 2019; Worku *et al*., 2020) have documented comparable trends in other study areas in Ethiopia.

CHAPTER SIX

6. Conclusion and Recommendation

6. 1. Conclusion

The study area was conducted in central zone of Tigray, Tanqua Mlash Woreda. Generally, in Wurna Community Protected Forest, one vulnerable and eight least concerns medium and large-sized mammal species were investigated. Averagely, 849 individuals, belonging to six orders and nine families of medium and large-sized mammals were recorded. A total of nine species and 1,698 individuals of medium and large-sized mammal species were recorded, four of them belonging to order carnivore species. From a total species, Rock Hyrax was the most abundant medium-sized mammal species, followed by Vervet Monkey in both seasons. The findings of the study revealed that Wurna Community Protected Forest supports a considerable number of medium and large-sized mammalian species, including the vulnerable *P. pardus*.

The number of medium and large-sized mammalian species recorded in the study area was higher in farmland in both seasons. However, in shrub land there was higher diversity of medium and large-sized mammal species in the study area. Generally, mammals recorded in the shrub land has evenly distributed in the forest than mammals recorded in the other three habitat types. Therefore, habitat types were a significant effects on abundance of medium and large-sized mammals in the study area. The Shanon weaver diversity index showed that the area harbors diverse mammalian species. This is the first ecological information on the diversity of mammalian species of the Wurna Community Protected Forest, which would serve as valuable baseline information for stakeholders to make impactive conservation decisions and for researchers wishing to conduct related ecological studies.

6.2. Recommendation

Despite the importance of Wurna Community Protected Forest, as the home for nine medium and large-sized mammalian species belonging to six orders and nine families, it is not legalized as a wildlife refuge area. Therefore, to ensure the long-term conservation of the mammalian species of the forest, the following recommendations are suggested: The federal and regional governments should legalize it as a wildlife refuge area to conserve mammalian species. Clear demarcation of the area is also essential. Knowledge-based conservation and management initiatives must be implemented. Furthermore, the Head of the Agbe District and the Woreda Peasant Association should collaborate with the local population to establish a restoration program to secure the forest. Furthermore, the researcher recommends that more extensive research will conduct on the availability of food, age structure, sex ratio and ecology of medium and large-sized mammalian species in the forest. And also recommended, further investigation on the cause and effects of human mammal conflict in Wurna Community Protected Forest and should be use a camera trap.

References

Abune, L. (2000). The Challenges of Conserving Ethiopian Wildlife. Walia. **21**: 56-62.

Afework, B. and Yalden, D. W. (2013). Mammals of Ethiopia and Eritrea, Addis Ababa University Press, Addis Ababa, Ethiopia.

Agebo, A. and Tekalign, W. (2022). Terrestrial Medium and Large-sized Mammalian Species Diversity in Michole Community Protected Forest, Southern Ethiopia. *Journal of Biological Management and Conservation of Zoology***. 7**: 1-10.

Allen, A. M. and Singh, N. J. (2016). Linking Movement Ecology with Wildlife Management and Conservation. *Frontier in Ecology and Evolution*. **3**(155): 1-13.

Alves Costa, C. P. and Eterovick, P. C. (2007). Seed Dispersal Services by Coatis (Nasua nasua, Procyonidae) and their Redundancy with other Frugivores in South Eastern Brazilian. *Journal of Agricultural Ecology*. **32**: 77-92.

Amare, A. (2015). "Conservation Challenges of Gibe Sheleko National Park, South Western Ethiopia," Natural Resources. **6**(4): 286-289.

Amare, A. (2015). Wildlife Resources of Ethiopia: Opportunities, challenges and future directions: From ecotourism perspective: A review paper. Natural Resource. **6**: 405-422.

Anonymous. (2002). Human Wildlife Conflict: Impact of African Elephant on vegetation. CABS. **42**: 85-93.

Asefa, A., Mengesha, G., Sori, T., and Mamo, Y. (2019). Local and Land Scape-level Effects of Land use Change on Bird Diversity in Abiata Shalla Lakes National Park, Ethiopia. *African Journal of Ecology*. **57**: 51–58.

Atnafu, G. and Yihune, M. (2018). Species Composition and Relative Abundance of Medium and Large Mammals in Mengaza Communal Forest, East Gojjam, Ethiopia. *Journal of Ecology and the Natural Environment*. **10**: 34-40.

Baillie, J. E., HiltonTaylor, C. and Stuart, S. N. (2004). A Global Species Assessment. IUCN, Cambridge.

Bantihun, G. and Bekele, A. (2015). Diversity and Habitat Association of Small Mammals in Aridity Forest, Awi Zone, Ethiopia. Science Press Zoological Research. **36**(2): 88-94.

Barrier, P., Hutterer, R., Nicolas, V., Querouil, S. and Colyn, M. (2006). Investigating the Role of Natural Gallery Forests outside the Congolese Rain Forest as a Refuge for African Forest Shrews. Belgium. *Journal of Zoology*. **135**: 2735.

Barua, M. (2011). Mobilizing Metaphors: The popular use of keystone, flagship and umbrella species concepts. Biodiversity and Conservation. **20** (7): 1427–1440.

Bekele and Yalden, D. W. (2014). Mammals of Ethiopia and Eritrea, Addis Ababa University Press, Addis Ababa, Ethiopia.

Bekele, A. and Yalden, D. (2013). The Mammals of Ethiopia and Eritrea. Addis Ababa University Press, Addis Ababa. **56**: 121-134.

Berger, J., Stacey, P.B., Bellis, L. and Johnson, P. (2001). A Mammalian Predator-prey Imbalance: Grizzly bear and wolf extinction affect avian neotropical migrants. *Ecology of Applied Science*. **11**: 947-960.

Bernardo, P. V. S. and Melo, F. R. (2013). Assemblage of Medium and Large-size Mammals in an Urban Semi Deciduous Seasonal Forest Fragment in Cerrado biome. *Biology of Neo tropical*. **13**(2): 76-80.

Blair, A. (2008). Human Wildlife Conflict in Laikipia North, Kenya: Comparing official reports with the experience of Maasai pastoralists a thesis submitted to McGill University in partial fulfilment of the requirements of the degree of Master of Science. Department of Geography McGill University, Montreal.

