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3

The Ecological Relationships of Afroalpine Rodents

Ecological relationships of Afroalpine rodent communities under different grazing land uses

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Abstract

Rodents are important biological indicators of the Afroalpine ecosystem. We studied how livestock grazing influenced rodent species richness and abundance among three plant community types (grassland, shrubland and mixed meadow) managed with or without grazing at Borena Sayint National Park. We used Sherman live traps and the Capture-Mark-Recapture method to estimate rodent population density. Then, we identified microhabitat factors influencing rodent density and factors impacted by livestock grazing. In total, 2311 individual small mammals were captured in a total of 4500 trap nights. Of these, 57.6% were trapped in areas of ungrazed land use. *Lophuromy flavopunctatus, Arvicanthis abyssinicus* and *Stenocephalemys griseicauda* were the rodent species whereas *Crocidura flavescens* and *Crocidura fumosa* were the shrew species captured in the area. The presence of *Tachyoryctes splendens* and *Otomys typus* were also evidenced indirectly. The total catch and relative abundance were highest for *L. flavopunctatus* (50.8%) and least for *C. fumosa* (0.91%). More small mammals were trapped in the mixed meadow habitat, followed by the *'guassa'* grassland and *'charranfe'* heath. The average rodent density across the study area was 65 individuals per hectare, significantly higher (P=0.0002) in areas of ungrazed land use compared to grazed land. Rodent population density per hectare correlated positively to the Afroalpine vegetation cover percentage and negatively to the total livestock signs present in the area. Overall, since livestock grazing reduced the ground vegetation cover percentage, our results underline the importance of careful grazing management to avoid a potential loss in rodent species and overall Afroalpine biodiversity.

Keywords

Afroalpine ecosystem, Borena Sayint National Park, Ethiopian wolf, livestock, small mammals

3.1 Introduction

Globally small mammals are important components and biological indicators of the natural ecosystem. Small mammals, principally rodents, adapt themselves to any natural ecosystem and play a vital role in the ecological interactions of a given ecosystem (Ryszkowski, 1975, Jones and Safi, 2011). In the Afroalpine ecosystem, rodents are the main food for survival of the Ethiopian wolves and also an important predictor of wolf density (Sillero-Zubiri and Gottelli, 1995, Ashenafi *et al.*, 2005, Marino *et al.*, 2010, Tallents *et al.*, 2012). Rodents are especially vital in grassland ecosystems for their top-down effects on plant communities (Brown and Heske, 1990) and bottom-up effects on predators (Korpimäki and Norrdahl, 1991, Torre *et al.*, 2007, Vial *et al.*, 2011b). In the terrestrial eco-regions rodents are herbivores of vegetation, they can sometimes become crop pests but they are also dispersers of seeds, pollinators of plants, engineers of the landscape, food for humans, prey of predators and good indicators of ecosystem health (Kotler, 1984, Kerley, 1992, Hughes *et al.*, 1994, Maron and Simms, 2001, Clausnitzer *et al.*, 2001, Johnson *et al.*, 2001, Dickman, 2003, Zhang *et al.*, 2003, Hoffmann and Zeller, 2005, Avenant, 2011, Vial *et al.*, 2011b, Jones and Safi, 2011).

