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Spatiotemporal changes in small mammal community of Wenchi highlands, central Ethiopia

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ABSTRACT: Small mammals show prominent spatial and temporal fluctuations. A study was conducted to assess the spatiotemporal dynamics of small mammals in Wenchi highlands, central Ethiopia. Sherman and snap traps were used to capture small mammals from four forests (Qibate, Lakeshore, Erica and Albesa), Hagenia woodland and Erica scrub in two dry and wet seasons between August 2019 and January 2021. A total of 959 small mammals represented by 12 rodent species (Arvicanthis abyssinicus, Desmomys yaldeni, Mastomys natalensis, M. awashensis, Stenocephaylemys albipes, Lophuromys flavopunctatus, L. brevicaudus, L. chrysopus, Dendromus lovati, Lophiomys imhausi, Graphirius murinus and an unidentified murid rodent), and 3 shrew species (Crocidura bailey, C. fumosa and C. olivieri) were recorded. Small mammals showed spatiotemporal variations. More individuals were trapped during the dry (58.29%) than the wet (41.71%) season. Lakeshore Forest yielded the highest number of small mammals, whereas Erica Forest contributed the least during both seasons. More small mammal individuals were trapped in the second (52.24%) than the first (47.75%) trapping year. Small mammals also showed significant variations between the trapping periods ($P<0.05$). High number of small mammals was trapped during the morning (84.98%) than evening traps. Seasonal differences in sexes and age groups were non-significant ($P>0.05$). The density of small mammals varied between seasons and habitats. Small mammals had higher density during the dry (83.33 ha^{-1}) than the wet (59.35 ha^{-1}) season. In conclusion, Wenchi highlands supported a diverse small mammal community that displayed spatiotemporal changes. As a result, priority should be given to conserve the area.

Key words/phrases: density, seasonality, small mammals, spatiotemporal variation, Wenchi highlands

INTRODUCTION

Small mammals are the most diverse group of mammals (Agerie Addisu and Afework Bekele, 2013; Kumaran *et al*., 2016). However, there is limited information about them as compared to the larger mammals (Kumaran *et al*., 2016) though studying these animals has paramount implications (Torre, 2004; Whitsitt and Tappe, 2009; Marques *et al*., 2015). Rodents are a group of small mammals that impact the global environment by providing many ecological, economic and cultural values (Kingdon, 1997; Tobin and Fall, 2004; Mesele Yihune and Afework Bekele, 2012; Agerie Addisu and Afework Bekele, 2013).

Some rodents are an important food source for humans (Tadesse Habtamu and Afework Bekele, 2008; Meyer-Rochow *et al*., 2015; Gruber, 2016). Others are model organisms for ecological studies and good environmental indicators (Tadesse Habtamu and Afework Bekele, 2012). However, a few rodent species are main pests of agriculture, and involved in the transmission of many pathogens (Mesele Yihune and Afework Bekele, 2012; Garba *et al*., 2013). The economic and ecological benefits of rodents, however, offset their adverse effects (Tadesse Habtamu and Afework Bekele, 2012; Agerie Addisu and Afework Bekele, 2013).

The diversity and population dynamics of small mammals in a particular area is primarily determined by several biological (Sintayehu Workeneh *et al*., 2011; Getachew Bantihun and Afework Bekele, 2015), climatic (Makundi *et al*., 2006) and anthropogenic (Addis Fekadu *et al*., 2015) factors. Small mammals' diversity and abundance display prominent seasonal and inter-annual fluctuations (Makundi *et al*., 2006; Sintayehu Workeneh *et al*., 2011; Agerie Addisu and Afework Bekele, 2015; Seyoum Kiros and

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Afework Bekele, 2021). Such fluctuations determine their distribution and relative abundance (Mohammed Kasso and Afework Bekele, 2011). Community organization and its temporal change echo the fluctuations of the local species populations (Brown and Heske, 1990). Estimating the population density of small mammals is used to quantify these fluctuations (Krebs *et al*., 2011).

Ethiopian highlands are the centers of small mammal species richness and endemism yet these areas are under severe threat (Yalden and Largen, 1992; Addis Fekdu *et al*., 2015; Lavrenchenko and Afework Bekele, 2017). This may also hold true for Wenchi highlands, where small mammals and birds are animal groups that relatively persisted in the modified habitats (Gemechu Shale *et al*., 2014). Understanding the spatiotemporal variations of small mammals in a particular area is very important for ecological, economic and conservation reasons (Lavrenchenko and Afework Bekele, 2017; Rocha *et al*., 2017; Seyoum Kiros and Afework Bekele, 2021).

