



University of Venda

**Spatial and reproductive differentiation of small terrestrial mammals in a complex environment in the western Soutpansberg Mountain, Limpopo Province.**

BY

NEMAKHAVHANI TSHIFHIWA

STUDENT NUMBER: 11521437

**Submitted in fulfilment of the requirements for the degree of Master of Environmental Sciences (MEnvSC) at the University of Venda**

**SUPERVISOR: MR. R.M BAXTER**

**CO-SUPERVISOR: PROF. P.J TAYLOR**

Department of Ecology and Resource Management  
School of Environmental Sciences  
University of Venda

June 2013

UNIVEN LIBRARY

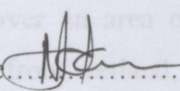
Library Item : 20141904



© University of Venda

The study was conducted in Limpopo conservation area, Limpopo province, South Africa, from

I **NEMAKHAVHANI TSHIFHIWA**, hereby declares that the dissertation for the degree of Master of Environmental Sciences at the University of Venda for Science and Technology, hereby submitted by me, has not been previously submitted for a degree at this university or any other university, that it is my own work in design and execution and that all reference material contained therein has been duly acknowledged.

Signature  Date.....

All small mammals were identified in the field and Durban museum.

The statistical software EstimateS (version 8.2, Colwell, 2009) was used to calculate expected species richness. The R Statistical program was used to test the influence of season, habitat and six climatic variables on both index of abundance, Minimum Number Above (MNA) as well as on species richness. Generalized Linear Models (GLM) were applied to develop five different models to test for the relative importance of different predictor variables, alone and in combination. The statistical software PASS (Paleontological Statistics) was used to run Correspondence analysis (CA) and cluster analysis to determine species habitat associations based on species abundance in various habitats. The model performances were compared using Akaike Information Criterion (AIC).

Trap success varied between months with mean trap success of 25.0% (1-37.7%) and peaked during autumn. There were a total of eight species of *Reithrodontomys* namely *Reithrodontomys incanus*, *Reithrodontomys mystacinus*, *Reithrodontomys moysi*, *Reithrodontomys mohlardi*, *Reithrodontomys moseleyi*, *Reithrodontomys nigripinnis*, *Reithrodontomys nigripinnis* and *Reithrodontomys pumilio*. There are only one species of Muridae, namely *Reithrodontomys mohlardi* and three species of Sorex, namely *Sorex caudatus*, *Sorex caudatus* and *Sorex caudatus*. The most abundant species was *Reithrodontomys pumilio* with 29.87 % value of the total captures.

The diversity and evenness of small mammals varied between habitats. Wetland habitat provided greater diversity of small mammals than grassland and rocky outcrops. The results indicated both seasonal and year round breeding patterns for different species. The species diversity of small mammals was found to correlate more with season and habitat rather than other parameters. The research found that there is a positive relationship between habitat type and small mammal richness, diversity and abundance.

The study was conducted in Lajuma conservation area, Limpopo province, South Africa, from August 2010 to August 2011. The aim of the study was to establish baseline ecological data on small mammal community structure, to identify small mammal habitat preferences, to determine small mammal reproduction pattern and population dynamics, as these could allow early detection of subtle changes in the ecosystem due to climate change.

Data on small mammal abundance were collected on square grids of 100 live Sherman traps, set out over an area of 100 x 100m. Traps were positioned at 10m intervals. Data was collected from wetland, grassland and rocky outcrop habitat and trapping was done monthly. All small mammals were identified in the field and Durban museum.

The statistical software EstimateS (version 8.2, Colwell, 2009) was used to calculate expected species richness. The R Statistical program was used to test the influence of season, habitat and six climatic variables on both index of abundance, Minimum Number Alive (MNA) as well as on species richness. Generalized Linear Models (GLM) were applied to develop five different models to test for the relative importance of different predictor variables, alone and in combination. The statistical software PAST (Paleontological statistics) was used to run Correspondence analyses (CA) and cluster analysis to determine species-habitat associations based on species abundance in various habitats. The model performances were compared using Akaike Information Criterion (AIC).

Trap success varied between months with mean trap success of 23.6% (7-37.7%) and peaked during autumn. There were a total of eight species of Rodentia namely *Dasymys incomtus*, *Dendromus mystacalis*, *Lemniscomys rosalia*, *Mus minutoides*, *Micaelamys namaquensis*, *Otomys angoniensis*, *Aethomys ineptus* and *Rhabdomys pumilio*. There was only one species of Macroscelidae, namely *Elephantulus myurus* and three species of Soricomorpha, namely *Crocidura cyanea*, *Crocidura mariquensis* and *Myosorex varius*. The most abundant species was *Rhabdomys pumilio* with 29.87 % value of the total capture.

The diversity and evenness of small mammal varied between habitats. Wetland habitat provided greater diversity of small mammals than grassland and rocky out crops. The results indicated both seasonal and year round breeding patterns for different species. The species diversity of small mammals was found to correlate more with season and habitat rather than other parameters. The research found that there is a strong relationship between habitat type and small mammal richness, diversity and abundance.

## ACKNOWLEDGEMENTS



I would like to thank the almighty for his outstanding love and for giving me wisdom and strength to live this life to the full, and manage to finish this study. I am very grateful to Mr. Roderick Baxter for being the best supervisor and mentor. He believed in me and helped me to reach my academic destiny. He always gave me courage and support to complete this work. I am also very grateful to my co-supervisor Mr. P.J. Taylor, for reading patiently all the chapters in this thesis and his encouragement and support throughout my studies.

I also thank Mr. Ian Gaigher and Mrs. Retha Gaigher for logistic support and hospitality at Lajuma Research Station, and also Mr. Oldrich and Mrs. Judy van Schalkwyk for their outstanding field work assistance and transportation. Special thanks to Mr. Korkor Francis for helpful comments in this study. To all my field assistance I express my greatest appreciation: Aubrey Munyai, Aluwani Nengovhela, Tswarelo Sape and various international students at Lajuma Research center.

I also thank Mrs. Ann Baxter and Mrs. Francis Taylor, and my best friends Thihanedzwi Ratshibvumo, Linah Tshikoro and Lufuno Mukwevho for being by my side all the time when I needed help during this study and before. I also thank Master's students and staff members in the Department of Ecology and Resource Management, University of Venda.

To my mom Grace Nemakhavhani, my family members (Matodzi, Lucy, Masala, Tshililo, Vhonani, Lindelani, Gundo, Mashudu) and Eddy Phaswana, I am honored to be part of your family and I am sincerely grateful for the support and love that you showed me throughout my studies till now; you play a crucial role in my life. I dedicate this research to my children (Mueletshedzi and Mutshidzi).

I am more than grateful to the University of Venda RPC, National Research Foundation-Scarce Skills programme and DAAD for providing funding towards this research.

Fig 3.1: Map showing position of study site in relation to vegetation types .....	19
Fig 3.2: Map showing vegetation types found at Lajuma .....	20
Table 3.1: Data trapped and trap success of small mammals at Lajuma .....	22
Fig 3.3: Shows habitat sampling design sketch map .....	22
Fig 5.1: Individual -based rarefaction curves show small mammal captured in different habitats in Lajuma from August 2010 to August 2011.....	28
Fig 5.2a: Shows small mammal species distribution across different habitats of Lajuma.....	30
Fig 5.2b: Shows the degree of similarity between small mammal communities in different habitats of Lajuma.....	30
Fig 5.3: Quilt plot for <i>A. ineptus</i> and <i>M. namaquensis</i> .....	31
Fig 5.4a: Shows small mammals Minimum Number Alive recorded in different season.....	33
Fig 5.4b: Shows the mean number of small mammal species (over 40 trapping nights) recorded in different habitats.....	33
Table 5.7: Shows sex ratio of individual small mammals recorded at Lajuma .....	34
Table 5.8a: Shows seasonal pattern of shrews species recorded at Lajuma .....	35
Table 5.8b: Shows seasonal pattern of shrews species recorded at Lajuma .....	35
Table 5.9: Shows seasonal reproduction patterns of small mammals .....	36

Table 3.1: Dominant plant species occurs at different vegetation types on the southern aspect of the Lajuma.....	18
Table 5.1: Data trapped and trap success of small mammals at Lajuma.....	25
Table 5.2: The species composition and relative abundance (%) of small mammals recorded in all habitats combined.....	26
Table 5.3: Observed (Obs spp) and expected species richness based on Chao 2 and Jackknife 2 richness estimators of small mammal assemblages in wetland, grassland and rocky-outcrop at Lajuma.....	27
Table 5.4: Diversity indices and evenness of small mammals in different habitats.....	28
Table 5.5: Shows Minimum Number Alive of small mammal species recorded in different habitats .....	29
Table 5.6: Akaike Information Criterion (AIC) values for five models tested to explain change in Minimum Number Alive (MNA), number of species and environmental variables .....	32
Table 5.7: Shows sex ratio of individual small mammals recorded at Lajuma .....	34
Table 5.8a: Shows seasonal pattern of shrews juveniles recorded at Lajuma .....	35
Table 5.8b: Shows seasonal pattern of shrews juveniles recorded at Lajuma.....	35
Table 5.9: Shows seasonal reproduction patterns of small mammals .....	36
Conclusion .....	15
CHAPTER THREE: DESCRIPTION OF THE STUDY AREA AND SAMPLING SITES.....	15
3.1 Location of the study site .....	15
3.1.1 Climate .....	16
3.1.2 Topography.....	16
3.1.3 Geology and soil.....	17
3.1.4 Vegetation.....	17

# TABLE OF CONTENTS



Pages

DECLARATION.....	I
ABSTRACT.....	II
ACKNOWLEDGEMENTS.....	III
LIST OF FIGURES.....	IV
LIST OF TABLES.....	V
<b>CHAPTER ONE: INTRODUCTION.....</b>	<b>3</b>
1.0 Background and rationale.....	3
1.1 Motivation.....	3
1.2 Research objective.....	4
1.3 Research hypotheses.....	4
1.4 Arrangement of the thesis.....	5
<b>CHAPTER TWO: LITERATURE REVIEW.....</b>	<b>6</b>
2.1 Small mammal distribution and diversity in Southern Africa.....	6
2.2 Abiotic and biotic factors shaping small mammal communities.....	7
2.3 Small mammal habitat preference.....	8
2.4 Small mammal species richness and diversity.....	10
2.5 Reproduction ecology of small mammals.....	11
2.5.1 Breeding season of small mammals.....	12
2.5.2 Litter size of small mammals.....	13
2.6 Population dynamics of small mammals.....	14
2.7 Conservation status of small mammals in South Africa.....	14
2.8 Conclusion.....	15
<b>CHAPTER THREE: DESCRIPTION OF THE STUDY AREA AND SAMPLING SITES.....</b>	<b>16</b>
3.0 Location of the study site.....	16
3.1 Climate.....	16
3.2 Topography.....	16
3.3 Geology and soil.....	17
3.4 Vegetation.....	17



3.5	Land use.....	18
4.0	Data collection period.....	21
4.1.1	Identification.....	22
4.1.2.	Processing of trapped animals.....	22
4.1.3.	Classification of castes based on sex and reproductive condition.....	22
4.2.	Data and statistical analysis.....	23
<b>CHAPTER 5: RESULTS AND DISCUSSION.....</b>		<b>25</b>
5.1.	Data on trap captures and trap success of small mammals recorded at Lajuma.....	25
5.2.	Species composition and occurrence of small mammals in different habitats.....	26
5.2.1	Observed and estimated small mammal richness and diversity recorded at Lajuma.....	27
5.3	Small mammals recorded in different habitats.....	28
5.3.1	Small mammals habitat preferences and community similarity across different habitats .....	29
5.3.2	Small mammal species niche separation.....	31
5.4	Environmental correlates of abundance/density (MNA) and species richness.....	32
5.5	Reproduction ecology of small mammals recorded at Lajuma.....	34
5.5.1	Sex ratio of individual small mammals recorded during the study.....	34
5.5.2	Population structure and breeding season of the most common small mammal species recorded at Lajuma during the study.....	34
<b>CHAPTER SIX: DISCUSSION, CONCLUSION AND RECOMMENDATION.....</b>		<b>37</b>
6.1	Discussion.....	37
6.1.1	Trap success and abundance (MNA) of small mammals recorded at Lajuma.....	37
6.1.2	Small mammals habitat preferences and community similarity across different habitats .....	38
6.1.3	Species niche separation.....	40
6.1.4	Small mammals species richness and diversity.....	40
6.1.5	Environmental correlates of abundance/density (MNA).....	41
6.1.6	Reproduction ecology of small mammals.....	43
6.2	Conclusion.....	46
6.3	Recommendation.....	47
<b>REFERENCES.....</b>		<b>48</b>

**1.0 Background and rationale**

Small terrestrial mammals are important components of ecosystems worldwide because they are bio diverse and abundant, they provide high quality food and have a high turnover rate, they are important consumers of plant seeds and act as seed disperse. They modify the environment for the benefit of other species and they provide an essential food source for a variety of predators. Some small terrestrial mammals can also become serious agricultural pests or they can transmit human diseases such as bubonic plague. They further serve as good indicators of environmental change and many species are threatened by extinction and require conservation actions (Lozada et al. 2000; Wilson & Reeder, 2005).

A knowledge of small terrestrial mammal ecology is therefore essential to develop sound conservation programmes. This is particularly so for the Soutpansberg which has a high diversity of this group and which has been identified as a priority area for conservation in South Africa. The present study determined small mammal’s spatial and reproductive differentiation in an area where, grassland, wetland and a rocky habitat occur in close proximity.

**1.1 Motivation**

There is a particular need for information on habitat segregation and life history patterns in small terrestrial mammals as a basis to model future impacts of climate change. The main aims of the project was to determine the relationship between habitat type and extent, and small mammal species richness and relative abundance and to record reproductive patterns. With this knowledge, characteristics of community structure can be identified and minimum size of a habitat patch needed to maintain diversity. The information can also be used to monitor environmental changes over time.

## 1.2 Research objective



To establish baseline ecological data on small mammal species composition, species richness, diversity, community structure, and population cycles in different habitat types in a complex mountain environment as a basis for conservation planning and monitoring of environmental changes.

### Specific objectives

- To identify species of small mammals at Lajuma.
- To measure species richness, diversity, abundance and community structure characteristics.
- To compare habitats in respect of above.
- Compare breeding cycles of different species of rodents, shrews and Sengis occupying the same environment.
- To determine the relationship between small mammals and rainfall and other environmental parameters.

### 1.3 Research hypotheses

- a) Individual species should have individual habitat preferences with some being generalist (*R. pumilio*) and others being habitat specialists.
- b) Habitat type (wetland) will influence small terrestrial mammal species composition, richness, diversity and abundance.
- c) Reproduction patterns are associated with seasons. Breeding should occur in summer because of rainfall which increases food availability.
- d) Population cycles should vary with season – with lower densities in winter – low rainfall and food availability (high mortality) and lack of breeding.
- e) Seasonal differences in population density/abundance (MNA) but not richness or diversity should be explained by climatic factors such as temperature and rainfall.
- f) Patterns may vary between insectivores (Shrews and Sengis) and herbivores (rodents)? Different diet and responses to rainfall, temperature and habitat may be expected.

- Chapter one explains the background, importance, objectives and the hypotheses of the research.
- Chapter two is a review of studies by other authors about the distribution and diversity of small mammal's in Southern Africa, abiotic and biotic factors shaping small mammal communities, small mammal habitat preference, species richness and diversity, reproduction ecology, population dynamics and conservation status in South Africa.
- Chapter three describes the location, climate variables and vegetation types of the study area.
- In chapter four, I explain when and how data were collected, species identification procedures, processing of trapped animals, classification of castes based on reproductive condition and how data were analysed.
- Chapter five involves the arrangement, summary, presentation and interpretation of data, and to support the research objectives, the result were discussed.
- Finally, chapter six summarises the research findings and recommends strategies based on the research findings.

## 2.1 Small mammal distribution and diversity in Southern Africa

Small mammals form the highest proportion of mammals all over the world (Chekol et al. 2012). Small mammals such as rodents have restricted dispersal ability and many display patchy distribution (Nicolas et al. 2009). Rodents are nearly cosmopolitan in distribution (Wilson and Reeder 2005). They are found in all continents other than Antarctica (Lambert et al. 2006). Rodents account for more than 40% of the mammalian species in the world with 21 living families, 443 genera and more than 2000 species (Chekol et al. 2012). Rodent diversity in Southern Africa is high, with about 85 species from 36 genera and seven families (Bronner et al. 2003). The success of this group is its adaptability to new food source and habitat and its relatively short reproductive cycle (Kingdon 1997).

Small mammal distribution was reported to be greatly affected by environmental variables and potential habitat changes (Taylor 2000; Russo et al. 2010). Generally, species of rodents, shrews and elephant shrews are found in Southern Africa particularly in the Limpopo, Gauteng and Mpumalanga provinces of South Africa (Newbery, 1999). The Soutpansberg has more mammal species than 11 out of the 27 recognized biodiversity hotspots of the world with a total of 145 mammal species. This correspond to 60% of all mammal species that occur in South Africa and compares favourably with the diversity of mammals in the recognized biodiversity hotspots of the world. It is also known that 31 rodents and 11 insectivores have been recorded at Soutpansberg (Gaigher 2006).

