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# Diversity, relative abundance and distribution of medium and large-sized mammals in Mago National Park, southern Ethiopia

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## Abstract

Most medium- and large-sized mammals have declined in Ethiopia, even within protected areas. However, there is still a lack of information to determine their status. Thus, the objective of this study was to investigate the diversity, relative abundance, and distribution of medium- and large-sized mammals in Mago National Park, Southern Ethiopia. A stratified systematic sampling design was used to establish line transects along the three main habitat types, namely: Woodland, Acacia savanna, and Riverine forest. A total of 45 line transects were established throughout the whole habitat, with transect lengths varying from 1.5 to 5 km, depending on the size and topography of the habitat. The data were analysed via EstimateS (EstimateS v. 9.1) and species diversity indexes in R version 3.6.2. Twenty-eight medium- and large-sized mammalian species, including six globally threatened species:the endangered Loxodanta african and Lycaon pictus, and the vulnerable Panthera pardus, Acinonyx jubatus, Nanger soemmerringii, and Panthera leo, were recorded in the area, belonging to eight families and five orders. During both the dry and wet seasons, the highest species diversity (H' = 2.81 and H' = 2.96), respectively, was recorded in Woodland habitat, whereas species diversity was the lowest ( H' = 2.5 and H'= 2.67), respectively, in Riverine forest. In terms of abundance, Tragelaphus imberbis (1773 ± 86, 12%) was the most abundant species, while Vulpes chama was the least abundant species (104 ± 13), representing only less than 1% of the total population. Therefore, Mago National Park harbours a high species diversity of medium- and large-sized mammals and could provide baseline information for the responsible bodies of the Park and for researchers who wish to conduct related ecological studies in the area.

**Keywords/Phrases:** Diversity indices, Species richness, Seasonal variation, Transect lines

## Introduction

Mammals are biologically the most successful group of animals, with the possible exception of arthropods (Shanko et al., 2021). Mammalian species are one of the most essential resources, and they are indicator and umbrella species of terrestrial ecosystems because of their large home range requirements and they also help to conserve other species and maintain ecosystem balance (Kristy et al., 2021). Mammals in terrestrial ecosystems provide a variety of roles, including ecological, economic, cultural, educational, and scientific functions (Kabeta et al., 2019).

Ethiopia's high faunal biodiversity reflects the existence of a large number of species of mammals. The country possesses 2970 described animal species, among which 311 extant mammal species belong to 14 orders, of which 55 are endemic (both small and large mammals) in Ethiopia (Kassahun et al., 2021). Of the mammal species found in Ethiopia, 60% are medium- and large-sized mammals (Afework and Yalden, 2014). Medium- and large-sized mammals play a fundamental role in ecosystem functions; they are key components of forest and savannah communities and are therefore considered good indicators of ecosystem health. However, most medium- and large-sized mammals have declined in Ethiopia, even within protected areas (Rabira et al., 2015). Mammals are threatened by various human-induced factors, including population growth, landscape modification, poaching, habitat destruction, and habitat loss (Chala and Afework, 2019). As a result, at least 36 mammalian species are threatened in the country. The impact is highly noticeable in large mammals that require large home ranges (Girma and Afework, 2008).

The most important requirement for determining the status of species is surveying mammals (Shanko et al., 2021). Surveys of mammalian diversity, abundance, and habitat conditions in a particular ecosystem are the first step in taking conservation action and provide information to establish appropriate conservation strategies (Ashenafi, 2022). The ecological relevance of mammals, the lack of ecological data, and increased human threats lead to a systematic survey, which is very essential and necessary to evaluate their current conservation status. The survey can also locate areas of high mammal diversity and help managers understand the effects of habitat fragmentation and habitat loss (Getachew and Mesele, 2017). However, there is still a lack of information on mammals, though there have been efforts to study the abundance, diversity, and distribution of birds and mammals elsewhere (e.g. Binega et al., 2022; Shanko et al., 2021; Lamesginew and Abebayehu, 2020; Fayera and Geremew., 2020; Rabira et al., 2015; Zerihun et al., 2012).

Many conservationists advocate the establishment and management of protected areas to effectively protect and conserve mammalian diversity (Struhsaker et al., 2005). To protect and conserve these diverse and important biological resources, the Ethiopian Wildlife Conservation Authority and the regional government have established twenty seven national parks, six wildlife reserves, two wildlife sanctuaries, twenty-five controlled hunting areas,five biosphere reserves, and eight community conservation areas (Mekbeb, 2019). In total, they account for about 8.3% (9,3182 km2) of the total land mass of the country.

Mago National Park is one of the national parks 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 park. 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 diversity, relative abundance, and distribution of medium- and large-sized mammals in Mago National Park.

## Materials and methods

### Description of the study area

The study was conducted in Mago National Park, which is located in the Regional State of Southern Nations, Nationalities, and Peoples. It is located at 5°22' 30'' to 5° 52' 30'' N latitude and 35° 52' 30'' to 36° 22' 30'' E longitude and is about 782 km from Addis Ababa and 530 km from Hawassa (Figure 1). It was established in 1970 and covers an area of 1867 $km^2$. Mago National Park (MNP) is located on the eastern side of a small spur of the eastern Rift Valley (Omo Depression) in the Debube-Omo Zone. The National Park is bordered by three protected areas: Tama Wildlife Reserve to the West (currently inhabited by the Mursi people), Omo National Park to the southwest, and the Murle Controlled Hunting Area (MCHA) to the South (Yirmed and Afework, 2000).

