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Seasonal variation of non-volant small mammals in Gibe Sheleko national park, Southwestern Ethiopia

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ABSTRACT: The species composition and abundance of small mammals can vary within space and time. The main objective of this study was to assess seasonal variation of non-volant small mammals from randomly selected *Acacia* woodland, bushland, farmland, grassland, riverine forest and wooded grassland habitats in Gibe Sheleko National Park, southwestern Ethiopia. Data were collected using 49 Sharman live traps in 70 x 70 m sized square girds from December, 2018 to August, 2020. Capture mark recapture technique was applied to estimate population size of the existing small mammals and the data were analyzed using a chi-square test. A total of 1160 individual small mammals belonging to 10 species and 2 families were recorded. Three non-captured species: *Hystrix cristata*, *Xerus rutilus* and *Tachyoryctes splendens* were also identified. There was a significant (χ^2= 31.12, df = 1, P < 0.05) difference in the total abundance of small mammals between seasons. Of the total individuals captured, 675(58.19%) were trapped during the wet season while 485(41.81%) individuals were during the dry season. Significant seasonal variation was also observed in the total abundance of both sexes, i e. males (χ^2= 11.99, df = 1, P < 0.05) and females (χ^2= 20.24, df = 1, P < 0.05). Among age groups, significant statistical seasonal variation was shown in adults (χ^2=15.14, df = 1, P < 0.05) and young (χ^2=44.61, df = 1, P < 0.05) but not significant in sub-adults (χ^2=0.75, df = 1, P >0.05). The identified small mammals exhibited seasonal changes in their abundance associated with changes in climatic and environmental conditions. However, a long-term and annual based study is required to see the overall dynamics of existing small mammals.

Key words/phrases: Abundance, age structure, Gibe Sheleko, seasonal variation, sex distribution, small mammals

INTRODUCTION

Small mammals have high reproductive potential and rapid turn-over rate to invade new environment and wide range of habitats (Agerie Addisu and Afework Bekele, 2015; Akpan *et al.*, 2015; Li *et al.*, 2015; Ofori *et al.*, 2015). The rapid turn-over rate in small mammals may be associated with their small body size, short breeding period and the ability to consume different food items (Akpan *et al.*, 2015; Adugnaw Admas and Mesele Yihune, 2016). Inter and intra-specific small mammals have different biotic potentials associated with geographical location, habitat heterogeneity and productivity, season and size of the female animals as well (Happold, 2013).

Species composition and abundance of small mammals vary within space and time. They exhibit notable seasonal and inter-annual differences in species composition and abundance (Sintayehu Workeneh *et al.*, 2011; Agerie Addisu and Afework Bekele, 2015; Ofori *et al.*, 2015). Changes in species composition or population size of small mammals in a particular area is mainly determined by habitat heterogeneity and productivity, climatic variation, availability of natural resources, natural predators, overgrazing, fire and the extent of invasive exotic species (Sintayehu Workeneh *et al.*, 2011; Ofori *et al.*, 2015). Occasionally, deforestation, habitat fragmentation and other anthropogenic activities such as agricultural management techniques have also a significant impact on the diversity and population dynamics of small animals (Gentili *et al.*, 2014; Gezahegn Getachew *et al.*, 2016).

Population dynamics of small mammals is also affected by the amount and pattern of rainfall in space and time, as rainfall is the main driving force of food availability which enhances the breeding potential of small mammals (Ejigu Alemayehu and Afework Bekele, 2013; Getachew Bantihun and Afework Bekele, 2015; Ofori *et al.*, 2015). In the savanna ecosystem type, for

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instance, *Mastomys natalensis* commonly breeds during the wet and early dry seasons of the year due to the presence of sufficient food availability and abundance (Happold, 2013). Overgrazing by domestic animals may also affect the abundance and species richens of herbivorous small mammals of a given area, resulting in food competition, habitat disturbance and exposure to natural predators (Addishiwot Fekadu *et al*., 2015; Gezahegn Getachew *et al.,* 2016).

Protected areas are established throughout the globe to conserve wildlife with special emphasis on large mammals and birds from being extinct. According to Caro (2001), in East Africa, protected areas are established primarily to conserve large mammals especially umbrella or flagship species considering their tourism revenue, but the importance and exploration of small mammals are poorly known. The same is true in some National Parks of Ethiopia including Gibe Sheleko National Park. Exploration on the species composition and population dynamics of small mammal communities is mandatory to enhance the effectiveness of the existing conservation and management strategies of the Park (Loeb *et al.,* 1999; Lavrenchenko and Afework Bekele, 2017).