The increase in human populations and geographic distribution associated with anthropogenic land use changes, like deforestation, agricultural intensification, livestock grazing and the introduction of exotic species, might influence the rodent community structure and species composition through local extinctions (Lovegrove and Siegfried, 1993, Knobel and Bredenkamp, 1999). Livestock grazing is known to have a direct effect on the vegetation and an indirect effect on vertebrate and invertebrate fauna (Smit *et al.*, 2001). The direct effects of livestock grazing on vegetation composition and dynamics have been extensively studied (Willatt and Pullar, 1984, Milchunas and Lauenroth, 1993, Davies *et al.*, 2010, Bueno *et al.*, 2011). Livestock affects vegetation through biomass removal but also modifies the vegetation structure through physical disturbance by trampling the soil (Smit *et al.*, 2001, Bueno *et al.*, 2011). Several studies indicate that livestock grazing is often regarded as one of the main causes of vegetation and soil degradation in sub-Saharan Africa, through the removal of both live and dead vegetation, through soil compaction, and the disturbance of nutrient cycles (Le Houérou and Hoste, 1977, Sinclair *et al.*, 1990, Vial *et al.*, 2011b). However, studies on indirect effects of livestock grazing on small mammals such as rodent communities are mostly limited (Dean and Milton, 1995, Rivers-Moore and Samways, 1996, Hoffmann and Zeller, 2005, Vial *et al.*, 2011a). Even the existing few studies that investigated the impacts of livestock grazing on small mammals varied greatly according to the stocking density, type of livestock grazers, the species of small mammals, the structure and composition of the vegetation on which the small mammals depend and the geographical region (Grant *et al.*, 1982, Hayward *et al.*, 1997, Steen *et al.*, 2005, Tabeni *et al.*, 2007). A study in Namibia indicated that small mammal density and species richness were lower in livestock-grazed areas compared to ungrazed areas and this has been confirmed by studies in other regions of the world (Rosenstock, 1996, Chapman and Ribic 2002, Bock *et al.*, 2006) and Bale Mountains National Park (BMNP) in Ethiopia (Vial *et al.*, 2011a). Rodents are a key prey species for many of the world's predators, including raptors, snakes, foxes (*Vulpes vulpes*), bobcats (*Lynx rufus*), and coyotes (*Canis latrans*) (Neale and Sacks, 2001, Lanszki and Heltai, 2002, Hoffmann and Zeller, 2005, Filippi *et al.*, 2005). In general, when livestock grazing reduces the available vegetation food resource, habitat structures like cover and shelters are also disrupted in a way that increases predation risk (Rosenstock, 1996, Knobel and Bredenkamp, 1999, Jones *et al.*, 2003, Bock *et al.*, 2006, Powers *et al.*, 2011). Grazing also modifies the physical condition of the soil through compaction caused by trampling, which may similarly destroy the burrows of small mammals. Thus, these changes impact small mammal abundance and species richness (Bailey, 2004, Holechek and Galt, 2004, Hoffmann and Zeller, 2005).

Highlands in Ethiopia account for 40% of the country's total land mass. They support 95% of the livestock and 88% of the human population as well as an exceptionally diverse array of endemic mammalian species (Thornton, 2002). Livestock grazing is the dominant land use practiced by highland communities in the Afroalpine range, which is also a habitat of the threatened Ethiopian wolf (*Canis simensis*), Walia Ibex (*Capra walia*), Gelada baboon (*Theropithecus gelada*) and rodents of the families Murinae and Spalacidae. Since livestock grazing has a direct effect on the Afroalpine vegetation, it may also have a significant indirect effect on small herbivores like rodents, and then subsequently may affect their top predator, the Ethiopian wolf. Investigating the impact of livestock grazing on Afroalpine rodent communities' abundance and species richness may therefore provide more insight into the relationship between grazing and rodent communities. This insight may eventually benefit ecologically responsive grazing management and the development of a conservation strategy that maintains optimal rodent prey densities capable of sustaining the existing small Ethiopian wolf populations. Studies indicating the impact of grazing as a form of land use on small rodents in the Ethiopian Afroalpine ecosystem have been scant in number and limited to south and central Ethiopia (Vial *et al.*, 2011b, Ashenafi *et al.*, 2012). In this study we investigated the effects of livestock grazing on small rodent communities in a spatial mosaic of Afroalpine habitat, the various areas having a similar vegetation type but different grazing histories. We studied the direct effect of grazing by surveying Afroalpine vegetation and edaphic microhabitat factors, and the indirect effect of grazing by assessing rodent species richness and population density in the study area. The aim of this study was to better understand how livestock grazing as a form of land use influences rodent species richness and density in areas managed with or without grazing. This was accomplished by conducting rodent and vegetation surveys in *a state-protected area* and in a *community area closure* both of which exclude livestock grazing, and in the adjacent *ranging land* that had similar plant communities but was used for livestock grazing. Results were analysed for differences in rodent population density and species richness among management type and plant community combinations.

3.2 Methods

3.2.1 Study area

The study was conducted in and around Borena Sayint National Park (BSNP) in North Ethiopia in an altitude range of 3400 to 3900 m asl between 10^{0}50’45.4”-10^{0}57’03” latitude and 38^{0}40’28.4”-39^{0}10’39” longitude (Fig.1). The study site covers an area of approximately 153 km^2, which includes 44 km^2 of the legally recognised National Park and an adjacent 109 km^2 proposed by the park office as an extension area to expand the National Park.