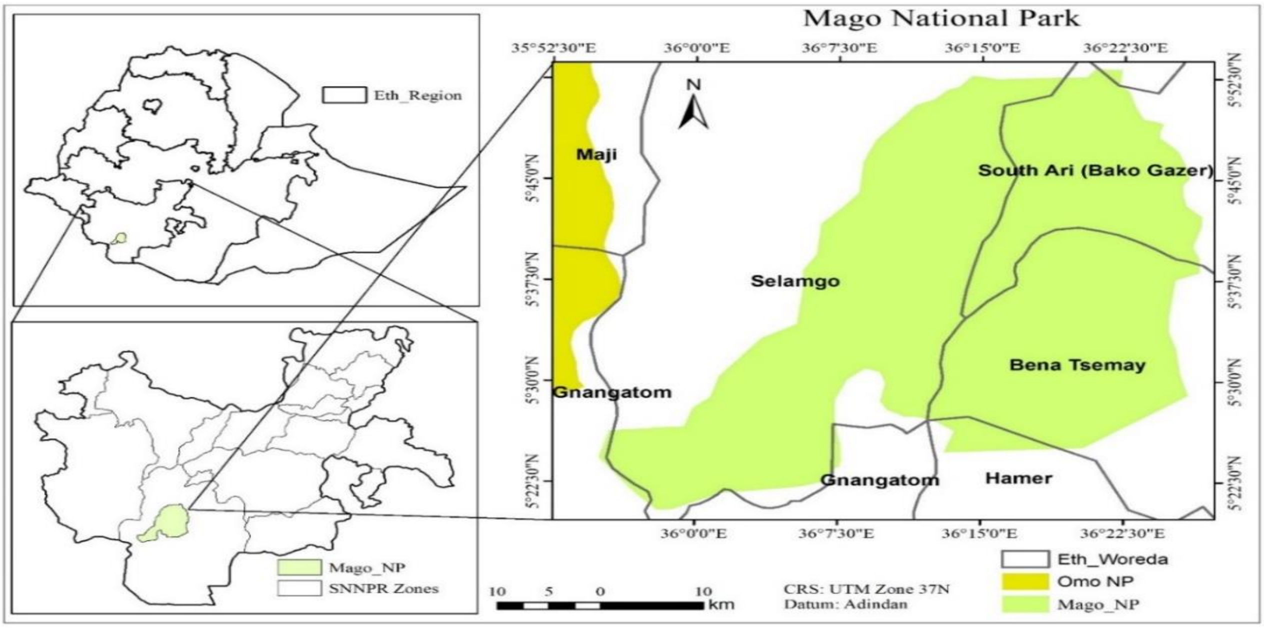


Figure 1. Location map of the study area

The study area has a bimodal rainfall distribution characterized by an extended rainy season from March to May and a light rainy season from September to November. The remaining months of the year are mostly dry in the study area. The average rainfall in the area ranges from 34 to 167 mm, and the average minimum and maximum temperatures range from 16°C to 35°C (Figure 2).

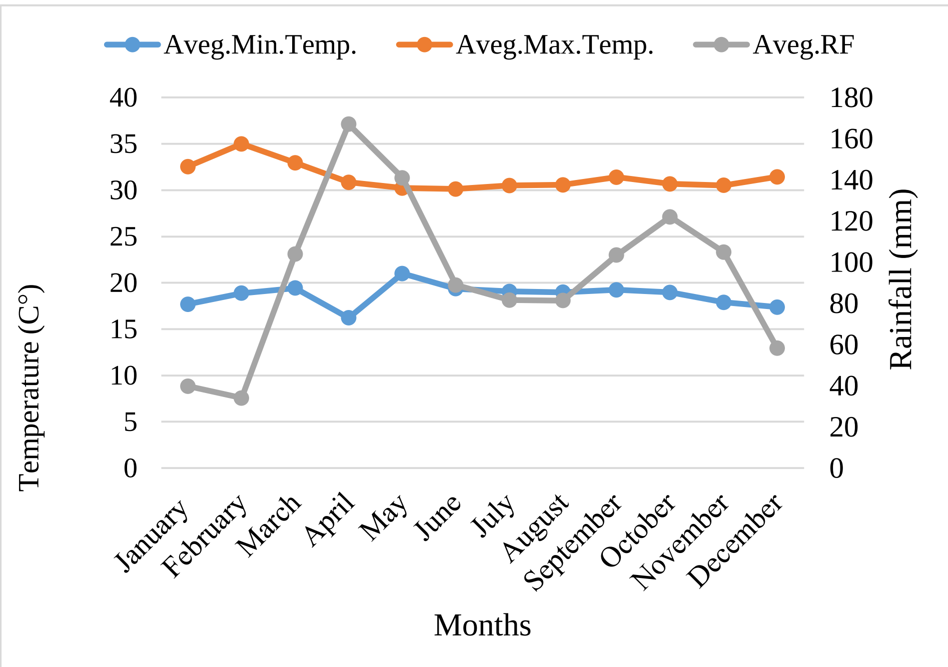


Figure 2. Average monthly rainfall and average maximum and minimum temperatures of MNP

## Sampling design and data collection

### Reconnaissance survey

Prior to the start of the actual data collection, a week-long preliminary survey was conducted during the second week of January 2020 to obtain a general overview of the area, including habitat identification (core areas), safety issues, and accessibility (internal roads). This helped the researchers to become familiar with the study area.

### Sampling design

Based on the predominant vegetation structures, land cover characteristics, and information obtained from Satellite Imagery using the Geographic Information System (GIS) and Remote Sensing, the park was divided into three habitat types (census zones). These were Woodland, Acacia savanna, and Riverine forest. Of the total area of Mago National Park, 20% (373.40 $km^2$) was sampled to represent the entire study area cover. The three stratified habitat types (census zones) cover an area of 189.6 $km^2$, 126 $km^2$, and 57.8 $km^2$, for Woodland, Acacia savanna, and Riverine forest habitats, respectively.

A stratified systematic sampling design was used to establish line transects in the three selected habitat types proportional to the area of the habitats to minimize sampling bias and obtain a representative sample. A total of 45 line transects were established across the three major habitat types; the number of transects placed in each habitat varied; for Woodland (19), Acacia savanna (15), and Riverine forest (11) habitats (Figure 3). The length and width of the transects were measured and located in the study area using a handheld Global Positioning System (GPS) and Compass. The length of the transects varied from 1.5 to 5km. The width of the transects also varied from 100 to 500 m. The variation was determined based on the size of the area, vegetation cover, visibility, and topography of each habitat type (census zones).

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The two consecutive transect lines were set at a minimum distance of 2 km, depending on the habitat type, to avoid double counting. To avoid edge effects, transects were spaced 500 m from the edges of habitat types. The beginning and ending points of each line transect were fed into a GPS unit and used for navigation during data collection, and line transects were placed across the area to be surveyed, following the slope of the ground (Figure 3).