In some developing nations including Ethiopia, some rodents are considered as a major challenge of human food security. Seasonal rodent pest outbreaks can cause human starvations due to considerable crop damage and yield losses by rodents. Ecological investigation on species composition and seasonal variation of small mammals of a particular area is very essential to identify economic importance of the species of that area and to develop effective rodent pest management strategies (Lavrenchenko and Afework Bekele, 2017). Understanding the species composition and seasonal variation of small mammals from Gibe Sheleko National Park deserves paramount importance for the documentation of the existing small mammals and to strengthen the conservation efforts of other co-occurring wildlife species. Therefore, this study was conducted to investigate the seasonal variations of small mammals in Gibe Sheleko National Park.

MATERIALS AND METHODS

Study Area

Gibe Sheleko National Park (GSNP) is located in Gurage zone, Southern Nations, Nationalities and Peoples' Region (SNNPR) at 178 and 18 km away from Addis Ababa and Wolkite town, respectively. It is geographically located at 8°5´ 00´´N to 8°16´00´´N latitude and 37°26´00´´E to 37°48´00'´E longitude (Fig. 1). The Park is bordered by three districts of the zone namely Abeshege, Cheha and Enemorener, and the Gibe River along the western side bordering the Oromia Regional State. The Park was established in 2009 considering its conservation significance for wildlife with special emphasis for birds. It covers 360 km² with variable altitudinal ranges 1050 to 1835 m asl (Alemneh Amare, 2015; Kassahun Abie *et al*., 2019).

The Park possesses diverse topographic features such as flat terrain, plateau, gorges, relatively undulating and rocky steep slopes (Hadis Tadele *et al*., 2020). The area is also endowed with streams, rivers and hot springs within and its surrounding. For instance, Wabe and Nekem rivers flow inside the Park.

The study area is recognized by having relatively hot weather condition. It receives a rainfall between 960 and 1400 mm per annum with average annual precipitation of 1163 mm. The heaviest rainfall concentration is recorded during the summer season (June to August) of the year. Monthly average maximum and minimum temperature of the area is about 29.1°C and 8.9°C, respectively, with average annual temperature of 19.6°C. The maximum temperature of the area is recorded during the dry season (December to February) of the year.

The study area is mainly covered by acrisol, nitisol and vertisol soil types derived from Eocene–Palaeocene basaltic rock type (Solomon Tadesse *et al*., 2003 as cited in Johansson *et al.,* 2021). The Park is covered by savannah woodland vegetation type. Relatively flatlands of the Park are covered by *Acacia* species such as *Acacia abyssinica, Acacia etbaica, Acacia nilotica, Acacia polyacantha* and *Acacia seyal.* Broad leaved species such as *Combretum molle*, *Combretum collinum, Cussonia holstii* and *Ficus sycomorus* cover most of the escarpment area of the Park. *Dicrostachys cinerea, Fluegga virosa* and *Searsia* *natalensis* are the dominant and widely distributed shrub species found in the study area. Among the existing grass species, *Hyparrhenia dregeana*, *Hyparrhenia filipendula* and *Bothriochloa insculpta* are the most common and widely distributed grasses. The surrounding area of streams and rivers of the Park are mainly covered by patches of evergreen woodland and gallery forest vegetation types, respectively (Johansson *et al.,* 2021).

According to archives of Gibe Sheleko National Park, the study area is endowed with different species of vertebrates such as mammals, reptiles, birds and fishes. Among mammals, ungulates such as bohor reedbuck (*Redunca redunca*), common bushbuck (*Tragelaphus scriptus*) bush pig (*Potamochoerus larvatus)*, hippopotamus (*Hippopotamus amphibious)*, warthog (*Phacochoerus africanus*) and waterbuck (*Kobus ellipsiprymnus)*, carnivores such as civet (*Civettistis civetta*), honey badger (*Mellivora capensis*), leopard (*Panthera pardus*) and spotted hyaena (*Crocuta crocuta*), primates such as colobus monkey (*Colobus guereza*), olive baboon (*Papio Anubis*) and vervet monkey (*Chlorocbus pygerythrus*) and, others like aardvark (*Orycteropus afer*), porcupine (*Hystirx cristata)*, and rock hyrax (*Procavia capensis*) occur. Reptiles such as the African rock python, Nile crocodile and Nile monitor are also found within the Park. According to Kassahun Abie *et al*. (2019) and Hadis Tadele *et al*. (2020), GSNP supports more than 110 bird species including endemic, near endemic, rare, threatened and migratory species.