Of those small mammals known to occur in the Soutpansberg, *Dasymys incomtus* is considered endemic to Eastern South Africa and South Western Zimbabwe (Mullin et al. 2005). *Aethomys chrysophilus* is wide spread in South Africa (Chimimba and Linzey 2008). *Mus minutoides* is widely found in southern and east Africa (Skinner and Smithers 1990). *Aethomys chrysophilus*, *Micaelamys namaquensis*, *Rhabdomys pumilio* and *Otomys angoniensis* were recorded in Limpopo province (Newbery 1999; Stuart and Stuart 2001). In Soutpansberg, Lajuma mountain reserve, *Dendromus mystacalis*, *Rhabdomys pumilio*, *Lemniscomys rosalia*, *Aethomys chrysophilus*, *Otomys angoniensis*, *Micaelamys namaquensis* have been recorded (Taylor et al. 2012).

Shrews make up the order Eulipotyphla, the suborder Soricomorpha and the single family Soricidae (Skinner and Chimimba 2005). Shrews are represented by more than 270 species (Churchfield 1990). Seventeen shrew species from four genera and one family have been recorded in Southern Africa (Bronner et al. 2003; Skinner and Chimimba 2005). Thirteen shrew species from three genera were recorded in KwaZulu-Natal (Taylor 1998). Species such as *Crocidura cyanea*, *Myosorex varius* and *Crocidura mariquensis* are dominant in Southern Africa and they were also recorded in South Africa, Limpopo province (Skinner and Smithers 1990; Nicoll and Rathbun 1990; Newbery 1999).

Sengis form the order Macroscelidea which represents the family Macroscelididae. They include three genera with nine species of *Elephantulus*. In southern Africa Sengis were recorded in Zambia, Mozambique, Zimbabwe, Lesotho, Botswana and South Africa (Skinner and Smithers 1990; Mills and Hes 1997). *Elephantulus* is endemic to Africa and its distribution includes Morocco, Algeria, Libya, Tunisia and South Africa (Perrin et al. 2008). In South Africa *Elephantulus myurus* has been recorded in North West, Gauteng, Mpumalanga, Kwazulu-Natal, Free State, Northern Cape and Limpopo provinces (Skinner and Chimimba 2005; Newbery 1999).

## 2.2 Abiotic and biotic factors shaping small mammal communities

The distribution and abundance of organisms is influenced by the abiotic and biotic factors (Takele et al. 2011). Small mammals community structure and species richness are related to biotic (e.g. predation and competition) and abiotic (e.g. habitat, soil and productivity) variables (Kerley et al. 1990; Else and Kerley 1996; Avenant, 2000). Both abiotic and biotic processes influence different parameters of the community structure of rodents and shrews at Mkhuze and KubeYini, South Africa (Delcros 2012). Abiotic factors such as habitat fragmentation have been a central theme in community ecology for at least 100 years (Rautenbach et al. 2014). Biotic filters such as competition should have a strong influence on the community of animals that have life histories characterized by low fecundity, low predation risk and stable population. Competition involves mechanisms such as extinction rate, distance and area effects and differential colonization. Predation is another biotic factor that highly influences the structure of non-Volant small mammal assemblages. For instance, experimental studies revealed that rodents and shrews change their foraging behavior directly in response to a predatory risk (Yunger et al. 2002; Kelt et al. 2005).

Processes rather than competition should influence the species composition of similar sized mammals such as rodents and shrews that have life histories characterized by fluctuating populations, high reproductive rates and short life expectancy. Small mammal's population numbers change seasonally and are positively correlated to rainfall and temperature (Else and Kerley 1996; Monadjem and Perrin 2003; Makundi et al. 2006; Massawe et al. 2011; Schoeman and Jacobs 2011; Rautenbach et al. 2014).

Reproductive performance is responsive to environmental differences, such as temperature and rainfall (Medger et al. 2012a). It has been shown that throughout Africa reproduction is associated with rainfall and that rainfall can improve reproductive output (Perrin et al. 1992; Perrin and Monadjem 1998).

Bradshaw and Holzapfel (2007) have observed different factors that may influence and shape seasonal reproduction of small mammals. Skinner and Chimimba (2005) have indicated that seasonal changes in quality and availability of food determine food preferences and that seasonal reproductive changes are often associated with changes in the diet (Perrin and Boyer 2000). The availability of breeding sites also plays a role in determining the breeding season (Makundi 1995).

### 2.3 Small mammal habitat preference

Habitat preferences of small mammals depend on a combination of several factors one of which is vegetation cover (Monadjem and Perrin 1998). In areas with strong seasonality, micro - habitat features are major factors which govern the composition and abundance of rodents in a given habitat (Lin and Batzli 2001 cited in Takele et al. 2011). Small mammals partition the habitat at both coarse and fine scales (Shepherd and Ditgen 2005). They occur in many habitats from the high Arctic tundra where they live and breed under snow to the hottest and driest desert. Small mammals in high altitude habitat have been studied in some of African mountains such as Cape Fold (Kok et al. 2011), Cameroon, Uganda and Drakensberg (Kasangaki et al. 2003) and small mammals are considered to be sensitive to habitat change (Mugabe, 2008). Wetlands are also important habitats for small mammals (Bowland and Perrin 1993).

Rodents occupy a wide range of habitat types from human settlement, grassland to secondary and mature forest (Kingdon 1997 cited in Mugatha, 2002). Habitat preferences of rodents are determined by the types of cover available to them (Geleta et al. 2011). Species such as *Rhabdomys pumilio* and *Otomys* have been shown to correlate strongly with the presence of the

grass cover (Wandrag et al. 2002; Mugatha 2002). *Thabdomys pumilio* occupy a wide variety of habitat types, from desert fringe to high-rainfall mountain areas. They are found on the outskirts of the forest (Schradin and Pillay, 2003, 2005). They also prefer grassland, but their habitat may also include bushy and semi-arid vlei country as well as dry riverbeds (Mills and Hes 1997).

In the case of *Otomys irroratus* and *Otomys angoniensis* their natural habitat is savanna, subtropical and tropical grassland and swamp areas along rivers and plantations (Siegfried and Brown 1992; Musser and Carleton 2005; Skinner and Smithers 1990). *Otomys angoniensis* was recorded in dense stands of reed, sedges or semi-aquatic grasses on the edge of permanent water sources (Mills and Hes 1997; Taylor 1998). *Dasymys incomtus* was recorded in South African wetland (Skinner and Chimimba 2005).

*Aethomys namaquensis* is a dominant species in the forest and rocky outcrops, covered with grass and shrubs (Van der Merwe 1999; Armstrong and Van Hensbergen 1996). *Aethomys chrysophilus* was found in general types of habitat, ranging from savanna woodland to grassland and forbs, shrub thickets, rocks and termites mounds (Chimimba and Linzey 2008). *Dendromus mystacalis* and *Lemniscomys rosalia* are found in areas of long grass (Avenant and Cavallin 2007). *Mus minutoides* has a wide habitat tolerance (Mugatha 2002). This species occur in the Karoo, savanna grassland, forest, woodland and areas of bare ground rock (Mills and Hes 1997; Stuart 2001).

Shrews occur in a wide range of habitats which include moist forest, wetland, marshes and woodland (Nicoll and Rathbun 1990; Skinner and Smithers 1990). Some shrews such as climbing shrews occur in areas with dense scrub and grass cover (Rychlik 2000; Stuart and Stuart 2007) whereas shrews such as *Myosorex varius* prefer moist conditions with dense grass cover and forest habitat (Mills and Hes 1997). It was observed in the moist misty conditions with low succulent bushes in drier areas and it also in the Fynbos (Siegfried and Browns 1992; Skinner and Smithers 1990). *Crocidura* species show preferences to dry savanna or semi desert conditions (Nicoll and Rathbun, 1990). *Crocidura cyanea* and *Crocidura mariquensis* were found in the vlei vegetation with marshy ground grass wetlands in South Africa (Fuller and Perrin 2001) and they were also found in rocky areas (FitzGibbon et al. 2008).

*Macroscelides* is restricted to arid gravel plains, which vary from the Namib Desert of Namibia with no significant vegetation, to the High Karoo of South Africa, where the gravel plains support scattered bushes and scattered boulders in savannah woodlands (Skinner and Smithers 1990).

*Elephantulus* species such as the *Elephantulus myurus* are restricted to rocky habitats while the bushveld Sengis was recorded in areas with sandy soil (Stuart and Stuart 2007).

*Elephantulus myurus* has been observed in a wide range of habitats but it mostly prefers large rock debris that offer large crevices and crannies for refuge (Mills and Hes 1997). It has been recorded in the coastal desert, bush land, rocky outcrop and the tropical forest, savanna, desert, strewn outcrops, thick forest, and thorn bush occupying variety of habitats (Perrin et al. 2008). In Limpopo province, Soutpansberg, *Elephantulus myurus* has been found to exist in rocky ridges of Buzzard mountain retreat and Lajuma Mountain (Taylor et al. 2012).

#### 2.4 Small mammal species richness and diversity

Species richness is a measure of diversity that considers only the numbers of different taxa not their relative abundance (Cowell 2009). It is a function of different distribution patterns of individual members of taxa within their distributional ranges. An increase in species richness might be a result of increased diversity of micro-environments, e.g. in a bush land and forest mosaic (Angelici and Luiselli 2005). Rahbek and Graves (1999) suggested that species richness gradients are affected by a combination of biotic and abiotic factors (Botes et al. 2006). Species richness of small mammals was found to decrease with an increase in altitude in Tanzania and Uganda (Kasangaki et al. 2003; Stanley and Hutter 2007).

Small mammal species richness is related to variables such as habitat structure and complexity, area, rainfall, productivity, predation, trampling, grazing surrounding landscape and the distance between similar habitats (Lambert et al. 2006). It has been observed that vegetation can be a contributing factor (Andrews and O'Brien 2000; Kerley et al. 1990). Van Deventer and Nel (2006) reported that species richness of small mammals is significantly correlated with shrub cover in Namaqualand, South Africa. And Kok et al. (2011) found that species richness and diversity of montane small mammals was high in the Cape Fold and Central Drakensberg Mountains. Habitat alteration reduces small rodent species richness and diversity through the decrease of herbaceous layer and changes in food availability (Monadjem and Perrin 1998a; Avenant 2000; Keesing 1998).

Munyai and Foord (2012) reviewed that climatic condition could set limits to species diversity and harsh condition at high altitude and elevation can limit the survival of the species in the area.

Low temperature and high precipitation influence species diversity at high elevation. Stanley and Hutter (2007) reported that species richness is higher in low latitudes than in high latitudes. McCain (2005) reported that species richness peaks at a mid-elevation.

Caro (2001) found increase in rodent species richness in the farmland during the dry season at Katavi National Park in Tanzania. Small mammals populations and communities can be quite unstable, fluctuating from year to year, e.g. at Mkuze (Delcros 2012; Rautenbach et al. 2014). Species richness may also be due to climatic variations, for example, increased rainfall is usually positively correlated with increased richness of small mammal species (Leirs et al. 1996; Morrison et al. 2002).

Species abundance fluctuated from months to months in Swaziland (Monadjem and Perrin 1998). In the high-altitude grassland of the Free State of South Africa small mammal species richness and diversity were low during summer months (Avenant 2000a). Similar results were obtained from grassland in Kwa-Zulu Natal, South Africa (Fuller and Perrin 2001). In Korannaberg conservancy there was high species abundance during the period of mid-autumn and early winter (Avenant 2000b). Avenant (2000a) observed high species diversity and richness in autumn in Willem Pretorius nature reserve in the Free State province.

The diversity of African shrews tends to be greatest in countries with moist forest habitats and least in arid countries (Nicoll and Rathbun 1990). Shrew species richness is high in mountain forest and woodland rather than lowlands on Mount Kilimanjaro in Tanzania (Mulungu et al. 2008). Species richness of *Elephantulus myurus* is low in upland succulent Karoo, dry riverine shrub and renosterveld in Namaqualand, South Africa (Van Deventer and Nel 2006).

## 2.5 Reproduction ecology of small mammals

There are several determinants which account for small mammal reproductive potential, namely: the age and sex, the litter size, and the frequency of litters. In an area the species can have markedly different reproductive potentials as indicated by the litter size. Reproductive performance is responsive to environmental differences, such as temperature and rainfall. These cause sharp regional shifts in litter size to occur in some species (Vaughan et al. 2000; Medger et al. 2012b).

The mating system of rodents depends upon the species (Nowak 1999). Few species are monogamous, thus forming male-female pairs that can last for multiple mating seasons. Other species have a harem-based mating systems, comprising male with a set group of females for the mating season. Many rodents are promiscuous, and mate randomly (Vaughan et al. 2000).

Mugabe (2008) has observed that small mammals breed only during a specific time of the year when environmental conditions are favourable. However, some small mammals are opportunistic and may breed during harsh conditions and ultimately maximize reproductive success. In the tropics, many mammals breed throughout the year because the environmental conditions are more stable than those in temperate regions (Medger et al. 2012a). Seasonal reproduction has been reported and normally occurs due to seasonal variation during rainfall period (Massawe et al. 2008).

Bradshaw and Holzapfel (2007) found different factors that may influence and shape seasonal reproduction of small mammals. Photoperiod is used by some subtropical rodents that occur in seasonally changing environments (Muteka et al. 2006b; Medger et al. 2012a).

### **2.5.1 Breeding season of small mammals**

Seasonal reproduction is a common characteristic of many small mammals which inhabit seasonal environments in temperate regions, the sub-tropics as well as the tropics (Medger et al. 2012b). It is important for an animal to reproduce during the most favourable time of the year to ensure the survival and maximization of the young (Makundi et al. 2007).

Most murids are seasonal breeders (Nowak 1999). Other species of rodents under favourable conditions would continue to exhibit active reproductive activity throughout the year although the peak of the activity occurs during the latter part of the wet season (Linn 1991). During the reproduction season small mammal testes increase in length and this is related to the age of the animals and also reflects a change in reproductive conditions (Jaroszewska and Wilczynska 2006).

In Southern Africa, a relationship between seasonal rainfall and reproduction has been reported (Muteka et al. 2006c; Medger et al. 2012b). Previous studies revealed that there is a relationship between seasonal rainfall and reproduction (Muteka et al. 2006a; Medger et al. 2012a). Massawe et al. 2008; Mugabe 2008) reported in separate development that rainfall is the major factor that controls seasonal reproduction at subtropical and tropical latitudes, especially in habitats with distinct wet and dry seasons.

In the savanna of Africa, rodent reproduction effectively ceases in the dry season. In South Africa, other studies reported that the breeding of *Mastomys natalensis* peaks during the latter part of the rainy season (Jackson and Van Aarde 2003). The reproductive season of *Mus minutoides* is reported to occur during summer season in Swaziland (Monadjem 1999). In contrast in northern Botswana, *Mus minutoides* appears to breed seasonally although in Swaziland it has been reported to breed throughout the year and with a peak during winter (Monadjem, 1999). Small mammal reproductive period seems to be largely confined to the rainy season. In most rodent families and sub families reproduction is limited to a particular season (Kingdom 1997). Some species of rodents would continue to exhibit active reproductive activity throughout the year and the peak of the activity occurs during wet seasons (Linn 1991).

Mugabe (2008) has observed that small mammals breed only during a specific time of the year when environmental conditions are favourable and to ensure the survival of the young (Makundi et al. 2007). In the drier parts of Malawi and Tanzania small mammals which live in the strongly seasonal habitat reproduce seasonally (Happold and Happold 1990; Makundi 1995). Massawe et al. 2011 observed that *Mastomys natalensis* breed throughout the whole year in Tanzania and the same applies to *Acomys cahirinus* in Malawi (Happold and Happold 1990).

Seasonal reproduction has been observed in *Micaelamys namaquensis* and *Aethomys ineptus* (Skinner and Chimimba 2005; Muteka et al. 2006b). Skinner and Chimimba 2005). In South Africa it has been reported that *Mus minutoides* breed throughout the year (Monadjem 1999). In addition ambient temperatures may also be responsible for shaping reproduction in elephant-shrew and may trigger the onset of reproduction in August (Rathbun 2009). Sengis are associated with seasonal reproduction at higher altitude (Ribble and Perrin 2006; Rathbun 2009; Medger et al. 2012b). Most *Elephantulus myurus* species investigated to date breed throughout the year, although three species, *Elephantulus myurus*, *Elephantulus rozeti* and *Elephantulus intufi* have been found to breed seasonally (Neal 1995; Woodall 1995; Medger et al. 2012a). *Myosorex varius*, *Myosorex cafer* and *Crocidura mariquensis* are seasonal breeder with peak reproduction during summer but in some areas, reproduction takes (Stuart and Stuart 2007; Medger et al. 2012b).

### 2.5.2 Litter size of small mammals

Litter size produced during a single season by murid type and insectivore are considered as high, whereas the Sengis group is considered as low (Neal 1995). Rats give birth to litters of five young,

for example *Dasymys incommisus*. Mice especially *Chrotomys* mice give birth with litter sizes of two to eight (Stuart and Stuart, 2007). The litter size of Sengis is one to two young born and is associated with seasonal reproduction at elevation of higher altitude (Rathbun 2009; Medger et al 2012b).