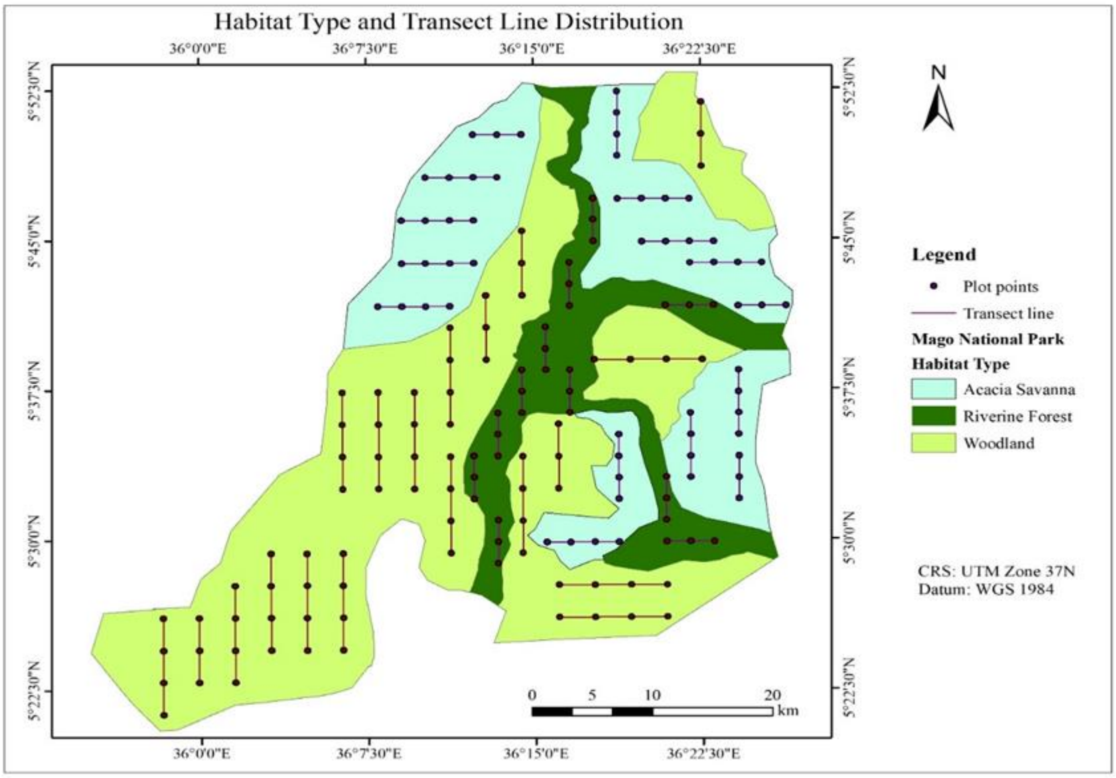


Figure 3. Habitat types of the study area and transect layout

Data collection

Data were collected by dividing the study period into dry and wet seasons at six-month intervals for the three selected habitats. Dry season data were collected from January to February 2020, and wet season data were collected from August to September 2020. The two periods of data collection represent the beginning and end (peak) of the dry and wet seasons in the area. This was assumed to achieve representative samples for the entire year and is relatively appropriate for obtaining the most likely data.

The medium- and large-sized mammalian species were counted in each habitat type simultaneously by direct observation, and two data collectors (observers) participated in collecting data from the right and left sides of each line transect. The observers were walking on foot along the line transect and counting and recording all the individuals sighted with their respective species and their perpendicular distance from the transect line using their naked eyes and pair of binocular. Accordingly, all transects were visited twice in one day, in the morning between 6:00 and 10:00 and in the afternoon between 16:00 and 19:00 following (Chala and Afework, 2019), when most medium- and large-sized mammals are more active.

During the study, body weight was the parameter used to categorize mammals as medium and large-sized; Thus, mammals weighing more than 7 kg were considered large-sized mammals, and mammals weighing between 2 and 7 kg were considered medium-sized mammals (Sutherland, 2006). Each species of medium- and large-sized mammal encountered was identified in the field based on the experience of the two researchers and the faunal knowledge of the data collectors. Whenever it is necessary, Kingdon and Largen's (2003) field guidebook is used for the identification of mammals. In addition to direct observation, some mammal species were identified using indirect methods such as footprints, faecal droppings, community information, digging marks, sound, spines, and other tangible evidence. These are convincing indirect methods and an option available to study the distribution and abundance of inaccessible mammals, such as nocturnal mammals.

Data analysis

The data were classified into different categories. Species accumulation curves and species richness estimations (non-parametric estimators of species richness) were analyzed using EstimateS (EstimateS v. 9.1) according to Colwell and Elsensohn (2014).

Diversity indices of medium- and large-sized mammal species were analyzed using Shannon-Weiner diversity and Simpson diversity indices in R version 3.6.2. Shannon-Wiever diversity index (H′) and Simpson's diversity Index (1-D) were used to determine the diversity of species in each habitat in the study area.

$$(H') = -\sum_{i=1}^{s} Pi \ln Pi \qquad \text{Eq.1}$$

Where: P*i* is the proportion of the *i*th species in the habitat and ln is the natural logarithm,

$$(1 - D) = \frac{1}{\sum_{i=1}^{s} Pi} 2 \qquad \text{Eq.2}$$

Where: P*i* is the proportion of the *i*th species in the habitat.

The evenness of mammalian species among habitat types was also calculated as

$$E' = \frac{H'}{H'max} \qquad \text{Eq.3}$$

Where: H' max= ln (s) is the number of species.

$$\text{Relative abundance: } \frac{\text{total number of individual of a species} * 100}{\text{Total number of individual's species in the sample habitat}} \qquad \text{Eq. 4}$$

The distribution of each species of mammals among habitat was maped bu using ArcGIS.

## Results

### Species composition of mammals

A total of 28 species of medium- and large-sized mammals belonging to 8 families and 5 orders were recorded during the present study. The order Artiodactyla is the most represented (50%) with 14 species, followed by Carnivora (28%) with 8 species, while the orders Perissodactyla and Proboscidea were represented each by one species (4%). Of the mammal species recorded, 14% were considered to be medium-sized mammals (*Madoqua kirkii, Valpes chama, Chlorocebus pygerythrus, and Felis silvestris*), and the remaining 86% were large-sized mammals, of which 2(7%) were endangered, 2(7%), were near-threatened, 4 (14%) were vulnerable), and 20 (72 %) were Least concerned) (Table 1).

Table 1 Medium and large-sized mammal species recorded and their IUCN red list of threat category

| Order | Family | Common name | Scientific name | Species identification methods | IUCN Red list status | Mammals | |
|---|---|---|---|---|---|---|---|
| | | | | | | Large-sized | Medium-sized |
| Artiodactyl | Suidae | Common warthog | *Phacochoerus africanus* | O,C | LC | *Phacochoerus africanus* | *Madoqua kirkii* |
| | Bovidae | Common water buck | *Kobus ellipsiprymnus* | O,D,C | LC | *Kobus ellipsiprymnus* | *Valpes chama* |
| | | Topi | *Damaliscus iunatus jimela* | O,C | LC | *Damaliscus iunatus jimela* | *Chlorocebus pygerythrus* |
| | | Cape Buffalo | *Syncerus caffer* | O,D,C | LC | *Syncerus caffer* | *Felis silvestris* |
| | | Soemmering's gazelle | *Nanger soemmerringii* | C,O | VU | *Nanger soemmerringii* | |
| | | Grant's gazelle | *Nanger granti* | O | LC | *Nanger granti* | |
| | | Lesser kudu | *Tragelaphus imberbis* | O,C | NT | *Tragelaphus imberbis* | |
| | | Kirk's dik-dik | *Madoqua kirkii* | O,D,C | LC | *Sylvicapra grimmia* | |
| | | Common duiker | *Sylvicapra grimmia* | O,D,C | LC | *Tragelaphus scriptus* | |
| | | Bush buck | *Tragelaphus scriptus* | O,D,C,P | LC | *Redunca fulvorufula* | |
| | | Mountain reedbuck | *Redunca fulvorufula* | D,C,O | LC | *Tragelaphus strepsiceros* | |
| | | Greater kudu | *Tragelaphus strepsiceros* | O,C | LC | *Redunca redunca* | |
| | | Bohor reedbuck | *Redunca redunca* | O | LC | *Potamochoerus larvatus* | |
| | | Bush pig | *Potamochoerus larvatus* | O,D | LC | *Crocuta crocuta* | |
| Carnivora | Hyaenidae | Spotted hyena | *Crocuta crocuta* | O,B,D,C | LC | *Acinonyx jubatus* | |
| | Canidae | Cape fox | *Vulpes chama* | O,C | LC | *Panthera pardus* | |
| | Felidae | Cheetah | *Acinonyx jubatus* | O,C | VU | *Panthera leo* | |
| | | Leopard | *Panthera pardus* | C,O | VU | *Lycaon pictus* | |
| | | Africa wild cat | *Felis silvestris* | O | LC | *Leptailurus serval* | |
| | | Lion | *Panthera leo* | O,C | VU | *Papio anubis* | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| | | African wild dog | *Lycaon pictus* | O | EN | *Colombus gureza* |
| | | Serval cat | *Leptailurus serval* | O | LC | *Erythrocebus patas* |
| Primates | Cercopithecidae | Anubis baboon | *Papio anubis* | O,D,C, | LC | *Equus quagga burchellii* |
| | | Gureza colobus | *Colombus gureza* | O,C | LC | *Loxodanta africana* |
| | | Vervet monkey | *Chlorocebus pygerythrus* | O | LC | |
| | | Patas monkey | *Erythrocebus patas* | O,C | LC | |
| Perissodactyla | Equidae | Burchell's zebra | *Equus quagga burchellii* | O,D,C | NT | |
| Proboscidea | Elephantidae | African elephant | *Loxodanta africana* | D,B,O,C | EN | |