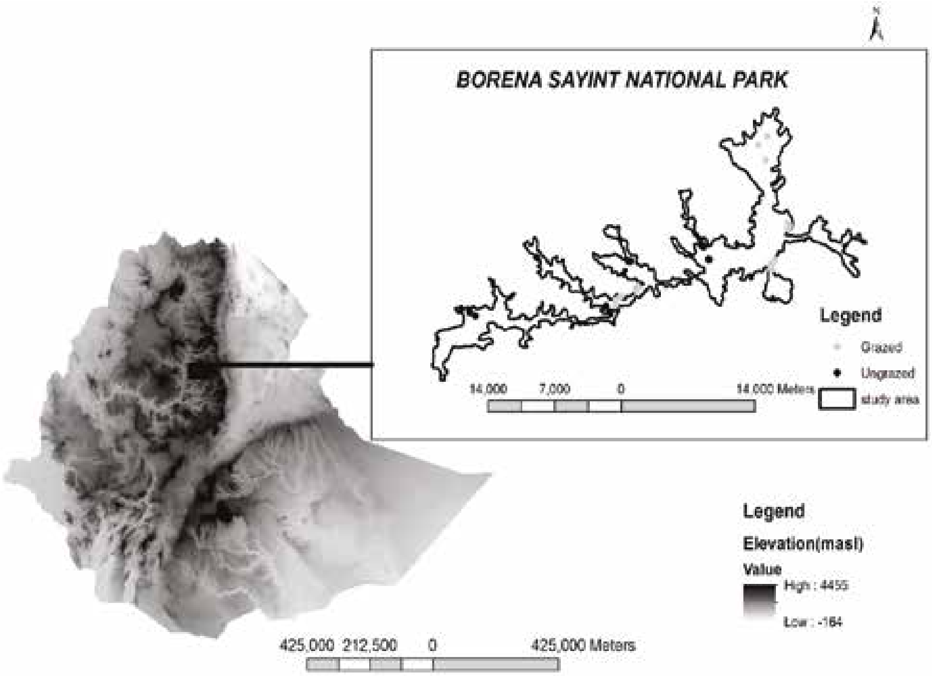

Figure 3.1
Map indicating the study area in Ethiopia and the location of rodent trapping grids in areas of grazed and ungrazed land use

The National Park is managed as *a state-protected area*, an area of land protected and managed by the regional state through legal and other effective means for its wildlife and scenic views in order to generate income from tourism. The proposed extension area adjacent to the orginal park is currently managed for two purposes, namely as *a community area closure*, i.e. land managed by the local community but excluding livestock grazing, agriculture and the collection of natural resources in order to rehabilitate and conserve biodiversity (Mengistu *et al.*, 2005); and as *livestock ranging land*, i.e where the assigned land use is livestock grazing. As both the state-protected area and the community area closure have excluded livestock grazing since 2009, we are calling them 'ungrazed land use' (UGLU), and the livestock ranging land we are calling 'grazed land use' (GLU).

3.2.2 Design

Thirty surveying grids (40 m × 40 m) were set up in three dominant Afroalpine vegetation types ('*guassa*' *Festuca* spp. grassland (GGL), '*charranfe*' *Euryops* spp. shrubland (CH) and mixed Afroalpine meadow (MM)) on both grazed and ungrazed land across the study area. The locations of these grids were chosen in consideration of the land use management history, visually dominant vegetation cover and the core Ethiopian wolf ranges throughout the study area. It was a balanced design, with five replicates of each of the three vegetation types in each of the two management practice areas. There were a total of 15 grids for each management practice and 10 grids for each vegetation type. After we conducted preliminary surveys in November 2013, actual rodent, vegetation and soil surveys took place during the dry season for two years in 2014 and 2015 (Table 3.1).

Table 1
Summary of trapping dates and number of grids sampled for each vegetation type per land use. (CH= '*charranfe*' heath, MM= mixed meadow and GGL= '*guassa*' grassland)

	Grazed (GLU)			Ungrazed (UGLU)		
	CH	MM	GGL	CH	MM	GGL
Nov. 2013	1	0	0	1	0	0
Jan. 2014	1	1	1	1	2	2
May 2014	0	1	1	0	0	0
Dec. 2014	1	1	0	0	0	0
Jan. 2015	1	0	1	2	2	2
Feb. 2015	0	1	1	0	1	1
May 2015	0	0	0	1	0	0
June* 2015	1	1	1	0	0	0
Total	**5**	**5**	**5**	**5**	**5**	**5**