According to Wen *et al*. (2014), field surveys should consider temporal sampling, and ignoring the temporal variation in population studies may result in considerable errors (Asher and Thomas, 1985). However, such studies are still poorly known for Wenchi highlands. Thus, this study aimed to explore the spatiotemporal fluctuations of small mammals in Wenchi highlands to document and monitor the existing small mammals, and enforce the conservation of these unique habitats and its wildlife. Such studies could also help in predicting the trends of faunal potential of the area and document them before their extinction (Lavrenchenko and Afework Bekele, 2017).

Materials and Methods

Description of the study area

The study was conducted in the central highlands of Ethiopia, Wenchi district of southwest Shewa Zone, Oromia region. The area is located between Ambo and Waliso towns, 155 km away from the capital, Addis Ababa (Fig. 1). The altitude of the area ranges between 2,810 and 3,386 m asl (Bizeayehu Tefera *et al*., 2002). It is characterized by highland sub-humid climate with the average annual rainfall of 1400 to 1420 mm (Gemechu Shale *et al*., 2014; Abebe Tufa *et al*., 2020). The rainfall is unimodal with longer rainy periods from May to September. The peak rainfall occurs in July and August, while the cold-dry season occurs between October and January (Fasil Degefu and Schargel, 2015; Abebe Tufa *et al*., 2020). The temperature of the area varies between 14 to 26 °C during the day and falls below 10 °C during the night (Fasil Degefu and Schargel, 2015).

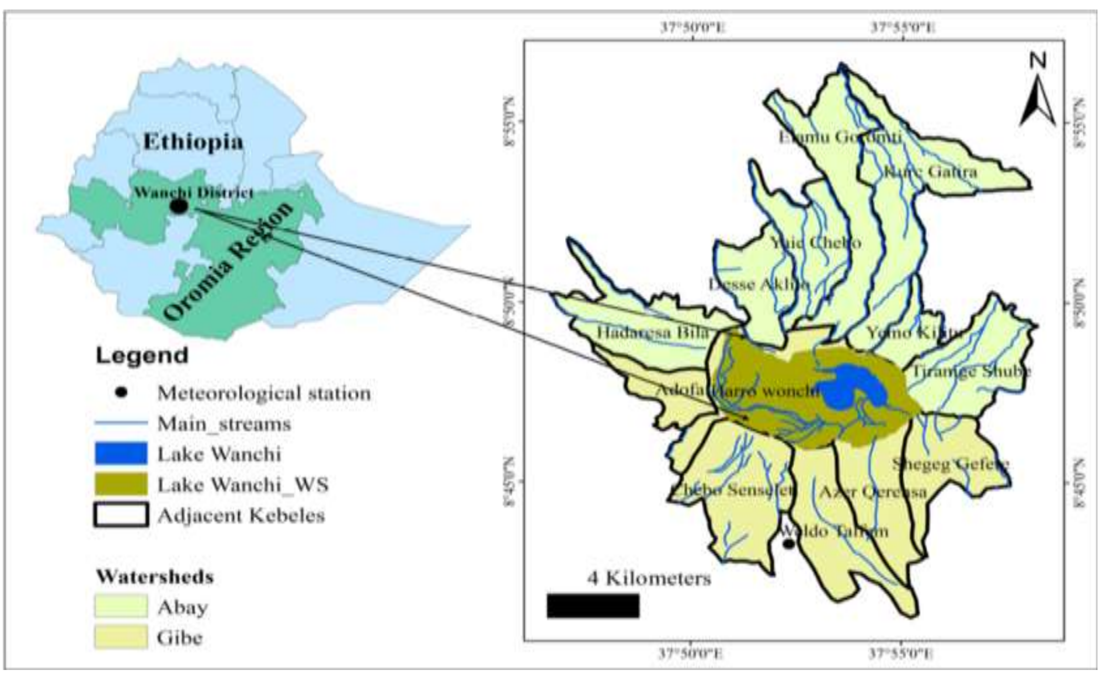

Figure 1. Map of the study area (Source: Abebe Tufa *et al*., 2022).

Wenchi highlands are characterized by a sub-afro alpine vegetation type. The uplands which make the Lake Wenchi watershed are dominated by *Erica* scrub. The lower altitude, Qibate forest and Lakeshore Forest, are occupied by an ever-green highland trees, shrubs and herbs. Abebe Tufa *et al*. (2020) identified several species of woody plants in the lake escarpment. Bracken fern, *Pteridium aquilinum* is a widespread invasive fern, whereas *Hagenia abyssinica, Juniperus procera, Olea europaea subsp. cuspidata, Ilex mitis* and *Myrsine melanophloeos* are some of indigenous tree species in the area.