O: direct observation of the species; C: community information; D: droppings; B: borrowing; P: photographic; LC: least concern; VU: vulnerable; NT: not threatened; EN: endangered

Species accumulation curve and species richness estimation

The observed relationship between study area, species richness, and habitat type per season with estimated richness (based on Chao 1) indicated that the sample is complete. The estimated species richness for all habitats based on Chao 1 was 27, which means that all species expected in the area were recorded.

At the habitat level, species richness was significantly different between seasons in each of the three habitats. Woodland habitat had a high species richness estimation of 24 during the dry season and 27 during the wet season; acacia savanna habitat had a species richness estimation of 20 during the dry season and 26 during the wet season), and riverine forest habitat had a low species richness estimation of 19 during the dry season and 22 during the wet season (Table 2).

Table 2. Estimates of species richness between habitat types during the dry and wet seasons

| | WL | | AS | | RF | |
|---|---|---|---|---|---|---|
| | Dry | Wet | Dry | Wet | Dry | Wet |
| No. of samples | 19 | 19 | 15 | 15 | 11 | 11 |
| No. of Indv. | 2868 | 3659 | 2445 | 2719 | 1718 | 1835 |
| $S_{obs}$ | 24 | 27 | 20 | 26 | 19 | 22 |
| Jack 1 | 30.63±2.05 | 27.95±0.95 | 27.47 | 27.87±1.27 | 25.36±2.03 | 26.55±2.07 |
| Jack 2 | 32.97 | 25.46 | 32.79 | 25.58 | 29.62 | 29.16 |
| Chao 1 | 24±0.03 | 27±0.09 | 20 | 26 | 19±0.34 | 22±0.05 |
| Chao 2 | 27.32±3.5 | 27±0.08 | 28.71±8.31 | 26.16 | 25.36 | 25.03±3.79 |
| ICE | 29.91 | 27.34 | 27.82 | 26.93 | 24.27 | 24.92 |

Note: WL: woodland; AS: acacia savanna; RF: riverine forest, $S_{obs:}$ the total number of species observed per habitat type between seasons; Jack 1: first-order Jackknife richness estimator; Jack 2: second-order Jackknife richness estimator; Chao 1: Chao 1 richness estimator based on abundance ; Chao 2: Chao 2 richness estimator based on incidence; ICE: incidence-based coverage estimator of species richness.

Similarly, species accumulation curves were generated (Figure 4) for medium- and large-sized mammals recorded in Mago National Park. The species accumulation curve among the three habitats between dry and wet seasons in the study area fully reached the asymptote, and no significant seasonal variation in species richness was observed between seasons, but there was a significant influence across the habitat types.

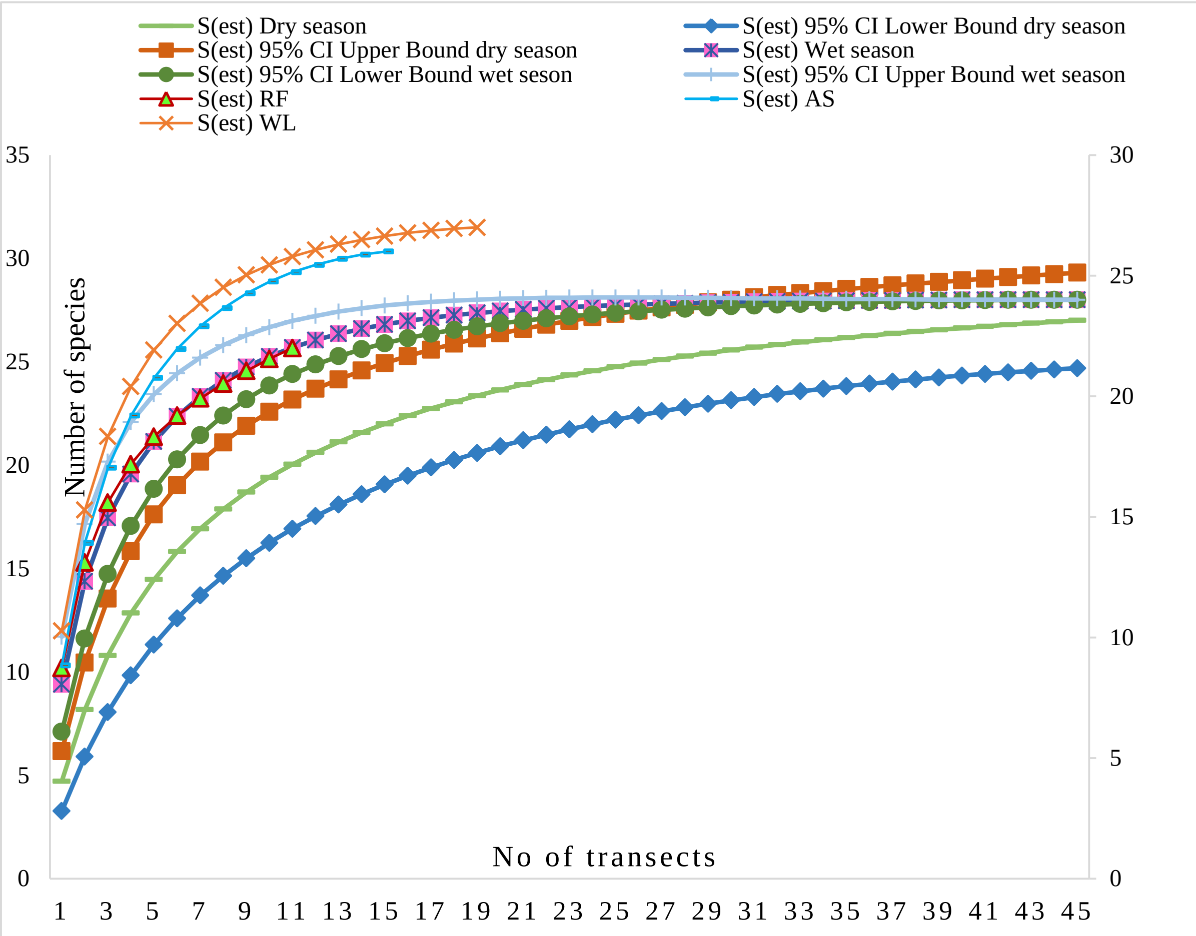


Figure 4. Species accumulation (rarefaction) curves of the recorded mammals in different habitat types and between seasons

Note: S(est): Estimated number of species in the assemblage represented by the three sampled habitat types (census zones) during dry and wet season; WL: Woodland; As: Acacia savanna; RF: Riverine forest habitat (the shortest line in left side).