Bobo, S., Kamgaing, L. and Ntumwel, C. (2014). Species Richness, Spatial Distributions and Densities of Large and Medium-Sized Mammals in the Northern Periphery of Boumba bek National Park, South Eastern Cameroon. African Study Monographs. **49**: 91-114.

Boddicker, M., Rodriguez, J.J. and Amanzo,J. (2002). Indices for Assessment and Monitoring of Large Mammals with in an Adaptive Management Framework. Environmental Monitoring and assessment. **76**(1): 105-123.

Boesch, L., Mundray, R., Kuehl, H. and Berger, R. (2017).Wild Mammals as Economic Goods and Implications for their Conservation. *Ecology and Society*. **22**(4): 36.

Bunney, K., Bond, W.J. and Henley, M. (2017). Seed Dispersal Kernel of the Largest Surviving Mega Herbivore. The African savanna Elephant. *Bio tropical*. **49(**3): 395-401.

Burton, A.C., Neilson, E., Moreira, D., Ladle, A., Steenweg, R.,Fisher, J. T., Bayne, E. and Boutin, S. (2015). Wildlife Camera Trapping: A review and recommendations for linking surveys to ecological processes. *Journal of Applied Ecology*. **52**(3): 675-685.

Butler, R. A. (2016). The Top Ten Most Biodiversity Countries: What are the world's most biodiversity countries?

Carvalho, D., Oliveira, R. and Pires, S. (2014). Medium and Large-sized Mammals of the Reservation Ecological. *Biology of Neo tropical*. **14**: 1-9.

Ceballos, G. and Ehrlich, P.R. (2006). Global Mammal Distributions, Biodiversity Hotspots, and Conservation. Proceeding of the National Academy of Science, USA. **103**: 19374-19379.

Chala Adugna and Afework Bekele. (2019). A Preliminary Survey of Medium and Large-sized Mammals from Lebu Natural Protected Forest, Southwest Showa, Ethiopia. *Ecological Evolution*. **9**(21): 322– 331.

Clinchy, M., Zanette, L.Y., Roberts, D., Suraci, J.P., Buesching, C. D., Newman, C. and Macdonald, D.W. (2016). Fear of the Human ¨Super predator" far exceeds the fear of large carnivores in a model meso carnivore. *Behavioral Ecology*. **27**(6): 1826-1832.

Cochrane, E.P. (2003). The need to be eaten: Balaniteswilsoniana with and without elephant seed-dispersal. *Journal of Tropical Ecology*. **19**(5): 579-589.

Corbet, G. B. and Hill, J. E. (1991). A World List of Mammalian Species. 3rd edn., Oxford University Press, Oxford.

Cortes Marcial, M., Y. M. Mart´ ınez Ay´ and M. Briones Salas. (2014). "Diversity of Large and Medium Mammals in Juchitan, Isthmus of Tehuantepec, oaxaca, Mexico," *Animal Biodiversity and Conservation*. **37**(1): 1-12.

CSAE. (2009). "Agricultural Sample Survey (AgSE2001). Report on Area and Production, Tigray Region. Version 1.1 - December 2007" Archived 14 November 2009 at the Wayback Machine.

Demissew, S., Friis, I. and Weber, O. (2021). Diversity and Endemism of the Flora of Ethiopia and Eritrea: State of knowledge and future perspectives. **32**: 675-697.

Dereje, N., Tsegaye, G. and Tadese, H. (2015). The Diversity, Distribution and Relative Abundance of Medium and Large-sized Mammals in Baroye Controlled Hunting Area, Illubabor Zone, Southwest Ethiopia. *International Journal of Molecular Evolution and Biodiversity*. **5**: 1-9.

Deresse, D. (2003). Attitudes and Perception of Local Community towards the Ethiopian Wolf. Durrell Institute of Conservation and Biology (DICE). University of Kent.

Dickman, A.J. (2010). Review on Complexities of Conflict: The importance of considering social factor for effectively resolving human wildlife conflict. Department of Zoology, Wildlife conservation research. University of Oxford.

Dinerstein, E. (2003). The Return of the Unicorns. Columbia University Press, New York.

Eden Tsegaye and Girma Mengesha. (2023). Diversity, Relative Abundance and Distribution of Medium and Large-sized Mammals in Mago National Park, Southern Ethiopia. College of Dryland Agriculture and Natural Resources, Mekelle University and Wondo Genet College of Forestry and Natural Resources, Hawassa University. *Journal of Science and Inclusive Development*. **5**(2): 1-23.

Elith, J. and Leathwick, J. R. (2009). "Species Distribution Models: Ecological explanation and prediction across space and time," Annual Review of Ecology, Evolution and Systematics. **40** (1): 677–697.

EWCA. (2015). Kafta Sheraro National Park. EWCA. Retrieved. Ethiopian Wildlife Conservation Organization. Elephant conservation Plan. Addis Ababa, Ethiopia.

EWCA. (2020). Review of the Leopard (*Panthera pardus*) Quota of Ethiopia.

Feddema, K., K. A. I. Nekaris, V. Nijman and P. Harrigan. (2021). Re-evaluating the Notion of Value in Wildlife Trade Research from a Service Marketing Perspective. *Biological Conservation*. 256.

Fetene, A., G. Mengesha and T. Bekele. (2011). "Spatial Distribution and Habitat Preferences of Selected Large Mammalian Species in the NechSar National Park (NSNP), Ethiopia." *Natural Sciences*. **9** (3): 80-90.

Frey, S., Fisher, J. T., Burton, A. C. and Volpe, J. P. (2017). Investigating Animal Activity Patterns and Temporal Niche Partitioning Using Camera Trap Data: Challenges and opportunities. *Remote sensing in Ecology and conservation*. **3**(3): 123-132.

Gaynor, K. M., Hojnowski, C. E., Carter, N. H. and Brashares, J. S. (2018).The Influence of Human Disturbance on Wildlife Nocturnality. *Agricultural Science.* **360**(6394): 1232-1235.