* Our survey was conducted during the dry seasons; in 2015 June was a dry month due to El Niño in Ethiopia

3.2.3 Data collection

Live rodent trapping survey

Twenty-five folding Sherman live traps (H.B. Sherman Traps, Florida, USA) arranged in five rows and five columns spaced 10 m apart were set within 40 m × 40 m surveying grids established in areas of grazed and ungrazed land use (Figure 3.2). Trapping was conducted over four consecutive days and the traps were pre-baited for one day and re-baited at each trapping session to re-fresh, with a mixture of peanut butter and barley flour. The traps were set in the morning and checked at midday and at dusk for diurnal rodents caught, and were left open at dusk to enable checking for the presence of nocturnal rodents the following morning. Trapped rodents were identified at species level, weighted, sexed and marked by fur clipping on their abdomen and then released at the capture site. A Capture-Mark-Recapture method was used (Amstrup *et al.*, 2010) to determine how livestock grazing affected the size of the rodent population in land use areas managed with or without grazing. For every recapture event, the farthest distance travelled (moved) between recaptures was recorded to calculate the effective sample area and then to calculate rodent population density (Efford *et al.*, 2009).

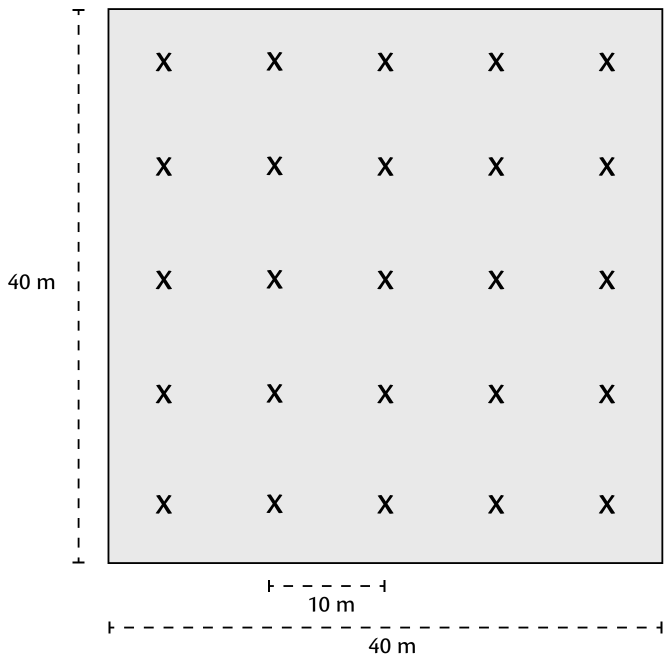

Figure 3.2
Rodent surveying grid with 5 × 5 grid layout. 'X' refers to a Sherman live trap at each trapping station. The total surveying grid area was 40 × 40 metres, with 10 metre spacing between stations

Vegetation and soil survey

Five 1 m^2 quadrants were placed systematically inside each 40 m × 40 m surveying grid in grazed and ungrazed lands for vegetation and soil survey (Figure 3.3). Vegetation cover percentage was estimated using the Braun-Blanquet scale (Wikum and Shanholtzer, 1978). Vegetation height was estimated visually using 1-4 scale (1= 0-10 cm, 2= 11-30 cm, 3= 31-50 cm, and 4= >51cm) and livestock signs such as dungs were counted within each quadrant. Similarly soil was sampled using core method applying an auger (core-sampler) from each quadrant (five soil samples) at surface level. Samples were sent to a local soil laboratory to test bulk density, a measure of compaction due to livestock trampling.

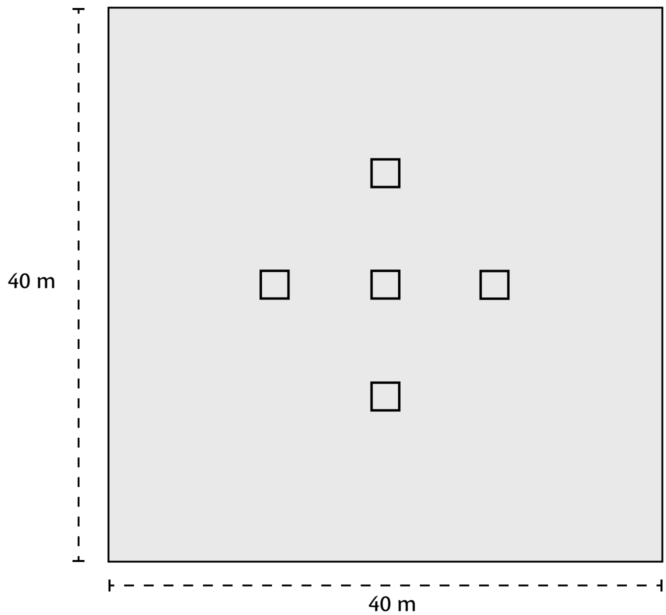

Figure 3.3
Five 1m^2 quadrants set out within a rodent surveying grid (40 m × 40 m) to survey vegetation and soil