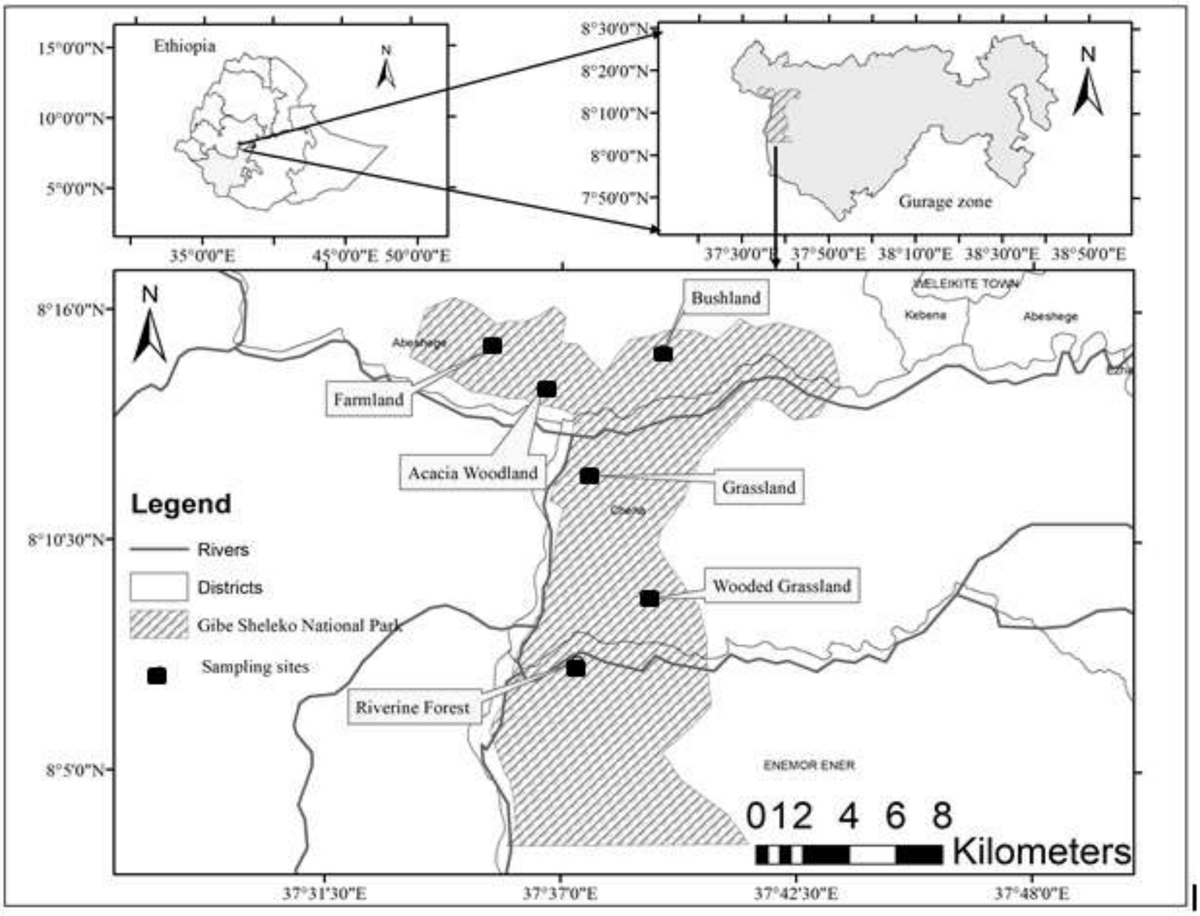

Figure 1. Map of the study area and location of the sampling sites.

METHODS

During this study, six habitat types were randomly selected based on the dominant vegetation type, altitudinal zonation, topographical feature and accessibility of the area. The identified habitat types were: wooded grassland (1634 m asl), bushland (1570 m asl), riverine forest (1490 m asl), farmland (1358 m asl), *Acacia* woodland (1300 m asl) and grassland (1100 m asl). Data collection was carried out for two successive years having two dry and two wet seasons from December, 2018 to August, 2020. Dry and wet season data collections were conducted between December to February and June to August, respectively. Data were collected using Sherman live traps, naked eye or binoculars aid visual surveys and using indirect evidence such as presence of quills, burrows and soil mounds for non-captured small mammals.