## 2.6 Population dynamics of small mammals

Species relative abundance is a component of biodiversity and refers to how common or rare species is relative to other species in a defined location or community (Stanley et al. 2007). Small mammal abundance in a habitat can be an important indicator of habitat quality (Kiwia 2006). Massawe et al. (2008) reported that environmental factors such as rainfall are responsible for the high population density of *Mastomys natalensis*. Rodent population fluctuations depend on rainfall pattern and the amount of rainfall. Geleta et al. (2011) reported that the soil structure, types and the properties of soil are very important in rodent population ecology.

Small mammal population is sensitive to habitat changes (Avenant 1996) and habitat changes reduce small rodent abundance (Keesing 1998). Small mammals show increased abundances with the habitat features indicative of the edge affected or disturbed habitats (Lambert et al. 2006).

Rodent populations show great seasonal and year to year variations (Makundi et al. 2005) and Mugabe (2008) observed more rodents during autumn in Western Cape. Wirminghaus (1990) observed high *Mastomys natalensis* abundance in South Africa, KwaZulu-Natal during early dry season. Monadjem (1999) reported that *Mus minutoides* population respond to vegetation changes in Swaziland and it was lowest during winter.

Shrew abundance is related to territorial, aggression and home ranges (Freeman 2008). Nicolas et al. 2009) has observed that shrew abundance varies among habitats. The disturbed grassland had the highest numbers of small shrews such as *Crocidura mariquensis* (Perrin 1995). Shrew abundance was higher in winter than in summer. This is surprising because food supply and plant cover increase in the wet season. Similar seasonal patterns have been recorded in southern Africa. Little is known with the regard to the population of *Elephantulus myurus* and it fluctuates naturally due to climatic factors such as rainfall (Skinner and Smithers 1990).

## 2.7 Conservation status of small mammals in South Africa

undulating. Lajuma highest peak is about 1748 m above sea level on the western half of the mountain (Bumby et al. 2001). The study site found at an altitude of 1200 m above sea level.

### 3.3 Geology and soil

The geology of Lajuma is characterized mostly by sand stone (quartzite), especially in areas with less water. The soil type is loamy sand that is covered by a lot of plant litter and is rich in organic matter depending on the habitat type. Some parts, such as the wetland, are characterized by peat which is formed due to continuous compaction of humus and organic matter. The soil found in the Mist belt forests are highly weathered, clay soils mainly of Avalon and Hutton soil forms (Bumby et al. 2001).

The area is comprised of quartzite associated with siltstone, shale and mudstone in the Soutpansberg group as well as ignimbrite, calcareous basalt, reddish, brownish, or variegated shale, shale sandstone, sandstone and quartzite sandstone in Tshifhefhe group (Bumby et al. 2001). The soil colour ranges from light to greyish and red to brownish but the types of soil include sandy, loamy clay, sandy and slit loam (Bumby et al. 2001).

### 3.4 Vegetation

Soutpansberg characterized by five vegetation types which are Soutpansberg Arid North Bushveld (ANB), Soutpansberg Leached Sandveld (LS), Soutpansberg Cool Mistbelt Vegetation (CMV), Soutpansberg Forest (SF) and Soutpansberg Moist Mountain Thickets (SMMT) (Figure 3.2) (Mostert et al. 2008). The dominant vegetation types found at Soutpansberg are shown in Table 3.1. An alternative vegetation classification system (SANBI: Mucina & Rutherford, 2006) recognized three vegetation types in the study area; Soutpansberg Mountain Bushveld, Northern Mistbelt Forest and Soutpansberg Summit Sour veld.

The vegetation is characterized by scrublands, thicket, woodland, forest, and grassland and herb land. The study area is characterized by the rugged summit crest and closed grasslands and scattered canopy bush clumps (Mucina and Rutherford 2006). Lajuma contains a remarkable diversity of plants, including a large number of endemics and rare and endangered species (Berger et al. 2003).

The higher parts of the mountain are covered with montane grassland, the south facing ridges covered with evergreen forest. Down slope is covered by semi deciduous woodland and thicket bisected by bands of riverine forest (Hahn 2006). Most common plant species found in the

wetland area are reeds, grasses, herbs and tree species (Mucina and Rutherford 2006). The sites in the Soutpansberg Moist Mountain Thickets (12S2, 10S and 09S) are closed bush land. The forest site (12S) is characterized by closed woodland. And on the southern aspect, Cool Mist belt vegetation (16S), are open sedge land and Cool Mist belt vegetation (14S) is a mosaic of woodland and grassland (Table 3.1).

**Table 3.1: Dominant plant species occurring at different vegetation types on the southern aspect of the Lajuma** (Mostert et al. 2008)

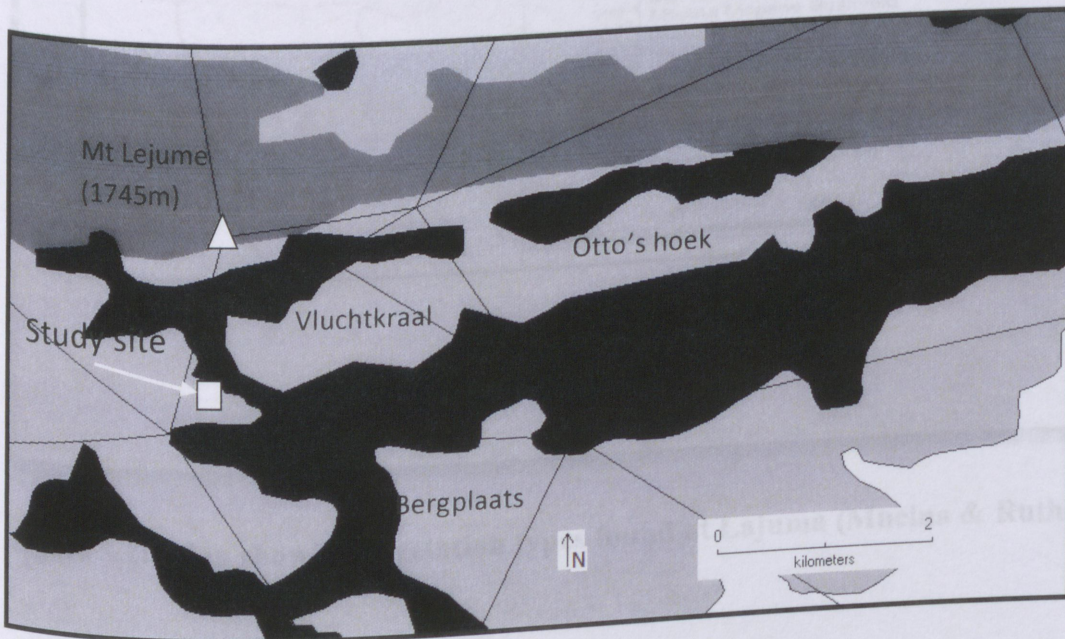
Vegetation types	Dominant woody species
Soutpansberg Moist Mountain Thickets (SMMT)	<i>Dichrostachys cinerea</i> <i>Acacia caffra</i> and <i>Olea europae</i>
Soutpansberg Forest (SF)	<i>Croton sylvaticus</i> <i>Ekebergia capensis</i>
Cool Mist belt Vegetation (CMV)	<i>Canthium inerme</i> <i>Psydrax obovata</i> <i>Coleochloa species</i>

### 3.5 Land use

Land use is the human modification of natural environment or wilderness into built environment such as fields, pastures, and settlements. There was limited agriculture practice. The timber plantations, game farming, cattle ranching, nut orchards, and avocado orchards were dominant land use at Western Soutpansberg. Land use practices have a major impact on natural resources including water, soil, nutrients, plants, and animals. Land use information can be used to develop solutions for natural resource management issues (Reyers 2003).



a.



b.

**Fig 3.1 a, b: Map showing position of study site in relation to vegetation types (Mucina and Rutherford 2006) and farm boundaries. Light grey = Soutpansberg Mountain Bushveld. Dark grey = Soutpansberg Summit Soutveld; Black = Northern Mistbelt Forest**

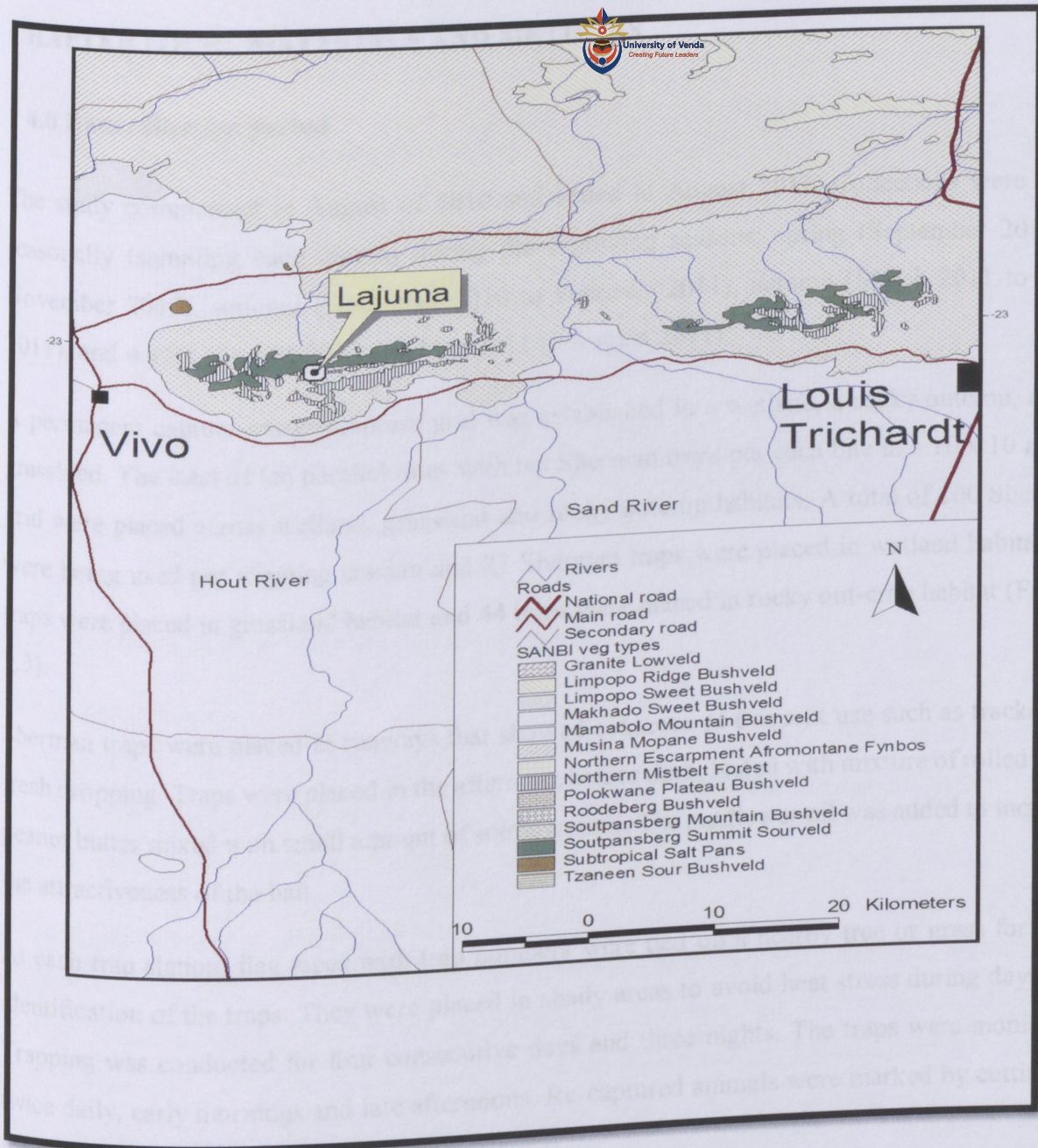


Figure 3.2: Map showing vegetation types found at Lajuma (Mucina & Rutherford 2006)

#### 4.0 Data collection period

The study commenced in August of 2010 and ended in August 2011. Collections were done seasonally (sampling each month) during the following seasons: spring (September 2010 to November 2010), summer (December 2010 to February 2011), autumn (March 2011 to May 2011), and winter (August 2010 and June 2011 to August 2011).

A permanent capture-mark-recapture grid was established in a wetland, a rocky outcrop, and a grassland. The total of ten parallel lines with ten Sherman traps per each line in a 10 x 10 meter grid were placed across wetland, grassland and rocky outcrop habitats. A total of 100 Sherman traps were being used per trapping session and 27 Sherman traps were placed in wetland habitat, 29 traps were placed in grassland habitat and 44 traps were placed in rocky out-crop habitat (Figure 3.3).

Sherman traps were placed in runways that showed evidence of frequent use such as tracks and fresh dropping. Traps were placed in the afternoon before dark, baited with mixture of rolled oats, peanut butter mixed with small amount of sunflower oil. The sunflower oil was added to increase the attractiveness of the bait.

At each trap station, flag tapes with trap numbers were tied on a nearby tree or grass for easy identification of the traps. They were placed in shady areas to avoid heat stress during daytime. Trapping was conducted for four consecutive days and three nights. The traps were monitored twice daily, early mornings and late afternoons. Re-captured animals were marked by cutting of fur and toe-clipping.

For future recognition, all captured animals were marked by the capture session, rodents with fur clipping and gloves with toe-clipping. They were released at the point of capture after identification. Data were recorded on field data sheets and later entered into MS Excel.

4.1.3. Classification of castes based on sex and reproductive condition  
Classification was based on body mass, body size and condition of reproductive system. Animals were categorized as juveniles and adults. Females were differentiated from males based on the appearance of the genitalia and the presence or absence of avian nipples. All specimens trapped were initially assigned to castes using the following criteria: males were designated as scrotal or

Line numbers	10 m x 10 m trap stations									
10	A10	B10	C10	D10	E10	F10	G10	H10	I10	J10
9	A9	B9	C9	D9	E9	F9	G9	H9	I9	J9
8	A8	B8	C8	D8	E8	F8	G8	H8	I8	J8
7	A7	B7	C7	D7	E7	F7	G7	H7	I7	J7
6	A6	B6	C6	D6	E6	F6	G6	H6	I6	J6
5	A5	B5	C5	D5	E5	F5	G5	H5	I5	J5
4	A4	B4	C4	D4	E4	F4	G4	H4	I4	J4
3	A3	B3	C3	D3	E3	F3	G3	H3	I3	J3
2	A2	B2	C2	D2	E2	F2	G2	H2	I2	J2
1	A1	B1	C1	D1	E1	F1	G1	H1	I1	J1
	Wetland			Grassland			Rocky			

Fig 3.3: Shows habitat sampling design sketch map

#### 4.1.1 Identification

Captured specimens were identified using a key developed by Newbery (1999). Small mammals which could not be identified with certainty in the field were sacrificed and sent to Durban Natural Science Museum as voucher specimens.

#### 4.1.2. Processing of trapped animals

Trapped animals were removed and placed in a polythene bag. They were identified and weighed using a Pesola spring balance. At each capture trap location, sex, reproductive status, body mass and age (based on the fur characteristics and body size) were recorded. The animals were recorded as juveniles (usually having darker pelage colour and small body size) or adult.

For future recognition all captured animals were marked in the capture session: rodents with fur clipping and shrews with toe-clipping. They were released at the point of capture after identification. Data were recorded on field data sheets and later entered into MS Excel.

#### 4.1.3. Classification of castes based on sex and reproductive condition

Classification was based on body mass, body size and condition of reproductive system. Animals were categorized as juveniles and adults. Females were differentiated from males based on the appearance of the genitalia and the presence or absence of swollen nipples. All specimens trapped were initially assigned to castes using the following criteria: males were designated as scrotal or

University of Venda  
Creating Future Leaders

non-scrotal depending on the presence or absence of testes in the scrotum. The vaginal patency in females was determined by observation and females were classified as perforate (reproductively active adult) and imperforate (non-reproductive adult). The condition of the nipples was indicative of current or recent lactation. Perforate females and scrotal males were regarded as reproductive.

Shrews were sexed by penile extrusion. Adult males have markedly larger penis and were regarded as reproductive. Females were regarded as reproductive if there was evidence of pregnancy or lactation or both.

#### 4.2. Data and statistical analysis

Trapping data were summarized by calculating the following common ecology parameters: number of captures, number of recaptures, and number of unique individuals (= number of captures minus number of re-captures), and trap success. Minimum Number Alive is the number of individuals caught in a capture season, plus those that were not caught at that time but were caught previously and subsequently. Species richness and diversity were also calculated using Shannon diversity index and Simpson index of diversity (Colwell, 2009).

Minimum number alive (MNA) was used to assess population size with capture-mark-recapture data. However, MNA uses information from prior and subsequent capture sessions to assess the population at each point in a longitudinal study (Efford, 1992).

Trap success without recaptures was calculated as the total number of small mammals captured per 100 trap-nights. A trap-night was defined as a trap that had been set for 24 hour period. Climatic variables such as rainfall, mean monthly minimum and maximum temperatures and wind speed were recorded from August 2010 to August 2011. Monthly data on rainfall, wind speed and temperature were downloaded from a permanent weather station located at Lajuma.