Geleta, M. and Bekele, A. (2016). Survey of Medium and Large-sized Mammals in Wacha Protected Forest, Western Ethiopia. *Scholarly Journal of Agricultural Science*. **6**: 71-79.

Gerardo Ceballos and Paul R. Ehrlich. (2009). Discoveries of New Mammal Species and Their Implications for Conservation and Ecosystem Services. Proceeding of the National Academy of Sciences. **106**(10): 1-6.

Getachew, A and Mesele, Y. (2018). "Species Composition and Relative Abundance of Medium and Large Mammals in Mengaza Communal Forest, East Gojjam, Ethiopia," *Journal of Ecology and the Natural Environment*. **10**(2): 34-40.

Girma, Z. and Worku, Z. (2020). Large Mammal Diversity in Nensebo Forest, Southern Ethiopia. *International Journal of Zoology*. 1-11.

Girma, Z., Mamo, Y. and Ersado, M. (2012). Species Composition, Distribution and Relative Abundance of Large Mammals in and around Wondo Genet Forest Patch, Southern Ethiopia. *Asian Journal of Applied Science*. **5**: 538-551.

Gonfa, R., Gadisa, T. and Habtamu, T. (2015). The Diversity, Abundance and Habitat Associations of Medium and Large-Sized Mammals in Dati Wolel National Park, Western Ethiopia. *International Journal of Biodiversity and Conservation*. **7**: 112-118.

Guldemond, R.A., Purdon, A. and Van Aarde, R.J. (2017). A Systematic Review of Elephant Impact Across Africa, PLoS One. **12**(6).

Hanks, J. (2006). Mitigation of Human Elephant Conflict in the Katanga Zambezi Transfrontier Conservation Area, with particular reference to the use of chili peppers. Cape Town: *Journal of International Conservation*.

Hashim and Mahgoub. (2007). "Abundance, Habitat Preference and Distribution of Small Mammals in Dinder National Park, Sudan."

Heinze, E., Boch, S., Fischer, M., Hessenmöller, D., Klenk, B., Müller, J. and Halle, S. (2011). Habitat Use of Large Ungulates in North Eastern Germany in Relation to Forest Management. *Journal of Ecology and Management*. **261**: 288-296.

Igziabher and Taddesse Gabre. (1972). Power Struggle in Tigray During Zamana Masafint. Addis Ababa: Haile Sellassie I University.

Isla-Escudero, J. (2024). Ecology of Plant Animal Interactions During Plant Population Expansion Processes.

IUCN. (2020). The IUCN Red List of Threatened Species of Mammals Tigray Region, Ethiopia.

IUCN. (2021). The IUCN Red List of Threatened Species. Version. **3**: 12

Jacob, M. and colleagues. (2013). "Assessing Spatio Temporal Rainfall Variability in a Tropical Mountain Area (Ethiopia) using NOAAs Rainfall Estimates". *International Journal of Remote Sensing*. **34** (23): 8305-8321.

Jan Nyssen, Meheretu Yonas, Soffie Annys, Tesfaalem Ghebreyonannes, Wolbert Smidt, Kiros Welegerima, Seifu Gebreslassie, Andrea Sembroni, Francesco Dramis, Cammille Ek and David Causer. (2020). "The Zeyi Cave Geosite in Northern Ethiopia". Geoheritage. **12** (1): 6.

Jardano, P., Garcla, C., Godoy, J. and Garcla-Castano, J. L. (2007). Differential Contribution of Frugivores to Complex Seed Dispersal Patterns. Proceedings of the National Academy of Sciences. **104**: 3278-3282.

Kassahun Abie, Belete Tilahun, Abel Feyisa,Tewodros Kumssa and Alemneh Amare. (2021). Diversity and Habitat Association of Medium and Large Mammals in Gibe Sheleko National Park, Southern Ethiopia. *Ecological Evolution*. **11**(18): 12251-12258.

Kasso, M. and Bekele, A. (2017). Diversity, Abundance and Distribution of Mammals in Fragmented Remnant Forests around Asella Town, Ethiopia. *MAYFEB Journal of Biology and Medicine*. **1**: 1-12.

Keeping, D. and Pelletier, R. (2014). Animal Density and Track Counts: Understanding the Nature of Observations Based on Animal Movements. **9**(5).

Kelbessa, E and Demissew, S. (2014). Diversity of Vascular Plant Taxa of the Flora of Ethiopia and Eritrea. *Ethiopian Journal of Biological Science.* **13**: 37-45.

Kerley, G.I.H. and Landman, M. (2006).The Impacts of Elephants on Biodiversity in the Eastern Cape Subtropical Thickets, South African. *Journal of Science.* **102**(10): 395-402.

Kingdon J. and Largen M. (2003). The Kingdon Field Guide to African Mammals. *Zoological Journal of Linn Soc*iology. **120**(4): 479.

Kingdon, J. (2001). The Kingdon Field Guide to African Mammals. Academic Press, San Diego. 476.

Kingdong, J. (2015). Kingdon Field Guide to African Mammalian Species: Bloomsbury natural history (2nd ed.).

Kristy Udy, Matthias Fritsch, Katrin M. Meyer, Ingo Grass and Sebastian Han. (2021). Environmental Heterogeneity Predicts Global Species Richness Patterns better than Area. *Global Ecological Biogeography*. **30**(51): 89.

Lavrenchenko, L. A. and Bekele, A. (2019). Diversity and Conservation of Ethiopian Mammals: What have learned in 30 years? Ethiopia. *Journal of Biological Science*. **16**: 1-20.

Legese, K., Bekele, A. and Kiros, S. (2019). A Survey of Large and Medium-sized Mammals in Wabe Forest Fragments, Gurage Zone, Ethiopia. *International Journal of Avian and Wildlife Biology*. **4**: 32-38.

Lemma, A. and Tekalign, W. (2020). Abundance, Species Diversity and Distribution of Diurnal Mammals in Humbo Community Based Forest Area, Southern Ethiopia. *International Journal of Zoology*.

Longshore, K., Lowrey, C. and Thompson, D. B. (2013). Detecting Short Term Responses to Weekend Recreation Activity: Desert bighorn sheep avoidance of hiking trails. *Wildlife Society*. **37**(4): 698-706.