Capture mark recapture method was applied to estimate the population size of the existing small mammals (Afework Bekele and Leirs, 1997). In all habitats, 70 x 70 m sized permanent square grid was randomly established. In each gird, a total of 49 Sherman live traps at 10 m intervals were placed for five consecutive days to make sure maximum chances of capturing rare and shy species. Trap stations were marked using yellow coloured plastic tag. In each trapping session, all traps were baited with a mixture of peanut butter, crushed maize and chickpea. To avoid small mammal mortality due to harsh temperature during the dry season and to minimize stealing from natural predators, traps were covered by the existing grasses or plant leaves. In each trapping session, traps were checked and refreshed in the morning (7:00–9:00 a.m) and late afternoon (4:00–6.00 p.m.) per day.

In all trapping sessions, information such as body weight, sex, approximate age structure and reproductive condition of each live trapped small mammal were assessed. Approximate age structure was determined by considering the pelage colour, body weight, and developmental status of external body parts as well as reproductive organs of the animal (Gezahegn Getachew *et al.,* 2016). Reproductive condition of each live trapped small mammal was identified following Afework Bekele and Leirs (1997), Monadjem and Perrin (2003), and Tsegaye Gadisa and Kitessa Hundera (2015). Thus, sexually matured males are determined by considering position of their testes either abdominal or scrotal. Body weight, vaginal orifice, abdominal and nipple sizes were used to determine the reproductive condition of female small mammals. Sex of young small mammals was determined by considering the distance between the anus and genital papilla, and the presence of scrotal septum between the penis and anus in males (Aplin *et al.,* 2003). Each live trapped small mammal was toe clipped and then released into its natural habitat. Scientific names of the live trapped small mammals were identified using standard literature and taxonomic keys (Yalden *et al.*, 1976; Kingdon, 1997; Afework Bekele and Yalden, 2013; Happold, 2013; Happold and Happold, 2013).

Data analyses

Trap success and relative abundance of small mammals were calculated by the following formulae:

$$TS = \frac{Nm}{Ntn} x100$$

Where, TS= trap success, Nm = the number of individuals trapped and Ntn = the number of trap nights.

$$Ra = \frac{n}{Ns} x100$$

Where, Ra = relative abundance, n = the total number of captured individuals of a single species and Ns = the total number of individuals of the whole species.

Density was calculated as follows:

$$D = \frac{N}{A}$$

Where, D = density, N = the total number of individuals per gird, A= area of the trapping gird (4900 m^2 = 0.49 ha) for each tapping season.

Chi-square test was applied to compare seasonal variations in small mammal species abundance, sex distribution and age structure. All statistical data were analyzed using SPSS version 24 computer software.

RESULTS

Seasonal variation

A total of 1160 live trapped small mammals belonging to 10 species were recorded from the six habitat types in Gibe Sheleko National Park. *Hystrix cristata*, *Xerus rutilus* and *Tachyoryctes splendens* were also documented through direct observation and using indirect evidences. Of these, 675(58.19%) individuals were trapped during the wet season, while 485(41.81%) were trapped during the dry season. There was a significant (χ^2= 31.12, df = 1, P < 0.05) difference in the abundance of small mammals between seasons. Of the total 2940 trap nights, overall trap success was higher during the wet season (22.96%) than the dry season (16.5%). Except population of *Mus tenellus* and *Rattus rattus*, more than 50% of the total populations of other species were recorded during the wet season of the study period (Fig. 2). However, significant seasonal variation was observed only in the abundance of three species; *Arvicanthis niloticus* (χ^2= 14.10, df = 1, P<0.05), *Lemniscomys striatus* (χ^2= 26.04, df = 1, P<0.05) and *Stenocephalemys albipes* (χ^2= 12. 52, df = 1, P <0.05).

Sex distribution and seasonal variation

In the present study, a total of 646(55.69%) male and 514(44.31%) female small mammals were recorded. There was a significant (χ^2= 15.02, df =1, P < 0.05) difference in the abundance of small mammals between sexes. Males had higher (10.99%) capture rate than females (8.74%) within 5880 trap nights. In *Grammomys dolichurus*, nearly equal numbers of male and female individuals were recorded. In other species, the total captured males were significantly higher than females. However, except in *Mastomys natalensis* (χ^2= 5.65, df =1, P < 0.05), no statistical significant difference was observed in the abundance of sexes (Fig. 3).

