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DIVERSITY, RELATIVE ABUNDANCE AND HABITAT ASSOCIATION OF RODENTS IN AQUATIMO FOREST PATCHES AND ADJACENT FARMLAND, EAST GOJJAM, ETHIOPIA

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ABSTRACT: Species diversity, relative abundance and habitat association of rodents in Aquatimo forest patches and its adjacent farmlands were studied using Sherman live traps and snap traps. Four habitat types such as forest, bushland, grassland and farmland were considered for the present study. A total of 49 Sherman traps and 25 snap traps were used for the study, and 316 individuals were captured by live traps in 2352 trap nights, and 58 individuals by snap traps in 1200 trap nights. Eight species of rodents and two species of insectivores were recorded during the study period. The relative abundance of rodent species identified were 132(41.8%) *Arvicanthis abyssinicus*, 49(15.5%) *Stenocephalemys albipes*, 46(14.6%) *Mus musculus*, 39(12.3%) *Mastomys natalensis*, 20(6.3%) *Lophuromys flavopunctatus*, 13(4.1%) *Grammomys dolichurus*, 7(2.2%) *Rattus rattus*, and 5(1.9%) *Dendromus lovati*. The insectivore species were 3(0.9%) *Crocidura flavescens* and 2(0.5%) *Crocidura fumosa*. The maize farm was found to be the habitat where species richness and relative abundance were the highest. Trap success in the grassland habitat differs significantly between the wet and dry seasons (χ^2=29.6, $p<0.05$). The distribution of rodent species varied based on habitats. This study about the ecology and biology of rodents is fundamental for proper monitoring of the environment in order to control and conserve small mammals.

Key words/phrases: Insectivores, Rodents, Sherman live traps, Snap traps, Species richness.

INTRODUCTION

Diverse types of ecosystems in Ethiopia ranging from alpine moorlands to savannah and arid lands to extensive wetlands have resulted in the presence of diverse biological resources including rodents (Yalden and Largen, 1992; Tesfaye Hundessa, 1997). The country is rich in its faunal diversity and as a result, over 320 species of mammals, 861 species of birds, 200 species of reptiles, 63 species of amphibians and 145 species of fish are known (Yalden and Largen, 1992; Malcolm and Sillero-Zubiri, 1997; Afework Bekele and Yalden, 2013).

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Among the mammalian orders, Rodentia contains the largest number of species (Kingdon, 1997; Vaughan *et al*., 2000; Tsegaye Gadisa and Afework Bekele, 2006), and they account for nearly 44% of the mammal species (Wolff, 2007). Rodent community structure and species richness have been related to habitat structure and complexity, area of productivity, predation and succession of the vegetation (Avenant and Cavallini, 2008). Rodents are the most ubiquitous and numerous (Delany, 1986; Afework Bekele, 1996), and show considerable diversity in their diet (Leirs *et al*., 2008).

Rodents comprise 26 orders, 29 families, 443 genera and more than 2000 species (Vaughan *et al*., 2000; Danell and Aave-Olsson, 2002). They are major agricultural pests, and most of them damage agricultural fields during the seedling stage and just before harvest (Fiedler, 1994; Stenseth *et al*., 2001). Fitzgibbon (1997) reported that high immigration rates of rodents from adjacent habitats and increased recruitment owing to food resources lead them to rapid population growth in agricultural fields. In addition to direct consumption, rodents cause severe damage indirectly by contaminating stored crops by their droppings, urine, hairs and microorganisms (Nowak, 1999).

The most common rodents in sub-Saharan African countries are *Mastomys* spp. that occurs all over the continent in natural grasslands, cultivated areas and in human habitats. Population explosion occurs at regular intervals, which causes up to 50% of crop losses (Leirs *et al*., 1996). Rodents damage and destroy 30% of the crops in both pre-harvest and post-harvest conditions (Singleton, 2001). In Ethiopia, Goodyear (1976) and Afework Bekele *et al*. (2003) have estimated that they destroy 20% to 26% of cereal crops.