Madden, F. (2008). The Growing Conflict between Humans and Wildlife: Law and policy as contributing and mitigating factors. *Journal of International Wildlife Law and Policy*. **11**: 189-206.

Maddox, T. M. (2003). The Ecology of Cheetahs and other Large Carnivores in a Pastoralist Dominated Buffer Zone. PhD. Thesis, University College London and Institute of Zoology *.Zoological Society of London.*

Mamo, Y., Asefa, A. and Mengesha, G. (2015). Habitat Use of Ungulates in Bale Mountains National Park, Ethiopia. *African Journal of Ecology*. **53**: 512-520.

Martin, G. (2003). The Role of Small Ground Foraging Mammals in Topsoil Health and Biodiversity: Implications to management and restoration. *Ecology of Management and Restoration*. **4**: 114-119.

Matthew Westerberg, Evan Craig and Yonas Meheretu. (2017). First Record of African Leopard (*Panthera pardus*) in Semi-arid Area of Yechilay, Northern Ethiopia. United States Peace Corps Volunteer. Ethiopia, Environment/Agriculture Sectors, Mekelle, Ethiopia. Department of Biology, Mekelle University, Mekelle, Ethiopia. *African Journal of Ecology* .**10**: 2-4.

McGeocha, L., Gordonb, I. and Schmitta, J. (2008). Impacts of land Use, Anthropogenic Disturbance and Harvesting on African Medicinal Liana. *Biological Conservation*. **141**: 2218-2229.

MDD, (2022). Mammal Diversity Database (1.9) [Data set]. *Zenodo*, https://doi.org/10.5281/zenodo.6407053.

Meheretu Yonas, Kiros Welegerima, Sluydts, V., Bauer, H., Kindeya Gebrehiwot, Deckers, J, Makundi, R. and Leirs, H. (2015). "Reproduction and Survival of Rodents in Crop Fields: The effects of rainfall, crop stage and stone-bund density". Wildlife Research. **42** (2): 158-164.

Mekbeb Eshetu. (2019). A Report Assessment of Threat Status in Five Selected Wildlife Protected Areas of Ethiopia. Ethiopian wildlife conservation authority Enhanced management and effectiveness of Ethiopia's Protected area estate. Ethiopia.

Merga G. (2020). Status of Large Mammals Diversity, Abundance and Drivers of Local Extinction: The Case of Gura Lopho Protected Area*,* in Amuru Woreda*,* Western Ethiopia*. Global scientific journals*. 7(8*):* 20-86.

Mograbi, P.J., Asner, G.P., Witkowski, E.T., Erasmus, B.F., Wessels, K.J. and Mathieu, R. (2017). Humans and Elephants as Treefall Drivers in African Savannas. *Journal of Ecological geography*. **40(**11): 1274-1284.

Mohammed Kasso and Afework Bekele. (2017). Diversity, Abundance and Distribution of Mammals in Fragmented Remnant Forests around Asella Town, Ethiopia. *MAYFEB Journal of Biology*. **1**: 1-12.

Mulonga.S.,Suich, H. and Murphy, C. (2003).The Conflict Continues: Human Wildlife.

Nichols, J. D. and Williams, B. K. (2006). Monitoring for Conservation. *Trends in Ecology and Evolution*. **21**(12): 668-673.

NLFC, (2005). Newhall Land and Farming Company. Assessment and Survey of Mammals within the Newhall Ranch Specific Plane Area. California. 57.

Nowak, R.M. (1999). Walker's Mammals of the World. 6th ed. John Hopkins University Press, Baltimore, London.

Nyssen, J. (2019). Description of Trekking Routes in Dogu'a Tembien. GeoGuide. Cham (CH): Springer Nature. 557-675.

Nyssen Jan, Tielens Sander, Gebreyohannes Tesfamichael, Araya Tigist, Teka Kassa, Van De Wauw Johan, Degeyndt Karen, Descheemaeker Katrien, Amare Kassa, Haile Mitiku, Zenebe Amanuel, Munro Neil, Walraevens Kristine, Gebrehiwot Kindeya, Poesen Jean, Frankl Amaury, Tsegay Alemtsehay and Deckers Jozef. (2019). "Understanding Spatial Patterns of Soils for Sustainable Agriculture in Northern Ethiopia's Tropical Mountains". **14** (10).

Ojeda, A., Blendinger, G. and Brandl, R. (2000). Mammals in South American Drylands: Faunal similarity and trophic structure. Global. *Ecology of Biogeography*. **9**. 115-123.

Owen Smith, N., Slotow, R., Kerley, G.I.H., Van Aarde, R.J. and Page, B. (2006). A Scientific Perspective on the Management of Elephants in the Kruger National Park and Elsewhere: Elephant conservation, South African. *Journal of Science.* **102**(9): 389-394.

Porras, P. Vazquez L. and Sarmiento Aguilar, R. (2016). Influence of Human Activities on Some Medium and Large-sized Mammals' Richness and Abundance in the Lacandon Rainforest. *Journal of Nature Conserv*ation. **34**: 75- 81.

Qufa, C.A. and Bekele, A. (2019). A Preliminary Survey of Medium and Large-sized Mammals from Lebu Natural Protected Forest, Southwest Showa, Ethiopia. *Ecology and Evolution*. **9**: 12322-12331.

Quirin, C. (2005). Crop Raiding by Wild Vertebrates in the Illubabor Zone, Ethiopia, A report submitted in partial fulfilment of the post graduate Diploma in wildlife management, University of Otego, Department of zoology. New Zealand. **28**: 68-72.

Reale, R. Fonseca, R. C. B. and Uieda, W. (2014). "Medium and Large-sized Mammals in a Private Reserve of Natural Heritage in the Municipality. **10** (5): 997-1004.

Ray, C. (1998). Temporal Variation of Predation on Rodents and Shrews by Small African Forest Carnivores. *Journal of Zoology*. **244**: 363 -370.

Scholes, J., Kuper, W. and Biggs, R. (2006). Biodiversity. Africa Environment Outlook (Our Environment, Our Wealth) Report, Nairobi. 261.