The statistical software EstimateS (version 8.2, Colwell 2009) was used to calculate expected species richness. It was also used to calculate the observed species richness (Mao Tau) for each sampling station per night. Adequacy of sampling effort was measured by comparing observed species richness at each site with the Chao2 and Jackknife2 richness estimates. Chao2 and Jackknife2 richness estimates were also used to assess the completeness of species inventories of small mammals (Delcros, 2012).

The R Statistical program was used to test the influence of season, habitat and six climatic variables (rainfall, minimum, maximum and mean temperature and mean and maximum wind speed) on both an index of abundance, Minimum Number Alive (MNA) as well as on species richness. Since the independent variables were counts which were not normally distributed, Generalized Linear Models (GLM) were applied to develop five different models to test for the relative importance of different predictor variables, alone and in combination. Model 1 was a full model including all variables. Model 2 included only habitat and season. Model 3 included all six climate variables, Models 4 and 5 included only habitat and season respectively. To correct for differences in trap effort between different habitats, log (trap number) was added as an offset term, as recommended by Mackenzie et al. (2012). The model performances were compared using Akaike Information Criterion (AIC).

The statistical software PAST (Paleontological statistics Hammer et al. 2001) was used to run Correspondence analyses (CA) and cluster analysis to determine species-habitat associations based on species abundance in various habitats.

In addition the Instat 3.10 (Graph Pad statistical software, 2009) was used to test non parametric statistics. Mann-Whitney U test was used to test the difference between sex ratio, habitat and trap success. Chi-Square test (Fisher test) was used to get the difference between observed and expected data, and to resemble a normalized sum of squared deviation between observed and expected data.

	traps	lights	captured	Not Captured	Recaptured	Trap success
Jan-11	100	3	74	26	44	24.7
Feb-11	100	3	92	8	71	30.7
Mar-11	100	3	80	20	30	26.7
Apr-11	100	3	110	10	41	36.7
May-11	100	3	110	10	53	36.7
Jun-11	100	3	76	24	19	23.3
Jul-11	100	3	59	41	42	19.7
Aug-11	100	3	45	55	38	15
Total	1200	48	931	269	540	305.2
Average	100	5	77.6	22.4	45	25.4

### 5.1. Data on trap captures and trap success of small mammals recorded at Lajuma

In this study trapping took place on 13 sampling trips covering 40 nights, and giving a total number of 931 (including recaptures) individuals, belonging to twelve species. The frequency of capture and recaptured animals differed monthly (Table 5.1). As trapping at each grid was performed over three or four nights, recaptures occurred in the second and third night after marking an individual. The results of the study indicate that there were more recaptured animals than newly captured animals. Trap success varied drastically between months and Mean trap success was 23.6 % (7.7 - 36.7) over 13 months. Trap success lowest value was recorded in August 2010 (winter) while peak in April and May 2011 (autumn) (Table 5.1).

**Table 5.1: Individuals trapped and trap success of small mammals at Lajuma**

Months	No. of traps	No. of nights	No. of individuals captured	Newly Captured	Recaptured	Trap success
Aug-10	100	3	23	19	4	7.7
Sep-10	100	4	50	33	17	12.5
Oct-10	100	3	51	35	16	17
Nov-10	100	3	80	32	48	26.7
Dec-10	100	3	87	24	63	29
Jan-11	100	3	74	30	44	24.7
Feb-11	100	3	92	21	71	30.7
Mar-11	100	3	80	30	50	26.7
Apr-11	100	3	110	49	61	36.7
May-11	100	3	110	57	53	36.7
Jun-11	100	3	70	31	39	23.3
Jul-11	100	3	59	17	42	19.7
Aug-11	100	3	45	7	38	15
<b>Total</b>	<b>1200</b>	<b>40</b>	<b>931</b>	<b>385</b>	<b>546</b>	<b>306.2</b>
<b>Average</b>	<b>100</b>	<b>3</b>	<b>71.6</b>	<b>29.6</b>	<b>42</b>	<b>23.6</b>

## 5.2. Species composition and occurrence of small mammals in different habitats

The inventory of small mammals was calculated as the ratio of observed species (Obs) to two. A total of 385 small mammals (12 species) excluding recaptures were recorded at the study site. In the Order Rodentia eight species were recorded in which *R. pumilio* was dominant whereas *L. rosalia* showed lowest relative abundance. For Order Soricomorpha three species were recorded where *C. mariquensis* was dominant while *E. myurus* was the only species recorded for the Order Macroscelidea. The Order Rodentia constituted a high percentage of the species composition compared to Soricomorpha and Macroscelidea (Table 5.2).

**Table 5.2: The species composition and relative abundance (%) of small mammals recorded in all habitats combined.**

Order	Name of species	Number of individuals	% of total
Rodentia	<i>Aethomys ineptus</i>	52	13.51
	<i>Dasymys incomtus</i>	7	1.82
	<i>Dendromus mystacalis</i>	3	0.78
	<i>Lemniscomys rosalia</i>	2	0.52
	<i>Mus minutoides</i>	3	0.78
	<i>Micaelamys namaquensis</i>	43	11.17
	<i>Otomys angoniensis</i>	17	4.42
	<i>Rhabdomys pumilio</i>	115	29.87
	<b>Total</b>	<b>242</b>	<b>62.86</b>
Soricomorpha	<i>Crocidura cyanea</i>	4	1.04
	<i>Crocidura mariquensis</i>	66	17.14
	<i>Myosorex varius</i>	64	16.62
	<b>Total</b>	<b>134</b>	<b>34.81</b>
Macroscelidea	<i>Elephantulus myurus</i>	9	2.34
	<b>Total</b>	<b>9</b>	<b>2.34</b>

### 5.2.1 Observed and estimated small mammal richness and diversity recorded at Lajuma

The inventory of completeness was calculated as the ratio of observed species (Sobs) to two species richness estimates which are Chao 2 and Jackknife 2 (using EstimateS). A species (rarefaction) curve was generated by counting the number of new species accumulated as more and more individuals are randomly gathered from a sampling area. Monthly samples recorded between three and nine species.

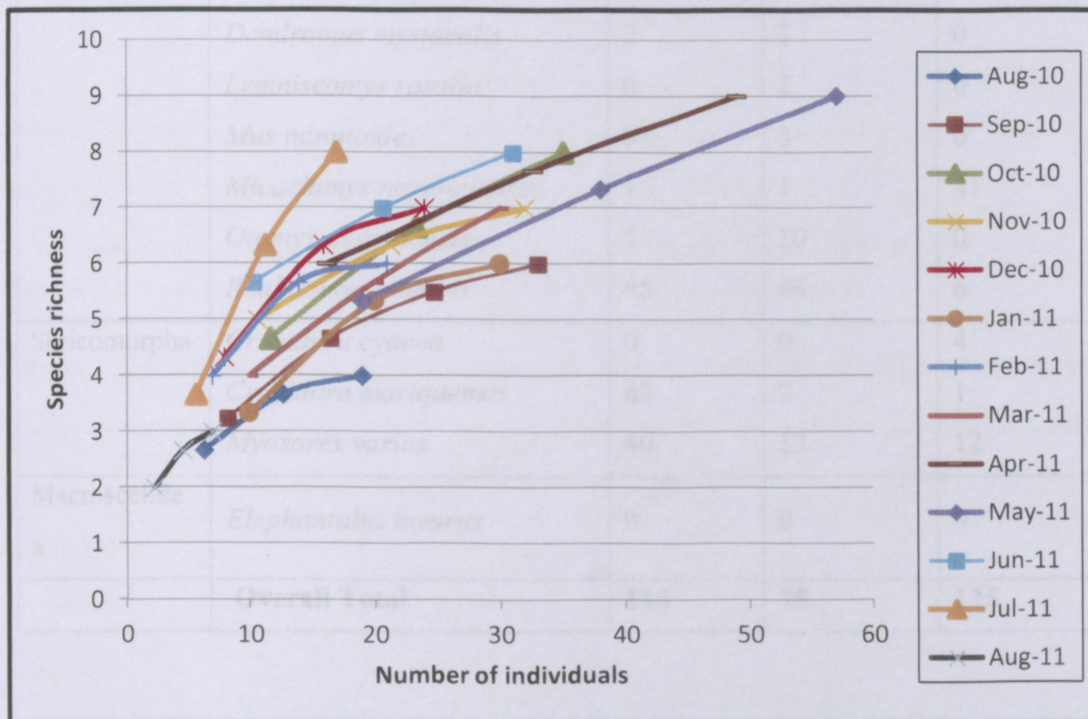
Based on richness estimators, communities were mostly completely samples (66-100%) (Table 5.3). Individual-based rarefaction curves indicated that species richness of small mammals was highest in May 2011 (autumn season) and lowest in August 2011 (winter season) (Fig 5.1). Diversity indices and evenness of small mammals varied between habitats. The highest diversity indices (both Shannon S and Simpson D) and evenness were recorded in the wetland and rocky out-crop habitat. Grassland habitat had the lowest diversity indices in the study site (Table 5.4).

**Table 5.3: Observed (Obs spp) and expected species richness based on Chao 2 and Jackknife 2 richness estimators of small mammal assemblages in wetland, grassland and rocky-outcrop at Lajuma. (%= Completeness of sampling effort, calculated as Obs spp\*100/value of the richness estimator).**

Months	Obs spp	Chao 2	%	Jackknife 2	%
Aug-10	4	4	100	4.67	86
Sep-10	6	6.25	96	7.83	77
Oct-10	8	9.33	86	11.67	69
Nov-10	7	7.22	97	8.67	81
Dec-10	7	7.13	98	8.33	84
Jan-11	6	6.13	98	7.33	82
Feb-11	6	6	100	6.33	95
Mar-11	7	9	78	10.83	65
Apr-11	9	11	82	12.83	70
May-11	9	12.33	73	13.83	65
Jun-11	8	9	89	10.83	74
Jul-11	8	9.67	83	12.5	64
Aug-11	3	3	100	3.83	78

**Table 5.4: Diversity indices and evenness of small mammals in different habitats**

	Wetland	Grassland	Rocky out crop
Number of species	7	8	7
Number of individuals	185	75	125
Simpson diversity index (D)	0.7108	0.6091	0.7016
Shannon diversity index (S)	1.39	1.312	1.439
Evenness	0.5738	0.4642	0.6026



**Fig 5.1: Individual based rarefaction curves showing small mammals captured in different habitats (combined) in Lajuma from August 2010 to August 2011**

### 5.3 Small mammals recorded in different habitats

The result shows that *Rhabdomys pumilio* was the most commonly recorded species followed by *Myosorex varius* and *Crocidura mariquensis* (Table 5.5). *Rhabdomys pumilio* was common in all habitats as was *Myosorex varius*, although the latter showed a preference for wetland. *Crocidura mariquensis* showed a very strong preference for the wetland while *Dasymys incomtus* was exclusively found in the wetland. The wetland yielded the highest number of individuals with *Crocidura mariquensis* dominantly while lowest numbers of individual species were recorded in

the grassland habitat with a low number of *Crocodyra mariquensis*. The results indicate that *Micaelamys namaquensis*, *Aethomys ineptus*, *Crocodyra cyanea* and *E myurus* were exclusively found in rocky-outcrop habitats. *Lemniscomys rosalia* and *Mus minutoides* were exclusively found in grassland habitats (Table 5.5).

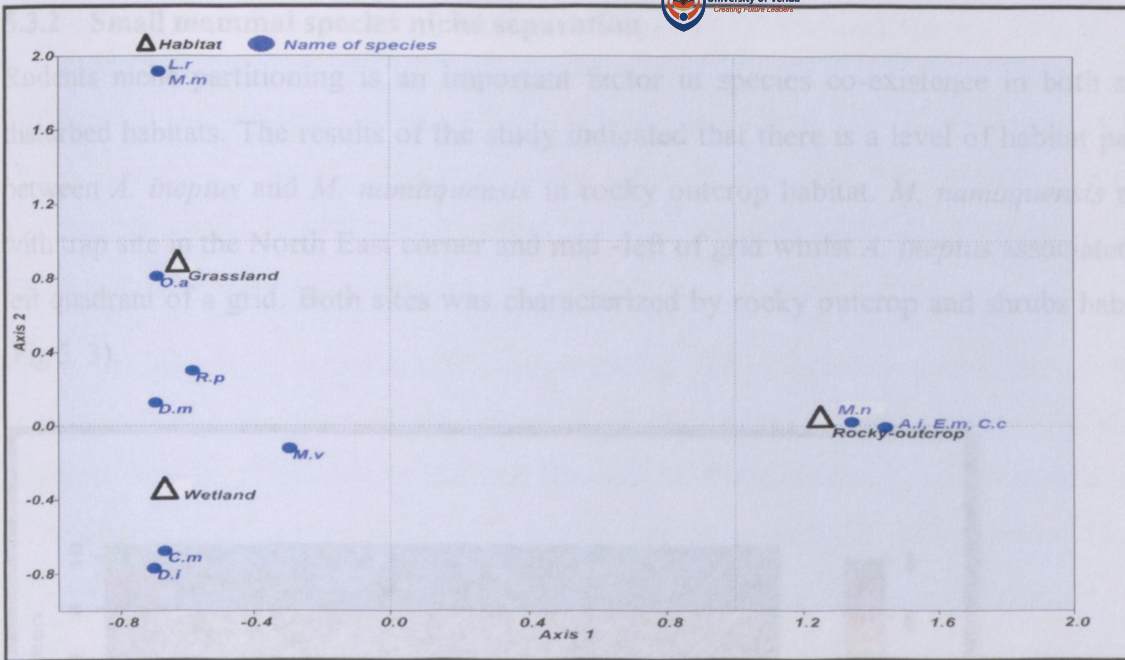
**Table 5.5: Shows Minimum Number Alive of small mammal species recorded in different habitats**

Order	Name of species	Wetland	Grassland	Rocky-outcrop	Total
Rodentia	<i>Aethomys ineptus</i>	0	0	52	52
	<i>Dasymys incomtus</i>	7	0	0	7
	<i>Dendromus mystacalis</i>	2	1	0	3
	<i>Lemniscomys rosalia</i>	0	2	0	2
	<i>Mus minutoides</i>	0	3	0	3
	<i>Micaelamys namaquensis</i>	1	1	41	43
	<i>Otomys angoniensis</i>	7	10	0	17
	<i>Rhabdomys pumilio</i>	65	44	6	115
Soricomorpha	<i>Crocodyra cyanea</i>	0	0	4	4
	<i>Crocodyra mariquensis</i>	63	2	1	66
	<i>Myosorex varius</i>	40	12	12	64
Macroscelidea	<i>Elephantulus myurus</i>	0	0	9	9
	<b>Overall Total</b>	<b>185</b>	<b>75</b>	<b>125</b>	<b>385</b>

### 5.3.1 Small mammals habitat preferences and community similarity across different habitats

The species distribution differed between habitats. *Crocodyra mariquensis* and *Dasymys incomtus* were positively associated with wetlands while *Mus minutoides* and *Lemniscomys rosalia* seemed to be associated with grassland habitat. *Aethomys ineptus*, *Micaelamys namaquensis*, *Elephantulus myurus* and *Crocodyra cyanea* were positively associated with rocky-outcrop habitat (Fig 5.2a).

The community similarity of small mammals showed a variation between habitats. There was an about 62% similarity between grassland and wetland with about 38% between the rocky-outcrop and grassland and wetland habitat (Fig 5.2b).



*A.i* (*Aethomys ineptus*), *D.i* (*Dasymys incomtus*), *D.m* (*Dendromus mystacalis*), *L.r* (*Lemniscomys rosalia*), *M.m* (*Mus minutoides*), *M.n* (*Micaelamys namaquensis*), *O.a* (*Otomys angoniensis*), *R.p* (*Rhabdomys pumilio*), *C.c* (*Crocidura cyanea*), *C.m* (*Crocidura mariquensis*), *M.v* (*Myosorex varius*) and *E.m* (*Elephantulus myurus*).