There are nine families of rodents in Ethiopia of which the family Muridea alone comprises 57 species (84% of the total number of species) and 93% of the total endemic rodents of Ethiopia (Afework Bekele and Corti, 1997). *Lophuromys flavopunctatus* is also the most common rodent in the moist eastern part of East Africa inhabiting wide range of habitats (Clausnitzer and Kityo, 2001).

The distribution and abundance of rodents is influenced by environmental factors such as nature and density of vegetation, food and shelter (Clout and Russell, 2004), climatic conditions, disease, predation and habitat manipulation by human beings (Odhiambo and Oguge, 2003). Ecologically disturbed ecosystem is often associated with decrease in small mammal diversity (Hoffmann and Zeller, 2005). Abundance of food increases rodent density in agricultural areas, grasslands, and forest habitats (Lentic and Dickman, 2005). The loss of ground vegetation leads to loss of cover and food supply for small mammals thereby decreasing rodent diversity but increasing predation risk (Hoffmann and Zeller, 2005).

Rodents respond quickly to disturbances in the habitat. They are mobile to disperse leaving unsuitable sites (Leirs *et al*., 2008). Change in land-use patterns due to human activities has a remarkable effect on the composition of rodent community (Happold and Happold, 1989). Rodents are important dietary components of many of the small carnivore mammals, raptors and reptiles (Davies, 2002). Jungle cat (*Felis chaus*), caracal (*Caracal caracal*) and golden jackal (*Canis aureus*) feed on rodents as the vital food item (Mukherjee *et al*., 2004). Rodents are also good biological indicators of ecosystem changes (Avenant and Cavallini, 2008; Leirs *et al*., 2008). Some rodents are also considered as pioneers of ecosystem succession (Davies, 2002).

In Ethiopia, many studies have been carried out about rodents. However, sufficient information about the ecology of rodents in the different localities of the country is not accessible. Hence, the present study was undertaken to determine diversity and relative abundance of rodents, and to identify distribution patterns and habitat association of rodents in one of the locations in East Gojjam, Ethiopia, in order to design appropriate control and conservation strategies for rodents.

MATERIALS AND METHODS

Description of the study area

Aquatimo forest patch is located in East Gojjam, Ethiopia (11°05′ N and 33°51′ E), at about 339 km northwest of Addis Ababa, the capital city of Ethiopia (Fig. 1). The altitudes of the area range between 2262 m to 2384 m a.s.l. The main rainy season is from June to September, while the dry season extends from December to April. This area has an average annual rainfall of 1200 mm, and the mean minimum and maximum annual temperature ranges between 6.7°C–11.2°C, and 20.5°C–26.3°C, respectively. *Zea mays*, *Triticum aestivum*, *Eragrostis teff*, and *Guizotia abyssinica* are major crops cultivated in the area.