Diversity and evenness index

The woodland habitat had the highest species diversity and evenness (H' = 2.81 and J = 0.88) during the dry season and (H'= 2.96 and J = 0.89) during the wet season, respectively. Species diversity and evenness were the lowest in the Riverine forest habitat (H' = 2.5 and J = 0.85) and (H'= 2.67 and J = 0.86) during the dry and wet seasons, respectively (Table 3).

Table 3. Diversity and evenness of species in different habitat types during dryand wet seasons

| Habitat type | No. of Species | | No. of individuals | | SWI (H' ) | | H'max | | H'/ H'max( Evenness) | | Simpson index of diversity (1-D) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet |
| Woodland | 24 | 27 | 2868 | 3659 | 2.810 | 2.960 | 3.170 | 3.290 | 0.880 | 0.890 | 0.927 | 0.937 |
| Acacia savanna | 20 | 26 | 2445 | 2719 | 2.610 | 2.840 | 2.990 | 3.250 | 0.870 | 0.870 | 0.913 | 0.926 |
| Riverine forest | 19 | 22 | 1718 | 1835 | 2.500 | 2.670 | 2.940 | 3.090 | 0.850 | 0.860 | 0.900 | 0.910 |

Relative abundance

A total of 7031 individual mammals (46%) during the dry season and 8213 (54%) during the wet season were recorded. This indicated that a total of 15,244 individuals of medium- and large-sized mammal species were recorded during the study period. Among these, Tragelaphus imberbis was relatively the most abundant species, accounting for 12% of individuals recorded, followed by *Syncerus caffer* (10%) and *Papio anubis* (9%), while *Erythrocebus patas* and *Vulpes chama* were the least abundant species, each accounting for only 1% of total observations in the study area (Table 4).

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Table 4. Relative abundance of the recorded mammals species in the study area

| Species name | Total number of individuals recorded | | |
|---|---|---|---|
| | Dry | Wet | Relative abundance (%) |
| *Tragelaphus imberbis* | 801 ±20 | 972 ±17 | 12% |
| *Syncerus caffer* | 746 ±33 | 823 ±30 | 10% |
| *Papio anubis* | 660 ±27 | 715 ±20 | 9% |
| *Kobus ellipsiprymnus* | 622 ±21 | 681 ±15 | 9% |
| *Damaliscus iunatus jimela* | 589 ±24 | 612 ±19 | 8% |
| *Phacochoerusafrican*us | 557 ±18 | 590 ±11 | 8% |
| *Tragelaphus strepsiceros* | 400 ±17 | 591 ±15 | 7% |
| *Tragelaphus scriptus* | 565 ±22 | 399 ±15 | 6% |
| *Nangersoemmerringii* | 226 ±10 | 315 ±9 | 4% |
| *Panthera pardus* | 221 ±22 | 190 ±13 | 3% |
| *Equus quagga burchellii* | 122 ±13 | 283 ±14 | 3% |
| *Chlorocebus pygerythrus* | 117 ±17 | 271 ±18 | 3% |
| *Colombus gureza* | 167 ±11 | 194 ±11 | 2% |
| *Loxodanta africana* | 183 ±10 | 166 ±11 | 2% |
| *Madoquakirki* | 160 ±8 | 188 ±7 | 2% |
| *Redunca fulvorufula* | 139 ±8 | 153 ±8 | 2% |
| *Acinonyx jubatus* | 171 ±13 | 98 ±7 | 2% |
| *Redunca redunca* | 108 ±9 | 149 ±9 | 2% |
| *Sylvicapra grimmia* | 91 ±5 | 115 ±4 | 1% |
| *Nanger granti* | 63 ±9 | 90 ±8 | 1% |
| *Leptailurus serval* | 0 | 147 ±4 | 1% |
| *Panthera leo* | 78 ±11 | 68 ±7 | 1% |
| *Felis silvestris* | 43 ±3 | 85 ±4 | 1% |
| *Lycaon pictus* | 30 ±4 | 93 ±6 | 1% |
| *Potamochoerus larvatus* | 45 ±3 | 73 ±4 | 1% |
| *Erythrocebus patas* | 69 ±7 | 47 ±5 | 1% |
| *Vulpes chama* | 39 ±4 | 65 ±4 | 1% |
| *Crocuta crocuta* | 19 ±2 | 40 ±2 | 0 |
| Total | 7031±474.9 | 8213±744.8 | |

Distribution of medium and large mammals

The distribution of medium- and large-sized mammals during the dry and wet seasons has shown that *Tragelaphus imberbis, Tragelaphus strepsiceros* and *Papio anubis* were widely distributed throughout the study period. However, *Vulpes chama, Crocuta crocuta,*and *Panthera pardus,* were found only in some areas during both the dry and wet seasons. In the dry season, *Tragelaphus* *strepsiceros* was widespread, followed by *Phacochoerus africanus* and *Tragelaphus imberbis*, while *Nanger soemmerringii* and *Vulpes chama* had the lowest distribution in the Acacia savanna habitat. In the Riverine forest habitat, *Papio anubis* was common, followed by *Tragelaphus imberbis* and *Kobus ellipsiprymnus***,** while *Crocuta crocuta*, and *Colombus gureza* had the lowest distribution (Figure 6). During the wet season, *Papio anubis* was widely distributed, followed by *Phacochoerus africanus* and *Tragelaphus imberbis*, while *Nanger granti* and *Panthera pardus* had the lowest distribution in the Acacia savanna habitat. In the Riverine forest habitat, *Phacochoerus africanus* was widely distributed, while *Acinonyx jubatus* had the lowest distribution (Figure 7).