Land-cover types, disturbances and elevation significantly modified the structure and vegetation composition of the area (Abebe Tufa *et al*., 2021). Forest land, bushland and lakeshore include the natural vegetation of the area. Forest land is the most common land type in the district after farmlands (District Land Administration Office, 2020). The main livelihood in the area is mixed agriculture (crop cultivation and livestock rearing), small and micro enterprises, and income generating activities from ecotourism (Gemechu Shale *et al*., 2014; Abebe Tufa *et al*., 2022). The average land holding size for a single household is 0.5 ha, and the major crops grown in the area are enset, barley, wheat, and potato (Gemechu Shale *et al*., 2014)

Trappings of small mammals

A reconnaissance survey was conducted in Wenchi highlands before the actual study was started to locate suitable sampling site and select sampling units. Then, four forest remnants were identified based on the topography, altitude, human disturbances and vegetation types, and further classified into dominant and representative habitats (Yonas Terefe and Fikrasilasie Samuel, 2015). For that reason, a single sampling site was allocated for the three forest fragments as they were characterized by a physically similar vegetation structure (Qibate, Albesa and Lakeshore Forests), while the remaining habitats were represented by two sampling areas due to their heterogeneity (i.e., *Hagenia* woodland and *Erica* Forests). *Erica* scrub is natural vegetation isolated from the main forests, and in the uplands of the lake watershed made the last habitat category.

The study was conducted for two dry and two wet seasons in between August 2019 and January 2021. A trapping year represented data from the two consecutive trapping seasons i.e., a wet and a dry season. Sherman live traps and snap traps were used to capture small mammals (Dawit Kassa and Afework Bekele, 2008; Yonas Terefe and Fikrasilasie Samuel, 2015). Live-trapping grids representing the available habitat types were established for capture-mark-recapture study. A single grid was set up in each of the representative sites of the habitat during the study periods. Each of the grids consisted of 7x7 lines at 10 m intervals. Then, a total of 49 Sherman live traps (5.5 x 6.5 x 16 cm size) at 10 m intervals were placed for three consecutive days for each habitat type. Traps were set in the afternoon and baited with peanut butter and barley flour. They were checked the following morning and evening, and old baits were replaced with new ones (Dawit Kassa and Afework Bekele, 2008; Venance, 2009). Traps were covered with grass to reduce mortality from cold and to avoid damage by other animals (Caceres *et al*., 2011; Sintayehu Workineh and Reddy, 2016). Each newly captured animal was marked by toe clipping and released at capture point (Tuyisingize *et al*., 2013; Getachew Bantihun and Afework Bekele, 2015; Sintayehu Workineh and Reddy, 2016).

Snap traps (20) were placed at 10 m intervals in each habitat, 200 m away from the live trapping grids for stomach contents analysis and embryo count (Demeke Datiko and Afework Bekele, 2013). Trapped animals were weighed using Pesola spring balances and species was identified using standard keys, and field guides (Kingdon, 1997, 2015; Afework Bekele and Yalden, 2013 and Happold, 2013), sex was determined, and morphometric measurements were taken using a ruler graded in mm from snap trapped animals

(Getachew Bantihun and Afework Bekele, 2015). Species that were difficult to identify in the field were compared to the specimens at Zoological Natural History Museum, Addis Ababa University. Personal observations and some indirect evidence such as quills, burrows and soil mounds were also employed to record some non-trapped rodents.

Data analysis

All statistical data were analyzed using SPSS version 21 software with a significance level of $P<0.05$. Data were analyzed based on captures per unit effort to account for variations in effort among the study sites. Spatiotemporal variations of small mammals were determined by comparing the number of individuals captured and the relative abundance in a specific season, time, year and habitat. Relative abundance was calculated by dividing the number of each species by total number of captured and multiplied by hundred (Agerie Addisu and Afework Bekele, 2013). Relative abundance in each habitat was calculated as the ratio between the number of species found in each habitat and the total number of species recorded in the study area (Venance, 2009). Trap success was also computed and compared with the relative abundance from the total number of trapped individuals and the overall trap nights (Tuyisingize *et al*., 2013; Yonas Terefe and Fikrasilasie Samuel, 2015; Kumaran *et al*., 2016). Small mammals' density was calculated as a ratio of abundance to trapping area (Wiewel *et al*., 2009; Seyoum Kiros and Afework Bekele, 2021). Data sets from capture recapture sampling techniques were used to estimate density (Wiewel *et al*., 2009; Krebs *et al*., 2011). Chi-square test (χ^2) was applied to compare spatiotemporal variations in small mammal species abundance, distribution and structure with respect to sex, age group, habitat and year.