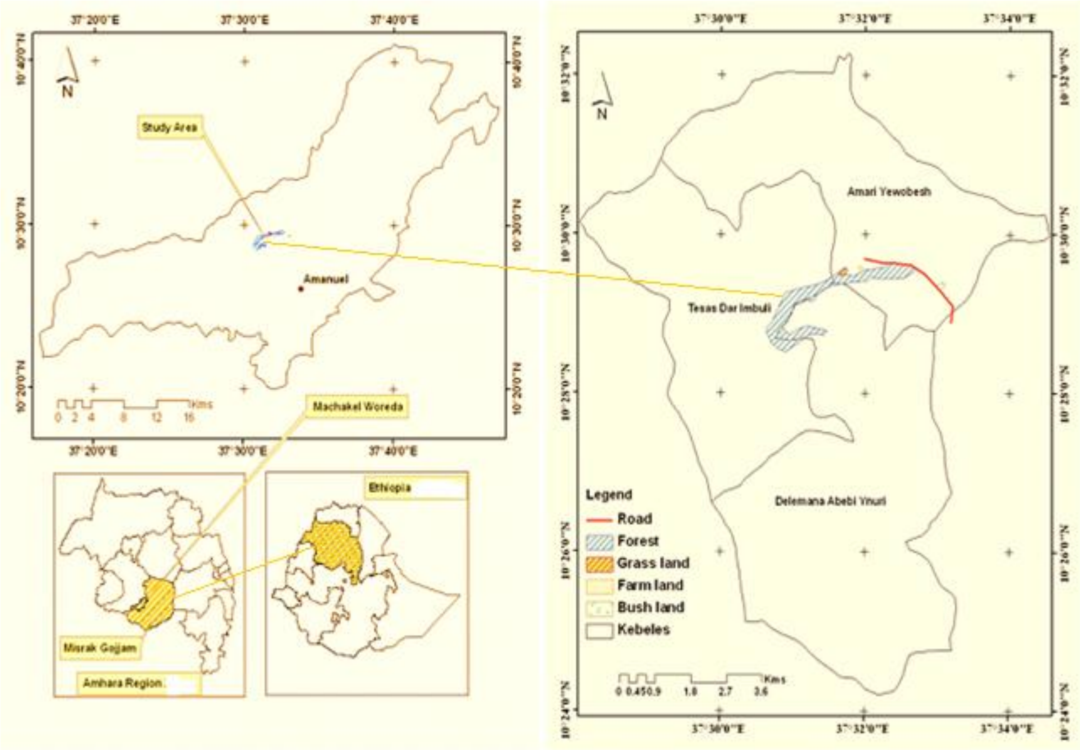

Fig. 1. Location map of the study area.

Methods

A preliminary survey was conducted in August 2013 to assess all relevant information about the study area including habitat types, climatic conditions and types of crops cultivated. Different vegetation types and representative habitat sites for detailed studies were identified. Based on the vegetation structure, the study area was classified into forest, bushland, grassland, and maize farm.

Data collection by Sherman live traps

Data for the present study were collected using Sherman live traps both during the wet and dry seasons. The wet season data were collected in September and October 2013, and the dry season data in February and March 2014. A total of 4900 m^2 live trapping grids were established using 49 Sherman live traps with seven rows by seven columns set per grid at 10 m intervals following Linzey and Kesner (1997). The traps were baited with peanut butter and barley flour. In each grid, traps were checked twice a day early in the morning (07:00 h to 08:00 h) and late in the afternoon (17:30 h to 18:30 h for six consecutive days. Traps were cleaned and re-baited if consumed. Rodents from the traps were transferred into transparent polyethene bags. Information on the species, sex, approximate age (juvenile, sub-adult, adult), and the reproductive condition (i.e., closed or perforated vagina for females, and the position of testes for males) of the trapped rodents were recorded. Sexual conditions in males were detected using the colour and position of testicles (scrotal or abdominal) following Ghobrial and Hodieb (1982). Pregnant females were identified using their enlarged nipples, large swollen abdomen and body weight. Approximate age structure was recorded based on their weight and pelage colour (Afework Bekele, 1996). Trapped individuals were marked by toe clipping and released at the site from where they were trapped. For each capture in each grid, habitat type, grid number, trap number, trap location, species type, time and date of capture were recorded.

Data collection by snap traps

In order to collect additional data, 25 snap traps were placed in five rows by five columns per grid at 20 m away from each other and 200 m away from the live trap grids (Linzey and Kesner, 1997), baited with peanut butter. These traps were placed at the same sites for three days and checked twice a day late in the afternoon and early in the morning hours. Snap trapped rodents were used to collect data on morphological measurements such as weight, head-body length, tail length, hind foot and ear length. Only adult rodents were considered for standard morphological measurements. Pregnant females were dissected, and the number of embryos in the left and right uterine horns of pregnant females was counted.

Voucher specimens were prepared for each of the species for identification using the field guide and catalogue (Yalden *et al*., 1976). For identification purpose, morphological features such as general body proportions, colour and texture of the fur, size, shape and hairiness of external ears, colour and length of whiskers on the face, size and colour of the incisor, colour and overall shape of the manes, size and shape of pads and claws, size and shape of the scrotal sac in males and number and distribution of teats in females were used (Singleton *et al*., 2007).