3.2.4 Data analysis and statistics

The abundance and species richness of small mammals were analysed for both grazed and ungrazed land uses. The rodent population density in each grid area for the two land uses were compared after the population size of captured rodents had been analysed using the MARK software (Otis *et al.*, 1978, White *et al.*, 1982). This software uses different models with different assumptions to generate population size estimates for the sampled land uses based on the number of rodents captured and recaptured. We ran the closed population assumption model for each of our encounter histories. Rodent density, the best ecological parameter, describes the number of individuals per effective sample area. The effective sample area was calculated by adding a boundary strip around each trapping grid whose length was equivalent to half of the maximum mean distance moved (MMDM) by recaptured animals between successive captures (Otis *et al.*, 1978). Species richness is the number of species in a community (Smith and Wilson, 1996). Trap success in% (T) across the study area was calculated as the number of individuals caught per 100 trap nights, i.e. T = (Nm/Ntn) X 100 where Nm is the number of individuals of a particular species and Ntn is the number of trap nights (Nicolas and Colyn, 2006).

The relationship between microhabitat factors and rodent density in different land uses was analysed using GLM models. One-way ANOVA with a post-hoc Tukey Kramer mean comparison test was conducted to establish the variation in rodent population density between grazed and ungrazed land uses. Finally, multiple regressions were conducted to establish the relationship between different microhabitat factors and rodent population density.

3.3 Results

A total of 2311 individual small mammals were captured in 4500 trap nights within grazed and ungrazed grids. The small mammals captured in the study area were three species of rodents and two species of shrew. *L. flavopunctatus*, *A. abyssinicus* and *S. griseicauda* were the rodent species, and C. *flavescens* and *C. fumosa* were the shrew species captured. We also evidenced the presence of the East African molerat (*T. splendens*) from its burrow and swamp rat (*O. typus*) from wolf scat in the study area. The relative abundance and trap success rate of small mammals varied between species. The total catch and relative abundance were highest for *L. flavopunctatus* (50.8%), followed by *A. abyssinicus* (29.55%), *S. griseicauda* (17.4%), *C. flavescens* (1.34%) and *C. fumosa* (0.91%), respectively. The overall trap success in the study area was 51.36%, with the highest success rate being for *L. flavopunctatus* compared to other species (Table 3.2).

Table 2
Species composition, number, relative abundances and trap success of small mammals across the study area

Small mammal species	Number of small mammals trapped	Relative abundance (%)	*Trap success (%)
L. flavopunctatus	1174	50.80	26.09
A. abyssinicus	683	29.25	15.18
S. griseicauda	402	17.40	8.93
C. flavescens	31	1.34	0.69
C. fumosa	21	0.91	0.47
O. typus	0	0	0
T. splendens	0	0	0
Total	**2311**	**100**	**51.36**

*30 grids x 25 traps x 6 sessions = 4500 trap nights

A variation was found in the number of small mammals trapped but not in species richness between livestock grazed and ungrazed land uses. Of the total 2311 small mammals captured, 1330 (57.55%) were trapped in ungrazed land use compared to 981 (42.45%) trapped in grazed land use. However, the relative abundance of *A. abyssinicus*, *S. griseicauda* and *C. fumosa* was higher in grazed land use, while *L. flavopunctatus* and *C. flavescens* were more abundant in ungrazed land use (Table 3.3).