RESULTS

Temporal Variations

A total of 959 small mammal individuals represented by twelve species of rodents and three species of shrews were trapped in 4,968 trapping efforts during the wet and dry seasons. These included: *A. abyssinicus*, *D. yaldeni*, *M. natalensis*, *M. awashensis*, *S. albipes*, *L. flavopunctatus*, *L. brevicaudus*, *L. chrysopus*, *D. lovati*, *G. murinus*, *L. imhausi* and an unidentified murid rodent (*Murid* spp. A). *Hystrix cristata* and *T. splendens* were only confirmed through indirect evidence. Specifically, porcupines were confirmed through quills, while burrows and soil mounds were used for mole rats. *Crocidura bailey*, *C. fumosa* and *C. olivieri* were the three identified shrew species in the two trapping seasons and years.

From the total small mammals, 559 (58.29%) individuals were trapped during the dry seasons, while the remaining 400 (41.71%) were trapped during the wet seasons. There was a significant difference in the total abundance of small mammals between seasons (χ^2=26.36; df=1; $P < 0.05$). Of the total 2484 trap nights, the overall trap success was higher during the dry (22.59%) than the wet (16.10%) seasons. The highest numbers of small mammal species (86.66%) were trapped during the wet seasons compared to the dry seasons (73.33%). There was a significant variation in the distribution of small mammal species between the seasons (χ^2=104.12; df=1, $P<0.05$).

During the dry seasons, *M. natalensis* (37.03%) was the most abundant small mammal species followed by *S. albipes* (28.44%), while two shrew species (*C. olivieri* and *C. bailey*) and *G. murinus* were the least abundant. *Stenocephalemys albipes* (26.75%) was the most abundant small mammal species followed by *M. natalensis* (22.25%) during the wet seasons, while *L. imhausi* and *D. yaldeni* were the joint least small mammal species each represented with one individual (Table 1).

Table 1. Temporal species distribution of small mammals.

Species	Seasons		Trapping time		Year		Total
	Wet	Dry	Morning	Noon	1st	2nd	
Mastomys natalensis	89	207	288	8	168	128	296
Mastomys awashensis	35	19	52	2	19	35	54
Lophuromys flavopunctatus	50	35	52	33	38	47	85
Lophuromys chrysopus	58	32	48	42	39	51	90
Lophuromys brevicaudus	22	21	25	18	21	22	43
Stenocephalemys albipes	107	159	240	26	114	150	266
Arvicanthis abyssinicus	-	5	4	1	1	4	5
Desmomys yaldeni	1	8	4	5	3	6	9
Murid spp. *A*	16	64	71	9	33	47	80
Dendromus lovati	6	-	6	-	3	3	6
Graphirius murinus	-	2	2	-	1	1	2
Lophiomys imhausi	1	-	1	-	1	-	1
Crocidura olivieri	6	2	8	-	5	2	8
Crocidura bailey	4	2	6	-	6	0	6
Crocidura fumosa	5	3	8	-	4	4	8
Total	400	559	815	144	456	503	959

The highest number of small mammals (84.98) was trapped during the morning trapping sessions, while the remaining 15.01% were the evening traps. There was a significant difference in the trapping of small mammals between the trapping periods (χ^2=469.490; df = 1, P< 0.05). All of the trapped small mammal species (15) were trapped in the morning trapping sessions, while only ten species were trapped in the evening. There was a significant variation in the number of trapped small mammal species between the trapping periods (χ^2=197.206; df=1, P<0.05).

Most of the small mammals in the present study favored nocturnal habits. *Lophiomys imhausi*, *D. lovati* and *G. murinus* were rodent species that were only trapped during the morning trapping periods. This also holds true for all the shrew species. It was only *Lophuromys* species that relatively showed a cathemeral distribution with 57.34% traps in the morning and 42.66% in the evenings. Species wise, it was only *L. chysopus* that showed significant variations between the trapping times and seasons (χ^2=197.206; df=1, P<0.05).

More individuals of small mammals (52.24%) were trapped during the second trapping year than the first year (47.75%). However, no statistically significant variation was observed in the abundance of small mammals between the trapping years (χ^2=1.928; df = 1, P > 0.05). All of the trapped small mammal species (15) were represented in the first trapping year, while 13 were trapped in the second trapping year. There was a significant dissimilarity in small mammal species richness between the trapping years (χ^2=30.548; df=1, P<0.05). *Crocidura bailey* and *L. imhausi* were the two species that were not trapped during the second trapping year. Statistically, *M. natalensis* (χ^2=8.678; df=1, P<0.05) and unidentified murid rodent (χ^2=14.045; df=1, P<0.05) were the only rodent species that showed significant variation in abundance between the trapping years.