Body weight of rodents was measured using a spring balance to the nearest gram before dissecting, skinning or preserving the animals. Head-body length was measured by placing the animal flat on its back on the tape measure, and tail length was measured to the nearest cm from the tip of the tail (excluding hairs) to the rear edge of the pelvis. Hind foot length was determined by flattening the toes between finger and thumb and measuring the hind foot from the tip of the heel to the tip of the middle toe (excluding claws).The ear length was measured from the lowest point of the basal notch to the furthest extremity, excluding hairs (Singleton *et al*., 2007).

Data analysis

Species richness of rodents was determined by the number of species captured from each grid, and the relative abundance of rodents in each habitat and season was assessed as the percentage of trap success between habitat types and seasons. Chi-square test, Shannon-Weaver diversity index (H′) (Shannon and Weaver, 1949), and species evenness index were used for data analysis. Trap success was calculated in percentage using the number of individuals caught and trapping nights. Habitat association of rodents was inferred by comparing the number of captured rodents in each habitat type. SPSS version 16.0 software was used to run the analysis.

RESULTS

Species composition and relative abundance

A total of 374 small mammals belonging to eight species of rodents and two species of insectivores were trapped during the wet and dry seasons. Out of the total captured rodents and shrews, 316 individuals were trapped by Sherman live traps in 2352 trap nights, and 58 were trapped by snap traps in 1200 trap nights. *Arvicanthis abyssinicus* had the highest relative abundance and *Crocidura fumosa* had the lowest (Table1).

Species richness and diversity

Species richness and diversity in rodents varied from habitat to habitat, and the maize farm was found to be with the highest species diversity (H′ = 0.99), while the grassland habitat was the lowest (H′ = 0.49). The highest species evenness was recorded in the bushland habitat and the lowest was in the grassland habitat (Table 2).

Table 1. Species composition and relative abundance of live trapped rodents and insectivores.

Common name	**Scienitific name**	**Total caught**	**Relative abundance (%)**
Grass rat	*Arvicanthis abyssinicus* (Rüppell, 1842)	132	41.8
White rat	*Stenocephalemys albipes* (Rüpell, 1842)	49	15.5
House mouse	*Mus musculus* (Linnaeus, 1758)	46	14.6
Multimammate rat	*Mastomys natalensis* (Smith, 1834)	39	12.3
Brush furred mouse	*Lophuromys flavopunctatus* (Thomas, 1888)	20	6.3
Woodland mouse	*Grammomys dolichurus* (Smut, 1832)	13	4.1
Black rat	*Rattus rattus* (Linnaeus, 1758)	7	2.2
Climbing mouse	*Dendromus lovati* (Winton, 1900)	5	1.9
Great musk shrew	*Crocidura flavescens* (Geoffroy, 1827)	3	0.9
Grass shrew	*Crocidura fumosa* (Thomas, 1904)	2	0.5
Total		316	100

Table 2. Species richness and diversity of rodents and insectivores in different habitats.

Grid	**No. species and diversity index**			
	Forest	**Bushland**	**Grassland**	**Maize farm**
Rodents trapped	27	67	62	155
Insectivores trapped	0	2	2	1
No. Species	3	4	3	6
H′	0.77	0.87	0.49	0.99
E	0.47	0.63	0.45	0.55

H′ = Shannon-Weaver diversity index; E = evenness

Distribution of species and habitat association

Some species such as *Grammomys dolichurus*, *Crocidura fumosa*, *Rattus rattus* and *Dendromus lovati* showed restricted habitat distribution. Moreover, species composition and their relative abundance also varied among the different habitat types. A total of 156 (49.4%) live rodents and insectivores were captured in the maize farm (Table 3).

Table 3. Distribution of rodents and insectivores in different habitats within the study area.