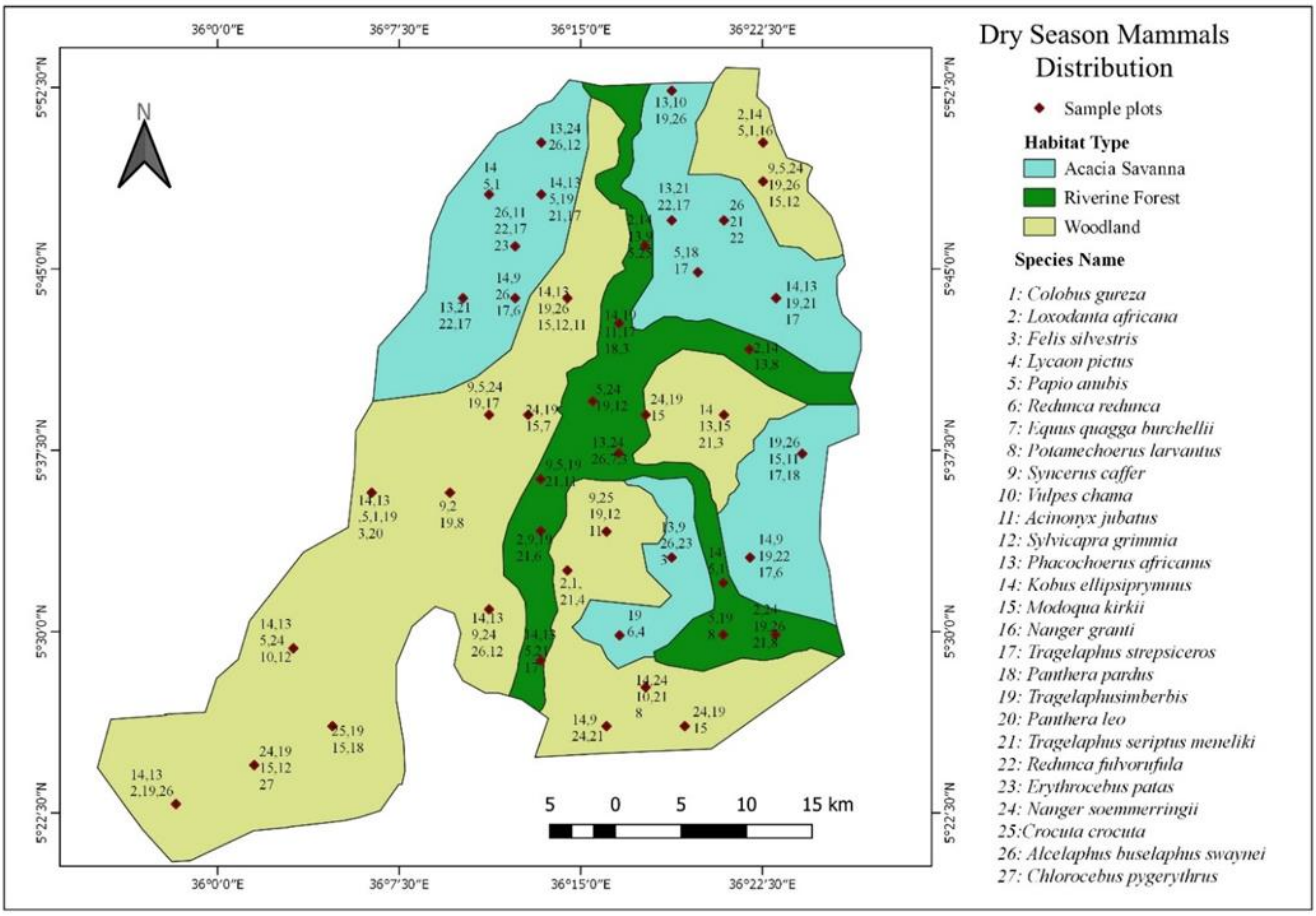


Figure 6. Distribution of medium and large-sized mammals among different habitats in Mago National Park during the dry season

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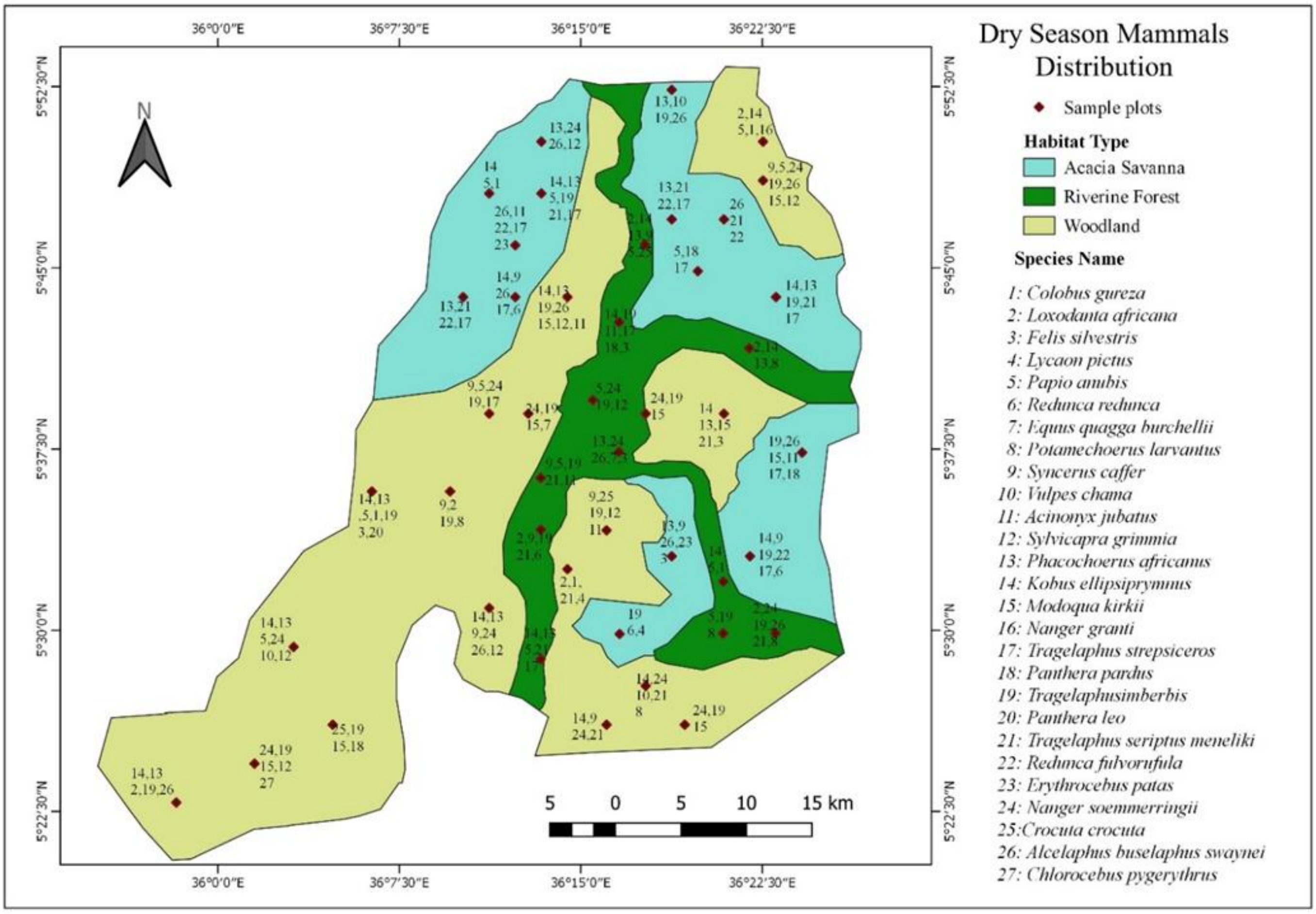


Figure 7. Distribution of medium and large-sized mammals among different habitats in Mago National Park during the wet season

## Discussion

A survey of mammals in national parks 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 28 species of medium- and large-sized mammals, including six globally threatened species: the endangered: *Loxodanta africana* and *Lycaon pictus* and the vulnerable: *Panthera pardus, Nanger soemmerringii, Acinonyx jubatus* and *Panthera leo* (IUCN, 2021), indicates that good efforts were made to monitor and count the resources.