From the total 465 male and 494 female small mammals, 191 (47.75%) males and 209 (52.25%) females were recorded during the two wet seasons. The remaining 274 (49.01%) males and 285 (50.9%) females were trapped during the two dry seasons. More female individuals were also trapped both in the morning and evening trapping sessions than males. There was non-significant difference in the sex structure of small mammals between the seasons (χ^2=0.15; df=1, P>0.05) and trapping times (χ^2=0.109; df=1, P>0.05). Although more female individuals were trapped than male counterparts in the trapping years, these numbers were not significantly different (χ^2=8.811; df=1, P>0.05). The capture rate of female small mammals (8.41%) was higher than the male counterparts (7.7%) between the two seasons (Table 2).

Table 2. Seasonal sex structure of small mammals.

Species	Wet season		Dry season		
	Male	Female	Male	Female	Male: Female
Mastomys natalensis	51	38	108	99	1.16:1
Mastomys awashensis	18	17	9	10	1:1
Lophuromys flavopunctatus	23	27	21	14	1.07:1
Lophuromys chrysopus	26	32	13	19	1:1.24
Lophuromys brevicaudus	9	13	4	17	1:2.3
Stenocephalemys albipes	52	55	77	82	1:1.06
Arvicanthis abyssinicus	-	-	2	3	1:1.5
Desmomys yaldeni	1	-	4	4	1.25:1
Murid spp. *A*	5	11	34	30	1:1.05
Dendromus lovati	-	6	-	-	0:6
Graphirius murinus	-	-	-	2	0:2
Lophiomys imhausi	-	1	-	-	0:1
Crocidura olivieri	1	5	2	-	1:1.67
Crocidura bailey	3	1	-	-	3:1
Crocidura fumosa	2	3	-	3	1:3
Total	191	209	274	285	1:1.06
Relative abundance (%)	19.91	21.8	28.57	29.72	48.48:51.51
Trap success (%)	7.69	8.41	11.03	11.47	9.36: 9.9

Age and sex structure

Most small mammal species in the present study area showed high male to female ratios (1:1.06). In most species (8), female abundance was higher during the wet season (52.75%) than dry season (47.25%). In contrast, the number of females increased during the dry seasons for *M. natalensis* (from 38 to 99), *S. albipes* (from 55 to 82) and *Murid* spp. *A* (from 11 to 30). *Crocidura fumosa* recorded a 1:1 male to female ratio during the wet seasons. Exceptionally, male individuals were not trapped throughout the study periods for *D. lovati*, *G. murinus* and *L. imhausi*.

The present study recorded a high number of adult small mammals and fewer juveniles during the trapping seasons, periods and years (Fig. 2). However, there was no significant difference in the age groups between seasons (χ^2=2.791; df=1, P>0.05), trapping periods (χ^2=2.791; df=2, P>0.05) and trapping years (χ^2=1.92; df=1, P>0.05). However, *L. brevicaudus* (χ^2= 9.92; df=2, P>0.05), *M. awashensis* (χ^2=2.79; df=2, P>0.05) and *Murid* spp. *A* (χ^2=3.88; df=2, P>0.05) were the only rodent species that showed a significant difference in their age structure between the seasons.