Shannon, G., Druce, D.J., Page, B.R., Eckhardt, H.C., Grant, R. and Slotow, R. (2008). The Utilization of Large Savanna Trees by Elephant in Southern Kruger National Park. *Journal of Tropical Ecology*. **24**(3): 281-289.

Shoshani and Yirmed. (2008). Report on the Kafta Sheraro National Park. In memorial to Professor Jeheskel Shoshani.Tigray Region, Ethiopia. **43**:321-326.

Sianga, K., Van Telgen, M., Vrooman, J., Fynn, R.W. and Van Langevelde, F. (2017). Spatial Refuges Buffer Landscapes Against Homogenisation and Degradation by Large Herbivore Populations and Facilitate Vegetation Heterogeneity. **59 (**2): 1-13.

Sillero Zubiri, C., Gottelli, D., Marino, J., Randall, D., Tallents, L. and Macdonald, D. W. (2011). Ecology and Reproductive Strategy of an Afroalpine Specialist: Ethiopian wolves in the Bale Mountains. Walia Special Edition on the Bale Mountains. 61-79.

Smith, J. A., Suraci, J. P., Clinchy, M., Crawford, A., Roberts, D., Zanette, L. and Wilmers, C. C. (2017). Fear of the Human 'Super predator' reduce feeding time in large carnivores. *Proceeding of the Royal Society: Biological Sciences*. **284**: 433.

Solari, S., Rodriguez, J., Vivar, E. and Velazco, M. (2002). A Framework for Assessment and Monitoring of Small Mammals in a Lowland Tropical Forest. Environmental Monitoring Assessment. **76**: 89-104.

Solomon Haylemariam. (2005). Preliminary Study of Mount Zuquala. Institute for sustainable development, Addis Ababa, Ethiopia

Stankowich, A. (2008). Ungulate Flight Responses to Human Disturbance: A review and meta-analysis. *Biological Conservation*. **141**: 2159-2173.

Stein, A.B., Athreya, V., Gerngross, P., Balme, G., Henschel, P., Karanth, U. and Ghoddousi, A. (2016). Panthera pardus. The IUCN Red List of Threatened Species.

Stephens, P. A., d'Sa, C. A., Sillero-Zurbri, C. and Leader-Williams, N. (2001). Impact of Livestock and Settlement on the Large Mamma Lion Wildlife of Bale Mountains National Park, Southern Ethiopia. *Biological Conservation*. **100**: 307-322.

Struhsaker, T. T., Struhsaker, P. J. and Siex, K. S. (2005). Conserving Africa's Rain Forests: Problems in protected areas and possible solutions. *Biological Conservation*. **123**: 45-54.

Sutherland, W. J. (2006). Ecological Census Techniques: A handbook (2nd ed., 450p). New York, NY: Cambridge University Press.

Tamirat Haile Chankallo, (2023). Species Composition and Relative Abundance of Medium and Large-sized Mammals in Woyde Woshe Community Reserve Forest Areas, Kucha Alpha Woreda, South Gamo Zone, Southern Ethiopia. Ethiopian Wildlife Conservation Authority, Nech Sar National Park, Ecologist, Arba Minch, Ethiopia. *Journal of Natural Sciences Research*. **14**(2): 1-7.

Tariku Mekonnen, Mohammed Yaba, Afework Bekele and Malcolm J. (2011). Food Selection and Habitat Association of Starck's Hare (Lepus starcki Petter, 1963) in the Bale Mountains National Park, Ethiopia. *Asian Journal of Applied Science*. **4**: 728-734.

Tefera, M. (2011). Wildlife in Ethiopia: Endemic large mammals. *Conservation Zoology*. **6**: 108-116

Teklay Girmay and Haylegebriel Tesfay, (2024). A Preliminary Survey of Medium- and Large-sized Mammals and Their Conservation Status in the Asimba Forest Priority Area, Semiarid Highlands of Northern Ethiopia. *International Journal of Ecology*. **8**: 3-7.

Terves, A. and Karanth, K.U. (2003). Human Carnivore Conflict and Perspectives of Carnivore Management Worldwide. *Conservation of Biology.* **17**(6):1491-1499.

Tessema, M. E. (2019). Assessment of Threat Status in Five selected Wildlife Protected areas of Ethiopia. Report. 59.

Tewodros, K. and Afework. B. (2008). Human Wildlife Conflict and Population Status of Swayne"s Hartebeest in (*Alcelaphusbuse laphus swaynei*) in Senkele Swayne"s Hartebeest Sanctuary, Master Thesis in Biology (Ecological and Systematic Zoology), Ethiopia.

Tilahun, Z. and Merewa, Z. (2020). Large Mammal Diversity and Endemism at Geremba Mountain Fragment, Southern Ethiopia. *International Journal of Ecology*.

Treves, A., Naughton-Treves, L., Harper, E.K., Mladenoff. D.J., Rose, R.A., Sickely, T.A. and Wydeven, A.P. (2003**).** Predicting Human Carnivore Conflict: A spatial model derived From 25 Years of data on Wolf predation or Livestock. *Conservation of Biology.* **18**(1):114-154

Valeix, M. Fritz, H. Canévet, V. Le Bel, S. and Madzikanda, H. (2009). Do Elephants Prevent other African Herbivores from Using Waterholes in the Dry Season. *Biodiversity and Conservation*. **18**:569-576.

Vaughan, A. T., Ryan, M. J. and Czaplewaki, N. (2000). Mammalogy. Saunders College Publishing. 4th edn., New York. 565.

Villagra, E., Defosse, E., del Valle, F., Tabeni, S., Rostagno, M., Cesca, E. and Abraham E. (2009). Land Use and Disturbance Effects on the Dynamics of Natural Ecosystems of the Monte Desert: Implications for their management. *Journal of Aridity Environment*. **73:** 202-211.

Vos, J. (2000). Food Habits and Livestock Depredation of two Iberian Wolf packs (*Canislupus signatus*) in the North of Portugal. London. *Journal of Zoology*. **251:** 457-462.