Figure 5.2a: Shows small mammal species distribution across different habitat of Lajuma

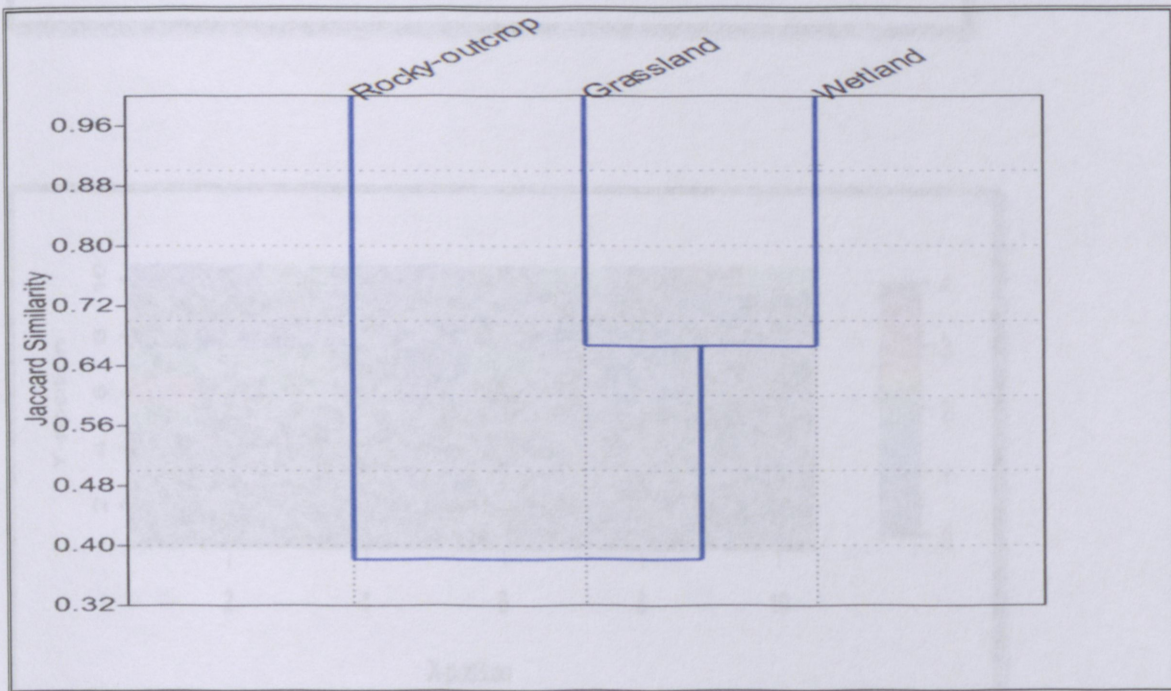


Figure 5.2b: Shows the degree of similarity between small mammal communities in different habitats of Lajuma.

### 5.3.2 Small mammal species niche separation

Rodents niche partitioning is an important factor in species co-existence in both stable and disturbed habitats. The results of the study indicated that there is a level of habitat partitioning between *A. ineptus* and *M. namaquensis* in rocky outcrop habitat. *M. namaquensis* associated with trap site in the North East corner and mid -left of grid whilst *A. ineptus* associated with top left quadrant of a grid. Both sites was characterized by rocky outcrop and shrubs habitat cover (Fig 5. 3).

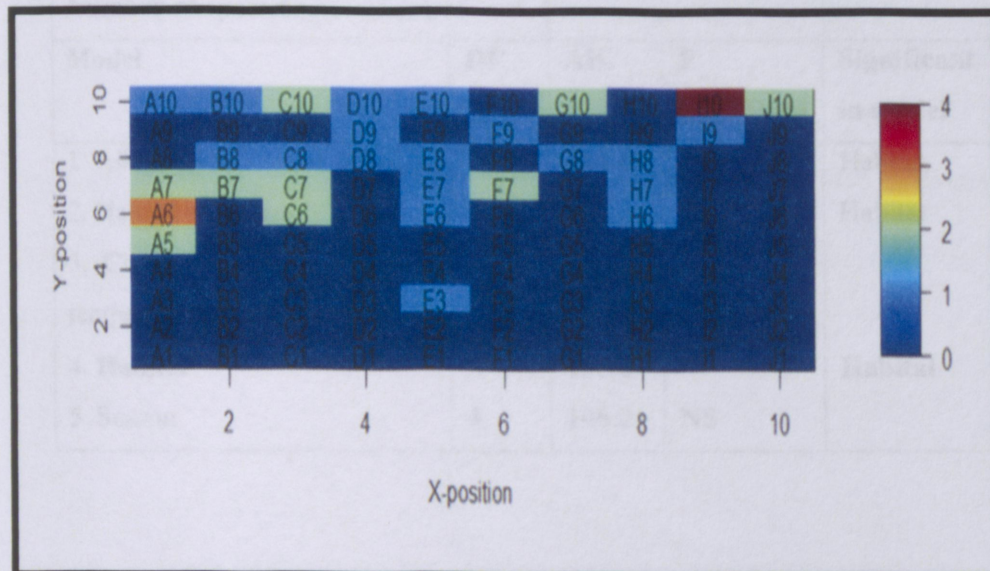
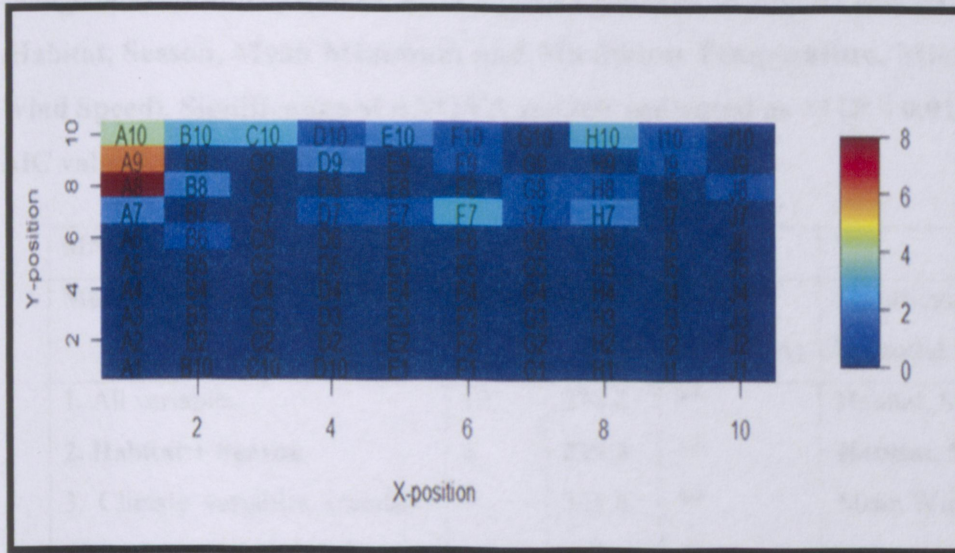


Fig 5.3: Quilt plot for *A. ineptus* (above) and *M. namaquensis* (below) in rocky outcrop

## 5.4 Environmental correlates of abundance/density (MNA) and species richness

Small mammal abundance (MNA) was significantly correlated with habitat and season and with climate variables (rainfall, temperature and wind speed) and the number of species was significantly correlated with habitat only (Table 5.6). Greatest MNA was obtained in the wetland habitat and in autumn (Figs 5.4a, b).

**Table 5.6: Akaike Information Criterion (AIC) values for five models tested to explain change in Minimum Number Alive (MNA), number of species and environmental variables (Habitat, Season, Mean Minimum and Maximum Temperature, Minimum and Maximum Wind Speed). Significance of ANOVA models indicated as \*\* ( $P < 0.01$ ). Best models (lowest AIC values) indicated in bold.**

<b>MNA</b>				
<b>Model</b>	<b>DF</b>	<b>AIC</b>	<b>P (ANOVA)</b>	<b>Significant variable terms in model</b>
1. All variables	12	234.2	**	Habitat, Season
<b>2. Habitat + Season</b>	<b>6</b>	<b>229.8</b>	**	<b>Habitat, Season</b>
3. Climate variables (rainfall, temperature, wind speed)	7	321.6	**	Mean Wind Speed
4. Habitat	3	268.2	**	Habitat
5. Season	4	303.2	**	Season
<b>Number of species</b>				
<b>Model</b>	<b>DF</b>	<b>AIC</b>	<b>P (ANOVA)</b>	<b>Significant variable terms in model</b>
1. All variables	12	146.8	**	Habitat
2. Habitat + Season	6	139.3	**	Habitat
3. Climate variables (rainfall, temperature, wind speed)	7	150.0	NS	
<b>4. Habitat</b>	<b>3</b>	<b>135.6</b>	**	<b>Habitat</b>
5. Season	4	146.2	NS	

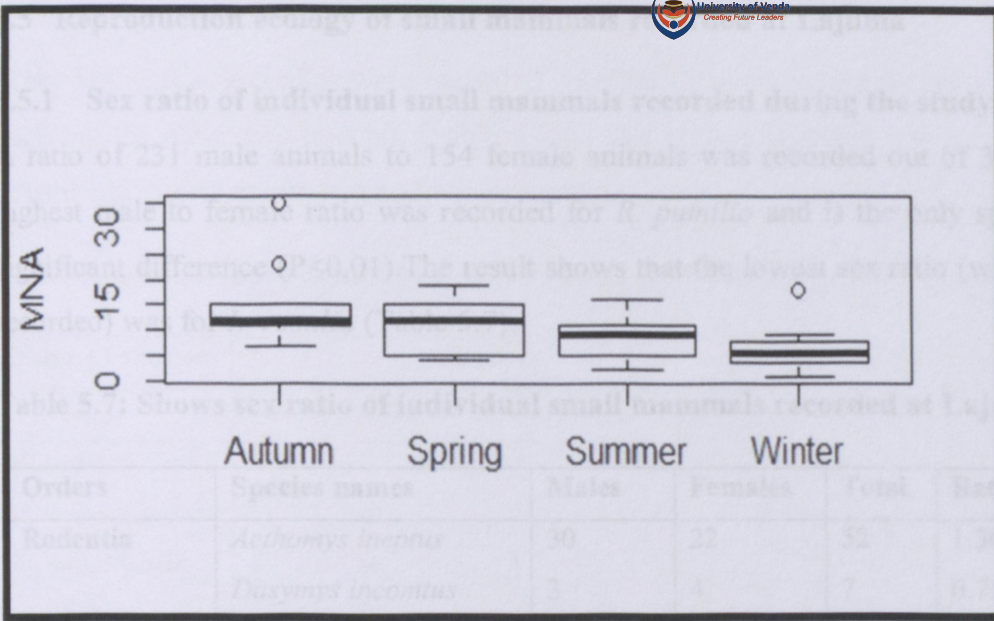


Figure 5.4a: Shows small mammal Minimum Number Alive recorded in different seasons

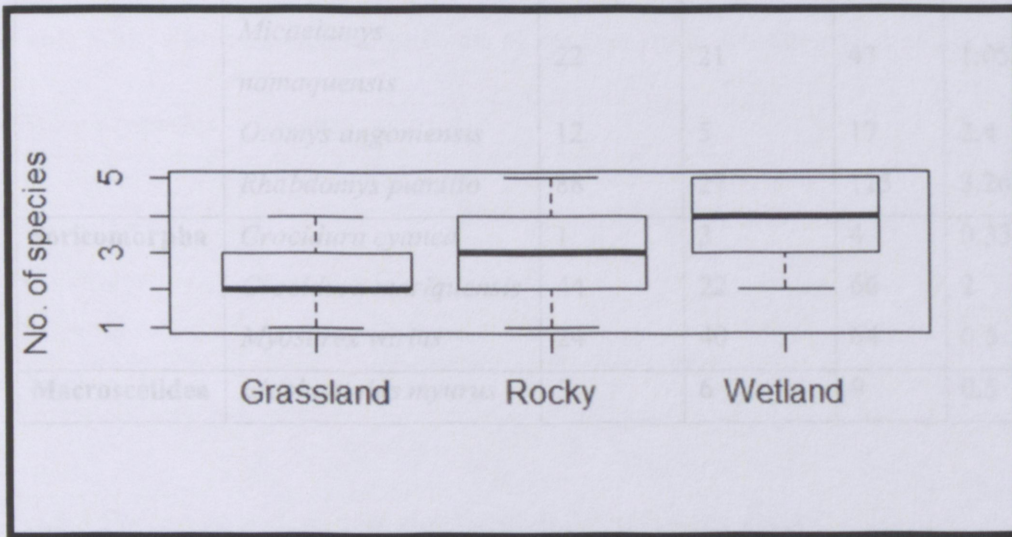


Figure 5.4b: Shows the mean number of small mammal species (over 40 trapping nights) recorded in different habitats.

## 5.5 Reproduction ecology of small mammals recorded at Lajuma

### 5.5.1 Sex ratio of individual small mammals recorded during the study

A ratio of 231 male animals to 154 female animals was recorded out of 385 specimens. The highest male to female ratio was recorded for *R. pumilio* and is the only species that shows a significant difference ( $P < 0.01$ ). The result shows that the lowest sex ratio (where no males were recorded) was for *L. rosalia* (Table 5.7).

**Table 5.7: Shows sex ratio of individual small mammals recorded at Lajuma**

Orders	Species names	Males	Females	Total	Ratio	P(value)
<b>Rodentia</b>	<i>Aethomys ineptus</i>	30	22	52	1.36	0.55
	<i>Dasymys incomtus</i>	3	4	7	0.75	1
	<i>Dendromus mystacalis</i>	3	0	3	0	0.42
	<i>Lemniscomys rosalia</i>	0	2	2	0	1
	<i>Mus minutoides</i>	1	2	3	0.5	1
	<i>Micaelamys namaquensis</i>	22	21	43	1.05	1
	<i>Otomys angoniensis</i>	12	5	17	2.4	0.3
	<i>Rhabdomys pumilio</i>	88	27	115	3.26	0.001
	<b>Soricomorpha</b>	<i>Crocidura cyanea</i>	1	3	4	0.33
<i>Crocidura mariquensis</i>		44	22	66	2	0.07
<i>Myosorex varius</i>		24	40	64	0.6	0.21
<b>Macroscelidea</b>	<i>Elephantulus myurus</i>	3	6	9	0.5	0.64

### 5.5.2 Population structure and breeding season of the most common small mammal species recorded at Lajuma during the study

#### 5.5.2.1 Rodent juveniles recorded during the study

The highest number of juvenile rodents recorded for the whole trapping period was for *Rhabdomys pumilio* and the lowest number of juveniles was recorded for *Otomys angoniensis*. The overall result indicated that the peak of rodent juveniles were recorded in autumn and winter and the lowest number was recorded in summer (Table 5.8a).

### 5.5.2.2 Shrews juveniles recorded during the study

Very few shrew juveniles were recorded (two for *C. mariquensis* recorded in spring) and one each for the other two species (Table 5.8b). The highest number was recorded during spring season and lowest in autumn and winter season.

**Table 5.8a: Shows seasonal pattern of rodents juveniles recorded at Lajuma**

Name of species	Season			
	Spring	Summer	Autumn	Winter
<i>A. ineptus</i>	3	0	3	3
<i>A. namaquensis</i>	2	4	5	1
<i>O. angoniensis</i>	1	0	1	1
<i>R. pumilio</i>	2	2	16	17
<b>Total</b>	<b>8</b>	<b>6</b>	<b>25</b>	<b>22</b>

**Table 5.8b: Shows seasonal pattern of shrews juveniles recorded at Lajuma**

Name of species	Season			
	Spring	Summer	Autumn	Winter
<i>C. cyanea</i>	0	0	1	0
<i>C. mariquensis</i>	2	0	0	0
<i>M. varius</i>	0	0	0	1
<b>Total</b>	<b>2</b>	<b>0</b>	<b>1</b>	<b>1</b>

### 5.5.2.3 Perforate rodent females recorded during the study

Perforated rodent females were recorded for *R. pumilio*, *A. ineptus* and *M. namaquensis*. The highest number of perforated females was recorded for *R. pumilio* during winter season while *A. ineptus* and *M. namaquensis* occurred in spring. The overall results indicate that the major perforated period of the rodent species was in spring season and lowest number of perforated females recorded in autumn season (Table 5.9).

### 5.5.2.4 Lactating rodent females recorded during the study

The highest number of lactating *M. namaquensis* was recorded in summer and spring season whereas *A. ineptus* and *R. pumilio* were recorded during spring season and lactating *O.*

*angoniensis* females was recorded in winter season. The overall results indicate that spring season is the major lactating period of the rodent species with a limited number of lactating females in winter months (Table 5.9).

### 5.5.2.5 Rodent scrotal males recorded during the study.

The highest number of scrotal males was recorded for *R. pumilio* in autumn season whereas the highest number for *A. ineptus* and *M. namaquensis* was recorded in spring season and the lowest number of scrotal males was recorded for *M. minutoides* during winter season. The overall results indicate that rodent scrotal males were recorded in all season but highest in autumn and lowest in summer season (Table 5.9).

**Table 5.9: Shows seasonal reproduction patterns of small mammals**

Name of species	Reproductive status											
	Perforated females				Lactating females				Scrotal males			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
<i>A. ineptus</i>	3	0	1	1	3	2	1	2	9	6	6	4
<i>M. namaquensis</i>	3	1	0	0	2	2	1	0	7	6	3	1
<i>R. pumilio</i>	2	2	1	3	4	1	1	0	15	10	36	18
<i>D. incomtus</i>	0	0	0	0	0	0	1	0	0	0	1	2
<i>M. minutoides</i>	0	0	0	0	0	0	1	0	0	0	0	1
<i>O. angoniensis</i>	0	0	0	0	0	1	1	2	3	4	2	2
<b>Total</b>	<b>8</b>	<b>3</b>	<b>2</b>	<b>4</b>	<b>9</b>	<b>6</b>	<b>6</b>	<b>4</b>	<b>34</b>	<b>26</b>	<b>48</b>	<b>28</b>

## 6.1 Discussion

### 6.1.1 Trap success and abundance (MNA) of small mammals recorded at Lajuma

The results of the study indicate that there were more recaptured animals than newly captured animals. There was a monthly variation in the total number of small mammals captured during the study. These findings are in line with the study done by Monadjem (1999) who observed lower number of small mammals captured than recaptured in Swaziland and there was low capture rate of *O. angoniensis*. The dominant species in Swaziland are *L. rosalia*, *D. mystacalis* and *M. minutoides* (Monadjem and Perrin 2003).