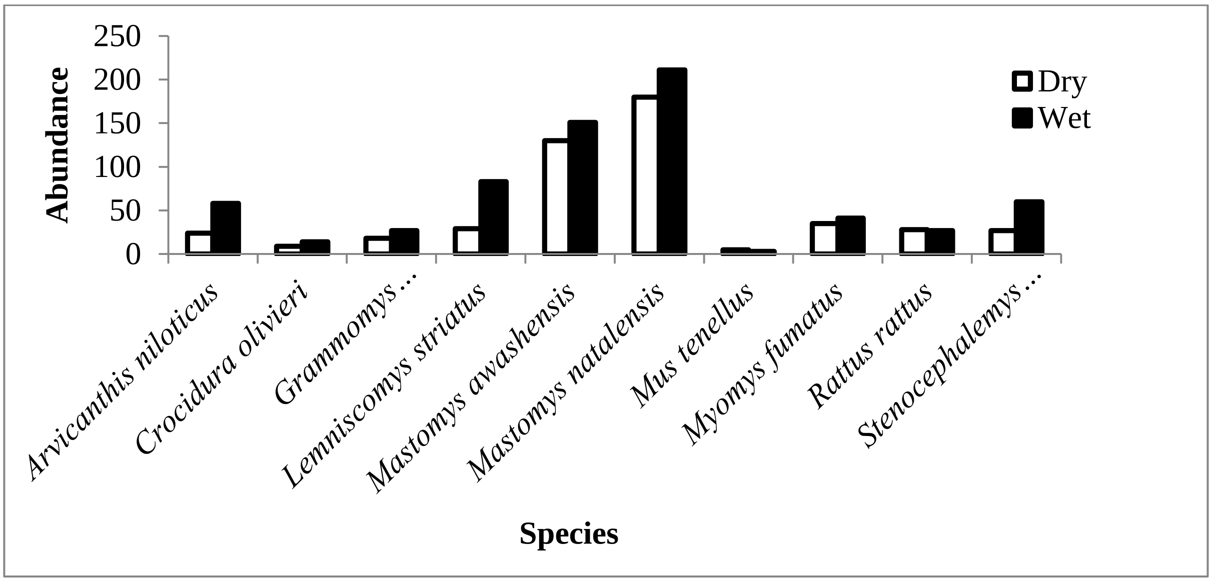

Figure 2. Seasonal variation in the abundance of small mammal species.