Wilson, D. E.; Reeder, D. A. (2005). Mammal Species of the World. A Taxonomic and Geographic Reference.- 3rd Edition, The Johns Hopkins University Press, Baltimore. 2142.

Woldegeorgis, G., and Wube, T. (2012). A Survey on Mammals of the Yayu Forest in South West Ethiopia. *Ethiopian Journal of Science*. **35**: 135-138.

Wolf, C. and Ripple, W. J. (2016). Prey Depletion as a Threat to the World's Large Carnivores. *R Sociology Open Science*. **3**: 160-252.

Worku, Z. and Girma, Z. (2020). Large Mammal Diversity and Endemism at Geremba Mountain Fragment, Southern Ethiopia. The endemic mammals of Ethiopia. *Mammalogy Review.* **22:**115-150.

Yalden, W. D., Largen, J. M., Kock, D. and Hillman, C. J. (1996). Catalogue of the Mammals of Ethiopia and Eritrea. 7. Revised checklist, zoogeography and conservation. *Tropical Zoology*. **9**: 73-164.

Yirga, G., de Iongh, H. H., Leirs, H., Gebrehiwot, K., Berhe, G., Asmelash, T. and Bauer, H. (2012). The Ecology of Large Carnivores in the Highlands of Northern Ethiopia. *African Journal of Ecology*. **51**: 78-86.

Yirmed, D. (2004). Elephants in Ethiopia (Amharic Version). Berhanena Selam Printing Enterprise, Addis Ababa, Ethiopia.**75.**

Young, J. (2012). Ethiopian Protected Areas: A "Snapshot". Word Press, Addis Ababa. **23**.

APPENDIX

Date:- ----------

Data collection sheet for direct observation of mammals
Name of data collector
1. ----------
2. ----------
3.----------
4. ----------
5. ----------
Place ----------
Season ----------

Table 9: Primary Data observation

Transect lines	Species Name		Sex		Age class			Number of species	Habitat type	Time bound	Disturbance	Remark
	Scientific Name	Local Name	M	F	A	SA	Ju					
	1.											
	2.											
	3.											
	1.											
	2.											
	3.											
	1.											
	2.											
	3.											
	1.											
	2.											
	3.											
Total												

NB:- M< Male, F< Female, A< Adult, SA< Sub Adult, Ju< Juvenile

Table 10: Background of KII and data observation sheet

Name of KII	Gender of KII	Age of KII	Education	Name of MLSM species
1 .				1 .
				2 .
				3 .

Table 11: Diversity of MLSM species in both seasons 2024.

	Woodland	Farmland	Shrub land	Riverine	Woodland	Farmland	Shrub land	Riverine
Taxa_S	5	6	5	4	6	6	5	4
Individuals	89	193	84	748	75	84	51	374
Dominance_D	0.3428	0.6245	0.3152	0.6079	0.5396	0.5615	0.3095	0.6188
Simpson_1-D	0.6572	0.3755	0.6848	0.3921	0.4604	0.4385	0.6905	0.3812
Shannon_H	1.284	0.8399	1.334	0.6428	0.9905	0.9656	1.302	0.6276
Evenness_e^H/S	0.722	0.386	0.7591	0.4754	0.4488	0.4377	0.7353	0.4683
Brillouin	1.196	0.791	1.241	0.6335	0.8893	0.8712	1.174	0.6122
Menhinick	0.53	0.4319	0.5455	0.1463	0.6928	0.6547	0.7001	0.2068
Margalef	0.8911	0.9501	0.9028	0.4534	1.158	1.128	1.017	0.5064
Equitability_J	0.7976	0.4688	0.8288	0.4637	0.5528	0.5389	0.809	0.4527
Fisher_alpha	1.145	1.175	1.165	0.555	1.535	1.479	1.373	0.6254
Berger-Parker	0.5056	0.7824	0.4524	0.7406	0.72	0.7381	0.3922	0.7513
Chao-1	5	6	5	4	6	6	5	4

Table 12: Abundance and Relative abundance of MLSM species in Wurna forest

Season	Habitat	*P. pardus*	*H.c ristata*	*P.ca pnesis*	*C.pyg erythrus*	*C.c rocuta*	*C.a ureus*	*L.ca pnesis*	*O.ore otragus*	*I. albi cauda*	Abundance	Relative abundance
Wet	Woodland	5	10	0	45	23	6	0	0	0	89	8%
Wet	Farmland	0	14	0	151	6	0	14	3	5	193	17%
Wet	Shrubland	0	9	38	0	5	7	25	0	0	84	8%
Wet	Riverine	0	8	554	182	0	0	4	0	0	748	67%
	Total	5	41	592	378	34	13	43	3	5	1114	100 %
	Relative Abundance	0.45 %	3.68%	53.14 %	33.93%	3.05 %	1.17 %	3.86%	0.27%	0.45%	100. 00%	
	Dry season										Total	
Dry	Woodland	1	5	0	54	8	5	2	0	0	75	13%
Dry	Farmland	0	2	0	62	2	0	5	6	7	84	14%
Dry	Shrubland	0	4	20	0	1	8	18	0	0	51	9%
Dry	Riverine	0	5	281	87	0	0	1	0	0	374	64%
	Total	1	16	301	203	11	13	26	6	7	584	100 %
		0.17 %	2.74%	51.54 %	34.76%	1.88 %	2.23 %	4.45%	1.03%	1.20%	100. 00%	

Table 13: Similarity index of mammal species in Wurna forest

			Wet Season				Dry Season						
	Woodland	Farmland	Shrub land	Riverine	Woodland	Farmland	Shrub land	Riverine					
Richness	5	6	5	4	6	6	5	4					
	WFSR	WFS	WFR	WSR	FSR	WF	WS	WR	FS	FR	SR		
WET Common species	1	2	2	1	2	3	2	2	3	3	3		
WET SI	0.2	0.375	0.4	0.214	0.4	0.55	0.4	0.44	0.55	0.6	0.67		
Dry common species	2	3	3	2	2	4	4	3	3	3	3		
Dry SI	0.38	0.53	0.563	0.4	0.4	0.67	0.73	0.6	0.55	0.6	0.67		