The highest species diversity and evenness of medium- and large-sized mammals were recorded in woodland habitats during both the dry and wet seasons. The presence of various plant species in woodland habitats might account for the high species diversity index in the area. While species diversity and evenness were comparatively low in the woodland habitat during the dry season. This is probably related to the fact that seasonal variations in the level of human disturbances in woodland habitat are relatively high (i.e., the number of illegal hunters and honey collectors increased in the area during this time of the year, the habitat was burned by honey collectors and illegal hunters, and the number of livestock encroaching was also higher during the dry season). This phenomenon leads to a decrease in the availability of grassy vegetation and water for herbivorous mammals. In contrast, human and livestock intrusion into the park is higher during the rainy season (Dejene and Demeke, 2018).

Similar studies in different parts of Ethiopia have also shown that mammal species diversity is often high in areas with adequate food and water resources and low poaching by local people (Fayera and Geremew, 2020), and therefore, the number of species recorded and their diversity depend on seasonal resource fluctuations.

In general, the number of species recorded in Mago National Park is comparable with other results on medium- and large-sized mammals in different protected areas in Ethiopia. For instance, Guta et al. (2020) in Loka Abaya national park recorded 28 species of medium and large-sized mammals; Fayera and Geremew (2020) in Adaba Community Forest recorded 27 species of medium and large-sized mammals; Oliveira and Hannibal (2017) in fragmented semi-deciduous forest, *Mastozoolgia Neotropical* recorded 22 species of medium and large-sized mammals; Kassahun et al. (2021) in Gibe Sheleko national park recorded 20 species of medium and large-sized mammals; and Amanuel Agebo and Wondimagegnehu (2022) in Michole Community Protected Forest recorded 17 species of medium and large-sized mammals.

The total individual number of mammals recorded during the wet season was 8213 (54%), which exceeds the number of mammals recorded during the dry season of 7031 (46%). This is in contrast with the work of Shanko et al. (2021), in Guda Forest, southwestern Ethiopia. There have also been studies on medium- and large-sized mammals in other parts of Ethiopia in line with this study; however, the number of individual mammals in Mago National Park was high. For example, Tiski Waterfall, Awi Zone, Ethiopia (Binega et al., 2022); Michole Community Protected Forest, southern Ethiopia (Amanuel and Wondimagegnehu, 2022); and Adaba Community Forest, West Arsi Zone, southeast Ethiopia (Fayera and Geremew, 2020) had a comparatively lower number of individual mammals than in this study.

The variation in species richness and a number of individual mammals may be due to variations in sample sites and sampling effort spent, quality of the habitat and preference of the species, and degree of anthropogenic impact in the study area (including illegal settlement, poaching, agricultural expansion, etc.) (Chala and Afework, 2019). According to Colwell et al. (2012), the number of species detected in a given study area during a given survey period is a function of sampling effort. More species could be recorded if additional sampling units are surveyed. However, this is not likely to be the case in this study because the rarefaction and estimated (Chao 1) richness curves formed a plateau, the observed species were similar to the expected richness per season, and all sampling was complete (i.e., species present in the study were detected). The results also indicate that season did not significantly influence species richness and composition, but there was a significant influence on habitat types.

The two cloven-hoofed and one primate species (*Tragelaphus imberbis, Syncerus caffer, and Papio anubis*) were the most abundant species in the study area. This could be related to the wide range of the species, high reproductive success, varied feeding behavior, and suitability of the patches especially for *Tragelaphus imberbis*. According to the African Wildlife Foundation (AWF, 2015), dense forest patches are the preferred habitat for *Tragelaphus imberbis,* as it prefers this type of habitat for protection from danger.

The next most abundant species in the study area was *Papio anubis,* which may be due to its survival and adaptability to a variety of foods and the challenging environmental conditions in the park. A similar finding showed that *Papio anubis* is an ecologically flexible and diurnal species and is considered a generalist that inhabits different habitats (Chala and Afework, 2019). Similarly, Zerihun et al. (2012) confirmed that the most abundant species in and around Wondo Genet Forest Patch, southern Ethiopia, was *Papio anubis*. This might be attributed to the behavior of the species, known to be widely distributed in a variety of habitats, which could be the reason why the species is relatively common in the study area after *Tragelaphus imberbis* and *Syncerus caffer*.

On the other hand, some mammals, such as *Crocuta crocuta* , *Felis silvestris, Panthera leo,* and *Acinonyx jubatus,* were the least abundant mammal species in the area. This could be due to the difficulty in sighting and counting these mammals because of their nocturnal behavior and deliberate avoidance (Ajibade et al., 2011), which might be due to the constant harassment of this species by poachers.

In addition, most Mursi people live in the park year-round, and some of the above mammals may be tracked and poached each year with automatic rifles, snares, and traps due to the lack of patrols and strict wildlife laws in the park, which is responsible for this destruction that may ultimately lead to the extinction of the mammal species in MNP and that were also observed during the survey period. The distribution result shows the distributional patterns of each species along with habitats between seasons in the survey area. 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 park. Thus, the 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).

The distributions of *Vulpes chama, Erythrocebus patas,* and *Panthera pardus* were low and limited compared to the distributions of other medium- and large-sized mammals in some parts of the study areas. This was possibly due to the presence of linkages and corridors that provide access to nearby areas such as Omo National Park, Tama Game Reserve, and Murle Controlled Hunting Area, and the National Park is under constant threat from human activities. While *Tragelaphus imberbis,Papio anubis,Syncerus caffer,Tragelaphus strepsiceros,Phcochoerus africanus,* and *Nanger soemmerringii* had relatively large ranges in all habitat types during the survey period, indicating that the species are resident in the study area throughout the year and the level of disturbance tolerance is relatively high compared to the other species. As reported by Johnson et al. (2012), the adaptation of these species helped them to be widely distributed across different habitat types in Africa.

More mammal species occurred in the woodland habitat in both seasons. The results agree with the species-area relationships, which indicate that habitats with large survey areas tend to have higher numbers of species compared to habitats with small survey areas. Since habitats with large areas tend to have diverse microhabitats and more heterogeneous vegetation structures that meet the basic needs (i.e., food, water, and shelter) of species with different food and microhabitat requirements (Kristy et al., 2021; Getachew and Afework, 2015).

**Conclusion and recommendations**

Despite the fact that Mago National Park is surrounded by hunter-gatherer communities and makes conducting the survey extremely difficult, the park harbours a considerable number of medium- and large-sized mammal species, including endangered and vulnerable species. The abundance and distribution of the mammal species in the park varied with seasonal resource fluctuations and habitat types. This is due to the destruction of natural habitats by poachers and harassment by an ever-increasing human population with an ever-increasing demand for land and livestock encroachment. Hence, equal conservation priority should be given to the mammals habitats. The diverse microhabitats among the habitats (census zones) and the ecological flexibility of species in the park also contributed to a significant number of species.

Therefore, cooperative conservation practices with the local community should be initiated to improve the welfare of the mammals and their ecology, and special attention needs to be paid to the conservation of one of the globally threatened mammals, *Loxodanta africana,* and its habitat. Knowing species diversity, relative abundance, and distribution at this scale is useful for focusing conservation efforts. The presence of rare and globally threatened species in the area also needs urgent care and provides baseline information on their occurrence in the study area and for researchers seeking to conduct related ecological studies. Since this is the first ecological information that cannot be used to provide the complete number of individuals and mammalian species in Mago National Park.