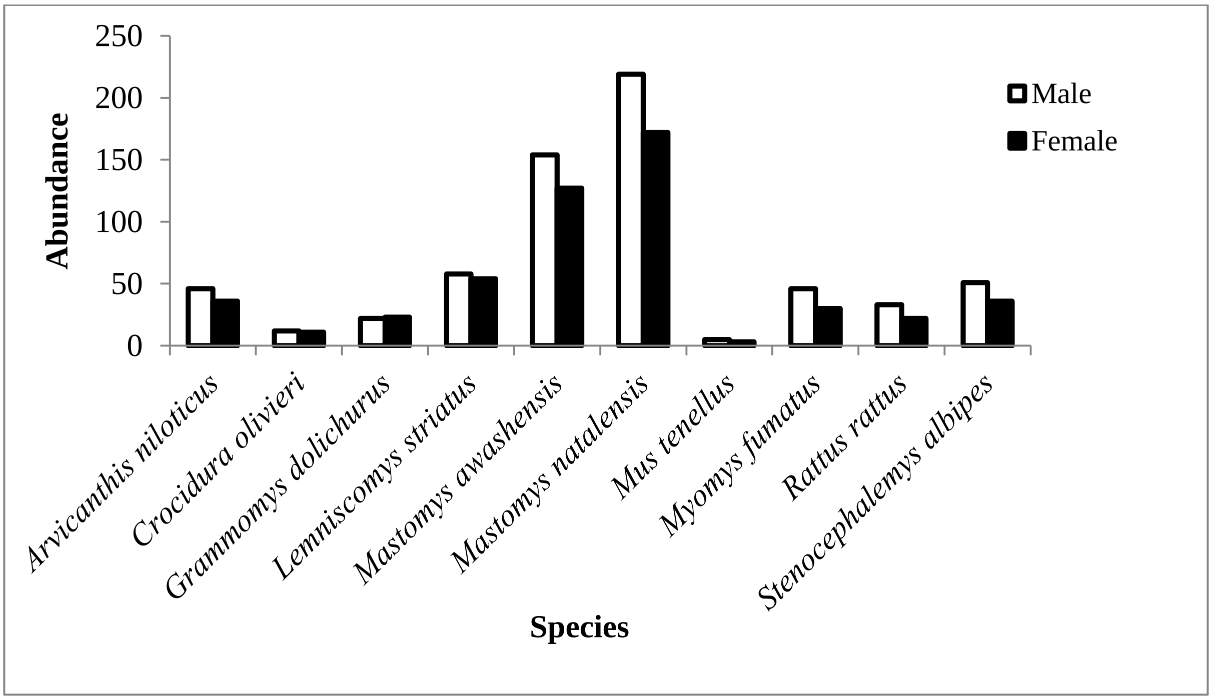

Figure 3. Abundance of male and female small mammals.

Seasonally, the overall abundance of male and female small mammals varied. Out of the total 646 male and 514 female small mammals, 367(56.81%) males and 308(59.92%) females were recorded during the wet season with capture rate of 12.48% and 10.48%, respectively in 2940 trap nights. While the remaining 279(43.19%) males and 206 (40.08%) females were registered during the dry season of the study period with 9.49% and 7.01% capturing rates, respectively (Table 1). Seasonal variation was observed in the total abundance of both sexes, i e. males (χ^2= 11.99, df = 1, P < 0.05) and females (χ^2= 20.24, df = 1, P < 0.05). In some species, the ratio of male to female showed some fluctuations within seasons. In *Crocidura olivieri,* 1:1 male to female ratio was recorded during the wet season. In most species, the numbers of females were higher during the wet season (Table 1).

Table 1. Seasonal variation and sex distribution of small mammals.

Species	Dry season		Wet season		
	Male	Female	Male	Female	Male: Female ratio
Arvicanthis niloticus	15	9	31	27	46:36
Crocidura olivieri	5	4	7	7	12:11
Grammomys dolichurus	10	8	12	15	22:23
Lemniscomys striatus	16	13	42	41	58:54
Mastomys awashensis	69	61	85	66	154:127
Mastomys natalensis	102	78	117	94	219:172
Mus tenellus	3	2	2	1	5:3
Myomys fumatus	24	11	22	19	46:30
Rattus rattus	19	9	14	13	33:22
Stenocephalemys albipes	16	11	35	25	51:36
Total	279	206	367	308	646:514
Relative abundance (%)	24.05	17.76	31.64	26.55	55.69:44.31
Trap success (%)	9.49	7.01	12.48	10.48	10.99:8.74

Age structure and seasonal variation

During the present study, a total of 785(67.67%), 262(22.59%) and 113(9.74%) adult, sub–adult and young mammals, respectively were recorded. A statistically significant (χ^2= 644.24, df = 2, P < 0.05) difference was observed in the total abundance of small mammals among the three age groups. Overall, adults had high (13.35%) capture rates, followed by sub-adults (4.46%) and young (1.92%) in 5880 trap nights. Seasonally, higher, 447(56.94%), 138(52.67%) and 92(81.42%) adult, sub–adult and young small mammals, respectively were recorded during the wet season (Fig. 4). Statistical seasonal variation was shown in adults (χ^2=15.14, df = 1, P < 0.05) and young ones (χ^2=44.61, df = 1, P < 0.05), but not in sub–adults (χ^2=0.75, df = 1, P >0.05). During the wet season, the number of trapped young ones increased by more than four times compared to the dry season (Fig. 4).

Seasonal variation in density and trap success

The overall small mammal density and trap success of the study area was 98.64/ha and 19.73%, respectively. Small mammal density and trap success also varied among habitat types and between seasons. Highest mean small mammal density was recorded in wooded grassland (152.04/ha) followed by farmland (147.96/ha) during the wet season. While the lowest mean small mammal density was 50/ha recorded in *Acacia* woodland during the dry season (Table 2). Overall, the highest (30.41%) and lowest (10%) trap success was recorded in wooded grassland and *Acacia* woodland habitats during the wet and dry seasons, respectively.