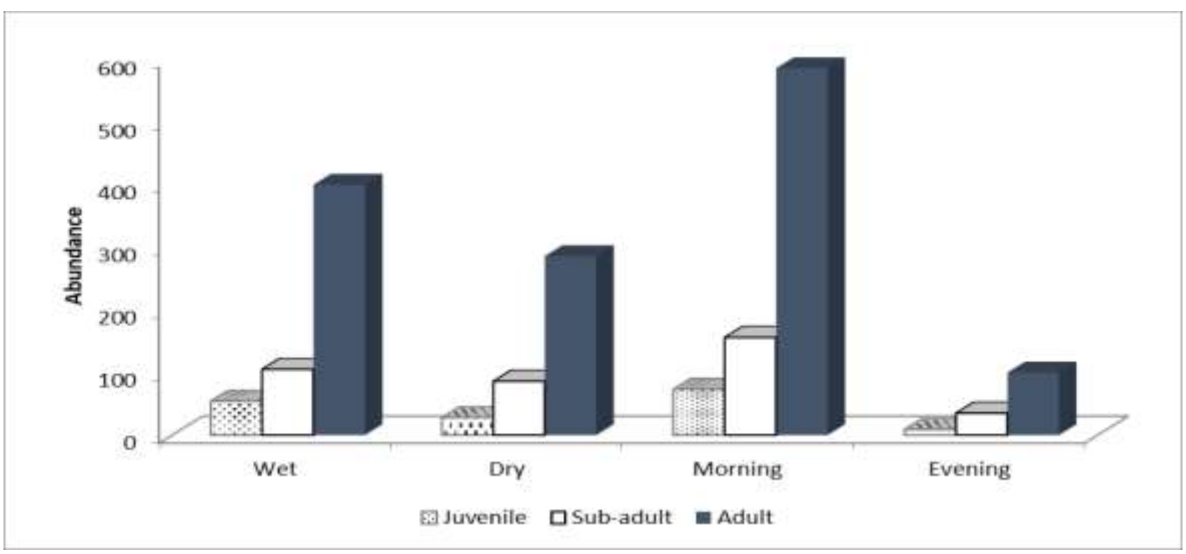

Figure 2. Temporal age structure of small mammals.

Habitat utilizations

The total abundance of small mammals was higher in all habitat types during the dry than wet seasons, except in Albesa Forest. Statistically, a significant variation was observed in the spatial distribution of small mammals between seasons (χ^2=30.11; df=5, P<0.05). Lakeshore Forest habitat yielded the highest proportions of small mammals during both dry (27.01%) and wet (28.75%) seasons. The least number of small mammals were trapped from *Erica* Forest habitat in both seasons (Table 3). There was also a significant difference in the capture of small mammals between times of the day across the habitat types (χ^2=12.917; df=5, P<0.05).

Table 3. Spatial abundance of small mammals between seasons.

Habitats	Seasons		Trap success	Trapping nights	Relative abundance	Total
	Wet	Dry				
HW	66	78	17.39	828	15.01	144
QF	78	127	23.43	828	20.23	194
LSF	115	151	32.12	828	27.73	266
EF	15	26	4.9	828	4.27	41
ES	42	103	17.51	828	15.12	145
AF	95	74	20.41	828	19.62	169
Total	400	559	19.30	4968	100	959

(HW= Hagenia Woodland, QF= Qibate Forest, LSF= Lakeshore Forest, EF= Erica Forest, ES= Erica Scrub, AF= Albesa Forest)

Mastomys natalensis (χ^2=34.40; df=4, P<0.05), *M. awashensis* (χ^2=14.30; df=3, P<0.05) *L. flavopunctatus* (χ^2=10.357; df=4, P<0.05) and *L. brevicaudus* (χ^2=11.15; df=2, P<0.05) were the only rodent species that showed a significant difference in distribution between the seasons across the habitat types. More small mammals were captured during the morning trapping sessions than the evening across the habitat types.

Small mammal density and trap success varied between the seasons and habitat types. Small mammals had higher density during the dry seasons (83.33 ha^{-1}) than wet seasons (59.35 ha^{-1}). The highest density was registered in Lakeshore Forest (135.71 ha^{-1}) followed by Qibate Forest (118.36 ha^{-1}) during the dry seasons. The lowest density (15.30 ha^{-1}) was recorded from *Erica* Forest during the wet seasons. The overall trap success of small mammals was 19.24. The highest trap success (90.47) was recorded from Lakeshore Forest, while *Erica* Forest (10.20) was the least (Table 4).

Table 4. Seasonality of small mammal density and trap success across the habitats.

Habitat	Season	Total captured	Density (ha^{-1})	Trapping nights	Trap success
HW	Wet	58	59.18	147	39.45
	Dry	57	58.16	147	38.77
QF	Wet	62	63.26	147	42.17
	Dry	116	118.36	147	78.91
LSF	Wet	102	104.08	147	69.38
	Dry	133	135.71	147	90.47
EF	Wet	15	15.30	147	10.20
	Dry	20	20.40	147	13.60
ES	Wet	35	35.71	147	23.8
	Dry	93	94.89	147	63.26
AF	Wet	75	76.53	147	51.0
	Dry	70	71.42	147	47.61

DISCUSSION

The present study recorded diverse small mammals in one of a high ground area of Ethiopia. This supports the general patterns of spatial and environmental preferences of small mammals (Yalden and Largen, 1992; Torre, 2004; Lavrenchenko and Afework Bekele, 2017). The diversity of small mammals also showed temporal variations. This supports the seasonal and inter-annual changes in the diversity and abundance of small mammals (Makundi *et al*., 2006; Sintayehu Workeneh *et al*., 2011; Wen *et al*., 2014; Agreie Addisu and Afework Bekele, 2015; Seyoum Kiros and Afework Bekele, 2021). Such variations in diversity patterns of small mammals may be attributed to the response of small mammals to the temporal changes in vegetation structure (Misher *et al*., 2022), seasonal appearance or disappearance of some species (Asher and Thomas, 1985) and micro habitats (Mohammed Kasso and Afework Bekele, 2011).