Species	**No. of individual captured from different habitats**				**Relative abundance**	χ^2
	Forest	**Bushland**	**Grassland**	**Maize farm**		
A. abyssinicus	–	–	51	81	132	318.99
S. albipes	10	39	–	–	49	9.58
M. musculus	–	12	–	34	46	6.56
M. natalensis	–	–	11	28	39	1.73
L. flavopunctatus	4	16	–	–	20	4.26
G. dolichurus	13	–	–	–	13	10.95
C. flavescens	–	2		1	3	25.9
R. rattus	–	–	–	7	7	19.2
C. fumosa	–	–	2	–	2	27.72
D. lovati	–	–	–	5	5	22.40
Total	27	69	64	156	316	447.23
χ^2	34.2	1.3	62.8	75.1	113.4	

The number of rodents and insectivores caught were significantly varied between species (χ^2=447.23, df=9, p<0.01). Number of individuals caught also varied between habitats (χ^2=113.4, df=3, p<0.01). The habitat association of *Arvicanthis abyssinicus* and *Mastomys natalensis* between the farmland and grassland habitats were statistically significant (χ^2=6.3, df=1, p<0.05; χ^2=7.4, df=1, p<0.05, respectively). *Stenocephalemys albipes* and *Lophuromys flavopunctatus* showed significant difference in habitat association between the forest and bushland habitats (χ^2=10.5, df=1, p<0.05; χ^2=7.2, df=1 p<0.05, respectively). *Mus musculus* also showed statistically significant difference in habitat association between the farmland and bushland habitats (χ^2=10.5, df=1, p<0.05). However, *Crocidura flavescens* did not show significant difference in habitat association between the maize farm and bushland habitats (χ^2=0.3, df=1, p>0.05) (Table 4).

Table 4. Percentage of trapped rodents and insectivores from different habitats.

Species	**Percentages of trapping**			
	Forest	**Bushland**	**Grassland**	**Maize**
A. abyssinicus	–	–	38.6	61.4
S. albipes	20.4	79.6	–	–
M. musculus	–	26.0	–	74.0
M. natalensis	–	–	28.2	71.8
L. flavopunctatus	20	80	–	–
G. dolichurus	100	–	–	–
C. flavescens	–	71.4	–	28.6
R. rattus	–	–		100
C. fumosa	–	–	100	–
D. lovati	–	–	–	100

Trap success

There were differences in trap success between different habitats and between seasons. Trap success was maximum (25.8%) in the maize farm and minimum (4.7%) in the forest habitat. The overall trap successes in bushland and grassland habitats were 12.2% and 11.4%, respectively. Trap success was higher during the dry season than during the wet season (Fig. 2).

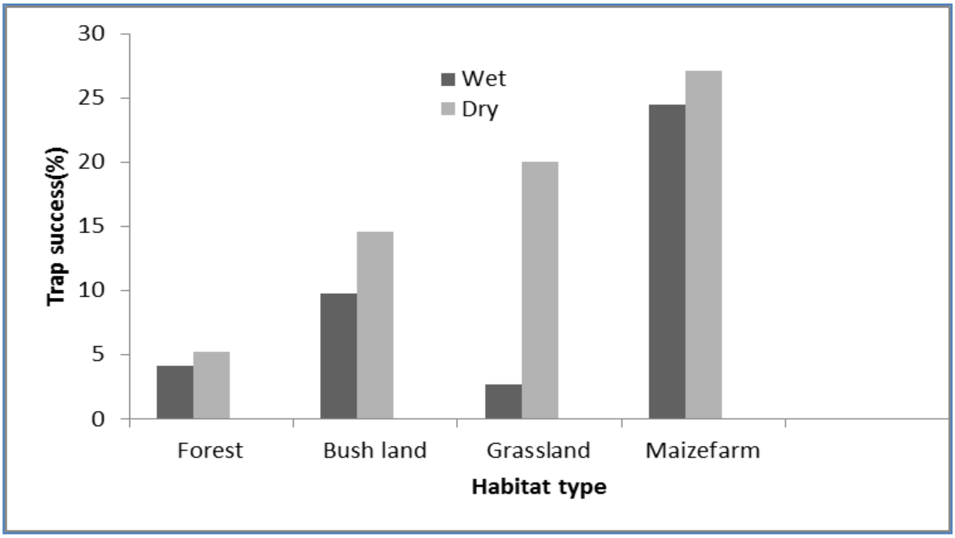

Fig. 2. Seasonal variation in trap success of rodents and insectivores among the four habitat types.