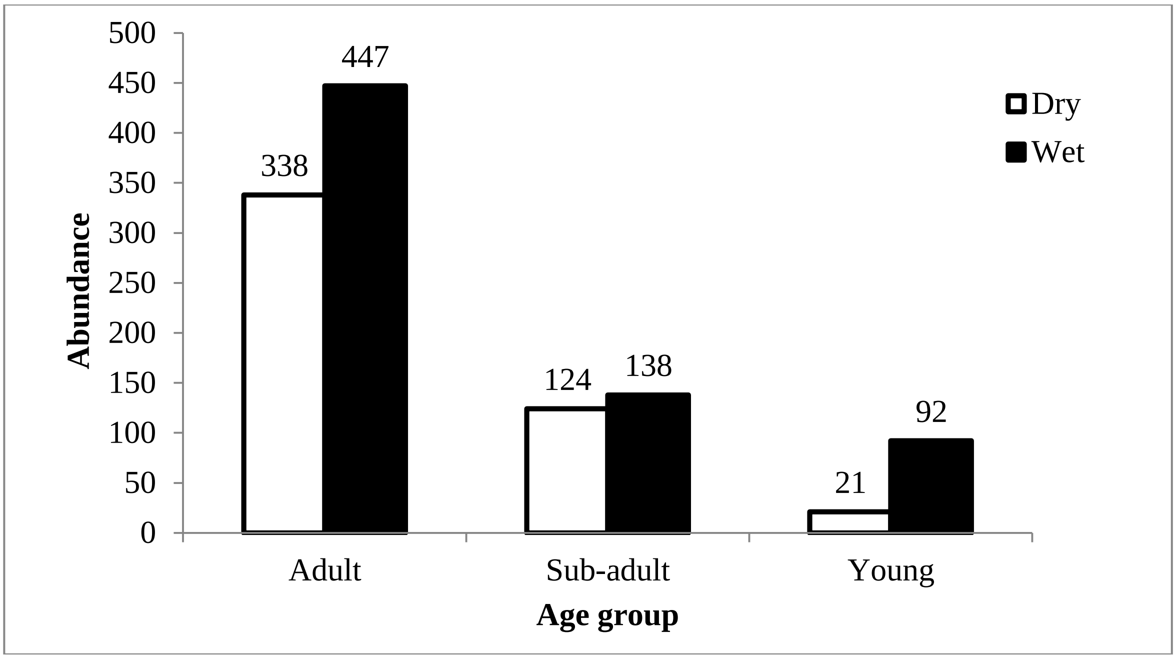

Figure 4. Seasonal variation in age groups of small mammals.

Table 2. Seasonal variation in small mammal density and trap success in six habitats.

Habitat	Season	Total captured	Density (ha^{-1})	Trap Nights	Trap success (%)
Acacia woodland	Dry	49	50	490	10
	Wet	86	87.76	490	17.55
Bushland	Dry	75	76.53	490	15.31
	Wet	89	90.82	490	18.16
Farmland	Dry	134	136.74	490	27.35
	Wet	145	147.96	490	29.59
Grassland	Dry	76	77.55	490	15.51
	Wet	107	109.18	490	21.84
Riverine forest	Dry	61	62.25	490	12.45
	Wet	99	101.02	490	20.20
Wooded grassland	Dry	90	91.84	490	18.37
	Wet	149	152.04	490	30.41

DISCUSSION

Having a scientific knowledge about the seasonal change of small mammals is very essential to determine the small mammals' life history, patterns of population fluctuation and density occurrences as well as the population regulatory factors involved (Massawe *et al*., 2011; Fischer *et al*., 2012; Ofori *et al*., 2015). It also helps to predict the rodent pest outbreak season and to apply appropriate rodent pest management strategies in a particular area (Massawe *et al*., 2011).

In this study, higher number of individual small mammals was recorded during the wet than the dry seasons. This result goes in line with Tilahun Chekol *et al.* (2012), Redwan Mohammed *et al.* (2017), and Alembrhan Assefa and Srinivasulu (2019). Capturing more individuals during the wet season is associated with the availability and quality of food and shelter. The presence of diverse herbaceous plants during the wet season may serve as a source of food and shelter for non–volant small mammals (Li *et al.*, 2015). Microhabitat features of a given area such as grass height and density, tree/shrub type and density and other features may also determine the species richness and abundance of small mammals during the dry season (Delcros *et al.*, 2015).

In contrast, Demeke Datiko *et al*. (2007), Tadesse Habtamu and Afework Bekele (2008), Sintayehu Workeneh *et al.* (2011), Demeke Datiko and Afework Bekele (2014), Delcros *et al.* (2015) and Gezahegn Getachew *et al*. (2016) reported more number of individual small mammals were documented during the dry season. This variation may be related with the differences in the degree of human induced disturbances, overgrazing, fire, diversity and abundance of natural predators and timing of the study period (Tilahun Chekol *et al.,* 2012; Alemrhan Assefa and Srinivasulu, 2019).