In this study, a high number of small mammal individuals were recorded during the dry than wet seasons. This result agreed with several reports from different parts of Ethiopia (Demeke Datiko *et al*., 2007; Tadesse Habtamu and Afework Bekele, 2008; Sintayehu Workeneh *et al*., 2011; Demeke Datiko and Afework Bekele, 2014 and Gezahegn Getachew *et al*., 2016), and elsewhere in the world (Delcros *et al*., 2015). The high abundance of small mammals during the dry seasons is widely associated to a superior bait attractiveness as a response to natural food items shortage (Demeke Datiko *et al*., 2007; Melese Yihune and Afework Bekele, 2012; Demeke Datiko and Afework Bekele, 2014; Delcros *et al*., 2015; Gezahegn Getachew *et al*., 2016; Rocha *et al*., 2017), a reproductive response to a previous rainy season (Tadesse Habtamu and Afework Bekele, 2008; Rocha *et al*., 2017), and the timing of the study period (Tilahun Chekol *et al*., 2012; Alembrhan Assefa and Srinivasulu, 2019, Seyoum Kiros and Afework Bekele, 2021). Some other scholars still argue that the increase is only limited to the early dry season following the rainfall patterns, and then decline as the season progresses and the resources runout (Happold and Happold, 1990; Mulatu Osie *et al*., 2010; Kiros Welegerima *et al*., 2020).

During our study, there was seasonal abundance of a widespread herbaceous plant, bracken fern. The presence of herbaceous plants and diverse microhabitat features plays a significant role in structuring the population of small mammals (Delcros *et al*., 2015; Li *et al*., 2015). Bracken ferns in the area flourish during the dry season and die out during the wet season, and could contribute to the shifts in the ground cover and the abundance of small mammals from the wet to the dry seasons. The ground cover of the area is well covered by dense bracken during the dry season than the wet seasons. This provides an ideal habitat for the insects that are the foods of insectivores (Zerihun Girma *et al*., 2012), and protects small mammals from livestock trampling and natural predators. Misher *et al*. (2022) also reported small mammal community fluctuations with the seasonal abundance of invasive shrub *Prosopis juliflora* in western India. The low population abundance of small mammals during the wetter seasons may perhaps attribute to the increase in the risks of predation and food starvation due to the absence and/or reduction in the ground cover (Seyoum Kiros and Afework Bekele, 2021).

This study recorded non-significant sex ratio variation though female was in more numbers during both seasons. This is in agreement to reports from different parts of Ethiopia (Tadesse Habtamu and Afework Bekele, 2008; Mohammed Kasso and Afework Bekele, 2011; Eshetu Moges *et al*., 2016; Alembrhan Assefa and Srinivasulu, 2019; Bewketu Takele *et al*., 2022). However, it contravenes with several findings across the country (Afework Bekele, 1996; Getachew Bantihun and Afework Bekele, 2015; Gezahegn Getachew *et al*., 2016; Seyoum Kiros and Afework Bekele, 2021). Such variation maybe associated with the difference in ecological distribution of resources between these areas.

The higher number of female individuals in the area is most probably due to the nutritional quality the area provides for small mammals. Females that inhabited a nutritionally deficient areas biased to produce a high number of female progenies (Rosenfeld and Roberts, 2004; Shilereyo *et al*., 2020). This assumption maybe the probable explanation to the current study because this area herbaceous diversity is primarily dominated by bracken ferns that may limit the feeding options of the small mammal, and leads to female skewed sex ratio. A relatively lower number of males in the area may also well explained by their more mobile nature and reproductive costs (Eshetu Moges *et al*., 2016; Bewketu Takele *et al*., 2022).

The abundance of adult small mammals was higher than other age groups during both seasons. Similar findings were reported across the country (Alembrhan Assefa and Srinivasulu, 2019; Seyoum Kiros and Afework Bekele, 2021; Bewketu Takele *et al*., 2022). The age structure of small mammal populations in different season is well explained by their reproductive seasonality (Tadesse Habtamu and Afework Bekele, 2008; Bewketu Takele *et al*., 2022). The result contradicts with the findings of Mohammed Kasso and Afework Bekele (2011) and Adugnaw Admas and Mesele Yihune (2016), where higher number of sub-adults are captured in wet season. This might be associated to the functional endurance of the adults than the other age groups. According to Seyoum Kiros and Afework Bekele (2021), higher smelling capacity to trapping baits and the utilization of relatively larger home ranges contributed to the higher abundance of adults.