The trap success varied significantly between months and season. The lowest trap success of 7.7% was in August 2010 (winter) and the highest of 36.7% was in April and May 2011 (autumn), giving the mean trap success of 23.6% as indicated in Table 5.1. This value is high, relative to other studies, and this probably indicates a productive environment. Breeding site causes high trap success due to juvenile recruitment during autumn. The lowest trap success during winter season may be attributed to a decreased density of species as a result of migration and mortality due to lack of food and other resources. Avenant (1997, 2011) reported lowest trap success of small mammals during spring and summer season at Willem Pretorius Nature Reserve; Korannaberg Conservancy, Sandveld Nature Reserve, Tussen-die-Riviere Nature Reserve and Caledon Nature Reserve.

Lowest trap success in winter was also found by Demeke et al. (2007) and Tadesse et al. (2008) who both recorded low trap success of small mammals during winter in Ethiopia. The result of this study is in contrast with the study by Wirminghaus (1990) who found that small mammal abundance peaked in autumn and early to mid-winter in the Free State grassland and Kwazulu Natal forest of South Africa. This study is supported by Massawe et al. (2008) who found that *M. minutoides* had less trap success in Tanzania and Monadjem and Perrin (1997) who recorded lowest number of *M. minutoides* during winter and high in autumn season in Swaziland. The bait type has also had influence on trap success. Demeke et al. (2007) suggested that the oily nature of peanut butter attracted ants to the traps and caused disturbance the trapping success of small mammals during the wet season.

## 6.1.2 Small mammals habitat preferences and community similarity across different habitats



Habitat preference of small mammals depends on a combination of several factors one of which is vegetation cover (Monadjem and Perrin 1998). Habitat preferences are related to foraging efficiencies (Bowland and Perrin 1993) and are reflection of species nutritional needs (Lancaster 2009). In areas with strong seasonality, micro habitat features are major factors which govern the composition and abundance of rodents in a given habitat (Lin and Batzli 2001, cited in Takele et al. 2011). Structural changes in vegetation characteristics are important determining factors of habitat for small mammals (Yarnell et al. 2007).

Small mammal communities may be composed of species that vary from having narrow habitat requirements (specialist) to very broad habitat requirements (generalist) (Lancaster 2009). As predicted, different small mammal species were associated with different habitats. As found by many authors (e.g. Pillay et al. (2003); Schradin and Pillay, 2003). *R. pumilio* was a habitat generalist in our study. Wetland specialists included *D. incomtus*, and *C. mariquensis* has supported by Skinner and Chimimba (2005).

Rocky-outcrop specialists in this study were *E. myurus* Both *M. namaquensis* and *A. ineptus*. However, the latter species occurs more broadly in savanna habitats including areas without rocks (Chimimba and Chimimba 2008; Gaigher 2006, unpublished data). Even within the grid, *M. namaquensis* and *A. ineptus* were often found in different trap sites indicating niche separation. *O. angoniensis* preferred wetland but was also found in grassland, which is typical of a savanna species associated with wetlands in savannas (Pillay et al. 1993).

The wetland had a high number of species with *M. mariquensis* being the most common, while low numbers of individual species was recorded in the grassland habitat with a low number of *M. namaquensis* and *Dendromus mystacalis*. The further investigation indicate that *A. ineptus*, *C. cyanea* and *E. myurus* are rocky-outcrop habitat specialists, and *L. rosalia* and *M. minutoides* are grassland specialist while *M. varius* and *C. mariquensis* are commonly found in all habitats (Table 5.5). Mulungu et al. (2008) recorded lowest trap success in grassland habitat and high trap success in shrubs habitat in Tanzania. Rajska-Jurgiel (1992) reported that the species composition of small mammals on grassland differs from those in the forest.

Nupp and Swihart (2000) reported that *R. pumilio* was the most abundant species in the Mount Elgon National Park. Lacey and Solomon (2003) suggested that the high abundance of *R. pumilio*

in some areas might be due to the fact that this species is very flexible and can adapt to the environmental changes.

Wirminghaus (1990), Pretorius et al. (2004) and Newbery (1999) reported that the abundance of *R. pumilio*, *M. namaquensis* and *A. Ineptus* was correlated with rains throughout their distribution range. These species occupy a wide variety of habitat types. They are found on the outskirts of the forest, grassland, and shrubs (Mills and Hes 1997; Schradin and Pillay 2003, 2005). Skinner and Chimimba (2005) have observed that *A. ineptus* and *M. namaquensis* natural habitats are temperate forests, shrub land, and grassland. Van der Merwe (1999) and Armstrong and Van Hensbergen (1996) have reported that they prefers habitat with substantial cover, shrubs and rocky outcrops.

*Otomys angoniensis* was found in wetland habitat and several authors (Skinner and Smithers 1990; Mills and Hes 1997; Taylor 1998; Siegfried and Brown 1992, Musser and Carleton 2005) reported that their natural habitat is savanna, grassland and swampy area, sedges and on the edge of permanent water sources. *Dasymys incomtus* was recorded in wetland and the result is in line with Muller and Erasmus (1995) during their study in a wetland habitat in South Africa.

*L. rosalia*, *M. minutoides*, *D. mystacalis* and *E. myurus* had the lowest relative abundance (Table 5.2) and this may be due to the lack of food resource replenishment which lowers winter carrying capacity. Avenant and Cavallin (2007) reported that *D. mystacalis* and *L. rosalia* were found in areas covered by vegetation. *M. minutoides* was observed in grassland and these findings are in line with Mills and Hes (1997), Stuart (2001) and Mugatha (2002) who also observed this species in grassland, forest, woodland and areas of bare ground rock.

Shrews occur in a wide range of habitats which include moist forest, wetland, marshes and woodland (Nicoll and Rathbun 1990; Skinner and Smither 1990; Siegfried and Brown 1992; Skinner and Smithers 1990). Further studies have revealed that *Crocidura* species show preferences to dry savanna Nicoll and Rathbun (1990). *C. cyanea* and *C. mariquensis* are mostly found in marshy ground grass, wetlands and rocky areas in South Africa (Fuller and Perrin 2001; FitzGibbon et al. 2008).

*C. mariquensis* and *M. varius* were the most dominant shrew species existing in all the three types of habitats. This may be due to the fact that *M. varius* has a wide habitat preference (Mills and Hes 1997; Skinner and Smithers 1990). *M. varius* was recorded in moist, densely vegetated areas,

ranging from forest to grassland of inland South Africa it prefers moist conditions with dense grass cover (Rautenbach 1982, cited in Skinner and Chimimba 2005; Skinner and Smithers 1990) and is also highly dependent on permanent water on the Highveld (Mills and Hes 1997). *E. myurus* is known to occur in a wide range of habitats including rocky out crop, savanna, desert, strewn outcrops, thick forest, and thorn bush (Mills and Hes 1997; Perrin et al. 2008).

### 6.1.3 Species niche separation

Habitat complexity may provide more niches that could be exploited by several species of rodent. Niche partitioning may occur if there is not sufficient ecological space for organisms to expand into. *A. ineptus* preferred areas with vegetation cover within the rocky out-crop while *M. namaquensis* showed greater preference for rocky out crop. Habitat selection, dispersion and inter-specific competition are the most important factors influencing the co-existence of species. The distinct patterns of spatial and temporal habitat preferences provided the main mechanism of co-existence.

The result of the study is also supported by Kelt et al. 2004 who reported that small mammal's partition niches, specifically according to habitat and resources. Baker (2011) reported that biotic and abiotic factors influenced species niche and co-existence.

### 6.1.4 Small mammals species richness and diversity

Small mammal species richness is related to variables such as habitat structure and complexity, area, rainfall, productivity, predation and the distance between similar habitats (Lambert et al. 2006). It has been observed that vegetation can be a contributing factor (Andrews and O'Brien 2000; Kerly 1992). Van Deventer and Nel (2006) reported that species richness of small mammals is significantly correlated with shrub cover in Namaqualand, South Africa. Mares (1997) recorded high species richness in Namib Desert.

Our study showed grassland to have a lower diversity (S and D) compared to wetland and rocky outcrops due to relative domination by one species (*R. pumilio*) compared to others. In wetland and rocky habitats, two or three species dominate (*C. mariquensis*, *M. varius* and *D. incomtus*). As species diversity was not calculated per session or modelled it is not discussed further, diversity values were comparable with studies by Monadjem and Perrin (2002). The results of this study indicated relatively high number of small mammal species (12 species, compared to values of seven species reported by Kok et al. 2011 for other studies of montane southern African small mammal communities conducted at Mountain Zebra National Park.

Individual-based rarefaction curves shown in Figure 5.1 indicated that observed and expected species richness of small mammals was highest in April and May 2011 (autumn season) and lowest in August 2011 (winter season) but seasonal differences in richness were not statistically significant (Table 5.6). Nevertheless, higher species richness in autumn was also found in Swaziland by Monadjem, (1997, 1998) and Avenant et al. (2008). Following studies in the high-altitude grassland of the Free State of South Africa and small mammal species richness and diversity were low during summer months (Avenant 2000a). Similar results of high small mammal's species richness and diversity were obtained during summer season by Fuller and Perrin (2001) in Kwa-Zulu Natal, South Africa.

In Korannaberg conservancy there was high species diversity during the period of mid-autumn and early winter (Avenant 2000b). Avenant (2000a 2011) observed high species diversity and richness in autumn in Willem Pretorius nature reserve in the Free State province. The work done by Orland and Kelt in 2005 revealed that availability of food and ground cover may be the cause of high species richness in autumn season (Orland and Kelt et al. 2005). Slabova et al. (2008) observed that limited resource availability leads to reduction in species richness or evenness of small mammals communities. Species diversity reflects the quality and functionality of a landscape.

Angelici and Luiselli (2005) indicated that species richness is a function of different distribution patterns of individual members of taxa within their distributional ranges. Rahbek and Graves (1999) and Botes et al. 2006) reported that species richness gradients are affected by a combination of biotic and abiotic factors. Richness of small mammals varied significantly between habitats (Table 5.6). Caro (2001) found increase in rodent species richness in the farmland during the dry season at Katavi National Park in Tanzania. Species richness may also be due to climatic variations, for example, increased temperature and rainfall were positively correlated with increased richness of small mammal species (Leirs et al. 1996; Morrison et al. 2002). But in our study we did not find any significant influence of rainfall or temperature on species richness throughout the year (Table 5.6).

#### **6.1.5 Environmental correlates of abundance/density (MNA)**

Climatic conditions can result in extreme fluctuation in population of small mammals. Small mammals show increased abundances with an increase in habitat features such as cover (Lambert et al. 2006). In our study, the best model (lowest AIC) included the predictor variables, habitat



and season; greatest MNA was obtained in the winter (Table 5.6; Figs 5.3 a, b, c). During autumn there is high species abundance as a result of juvenile's recruitment. Abiotic factors such as the timing and quantity of rain may trigger peaks in small mammal abundance (Takele et al. 2011).

The model which included climate variables (rainfall, temp, wind speed) was also significant although it was not the best model. As expected MNA was lowest in winter when food availability would be expected to be low due to cold weather conditions. Monadjem and Perrin (2003) recorded highest abundance of *M. minutoides* and *L. rosalia* in winter months and low numbers in autumn in Swaziland. Small mammal abundance in a habitat can be an important indicator of habitat quality (Kiwia 2006). Monadjem (1999) reported that *M. minutoides* population responded to vegetation changes in Swaziland and it was lowest in winter season

Season also appears to influence small mammal community response to the habitat as measured by the model (Table 5.6). During the winter and spring season the model estimate lower species richness and higher in summer and autumn. Rainfall is a primary determinant of population size in small mammals in Africa as it affects food production (Van Hensbergen and Martin 1993; Monadjem and Perrin 1998b; Keesing, 1998; Letnic 2003; Constantine et al. 2004; Massawe et al. 2011; Witecha 2011; Takele et al. 2011).

Geleta et al. (2011) reported that the soil structure, types and the properties of soil are very important in rodent population ecology. Small mammal population is sensitive to habitat changes (Avenant 1996) and habitat changes may reduce small rodent abundance (Keesing 1998). Makundi et al. (2005) observed that rodent populations show great seasonal and year to year variation and Mugabe (2008) observed more rodents during autumn in Western Cape. Wirminghaus (1990) observed high *M. natalensis* abundance in KwaZulu-Natal, South Africa, during early dry season.

Nicolas et al. (2009) observed that shrew abundance varies among habitats and their availability in the microhabitats depend on resource availability (Castien and Gosalbez 1999). Shrew abundance is related to territorial, aggression and home ranges (Freeman 2008). Nicolas (2009) has observed that shrew abundance varies among habitats. The disturbed grassland has the highest numbers of small shrews such as *C. mariquensis* (Perrin 1995). Shrew abundance is higher in winter than in summer. This is surprising because food supply and plant cover increase in the wet

season. Little is known with regard to the population of *myurus* as it fluctuates naturally due to climatic factors such as rainfall (Skinner and Chimimba 2005).

## 6.1.6 Reproduction ecology of small mammals

### 6.1.6.1 Rodents seasonal reproduction pattern

Most small mammals from southern Africa breed in summer (Skinner and Chimimba 2005). Important factors contributing to reproduction are ambient temperature, rainfall, food availability and availability of breeding site (Perrin et al. 1992; Makundi 1995; Perrin and Monadjem 1998; Perrin and Boyer 2000; Muteka et al. 2006a; Mugabe 2008, Rathbun 2009; Massawe et al. 2008; Medger et al. 2012b).

Our data shows that for four species for which we had sufficient data, reproduction (based on presence of scrotal males and lactating females) was not restricted to spring and summer as expected but occurred throughout the year. The highest sex ratio for *R. pumilio* may be explained by the fact that this species is opportunistic in nature. Yarnell and Scott (2006) and Monadjem (1999) reported that any small mammal species in South Africa has a sex ratio that approximates 1:1 although Monadjem (1997) found that the sex ratio of *L. rosalia* population is skewed towards males.

The highest number of males in *R. pumilio* may be due to the fact that males are more likely to enter the traps than females because males may be more active and therefore have higher chances of being captured. This discrepancy could also be attributed to their larger home ranges. This result is in line with the study conducted by Geleta et al. (2011) in Komto protected forest Ethiopia where more males than females were recorded.

The overall results indicate that the major perfoating period for rodent females was in spring season and lowest number was recorded in autumn season (Table 5.9). The major lactating period of the rodent species was during spring season with a limited number of lactating females in winter season (Table 5.9).

In Southern Africa, perfoating and lactating rodent females were captured between Augusts and May (Skinner and Chimimba 2005). It may be due to the fact that rodents become reproductively active in different season differing with species and year. In Southern Africa breeding is interrupted during mid-winter (June and July). Monadjem and Perrin (2003) reported that rodents become reproductively active between the months of September and May in Swaziland grassland.

Rodent lactation is also influenced by resource and climatic factors (Kerley et al. 1990). Skinner and Chimimba (2005) have indicated that seasonal changes in quality and availability of food determine food preferences and control the timing of breeding of small mammals.

Caro (2001) reported the highest percentage of species with the lactating females in the dry season. The result of my study is not in line with studies done by Phillips et al. (1997) who reported that In Kenya, *O. angoniensis* breeding continues throughout the year with peak in wet months. Chimimba and Linzey (2008) observed that *Aethomys* species become reproductively active during summer season in Mozambique.

The overall result indicated that greater numbers of rodent juveniles were recorded during autumn season and the lowest number recorded during summer season (Table 5.8a). Rodents produce higher number of litters during a single season than the Sengis (Neal 1995). Demeke et al. (2007) recorded higher numbers of juveniles during the wet season than the dry season in Ethiopia. This confirms that the reproductive period of most rodents occurs during the wet season.

The highest numbers of rodents juveniles recorded for the whole trapping period was for *R. pumilio* and the lowest number was for *O. angoniensis* (Table 5.8a). According to Bronner and Meester (1988) there is a variation in litter size of *O. angoniensis* and usually it has a maximum of four young and they produce litters during the period of maximum rainfall.

#### 6.1.6.2 Shrew seasonal reproduction pattern

The highest number of shrew juveniles was recorded in spring season and lowest in winter and autumn season (Table 5.9b). The highest numbers of shrew juveniles recorded for the whole trapping period was for *C. mariquensis* and the lowest for *M. varius* and *C. cyanea*.

Shrews have distinct breeding seasons. They breed in August, and September, which correspond to the warm and wet months in Southern Africa. *Crocidura* also mostly give birth during the wet summer months but in some areas in cooler months (Stuart and Stuart 2007). *Crocidura cyanea* gives birth during warm, wet summer months and spring season in Free State and Kwa-Zulu natal provinces (Taylor 1998, cited in Skinner and Chimimba 2005). Lactating females of *Crocidura mariquensis* were observed during summer season in the former Transvaal (Rautenbach 1982, cited in Skinner and Chimimba 2005).

*Myosorex varius* is a seasonal breeder with peak reproduction during summer (Stuart and Stuart, 2007). This species is known to be a seasonal breeder and its breeding season is the wet season.

Pregnant females have been collected during the summer season in the KwaZulu-Natal Drakensberg (Skinner and Chimimba 2005). In the former Transvaal it also breeds during the summer season (Rautenbach, 1982 cited in Skinner and Chimimba 2005).