Trap success also varied from season to season and from habitat to habitat (Table 5). The overall trap success for the two seasons was 12.5%. However, among the different habitat types in different trapping occasions, capture rates varied from 1.7% to 50.3%. There was statistically significant difference in trap successes between the wet and dry seasons in the grassland habitat (χ^2=29.6, p<0.05). However, no significant difference in trap success was observed in the forest, bushland, and farmland habitats between the wet and dry seasons (p>0.05).

Table 5. Trap success during the wet and dry seasons in different habitat types.

Grid	Habitat type	Season	Trapping season	Month	Total caught	Trap night	Trap success (%)
G1	Forest	Wet	1	September 2013	5	147	3.4
		Wet	2	October 2013	7		4.8
		Dry	1	January 2014	13		8.8
		Dry	2	March 2014	2		1.7
G2	Bushland	Wet	1	September 2013	14		9.5
		Wet	2	October 2013	15		10.2
		Dry	1	January 2014	28		I9.0
		Dry	2	March 2014	15		10.2
G3	Grassland	Wet	1	September 2013	4		2.7
		Wet	2	October 2013	4		2.7
		Dry	1	January 2014	9		6.1
		Dry	2	March 2014	50		34.0
G4	Maize farm	Wet	1	September 2013	20		13.6
		Wet	2	October 2013	52		35.5
		Dry	1	January 2014	74		50.3
		Dry	2	March 2014	6		4.0

DISCUSSION

In the present study, more species diversity of rodents was recorded in the farmland habitats than in the natural habitats. However, Demeke Datiko *et al*. (2007) reported the presence of more rodent species diversity in the natural habitats than in modified ones. The overall rodent species composition is comparable to the studies conducted by other researchers in other regions of Ethiopia. Afework Bekele (1996) in Menagesha state forest reported six rodent species, and Yalden (1988) recorded seven species of rodents from Bale Mountains.

More individuals of grass rat (*A. abyssinicus*) were captured during pre-harvest period in the maize farmland and during post-harvest period in the grassland habitat. It is one of the common rodent species of the Ethiopian plateaux (Yalden *et al*., 1976). Manyingerew Shenkut *et al*. (2006) recorded more individuals of *A. abyssinicus* in the natural vegetation than in farmlands. However, Tilaye Wube (2005) recorded more individuals of the same species in the crop field than bushland habitat. The species might reproduce rapidly as a result of the presence of nutritious food in the farmland area during the pre-harvest period and might have moved into the grassland habitat from the nearby farmland area in search of food and shelter during the post-harvest period.

White-footed mouse (*S. albipes*) was the second most abundant species in the study area next to *A. abyssinicus*. Yalden and Largen (1992) described this species as one of the most common and abundant endemic rodent species of Ethiopia. In the present study, *S. albipes* was trapped both in the bushy and forest vegetation, which is in agreement with Yalden *et al*. (1976) and Afework Bekele (1995; 1996). Tilaye Wube (2005) trapped this species both from bushy vegetation and agricultural fields.

The house mouse (*M. musculus*) is more abundant in the maize farms than in bushy habitats. Demeke Datiko *et al*. (2007) also reported that this species is more abundant in maize farm than in bushy habitats. Yalden (1988) described *M. musculus* as a widely distributed species in Ethiopia. The multimammate rat (*M. natalensis*) is the most common rodent pest in sub-Saharan African countries (Fiedler, 1994). According to Yalden *et al*. (1976) and Afework Bekele and Liers (1997), *M. natalensis* is a widely distributed species in most regions of Ethiopia. Demeke Datiko *et al*. (2007) also reported that this species was common in crop fields than in natural vegetation. Tadesse Habtamu and Afework Bekele (2008) recorded this species in different habitat types including human environment. The abundance and distribution of this species in different areas also show the heterogeneous nature of the habitats of *Mastomys* (Taylor and Green, 1976). In the present study, this species was found in the grassland and farmland areas and they were more abundant in the maize farm than in grassland habitats.