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**Data availability**

The data used to support the findings of this study are available from the corresponding author upon request.

**Conflicts of interest**

None of the authors have competing interests.

**Authors contributions**

Eden Tsegaye: Conceptualization (lead); Data curation (lead); Formal analysis (lead); Investigation (lead); Methodology (lead); Resources (lead); Softwae (lead); Writing – original draft (lead); Writing – review and editing (lead). Funding acquisition (lead). Girma Mengesha: Methodology (supporting); Software (supporting); Supervision (supporting); Writing- review and editing (supporting).

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**References**

Afework Bekele, Yalden DW. 2014. The mammals of Ethiopia and Eritrea, Ababa University Press, Addis Ababa, Ethiopia.

African Wildlife Foundation (AWF), 2015. Humans covet the kudu's Majestic horns: Kudu. Available from:http://www.awf.org/wildlife-conservation/kudu.

Ajibade, WA, Adeyemo AI, Agbelusi EA. 2011. Population density and distribution of green monkey (Cercopithecus aethiops. linnus 1758) at Zugurma sector of Kainji lake national park, Nigeria. Afr J Agric Res. 6: 2456-2460.

Amanuel Agebo, Wondimagegnehu Tekalign. 2022. Terrestrial medium and large sized mammalian species diversity in Michole Community Protected Forest, southern Ethiopia. BMC Zool. 7:20.

Ashenafi Tegegn, Belete Tilahun, Demelash Sime. 2022.Species diversity and abundance of Mammals (Medium and Large sized) in Yotyet/Yewezera Community Forest, Gurage Zone, Southern Ethiopia. Authorea. https://www.authorea.com/users/468210/articles/561961

Binega Derebe, Yonas Derebe, Melkamu Kassaye. 2022. Diversity, abundance, and habitat association of medium and large-sized mammals in Tiski Waterfall, Awi Zone,Ethiopia. Int J Zool. Article ID 4927041.

Chala Adugna, Afework Bekele. 2019. A preliminary survey of medium and large-sized mammals from Lebu Natural Protected Forest, Southwest Showa, Ethiopia. Ecol Evol. 9(21): 12322–12331.

Colwell Robert K, Anne Chao, Nicholas J. Gotelli, Shang-Yi Lin, Chang Xuan Mao, Robin L. Chazdon, John T. Longino. 2012. Models and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of assemblages. J Plant Ecol J Plant Ecol. 5: 3–21.

Colwell RK, Elsensohn J.E. 2014. EstimateS turns 20: statistical estimation of species richness and shared species from samples, with non-parametric extrapolation. Ecography 37: 609–613.

Dejene Worku, Demeke Datiko. 2018. Population status, distribution and social grouping patterns of Menelik's Bushbuck (*Tragelaphus scriptus meneliki*) in Hanto Controlled Hunting area, Ethiopia. Asian J Sci Technol. 9(10): 8727-8734.

Fayera Bakala, Geremew Mekonen. 2020. Species diversity and relative abundance of medium and large-sized wild mammals: a study from Adaba community forest, West Arsi zone, Southeast Ethiopia. Afr J Ecol. 59(2): 538–543.

Getachew Bantihun, Afework Bekele. 2015. Diversity and habitat association of Small mammals in Aridtsy forest, Awi Zone Ethiopia. Zool Res. 36(2): 88–94.

Shanko G, Tona B, Adare B. 2021.Species composition, distribution and relative abundance of medium and large sized mammals in Guda forest, south western Ethiopia. Ukr J Ecol. 11 (8): 40-47.

Guta Diriba, Sintaheyu Tamene, Girma Mengesha , Addisu Asefa. 2020. Diversity of medium and large mammals in the Loka Abaya national park, southern Ethiopia. Ecol Evol. 10(18): 9896–9905.

IUCN .2021. IUCN red list of threatened species. Retrieved from http:// www.iucn.org

Johnson C, Swedell L, Rothman J. 2012. Feeding ecology of olive baboons (*Papio anubis*) in Kibale National Park, Uganda: Preliminary results on diet and food selection. Afr J Ecol. 50(3): 367–370.

Kabeta Legese, Afework Bekele, Seyoum Kiros. 2019.A survey of large and medium-sized mammals in Wabe forest fragments, Gurage zone, Ethiopia. Int J Avian Wildl Biol. 4(2): 32–38.

Kassahun Abie, Belete Tilahun, Abel Feyisa,Tewodros Kumssa, Alemneh Amare. 2021. Diversity and habitat association of medium and large mammals in Gibe Sheleko National Park, Southern Ethiopia. Ecol Evol.11(18):12251–12258.

Kingdon J, Largen M. 2003. The kingdon field guide to african mammals. Zool J Linn Soc.120(4): 479.

Kristy Udy, Matthias Fritsch, Katrin M. Meyer, Ingo Grass, Sebastian Hanß et al. 2021. Environmental heterogeneity predicts global species richness patterns better than area. Glob Ecol Biogeo. 30:842–51.

Lamesginew Tadesse, Abebayehu Desalegn. 2020. The abundance, diversity and distribution pattern of avian species in the Fentie Community Conservation Area, Ethiopia. J Sci Incl Dev. 2(2): 66-85.

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.

Mohammed Yaba, Tariku Mekonnen, Afework Bekele, James Malcolm, 2011. Food selection and feeding behavior of Giant Mole Rat (*Tachyoryctes macrocephalus*, Ruppell, 1842) from the Sanetti Plateau of Bale Mountains National Park, Ethiopia. Asian J Appl Sci. 4: 735-740.

Oliveira FR, Hannibal W. 2017. Effects of patch attributes on the richness of medium and large-sized mammals in fragmented semi-deciduous forest. Mastozool Neotrop. 24(2), 401– 408.

Rabira Gonfa,Tsegaye Gadisa, Tadesse Habtamu. 2015.The diversity, abundance and habitat association of medium and large-sized mammals of DatiWolel National Park, Western Ethiopia. Int J Biodivers Conserv. 7(2):112-118.

Struhsaker TT, Struhsaker PJ, Siex KS. 2005. Conserving Africa's rain forests: problems in protected areas and possible solutions. J Biol Conserv. 123(1):45

Sutherland WJ. 2006. Ecological census techniques*:* A handbook (2nd ed.). New York, NY: Cambridge University Press.

Tariku Mekonnen, Mohammed Yaba, Afework Bekele, Malcolm J. 2011. Food selection and habitat association of Starck's Hare (*Lepus starcki* Petter, 1963) in the Bale Mountains National Park, Ethiopia. Asian J Appl Sci. 4: 728-734.

Wolf C, Ripple WJ. 2016. Preydepletion as a threat to the world's largecarnivores.R Soc Open Sci. 3: 160252.

Yirmed Demeke, Afework Bekele. 2000. Population estimates and threats to elephants Loxodonta africana (Blumenbach 1797) in the Mago National Park, Ethiopia. Trop Zool. 13(2):227-237.

Zerihun Girma, Yosef Mamo, Mateos Ersado. 2012. Species composition, distribution and relative abundance of large mammals in and around Wondo Genet Forest Patch, Southern Ethiopia. Asian J Appl Sci. *5*: 538–551.