The breeding season of Sengis, especially *E. myurus* in southern Africa is summer, with minimal breeding in winter (Ribble and Perrin 2006). It has been reported that the breeding period of *E. myurus* is warm-wet season in Zimbabwe (Neal 1995).

Trap success increased in summer due to reproduction and declined again towards winter due to mortality. There was high trap success in April and May 2011. An ecological disturbance of the habitat is often associated with decrease in small mammal abundance during winter. The geographical position of the study area and the diversity of its natural habitat types provide conditions to maintain a high species richness. Small terrestrial mammals obviously play a very important ecological role in this environment.

Communities were different in each habitat type in terms of species composition and relative abundance. *R. pumilio* and *M. varius* are generalists and *A. inepus*, *C. cynosura* and *E. myurus* are rocky out-crop specialists. *L. rosalia* and *M. similis* are grassland specialists, and *C. marquetensis* and *D. incanus* are wetland specialists. The highest species richness occurred in the wetland habitat showing how important this habitat type is for terrestrial mammals.

The results indicated that small mammal diversity changes with change in habitat. Some habitats will have higher diversity than others due to their differences in microhabitats and also due to the animals' habitat preferences. Generalized Linear Models revealed a positive correlation between small mammal minimum number alive and season but not with rainfall, temperature, wind speed and humidity. Season was found to determine the change in species diversity, richness and abundance that occur in the habitat series from wetland, grassland to rocky-outcrop.

Classification of the habitat by cluster analysis revealed a higher degree of similarity between wetland and grassland than rocky-out-crop. The population of *Thomomys pumilio* was characterized by more males than females. This will have negative impacts on the reproduction cycle at the study site. This study also showed the possible role that commensals play in the conservation of small mammals and the functionality of complete ecosystems.

The findings of this study indicates that small mammal's diversity changes with change in habitat and shows a relationship between small mammal's abundance and habitat type. Habitat selection, dispersion and inter-specific competition are the most important factors influencing the co-existence of species. Habitat complexity and climatic conditions were expected to increase abundance and diversity of small mammals in summer. The distinct patterns of spatial and temporal habitat preferences provided the main mechanism of co- existence.

Trap success increased in summer due to reproduction and declined again towards winter due to mortality. There was high trap success in April and May 2011. An ecological disturbance of the habitat is often associated with decrease in small mammal abundance during winter. The geographical position of the study area and the diversity of its natural habitat types provide conditions to maintain a high species richness. Small terrestrial mammals obviously play a very important ecological role in this environment.

Communities were different in each habitat type in terms of species composition and relative abundance. *R. pumilio* and *M. varius* are generalists and *A. ineptus*, *C. cyanea* and *E. myurus* are rocky out crop specialists. *L. rosalia* and *M. minutoides* are grassland specialists, and *C. mariquensis* and *D. incomtus* are wetland specialists. The highest species richness occurred in the wetland habitat showing how important this habitat type is for terrestrial mammals.

The results indicated that small mammal diversity changes with change in habitat. Some habitats will have higher diversity than others due to their difference in microhabitats and also due to the animals' habitat preferences. Generalized Linear Models revealed a positive correlation between small mammal minimum number alive and season but not with rainfall, temperature wind speed and humidity. Season was found to determine the change in species diversity, richness and abundance that occur in the habitat series from wetland, grassland to rocky-outcrop.

Classification of the habitat by cluster analysis revealed a higher degree of similarity between wetland and grassland than rocky out-crop. The population of *Rhabdomys pumilio* was characterized by more males than females. This will have negative impacts on the reproduction cycle at the study site. This study also showed the possible role that conservancies play in the conservation of small mammals and the functionality of complete ecosystems.

### 6.3 Recommendation



Biodiversity of small mammals can be used as an indicator of disturbance in an ecosystem because small mammals are abundant and their community characteristics can reflect ecological disturbance. The high diversity obtained within the present study suggests that Lajuma has a high diversity of small mammals and therefore a high diversity of other animal species (predators and other animals from higher trophic levels).

Preparation of voucher specimens, analysis of soil and habitat variable at various sites will provide useful baseline data on small mammals ecology. The continuous placement small mammal traps in rocky out-crop habitats will provide useful information about the reproduction of *Sengis* species.

Further studies should focus on *Aethomys* identification and their species niche separation. There is also a need to generate a model to understand and support the morphometric distinctions within *Aethomys*. Genetic studies should be conducted to explore genetic drift process among the *Aethomys* species.

Furthermore, a study focused on predation, diseases and population dynamics of small mammals will aid in understanding of the population status of small mammals recorded in Lajuma research centre. Because small mammals are basal to many food webs, further studies focused on species with more restricted habitat requirement would be very useful for understanding, monitoring and managing of the study site. It is important to conserve this area as it is a biodiversity hotspot and it can be used for monitoring biodiversity changes due to global climate change. In this study there were no indicator species such as *Mastomys* recorded during the study. In a nutshell Lajuma is a biodiversity hotspot and has a high conservation value.

## REFERENCES



- Andrews, P. & O'Brien, E.M., 2000. Climate, vegetation, and predictable gradients in mammal species richness in Southern Africa. *Journal of Zoology* 251: 205-231.
- Angelici, M.A. & Luiselli, L., 2005. Patterns of specific diversity and population size in small mammals from arboreal and ground-dwelling guilds of a forest area in southern Nigeria. *Journal of Zoology* 265: 9-16.
- Armstrong, A.J. & Van Hensbergen, H.J., 1996. Small mammals in Afforestable montane grassland of the Northern Eastern Cape Province, South Africa. *South African Journal of Wildlife Research* 26: 11-17.
- Avenant, N.L., 1996. Identification and distribution of two *Mastomys* species in Lesotho and part of South Africa. *Navorsing van die Nasionale Museum, Bloemfontein* 12: 49-58.
- Avenant, N.L., 1997. Mammals recorded in the QwaQwa National Park (1994-1995). *Koedoe* 40: 31-40.
- Avenant, N.L., 2000a. Small mammal community characteristics as indicators of ecological disturbance in the Willem Pretorius Nature Reserve, Free State, South Africa. *South African Journal of Wildlife Research* 30: 26-33.
- Avenant, N.L., 2000b. Terrestrial small-mammal diversity in Korannaberg Conservancy, Free State, South Africa. *Navorsing van die Nasionale Museum, Bloemfontein* 16: 69-82.
- Avenant, N.L., 2011. The potential utility of rodents and other small mammals as indicators of ecosystem 'integrity' of South African grasslands. *Wildlife Research* 38: 626-639.
- Avenant, N.L. & Cavallini, P., 2007. Correlating rodent community structure with ecological integrity, Tussen-die-Riviere Nature Reserve, Free State Province, South Africa. *Integrative Zoology* 2: 212-219.
- Avenant, N.L., Watson, J.P., & Schulze, E., 2008. Correlating small mammal community characteristics and ecosystem integrity in the Caledon Nature Reserve, South Africa. *Mammalia* 72: 186-191.
- Baker, M.A.A., 2011. Cape to Cairo: Habitat selection and community structure of South African and Egyptian small mammals. PhD theses, University of Illinois at Chicago.

Downloaded on 29 July 2007.

Baxter, R.M., 2004. *Myosorex cafer*, 2006. IUCN Red list of threatened species. Downloaded on 30 July 2006.

Botes, A., Mcgeoch, M.A., Robertson, H.G., Van Niekerk, A., Davids, H.P. & Chown, S.L., 2006. Ants, altitude and change in the Northern Cape Floristic Region. *Journal of Biogeography* 33: 71-90.

Bowland, J.M. & Perrin, M.R. 1993. Wetlands as reservoirs of small mammal's population in the Natal Drakensberg. *South African Journal of Wildlife Research* 23: 39-40.

Bradshaw, W.E. & Holzapel, C.M., 2007. Evolution of animal photoperiodism. Annual. Review of *Ecology, Evolution and Systematics*. 38: 1-25.

Bronner, G.N., Hoffmann, M., Taylor, P.J., Chimimba, C.T., Best, P.B., Matthee, C.A. & Robinson, T.J., 2003. A revised systematic checklist of the extant mammals of the Southern African subregion. *Durban Museum Novitiates* 28: 56-106.

Bronner, G.N. & Meester, J.A. J., 1988. *Otomys angoniensis*. *Mammalian species*, 306: 1-6.

Caro, T.M., 2001. Species richness and abundance of small mammals inside and outside an African National Park. *Biological Conservation* 98: 251-257.

Castién, E. & Gosálbez, J., 1999. Habitat and food preferences in a guild of insectivorous mammals in the Western Pyrenees, *Acta Theriologica* 44: 1-13.

Chekol, T., Afework, B. & Balakrishnan, M., 2012. Population density, biomass and habitat association of rodents and insectivores in Pawe area, North-western Ethiopia. *Tropical Ecology* 53: 15-24.

Chimimba, C.T., & Linzey, A.V., 2008. *Aethomys ineptus*. *Mammalian Species* 809:1-7.

Churchfield, S., 1990. The Natural History of Shrews. London: Christopher Helm and A. & C. Black.

Clutton-Brock, J. & Wilson D.E., 2002. Mammals. Smithsonian Handbooks. Dorling Kindersley, New York, 400 pp.

Coetzee, N. & Van der Straeten, E., 2008. *Elephantulus pumilio*, 2012. IUCN Red List of Threatened Species. Downloaded on April 25, 2012.

Colwell, R.K. 2009. Estimates: Statistical estimation of species richness and shared species from Samples. Version 8.2. User's Guide and application published at: [Http://purl.oclc.org/estimates](http://purl.oclc.org/estimates).

Constantine, N.L., Campbell, T.A., Baughman, W.M., Harrington, T.B., Chapman, B.R., & Miller, K.V., 2004 Effects of clear cutting with corridor retention on abundance richness of small mammals in the coastal plain of South Carolina, USA. *Forest Ecology and Management* 202: 293-300.

Delcros, G., 2012. The influence of abiotic processes, competition and predation on the community structure of rodents and shrews. PhD Thesis, University of KwaZulu-Natal.

Demeke, D., Afework, B. & Gurja, B., 2007. Species composition, distribution and habitat association of rodents from Arbaminch forest and farm land, Ethiopia. *African Journal of Ecology* 45: 651-657.

Efford, M., 1992. Comment- revised estimates of the bias in the minimum number alive estimator. *Canada Journal of Zoology* 70: 628-63.

Fitzgibbon, C., Perrin, M.R, & Stuart, C., 2008. *Elephantulus fuscipes*. 2008 IUCN Red List of Threatened Species, IUCN 2008 retrieved on 29 December 2008.

Freeman, A., 2009. The effects of coarse woody debris on species diversity in the boreal forest. Department of Environment and Resource Studies, University of Waterloo, Waterloo, Ontario.

Fuller, J.A. & Perrin, M.R., 2001. Habitat assessment of small mammals in the Umvoti Vlei Conservancy, KwaZulu-Natal, South Africa. *South African Journal of Wildlife Research* 31: 1-12.

Gaigher, I.G., 2006. Lajuma Environmental Research Centre, Makhado (Louis Trichardt), South Africa. Online at: <http://www.lajuma.com/>.

Geleta, M., Mamo, Y. & Afework B., 2011. Species richness, abundance and habitat preference of rodents from Komto protected forest, western Ethiopia. *Journal of Agriculture and Biological Sciences* 2: 166 -175.

Hahn, N., 2002. Endemic flora of the Soutpansberg Mountain. MSc thesis, University of Natal, South Africa.

- Hammer, Ø.H., David, A.T., & Ryan, P.D. 2001. Past: Paleontological Statistics Software Package for Education and Data Analysis. <http://palaeo-electronica.org>.
- Happold, D.C.D. & Happold, M., 1990. An ecological study of small rodents in the woodland savanna of Liwonde National Park, Malawi. *Journal of Zoology* 221: 219-235.
- IUCN, 2006. IUCN red list of threatened species. Downloaded July 2006.
- Jackson, T. & Van Aarde, R.J., 2003. Diet quality differentially affects breeding effort of *Mastomys coucha* and *Mastomys natalensis*: implications for rodent pest. *Journal of Experimental Zoology* 301A: 97-108.
- Jaroszewska, M. & Wilczynska, B., 2006. Dimension of surface area of alimentary canal of pregnant and lactating female common shrews. *Journal of Mammalogy* 87: 589-597.
- Kabanda, T.A., 2003. A first synthesis of the environmental, biological, and cultural assets of the Soutpansberg. In Macdonald, I.A.W., Gaigher, I., Gaigher, R., & Berger, K. <http://www.soutpansberg.com/workshop/synthesis/climate.htm>.
- Kasangaki, A., Kityo R. & Kerbis, J., 2003. Diversity of rodents and shrews along an elevational gradient in Bwindi impenetrable national park, South Western Uganda. *African Journal of Ecology* 41: 115-123.
- Keesing, F. 1998. Impacts of ungulates on the demography and diversity of small mammals in Central Kenya. *Oecologia* 116:381-389.
- Kelt, D.A., Wilson, J.A. & Konno, E.S., 2005. Differential response of two kangaroo rats (Dipodomys) to the 1997-1998 EL NINO southern oscillation events. *Journal Mammalogy* 86: 265-274.
- Kerley, G.I.H., Knight, M.H. & Erasmus, T., 1990. Small mammal microhabitat use and diet in Zululand (KwaZulu-Natal), South Africa. *South African Journal of Wildlife Research* 31:127-134.
- Kingdon, J., 1997. The Kingdon Field Guide to African Mammals. Academic Press, London.
- Kiwia, H., 2006. Species richness and abundance estimates of small mammals in Zaraninge coastal forest in Tanzania. *Tanzanian Journal of Science* 32: 52-60.

Kok, A.D., Parker, D.M. & Barker, N.P., 2011. Life on high: the diversity of small mammals at high altitude in South Africa. *Biodiversity and conservation* 21: 2823-2843.

Lacey, E.A. & Solomon G.N., 2003. Social biology of rodents: trends, challenges, and future directions. *Journal of Mammalogy* 84: 1135-1140.

Lambert, T.D., Malcolm, R.J. & Zimmerman, B.L., 2006. Amazonian small mammal's abundance in relation to habitat structure and resource abundance. *Journal of Mammalogy* 87: 766-776.

Lancaster, J.L., 2009. Population and life characteristics of coexisting small mammal's species in a grassland habitat. PhD Thesis, University of Witwatersrand.

Leirs, H., Verhagen, R., Verheyen, W., Mwanjabe, P. & Mbise, T., 1996. Forecasting rodent outbreaks in Africa: an ecological basis for *Mastomys* control in Tanzania. *Journal of Applied Ecology* 33:937-943.

Letnic, M., 2003. The effects of experimental patch burning and rainfall on small mammals in the Simpson Desert, Queensland. *Wildlife Research* 30: 547 - 563.

Linn, I.J., 1991. Influence of 6 Methoxyben zoxazolinone and green vegetation on reproduction of the multimammate rat (*Mastomys coucha*). *South African Journal of Wildlife Research* 21: 33-37.

Linn, Y.K. & Batzli, G.O., 2001. The influence of habitat quality on dispersal, demography and population dynamics of voles. *Ecological Monographs* 71: 245-257.

Linzey, A.V. & Kesner, M.H., 1997. Small mammals of a woodland-savannah ecosystem in Zimbabwe. I. Density and habitat occupancy patterns. *Journal of Zoology* 243:137-152.

Lozada, M., Guthmann, N., & Baccala N., 2000. Microhabitat selection of five sigmodontine rodents in a forest-steppe transition zone in northwest Patagonia. *Studies in Neotropical Fauna and Environment* 35: 85-90.

Lynch, C.D., 1994. The mammals of Lesotho. *Navorsinge van die Nasionale Museum Bloemfontein* 10: 177-241.

- Mackenzie, M., Donovan, C., Borchers, D., Scott, L., Hayward, L., Photopoulou, T., Kidney, D., & Oedekoven, C., 2012. Statistical Modelling Workshop 17-20 July. Cape Town, South Africa.
- Makundi, H.R., 1995. Annual changes of reproduction in rodents in the western Usambara Mountains, North East Tanzania. *Journal of African Zoology* 109: 15-21.
- Makundi, R.H., Bekele, A., Leirs, H., Massawe, A.W., Rwamugira, W., and Mulungu, L.S. 2005. Farmer's perceptions of rodents as crop pests: knowledge, attitudes, and practices in rodent pest management in Tanzania and Ethiopia. *Belgian Journal of Zoology* 35: 153-157.
- Makundi, R.H., Massawe, A.W., Mulungu, L.S., 2006. Breeding seasonality and population dynamics of three rodent species in the Magamba Forest Reserve, Western Usambara Mountains, and North-east Tanzania. *African Journal of African Ecology*. 45: 17-21.
- Mares, M.A., 1997. The geobiological interface: granitic outcrops as a selective force in mammalian evolution. *Journal of the Royal Society of Western Australia* 80: 131-139.
- Massawe, A.W., Mulungu, L.S., Makundi, R.H., Dlamini, N., Eiseb, S.J., Kirsten, F, Mahlaba, T., Malebane, P., Maltitz, E.V., Monadjem, A., Taylor, P., Tutjavi, V. & Belmain, S.R., 2011. Spatial and temporal population dynamics of rodents in three geographically different regions in Africa: Implication for ecologically-based rodent management. *African Zoology* 46: 393-405.
- McCain, C.M., 2005. Elevational gradients in diversity of small mammals. *Ecology* 86: 366-372.
- Medger, K., Chimimba, C.T. & Bennett, N.C., 2012a. Reproductive photo responsiveness in male spiny mice from South Africa. *Journal of Zoology (Lond.)* 286: 243-249.
- Medger, K., Chimimba, T.C & Bennet, N.C., 2012b. Seasonal changes in reproductive development of male spiny mice (*Acomys spinosissimus*) from South Africa. *Mammalian Biology* 77: 153-159.
- Mills, M.G.L. & Hes, L., 1997. The complete book of South African mammals. Struik Publishers, Cape Town.
- Monadjem, A., 1997. Habitat preferences and biomass of small mammals in Swaziland. *African Journal of Ecology* 35: 64-72.