Table 3.3
Number of small mammals trapped and their relative abundance per land use

	Grazed land use		Ungrazed land use	
Small mammal species	Number of small mammals trapped	Relative abundance (%)	Number of small mammals trapped	Relative abundance (%)
L. flavopunctatus	462	47.09	712	53.53
A. abyssinicus	322	32.82	361	27.14
S. griseicauda	176	17.94	226	17.00
C. flavescens	12	1.23	19	1.43
C. fumosa	9	0.92	12	0.90
O. typus	0	0	0	0
T. splendens	0	0	0	0
Total	**981**	**100**	**1330**	**100**

Across the study area more *L. flavopunctatus* and *S. griseicauda* were captured in mixed meadows than in other habitats while more *A. abyssinicus, C. flavescens* and *C. fumosa* were captured in *'guassa'* grassland than in other habitats (Figure 3.4).

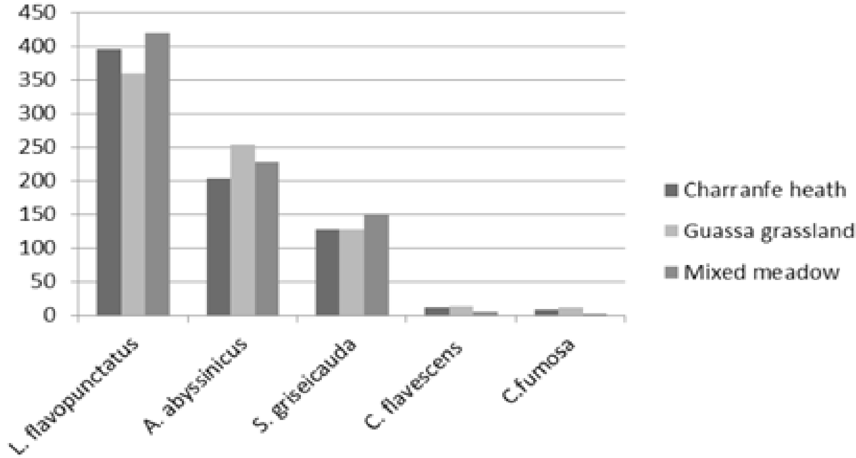

Figure 3.4
Distribution of small mammal species in number among the three habitats across the study area

For both land uses, the mixed meadow habitat provided the largest number of small mammals trapped, followed by '*guassa*' grassland and '*charranfe*' heath respectively (Figure 3.5).

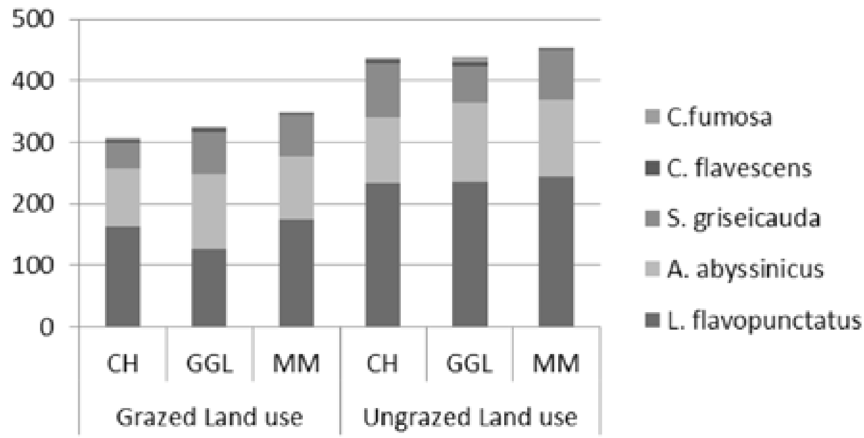

Figure 3.5
Land use distribution of small mammals in number among the three habitat types

The mean maximum distance moved and the associated effective area used by recaptured rodents was different for grazed and ungrazed land uses. Rodents captured in grazed land use moved a mean distance of 19.99 m within an area of 2499.5 m^2 while in ungrazed land use they moved a mean distance of 18.36 m within an area of 2418.7 m^2. Based on an estimate provided by MARK software, the average rodent population density across the study area was 65 individuals per hectare. The rodent population density was significantly higher (P=0.0002) in ungrazed land use as compared to livestock grazed land (Table 3.4).

Table 3.4
One-way ANOVA table indicating rodent population density by land use

Analysis of Variance					
Source	**DF**	**Sum of squares**	**Mean square**	**F ratio**	**P value**
Land use	1	4236.6	4236.7	17.78	0.0002***
Error	28	6673.2	238.3		
C. Total	29	10909.8			
Mean for one-way ANOVA					
Level	**Number**	**Mean**	**Std error**	**Lower 95%**	**Upper 95%**
Grazed	15	54.97	3.99	46.81	63.14
Ungrazed	15	78.74	3.99	70.58	89.91

Level of significance shown with*=P<0.05, **=P<0.01, ***=P<0.001

Rodent population density per hectare correlated positively to the Afroalpine vegetation cover percentage and negatively to total livestock signs present at BSNP (Table 3.5).