According to Mulatu Osie *et al.* (2010) and Kiros Welegerima *et al*. (2020), high individual small mammals were recorded at the early dry season due to the presence of sufficient food and shelter following the rainfall patterns. However, as the dry season progressed, the availability and abundance of natural resources such as food and water become scarce and hence, species richness and abundance of small mammals decline as a result of starvation and increasing mortality rate (Happold and Happold, 1990).

In the study area, seasonal human induced fire, deforestation, overgrazing and presence of natural predators particularly snakes may affect the species richness and abundance of small mammals. According to Mulatu Osie *et al. (*2010), due to the absence and/or reduction of plant ground cover during the dry season, small mammals may be exposed to natural predators and food starvation. Burned areas during the dry season may support few numbers of small mammal species and individuals **(**Happold and Happold, 1990).

In the present study, sex ratio was male biased during both seasons. This is in line with Afework Bekele (1996), Getachew Bantihun and Afework Bekele (2015), Gezahegn Getachew *et al.* (2016) and Shilereyo *et al.* (2020). Capturing of more males may be related to larger home range utilization behaviour of males to search for food or receptive females. Lower number of trapped females may also be associated with reproductive costs of females such as in parental care, pregnancy and lactation periods (Shilereyo *et al.,* 2020). In contrast, Tadesse Habtamu and Afework Bekele (2008) and Alembrhan Assefa and Srinivasulu (2019) reported that the number of captured females was higher than the males, this may be associated with the variations in ecological conditions of the study areas such as variations in natural resources. According to the Trivers-Willard hypothesis, maternal diet status of female small mammals plays an important role in sex ratio bias, that is, females inhabited nutritionally deficient areas such as caloric content can produce more female offspring and then, female skewed sex ratio may occur (Rosenfeld and Roberts, 2004; Shilereyo *et al.*, 2020).

In this study, during both seasons, the abundance of adult small mammals was higher than the number of sub–adult and young small mammals. This is in agreement with the studies of Redwan Mohammed *et al.* (2017) and Alembrhan Assefa and Srinivasulu (2019), where capturing of more adult small mammals may be associated with their body size making it suitable for trappings or adults may have higher smelling capacity to human induced food items such as mixed peanut butter bait, as well as utilization of relatively larger home ranges.

In this study, the abundance of young increased during the wet season of the study period. Reproductive potential of females may be enhanced with the availability and quality of food items. According to Afework Bekele and Leirs (1997), Demeke Datiko *et al*. (2007), Tadesse Habtamu and Afework Bekele (2008), Sintayehu Workeneh *et al.* (2011), Tilahun Chekol *et al.* (2012), Getachew Bantihun and Afework Bekele (2015), Gezahegn Getachew *et al*.(2016), Redwan Mohammed *et al.* (2017), Alemrhan Assefa and Srinivasulu (2019), and Shilereyo *et al.* (2020), increasing in the abundance of lactating, pregnant and young of most small mammals during the wet season could be assisted by the availability of sufficient and nutritious food items and sufficient vegetation cover. Capturing low abundance of young during the dry season may be due to their vulnerability towards natural predators and harsh weather condition as a result of reduction in ground cover (Redwan Mohammed *et al*., 2017).

Overall, trap success was higher during the wet season than the dry season. Among the six habitat types, the highest and lowest trap success and small mammal density were recorded in wooded grassland and *Acacia* woodland habitats during the wet and dry seasons, respectively. According to Afework Bekele and Leirs (1997), Mulatu Osie *et al.* (2010), Tilahun Chekol *et al*. (2012), Dawd Yimer and Solomon Yirga, (2013), and Redwan Mohammed *et al.* (2017), trap success and density in a given area and time may be attributed to several factors including habitat heterogeneity and productivity, availability of food and shelter, reproductive pattern, diversity and abundance of natural predators and degree of anthropogenic factors.

The study provided baseline information on the small mammal species composition and their temporal variations in Gibe Sheleko National Park. From the present study, it is clear that the small mammal species composition and abundance varied spatially and temporally. Among the identified species, *Arvicanthis niloticus, Lemniscomys striatus, Mastomys awashensis, Mastomys natalensis, Rattus rattus* along with *Hystrix cristata* and *Tachyoryctes splendens* were listed as the crop pests of the study area. Hence, understanding the dynamics of these species has a significant impact for rodent pest management planning and implementation. However, frequent ecological assessments are needed to see the overall seasonal variations of small mammals, as well as the causal factors involved.

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