Table 14: Occurrence of MLSM species in wurna forest

Species	Woodland	Farmland	Shrub land	Riverine
P. pardus	Yes	No	No	No
H.cristata	Yes	Yes	Yes	Yes
P.capnesis	No	No	Yes	Yes
C.pygerythrus	Yes	Yes	No	Yes
C.crocuta	Yes	Yes	Yes	No
C.aureus	Yes	No	Yes	No
L.capnesis	Yes	Yes	Yes	Yes
O.oreotragus	No	Yes	No	No
I. albicauda	No	Yes	No	No

Table 15: Correlation among total number of individual species and season, month, habitat type and number of species

Correlations

		Total number of individual species	Season	Month	Habitat type	number of species
Pearson Correlation	Total number of individual species	1.000	-.154	-.184	.636	.210
	Season	-.154	1.000	.888	-.023	-.195
	Month	-.184	.888	1.000	-.034	-.247
	Habitat type	.636	-.023	-.034	1.000	.110
	number of species	.210	-.195	-.247	.110	1.000
Sig. (1-tailed)	Total number of individual species	.	.052	.026	.000	.013
	Season	.052	.	.000	.405	.019
	Month	.026	.000	.	.360	.004
	Habitat type	.000	.405	.360	.	.123
	number of species	.013	.019	.004	.123	.
N	Total number of individual species	113	113	113	113	113
	Season	113	113	113	113	113
	Month	113	113	113	113	113
	Habitat type	113	113	113	113	113
	number of species	113	113	113	113	113

Analysis of season on specie richness

Chi-Square Tests

	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	.667[a]	2	.717
Likelihood Ratio	.680	2	.712
N of Valid Cases	8		

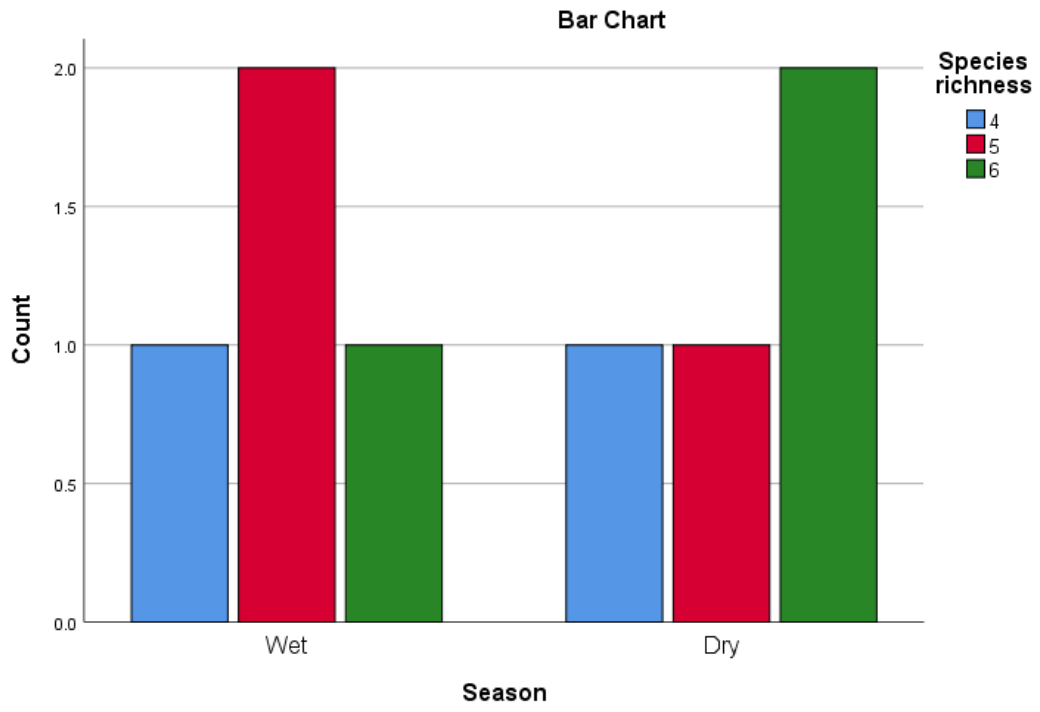

Figure 11: Richness of Medium and Large-sized Mammals in both Seasons

Analysis of habitat type on richness

Chi-Square Tests

	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	13.333[a]	6	.038
Likelihood Ratio	14.543	6	.024
N of Valid Cases	8		