Table 3.5
Multiple regressions indicating relationships between different ecological factors and rodent population density

Variables	Estimate	Std error	t ratio	P value
Habitat type [Charrafe heath]	2.835	6.313	0.45	0.658
Habitat type [Guassa grassland]	-0.142	7.117	-0.02	0.984
Soil bulk density gm/cm^3	-18.647	64.941	-0.29	0.777
% vegetation cover	33.299	8.861	3.76	0.001***
% rock cover	-12.232	12.045	-1.02	0.321
Altitude	0.043	0.047	0.91	0.372
Livestock signs	-0.438	0.187	-2.34	0.029*
R^2	0.62			
Observations	30			

Level of significance shown with*=P<0.05, **=P<0.01, ***=P<0.001

3.4 Discussion

The aim of our study was to investigate the effect of livestock grazing on rodent density and species richness in grazed and ungrazed Afroalpine grasslands within BSNP, and our results revealed the occurrence of similar species but higher rodent density per hectare in areas of ungrazed land use. We found that livestock grazing reduced the Afroalpine vegetation cover percentage at ground level. Furthermore, Afroalpine vegetation cover percentage and signs indicating livestock presence were the significant predictors of rodent density per hectare in the study area.

Information on small mammal population densities and species richness is important to wildlife conservation and ecological surveys (Leirs *et al.*, 1997, Hopkins and Kennedy, 2004). According to our rodent trapping survey in areas of grazed and ungrazed land uses, the soft furred rat (*L. flavopunctatus*) was the most common species, followed by the grass rat (*A. abyssinicus*). This corroborates the findings of Clausnitzer and Kityo (2001), who suggested that *L. flavopunctatus* was one of the most common rodents in the humid areas of East Africa, occupying a wide range of Afromontane highland habitats. This highest trap success and relative abundance in comparison to other rodents makes *L. flavopunctatus* ecologically the most successful and adaptive species in the area.

In the study area *L. flavopunctatus* and *A. abyssinicus* are mostly diurnal whereas *S. griseicauda* has a nocturnal activity pattern. All these rodents were identified in the Ethiopian wolves scat study in North and Central Ethiopia (Ashenafi *et al.*, 2005, Marino *et al.*, 2010). Logically this indicates that Ethiopian wolves feed on all of these rodents, including the swamp rat *O. typus* (which was not trapped in our live trap but only found in wolf scats) and the East African molerat *T. splendens.* In our survey all the small mammals previously identified in the diet of Ethiopian wolves, except *O. typus* and *T. splendens,* were captured using live Sherman traps. According to Yalden (1988) and Sillero-Zubiri *et al.* (1995), *O. typus* is an Afroalpine moorland specialist well represented in the diet of Ethiopian wolves at Sanetti and Tullu Deemtu in Bale but never or rarely captured in these zones. Similarly the fossorial East African molerat *T. splendens* was behaviourally adverse to capture with Sherman traps (Schlitter *et al.*, 2008). We instead simply identified this species from its tunnelled burrow system, constructed in the landscape by heaping up soil around the burrow (Delany, 1972). Previous studies in North Central Ethiopia have noted that the East African molerat is the one that replaced the endemic giant molerat (*Tachyoryctes macrocephalus*) of South East Ethiopia (Ashenafi *et al.*, 2005). This species has also been identified as one of the components of the Ethiopian wolf diet in North and Central Ethiopia (Ashenafi *et al.*, 2005, Marino *et al.*, 2010). In our study the efficient means available for surveying the community structure and population dynamics of small mammals per land use was the capture of live individuals. However, as suggested by Slade and Blair (2000), it is seldom that all individuals captured are used to estimate population size. In our study, for example, as we rarely captured the two species of shrew (*C. fumosa* & *C. flavescens*) and did not capture the two species of rodent (*T. splendens* & *O. typus*), these were not included in the MARK software population size estimate analysis. All the small mammal species documented in this study are only those directly captured and indirectly evidenced in the Afroalpine grasslands of the core wolf habitats. We did not include in this study subalpine and forested areas, which may harbour several other species of small mammals (Chane and Yirga, 2014).