- Monadjem, A., 1998. Reproductive biology, community structure, and diet of *Mastomys natalensis* (Muridae: Rodentia) in a Swaziland grassland. *Zeitschrift für Säugetierkunde*. 63: 347-356.
- Monadjem, A. 1999. Population dynamics of *Mus minutoides* and *Steatomys pratensis* (Muridae: Rodentia) in a subtropical grassland in Swaziland. *African Journal of Ecology* 37: 202-210.
- Monadjem, M. & Perrin, M.R., 1998a. Effects of supplemental food on the habitat selected by *Mastomys natalensis* (Muridae: Rodentia) in a subtropical grassland in Swaziland. *South African Journal of Zoology* 33: 172-177.
- Monadjem, A. & Perrin, M.R., 1998b. The effect of supplementary food on the home range of the multimammate mouse (*Mastomys natalensis*). *South African Journal of Wildlife Research* 28: 1-3.
- Monadjem, A. & Perrin, M., 2003. Population fluctuations and community structure of small mammals in a Swaziland grassland over a three-year period. *African Journal of Ecology* 38: 127-137.
- Morrison, M.L., Kuenzi, A.J. Brown, C.F. & Swann, D.E., 2002. Habitat use and abundance trends of rodents in Southeastern Arizona. *The Southwestern Naturalist* 47: 519-526.
- Mostert, T.H.C., Bredenkamp, G.J., Klopper, H.L., Verwey, C., Mostert, R.E. & Hahn, N., 2008. Vegetation types of the Soutpansberg Conservancy and the Blouberg Nature Reserve, South Africa. *Koedoe* 50: 32-48.
- Mugabe, J.C., 2008. Small mammal communities in the transformed landscapes of the Western Cape lowlands and their role in alien invasion into Fynbos remnants. MSc in conservation, Stellenbosch University.
- Mugatha, S.M., 2002. Influence of land use patterns on diversity, distribution and abundance of small mammals in Gachoka Division, Mbeere district Kenya. The land use change, impacts and dynamics project (LUCID), working paper series number 8.
- Mullin, S.K., Pillay, N. & Taylor, P.J., 2005. The distribution of the water rat *Dasymys* (Muridae) in Africa: a review. *South African Journal of Science* 101: 117-124.

- Mulungu, L.S., Makundi, R.H., Massawe, A.W., Machanga, R.S., & Mbije, N.E., 2008. Diversity and distribution of rodent and shrew species associated with variation in altitude on Mount Kilimanjaro, Tanzania. *Mammalia* 72: 178-185.
- Munyai, T.C., & Foord, S.H., 2012. Ants on a mountain: spatial, environmental and habitat associations along an altitudinal transect in a centre of endemism. *Journal of Insect Conservation* 16: 677-695.
- Musser, G.G. & Carleton, M.D., 2005. Family Muridae. In *Mammal species of the world: a taxonomic and geographic reference*. Wilson, D. E. and D. M. Reeder, editors. 3rd Ed. Johns Hopkins University Press. Baltimore, Maryland, 1189-1531.
- Muteka, S.P., Chimimba, C.T. & Bebbett, N.C., 2006a. Reproductive seasonality in *Aethomys namaquensis* (Rodentia: Muridae) from Southern Africa. *Journal of Mammalogy* 87: 67-74.
- Muteka, S.P., Chimimba, C.T., Bennett, N.C., 2006b. Reproductive photoresponsiveness in *Aethomys ineptus* and *A. namaquensis* (Rodentia: Muridae) from southern Africa. *Journal of Zoology* 268: 225-231.
- Muteka, S.P., Chimimba, C.T., Bennett, N.C., 2006c. Reproductive seasonality in the Tete veld rat (*Aethomys ineptus*) (Rodentia: Muridae) from southern Africa. *Journal of Zoology* 270: 314-322.
- Neal, B. 1995. The ecology and reproduction of the Short-snouted elephant shrew (*Elephantulus brachyrhynchus*) in Zimbabwe, with a review of the reproductive ecology of the genus *Elephantulus*. *Mammal Review* 25 (1&2): 51-60.
- Newbery, C, H., 1999. A key to the Soricidae, Macroscelididae, Gliridae and Muridae of Gauteng, North West, Mpumalanga and the Northern Province South Africa. *Koedoe* 42: 51-55.
- Nicolas, V., Barriere, B., Tapiero, A. & Colyn, M., 2009. Shrew species diversity and abundance in Ziama Biosphere Reserve (Guinea): comparison between primary forest, degraded forest and restoration plots. *Biodiversity and Conservation* 18: 2043-2061.
- Nowak, R., 1999. *Walker's Mammals of the World*; 6th Ed, Vol. II. Baltimore and London: John Hopkins University Press.

- Nupp, T.E. & Swihart, R.K. 2000. Landscape-level correlates of small-mammal assemblages in forest fragments of farmland. *Journal of Mammalogy* 81: 512-526.
- Perrin, M., 1995. Comparative aspects of the metabolism and thermal biology of elephant-shrews. *Mammal Review* 25: 61-78.
- Perrin, M.R., and Boyer, D.C., 2000. Seasonal changes in the population dynamics of hairy-footed gerbils in the Namib Desert. *South African Journal of Wildlife Research* 30: 73-83.
- Perrin, M., Fitzgibbon, C., Stuart, C., Griffin, M. & Smith, H., 2008. *Elephantulus rupestris*. 2008. IUCN Red List of Threaten Species, Downloaded on 29 December 2008.
- Phillips, J., Kearney, T., Pillay, N. & Willan, K., 1997. Reproduction and postnatal development in the Angoni vlei rat *Otomys angoniensis* (Rodentia, Muridae). *Mammalia* 61: 219-229.
- Pillay, N., William, K. & Wolhuter, W., 1993. Pup retrieval in the African bush Karoo rat. *Acta Theriologica* 38: 339 - 343.
- Pretorius, A.M., Beati, L. & Birtles, R.J., 2004. Diversity of artonellae associated with small mammals inhabiting Free State province, South Africa. *International Journal of Systematic and Evolutionary Microbiology* 54: 1959-1967.
- Rahbek, C. & Graves, G.R., 2001. Multiscale assessment of patterns of avian species richness. *Proceedings of the National Academy of Science* 98: 4534-4539.
- Rajska-Jurgiel, E., 1992. Demography of woodland rodents in fragmented habitat. *Acta Theriologica* 37: 73-90.
- Rathbun, G.B., 2009. Why is there discordant diversity in sengi (Mammalia: Afrotheria: *Macroscelidea*) taxonomy and ecology? *African Journal of Ecology* 47: 1-13.
- Rautenbach, A., Dickerson, T.D. & Schoeman, M.C., 2014. Diversity of rodent and shrew assemblages in different vegetation types of the savanna biome in South Africa: no evidence for nested subset or competition. *African Journal of Ecology* 52: 30-40.
- Rautenbach, I.L. 1982. Mammals of the Transvaal. *Ecoplan Monography* 1: 1-211.
- Reed, A.W. & Slade, N.A., 2008. Density-dependent recruitment in grassland small mammals. *Journal of Animal Ecology* 77: 57-65.

- Ribble, D. & Perrin, M.R., 2006. Social organization of the eastern rock elephant-shrew (*Elephantulus myurus*): the evidence for mate guarding. *Belgian Journal of Zoology* 135 (Suppl.): 137-143. *Journal of East African Natural History* 96: 47-71.
- Russo, I.M., Chimimba, C.T & Bloomer, P., 2010. Bioregion heterogeneity correlates with extensive mitochondrial DNA diversity in the Namaqua rock mouse, *Micaelamys namaquensis* (Rodentia: Muridae) from Southern Africa - evidence for a species complex. *BMC Evolutionary Biology* 10: 307-313.
- Rychlik, L., 2000. Habitat preferences of four sympatric species of shrews. *Acta Theriologica* 45, (Suppl. 1): 173-190.
- Schradin, C. & Pillay, N., 2003. Paternal care in the social and diurnal striped mouse (*Rhabdomys pumilio*): Laboratory and field evidence. *Journal of Comparative Psychology* 117: 317-324.
- Schradin, C. & Pillay, N., 2005. Intraspecific variation in the spatial and social organization of the African striped mouse. *Journal of Mammalogy* 86: 99-107.
- Shepherd, J.D. & Ditgen, R., 2005. Human use and small mammal's communities of Araucaria forests in Neuquén, Argentina. *Mastozoologia Neotropical* 12: 217-226.
- Siegfried, W.R. & Brown, C.A., 1992. The distribution and protection of mammals endemic to South Africa. *South African Journal of Wildlife Research* 22: 11-15.
- Skinner, J.D. & Chimimba, C. T., 2005. Mammals of the Southern African sub region (3rd Ed) Cambridge University press, Cape Town.
- Skinner, J.D. & Smithers, R.H.N., 1990. The Mammals of the Southern African Sub region. Pretoria, South Africa: University of Pretoria.
- Slabova, M. Broumova, H. & Pecharova, E., 2008. Communities of small mammals as indicators of biodiversity changes in reclaimed areas after coal mining. University of South Bohemia, Czech Republic. [http://www.imwa.info/docs/imwa\\_2008/IMWA2008\\_102\\_Slabova.pdf](http://www.imwa.info/docs/imwa_2008/IMWA2008_102_Slabova.pdf).
- Stanley, W. T. & Hutter, R., 2007. Differences in abundance and species richness between shrews and rodents along an elevational gradient in the Udzungwa Mountains, Tanzania. *Acta Theriologica* 52: 259-273.
- Van Hensbergen, H.J. & Martin, S.C., 1993. Climatic factors affecting the distribution of South African small mammals. *South African Journal of Wildlife Research* 23: 1-10.

- Stanley, W.T., Rogers, M.A., Senzota, R.B., Mturiki, F.A., Kihale, P.M., Moehlman, P.D., Barry, M.O. & Connor, B.M., 2007. Surveys of small mammals in Tarangire national park, Tanzania. *Journal of East African Natural History* 96:47-71.
- Stanley, W.T., Kihale, P.M. & Munissi, M.J., 2007. Small mammals of two forest reserves in the North Pare Mountains, Tanzania. *Journal of East African Natural History* 96: 215-226.
- Stuart, C. & Stuart, T., 1992. Mammals of Southern Africa. Struik Publishers, Cape Town.
- Stuart, C., 2001. Field guide to mammals of Southern Africa 3th ed. Struik Publishers, Cape Town, 1-272.
- Stuart, C. & Stuart, T., 2007. Mammals of Southern Africa. Struik Publishers, Cape Town.
- Tadesse, H. & Afework, B., 2008. Habitat association of insectivores and rodents of Alatish Proposed National Park, North-western Ethiopia. *Tropical Ecology* 49:1-11.
- Takele, S., Afework, B., Gurja, B. & Balakrishnan, M., 2011. A comparison of rodent and insectivore communities between sugarcane plantation and natural habitat in Ethiopia. *Tropical Ecology* 52: 61-68.
- Taylor, P.J., 1998. The smaller mammals of KwaZulu-Natal. University of Natal Press, Pietermaritzburg, South Africa, 141 pp.
- Taylor, J.P., 2000. Patterns of chromosomal variation in Southern African rodents. *Journal of Mammalogy* 81: 317-331.
- Taylor, P.J., Munyai, A., Nengovhela, A., Baxter, R.M., Sape, T., Nemakhavhani, T., 2012. University of Venda mammals list. Unpublished data.
- Van der Merwe, M., 1999. Breeding season and breeding potential of the greater cane rat (*Thryonomys swinderianus*) in captivity in South Africa. *South African Journal of Zoology* 34: 69-73.
- Van Deventer, M. & Nel J. A.J., 2006. Habitat, food, and small mammal's community structure in Namaqualand. *Koedoe* 49: 99-109.
- Van Hensbergen, H.J. & Martin, S.C., 1993. Climatic factors affecting trapping success of some South African small mammals. *South African Journal of Wildlife Research* 23: 87-92.

Vaughan, T.A., Ryan, J. M. & Czaplewski, N.I. 2000. Mammalogy. 4th Ed. Saunders College Publishing, Orlando, 565 + pp.



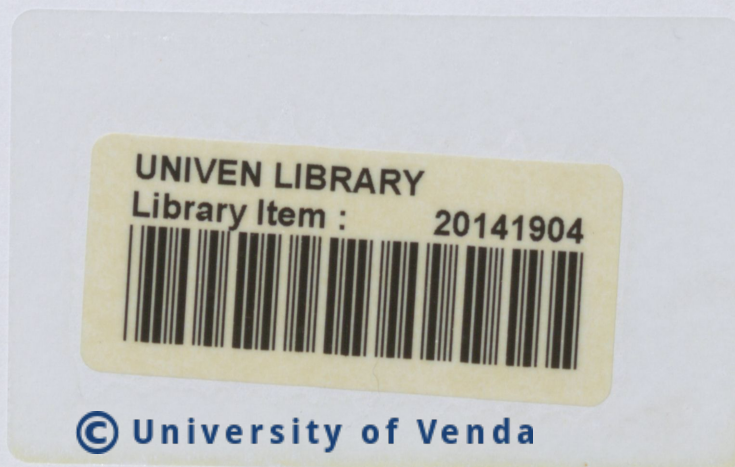
Wandrag, G.F., Watson, J.P. & Collins, N.B. 2002. Rodent and insectivore species diversity of Seekoeivlei provincial nature reserve, Free State province, South Africa. *South African Journal of Wildlife Research* 32: 137-143.

Wilson, D. & Reeder, D., 2005. Mammal species of the world. 3rd Ed. Baltimore: John Hopkins University press.

Wirminghaus, J.O., 1990. The role and significance of rodents in the functioning of a forest ecosystem. MSc thesis, University of Natal, Pietermaritzburg.

Witecha, M.J., 2011. Effects of fire and precipitation on small mammal populations and communities. MSc Thesis, Texas A & M University, Kingsville.

Woodall, P., 1995. The male reproductive system and the phylogeny of elephant-shrews. *Mammal Review* 25 (1&2): 87-93.



## 6.1.2 Small mammals habitat preferences and community similarity across different habitats

Habitat preference of small mammals depends on a combination of several factors one of which is vegetation cover (Monadjem and Perrin 1998). Habitat preferences are related to foraging efficiencies (Bowland and Perrin 1993) and are reflection of species nutritional needs (Lancaster 2009). In areas with strong seasonality, micro habitat features are major factors which govern the composition and abundance of rodents in a given habitat (Lin and Batzli 2001, cited in Takele et al. 2011). Structural changes in vegetation characteristics are important determining factors of habitat for small mammals (Yarnell et al. 2007).

Small mammal communities may be composed of species that vary from having narrow habitat requirements (specialist) to very broad habitat requirements (generalist) (Lancaster 2009). As predicted, different small mammal species were associated with different habitats. As found by many authors (e.g. Pillay et al. (2003); Schradin and Pillay, 2003). *R. pumilio* was a habitat generalist in our study. Wetland specialists included *D. incomtus*, and *C. mariquensis* has supported by Skinner and Chimimba (2005).

Rocky-outcrop specialists in this study were *E. myurus* Both *M. namaquensis* and *A. ineptus*. However, the latter species occurs more broadly in savanna habitats including areas without rocks (Chimimba and Chimimba 2008; Gaigher 2006, unpublished data). Even within the grid, *M. namaquensis* and *A. ineptus* were often found in different trap sites indicating niche separation. *O. angoniensis* preferred wetland but was also found in grassland, which is typical of a savanna species associated with wetlands in savannas (Pillay et al. 1993).

The wetland had a high number of species with *M. mariquensis* being the most common, while low numbers of individual species was recorded in the grassland habitat with a low number of *M. namaquensis* and *Dendromus mystacalis*. The further investigation indicate that *A. ineptus*, *C. cyanea* and *E. myurus* are rocky-outcrop habitat specialists, and *L. rosalia* and *M. minutoides* are grassland specialist while *M. varius* and *C. mariquensis* are commonly found in all habitats (Table 5.5). Mulungu et al. (2008) recorded lowest trap success in grassland habitat and high trap success in shrubs habitat in Tanzania. Rajska-Jurgiel (1992) reported that the species composition of small mammals on grassland differs from those in the forest.

Nupp and Swihart (2000) reported that *R. pumilio* was the most abundant species in the Mount Elgon National Park. Lacey and Solomon (2003) suggested that the high abundance of *R. pumilio*