The highest trap success was recorded during the dry than the wet seasons in Lakeshore Forest. The overall trap success in this study (19.24%) is higher than several reports from protected areas (Demeke Datiko and Afework Bekele, 2014; Alembrhan Assefa and Srinivasulu, 2019), and outside protected areas (Tilahun Chekol *et al*., 2012). However, it is lower than the findings from numerous protected areas (Tadesse Habtamu and Afework Bekele, 2008; Sintayehu Workeneh *et al*., 2011; Mohammed Kasso and Afework Bekele, 2011; Eshetu Moges *et al*., 2016; Seyoum Kiros and Afework Bekele, 2021). Such spatiotemporal variations in trap success could be associated to the varying in the climatic conditions, habitat structure, food and shelter availability, reproductive pattern, predators and other anthropogenic disturbances in these areas (Tilahun Chekol *et al*., 2012; Seyoum Kiros and Afework Bekele, 2021). Habitat type, seasonality and microclimates had the strongest influence on the abundance and diversity of small mammals (Stephenson, 1994; Mohammed Kasso and Afework Bekele, 2011; Bösing *et al*., 2014).

Small mammals showed marked fluctuations in abundance and distribution between the trapping times, and inter annually. Inter-annual fluctuations of small mammals are widely documented (Butet *et al*., 2006; Makundi *et al*., 2006; Agerie Addisu and Afework Bekele, 2015). Most of the small mammals favored a nocturnal habit. However, *Lophuromys* species relatively showed a cathemeral distribution. The variations in the trapping times may be well explained by the adaptations of mammals to avoid high level disturbances such as cattle trampling and to reduces the risks of predation (Afework Bekele and Yalden, 2013).

The higher number of small mammals during the second trapping year could be well explained by the inter-annual difference in the climatic conditions, rainfall in particular because of its effect on vegetation (Makundi *et al*., 2006). The higher rainfall across the country in the second trapping year, therefore, could contributed to the higher abundance of small mammals in the area in that year. Higher reproduction after long rainy seasons and increased small mammal populations thereafter is well documented (Happold and Happold, 1990; Mulatu Osie *et al*., 2010; Kiros Welegerima *et al*., 2020).

The highest population density of small mammals was registered during the dry than the wet season. Wirminghaus and Perri (1993) also reported seasonal variations of small mammal densities. Seasonality strongly influences the population dynamics of small mammals (Makundi *et al*., 2006; Wen *et al*., 2014; Agerie Addisu and Afework Bekele, 2015; Rocha *et al*., 2017). This is against the general trends of population density of small mammals in Ethiopia and African countries (Apia *et al*., 2011; Bewketu Takele *et al*., 2022). These fluctuations might be attributed to the differences in the densities of annual plants (Brown and Heske, 1990), the fluctuations of some small mammal populations (Brown and Heske, 1990; Rocha *et al*., 2017), and degree of disturbances and environmental variables (Tilahun Chekol *et al*., 2012; Sintayehu Workineh and Reddy, 2016; Seyoum Kiros and Afework Bekele, 2021) of these areas.

The flourishment and widespread nature of bracken during the dry seasons might have contributed to the rise in the population of worms and arthropods (Mossisa Geleta *et al*., 2011) as food sources of insectivores (Zerihun Girma *et al*., 2012). Lakeshore Forest recorded the highest density of small mammals. Wiewel *et al*. (2009) also reported a spatial difference in mammalian density. However, the result is against reports from Ethiopia (Ashetu Debelo and Afework Bekele, 2020; Bewketu Takele *et al*., 2022), and elsewhere (Apia *et al*., 2011). The level of population density recorded in this study habitat is also higher than that of Bewketu Takele *et al*. (2022). This might be attributed to the variation in the habitat structure, degree of disturbances, and the abundance of natural predators (Wiewel *et al*., 2009).

Wenchi highlands host a diverse and abundant small mammal community that displayed spatiotemporal changes. This supports the seasonal and inter-annual changes in the diversity and abundance of small mammals. The community structure of small mammals in the area is principally associated with the seasonal abundance and widespread nature of bracken fern. The findings of this study suggest the need for the conservation of the area to ensure the continued survival of these mammals.

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