The reported effects of grazing on small mammals are varied (Mathis *et al.*, 2006, Rickart *et al.*, 2013). However, our study confirms a decrease in rodent community abundance in grazed land use, which concurs with the findings of other authors (Bock *et al.*, 1984, Mathis *et al.*, 2006, Rickart *et al.*, 2013). We found similar rodent species in both grazed and ungrazed land uses alike in BMNP (Vial *et al.*, 2011a). The habitat preference of rodents is important to determine how various rodent species respond to environmental heterogeneity within the ecosystem (Martin, 1998). In our study even if rodent species displayed the tendency of favouring assemblage in a mixed meadow, followed by '*guassa*' grassland and '*charranfe*' heath respectively, their overall distribution does not differ significantly throughout the microhabitat of the Afroalpine vegetation types. However, their assemblage significantly increased with dense vegetation cover and decreased with the presence of livestock grazing. Our average rodent population density of 65 individuals per hectare is lower than the 80 individuals per hectare found in BMNP, habitat for more than half of the global Ethiopian wolf populations (Vial *et al.*, 2011a). The range of rodent population density across our study area is 4.1 to 109.6 individuals per hectare, which is also lower than Bale rodent population density, which is between 3.2 to 127 individuals per hectare (Sillero-Zubiri *et al.*, 1995). However, the rodent population density in our study area is higher than the density in Guassa, which is between 15.12 and 56.32 individuals per hectare (Ashenafi, 2001). Our rodent trap success rate of 51.4% is much higher than reported for the Simien Mountains National Park (SMNP), which is 22.9% (Yihune and Bekele, 2012) but lower than for the Arsi Mountains (Chilalo, Galama, Kaka & Hunkolo), which is 61.1% (Kasso *et al.*, 2010, Zerihun *et al.*, 2012). In general, considering some fluctuations in trap success data, this result may be a good indicator for BSNP as a potential wolf habitat in addition to Bale and Arsi.

Our study suggests vegetation cover correlated positively with rodent density i.e. the higher vegetation cover percentage implies a better habitat for rodents. Therefore, in ungrazed land use with more vegetation cover rodents benefit in terms of increased food availability and in sheltering from predation risk (Kotler, 1984, Kotler and Blaustein, 1995, Keesing, 1998, Smith *et al.*, 2010). With no competition from livestock the increase of vegetative biomass cover in ungrazed land use will cause an increase availabile food for rodents. Keesing (2000) suggested a negative impact of livestock on the density of rodent populations, presumably due to competitive interactions. In our study the other factor that correlated negatively with rodent population density was the presence of signs indicating livestock grazing. We concluded that the presence of livestock grazing affects the quality of the rodent habitat, through changes in vegetation cover. Similarly other studies reported that grazing influences the physical properties of soil and vegetation structure (Guttinger *et al.*, 1998). Surprisingly, our soil lab result has no significant relationship with rodent population density. This may be associated with the presence of an extensive mosaic of moisture-rich, spongy-like soil types within the Afroalpine ecosystem. Rather than compacting the soil, livestock grazing on land with this type of soil may create micro-sunken holes that hold water and facilitate hole-digging for rodents, unlike other soil types where trampling leads to soil compaction. In general, our study suggests that the distribution of rodent species in the study area was related to vegetation biomass cover and a human–livestock presence that drives changes directly impacting the vegetation structure. Since rodents are the main component of the Ethiopian wolf's diet (Marino *et al.*, 2010), it is also suspected that livestock grazing will have indirect negative effects on wolf populations (Nievergelt, 1998, Stephens *et al.*, 2001, Ashenafi, 2001, Vial *et al.*, 2011b). Hence the co-existence of species can be determined by resource availability, and by understanding which species utilises which habitat and how each species interacts with others (Schoener, 1983).

To conclude, this study demonstrates how livestock grazing can impact the rodent population density of the Afroalpine ecosystem by affecting vegetation and other microhabitat factors. These results underline the importance of the careful application of grazing management techniques in order to avoid a potential loss of/change in rodent species and overall Afroalpine biodiversity. Additionally, it is important to bear in mind that such changes are likely to have strong trickle-down effects on predatory species such as the Ethiopian wolf and raptors dwelling in the ecosystem. We suggest that monitoring the small mammal populations, their species richness, density, the status of vegetation they depend on and other related microhabitat factors could be used as important controlling tools to assess the stability and health of the ecosystem.

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