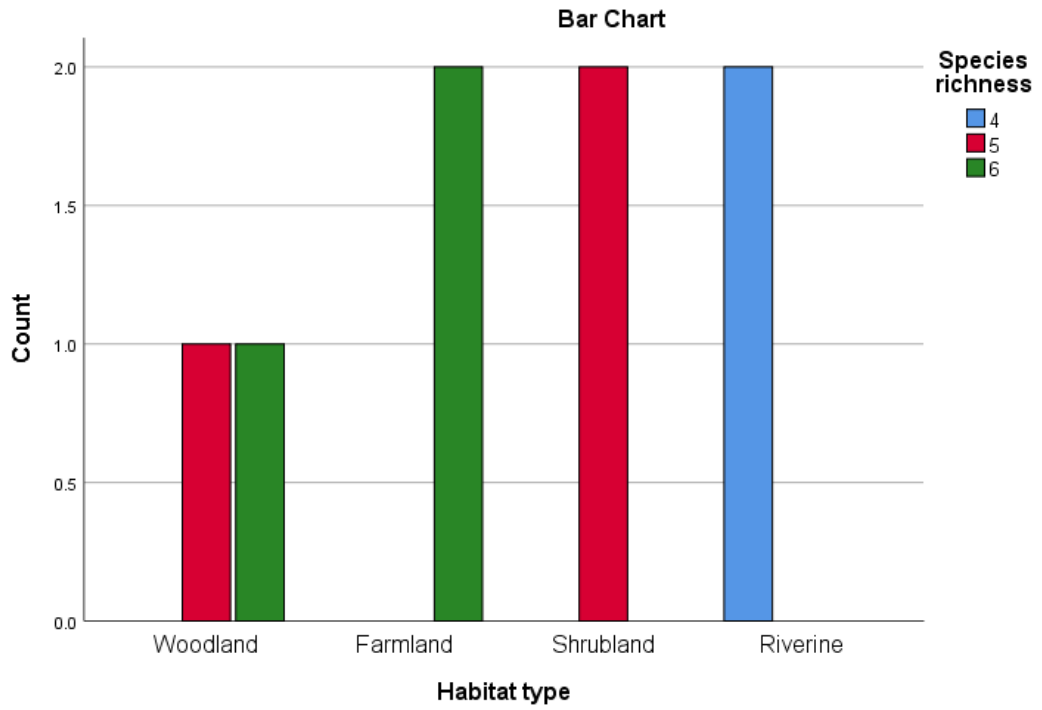

Figure 12: Richness of Medium and Large-sized Mammals in Different Habitat Type

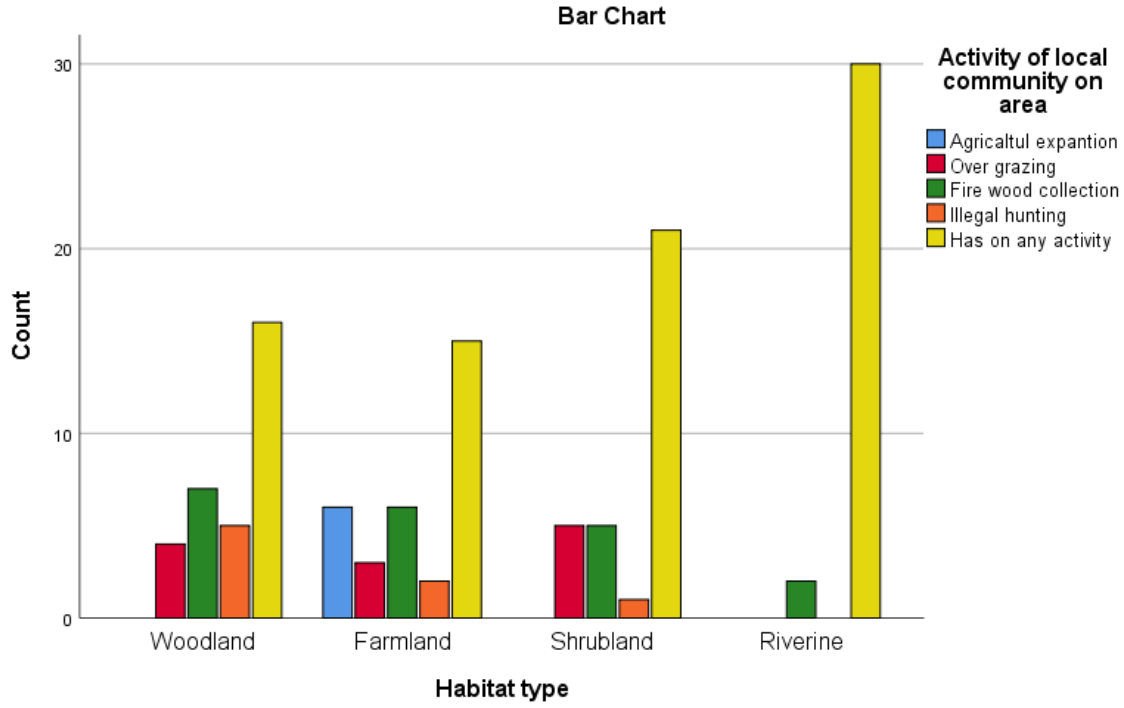

Figure 13: Local Community Activities, Recorded During the Survey Period

Table 16: Analysis of mammals recorded in Wurna forest

Statistics

	P. pardus	*H.cristata*	*P.capnesis*	*C.pygerythrus*	*C.crocuta*	*C.aureus*	*L.capnesis*	*O.oreotragus*	*I. albicauda*
N	6	40	43	53	29	21	38	8	7
Mean	1.00	1.43	20.77	10.96	1.55	1.24	1.82	1.13	1.71
Std. Error of Mean	.000	.094	2.527	.752	.176	.095	.112	.125	.286
Std. Deviation	.000	.594	16.570	5.474	.948	.436	.692	.354	.756
Variance	.000	.353	274.564	29.960	.899	.190	.479	.125	.571
Std. Error of Skewness	.845	.374	.361	.327	.434	.501	.383	.752	.794
Range	0	2	49	22	4	1	2	1	2
Minimum	1	1	1	3	1	1	1	1	1
Maximum	1	3	50	25	5	2	3	2	3
Sum	6	57	893	581	45	26	69	9	12

	L	*P*	*Rh*	*Vm*	*Sh*	*Cj*	*Ch*	*Ks*	*Wm*
Taxa_S	6	40	43	53	29	21	38	8	7
Individuals	6	57	893	581	45	26	69	9	12
Dominance_D	0.1667	0.02924	0.03772	0.02348	0.04691	0.05325	0.03004	0.1358	0.1667
Simpson_1-D	0.8333	0.9708	0.9623	0.9765	0.9531	0.9467	0.97	0.8642	0.8333
Shannon_H	1.792	3.611	3.419	3.85	3.223	2.992	3.566	2.043	1.864
Evenness_e^H/S	1	0.9253	0.71	0.8869	0.8659	0.9484	0.9307	0.9644	0.9211
Brillouin	1.097	2.874	3.317	3.669	2.551	2.223	2.931	1.345	1.343
Menhinick	2.449	5.298	1.439	2.199	4.323	4.118	4.575	2.667	2.021
Margalef	2.791	9.646	6.181	8.17	7.356	6.139	8.739	3.186	2.415
Equitability_J	1	0.979	0.9089	0.9698	0.9572	0.9826	0.9803	0.9826	0.9577
Fisher_alpha	0	59.62	9.427	14.18	35.25	50.85	34.73	34.61	7.028
Berger-Parker	0.1667	0.05263	0.05599	0.04303	0.1111	0.07692	0.04348	0.2222	0.25
Chao-1	21	61.43	43	53	53.43	41	41.9	18.5	7.75