There are few differences in species richness and diversity among the habitat types. However, the relative abundance of rodents showed variation across habitat types with high number of individuals captured from the maize farm. Moreover, the distribution of species is not uniform across the habitat types. The highest number of species is recorded more from farmland habitat than the natural habitats. Farmlands usually harbour higher number of rodent pests than natural forests (Demeke Datiko *et al*., 2007). Higher preference of the farmland habitat compared to the natural habitat might be due to the availability of nutritious food in the farmland. Availability of resources increases rodent abundance (Lentic and Dickman, 2005). The farmland habitat is more preferred during the fruiting and before harvesting period. This habitat type might provide enough cover and nutritious food in the fruiting and maturation stages as the farmers practice traditional farming system. Prior to the harvesting season, an agricultural area becomes highly favourable for rodents as it provides food and cover (Tsegaye Gadisa and Afework Bekele, 2006). The bushy habitat type is also inhabited by more species than the grassland and the forest habitats. This might be because the bushy habitat provides enough food and cover than the grassland and forest habitats. Bushy vegetation provides safe sites for germination and growth of herbaceous plants, thereby enhancing the diversity of the potential food resources for small mammals (Kerley *et al*., 2004).

In the present study, significant fluctuation of population size was observed in the maize farm and grassland habitats. Population size of rodents fluctuates greatly as a result of change of quality and quantity of resources (Makundi *et al*., 2005). The movement patterns of rodents change from time to time based on season and on the availability of essential resources (Taylor and Green, 1976). In the agricultural field, the maximum population size of rodents recorded in the fruiting and maturation periods of crops and the maximum population size of rodents is recorded in grassland habitat near the farmlands after crop harvesting.

As rainfall is seasonal in the area, it facilitates ground cover and increases the abundance and quality of food during the wet season. This in turn, can result in the increase of rodent population in this season. The pattern of rodent movement varies with a change of season and availability of shelter and food. When there is inadequate food and cover, rodents are forced to migrate to areas where food and shelter are available (Tsegaye Gadisa and Afework Bekele, 2006). In the more heterogeneous habitats such as bushland and forest, significant variation of population sizes might not be observed with seasonal variations. The more stability and relatively lower disturbance of the bushland and forest vegetation might help the species to attain stable population, which does not show remarkable population size fluctuations at different seasons. Species that live in relatively stable habitats show less changes in number compared to those living in disturbed habitats (Makundi *et al*., 2005).

Trap success varied from season to season and from habitat to habitat types. This variation in trap success is due to different factors including changes in the availability of food, cover, habitat type and activity of animals (Sillero-Zubiri and Gottelli, 1995). Population size affects trap success (Tsegaye Gadisa and Afework Bekele, 2006). Trap success was maximum in the maize and minimum in the forest habitat. However, among the different habitat types in different trapping occasions, capture rate varied. Trap success was significantly higher during the dry season than the wet season. This might be due to unattractiveness of the bait as different food resources are available in the surrounding area during the wet season. It might also be possible that the majority of individuals do not reach trappable age during the wet season since most of them reproduce during the wet season. The overall trap success in the present study is 13.6%, which is comparable to the finding of Tsegaye Gadisa and Afework Bekele (2006) and Demeke Datiko *et al*. (2007) who have reported 15.4% in the Bilalo areas, and 17.6% in the Arbaminch area, respectively.

The present study provides valuable information on the species composition, relative abundance, distribution and habitat association of rodent and insectivore species in the study area. Out of the total species captured, *S. albipes* and *D. lovati* are endemic species to Ethiopia. The study also indicated that the distribution of rodent species vary with habitat types. Habitat association and distribution of rodents in the study area might be determined by the extent of ground cover, habitat structure and availability of food.

Rapid human population growth along with poverty is the main cause for destruction of natural habitats in the study area. This will affect the distribution of endemic species of small mammals leading to their local extinction. Therefore, it is mandatory to conserve the natural habitats by implementing community-based conservation strategies and create awareness among the local community towards biodiversity conservation.

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