

**ASSESSING THE EFFECTS OF GRAZING INTENSITY BY LARGE  
HERBIVORES ON SPECIES DIVERSITY AND ABUNDANCE OF  
SMALL MAMMALS AT WATERBERG PLATEAU PARK, NAMIBIA.**

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

OF

THE UNIVERSITY OF NAMIBIA

AND

THE HUMBOLDT-UNIVERSITÄT ZU BERLIN

BY

**JULIUS BOAS ERCKIE**

APRIL 2007

SUPERVISOR: DR. J.K. MFUNE

CO-SUPERVISOR: PROF. DR. ULRICH ZELLER

**ASSESSING THE EFFECTS OF GRAZING INTENSITY BY  
LARGE HERBIVORES ON SPECIES DIVERSITY AND  
ABUNDANCE OF SMALL MAMMALS AT WATERBERG  
PLATEAU PARK, NAMIBIA.**

A thesis submitted in partial fulfilment of the requirements for the degree of  
Master of Science in Biodiversity Management and Research at  
University of Namibia and Humboldt-Universität zu Berlin

By

Julius Boas Erckie

Supervisor: Dr. J.K. Mfune (University of Namibia)

Co-supervisor: Prof. Dr. Ulrich Zeller (Humboldt-Universität zu Berlin)

APRIL 2007

## ABSTRACT

This study focused on the effects of disturbance by large herbivores on the species diversity of small mammals at Waterberg Plateau Park in northern Namibia. The effects of large herbivores on species diversity (species richness and evenness) and composition were investigated in the vicinity of two waterholes, Duitse Post and Securidaca. At each watering point, two sites along the rangeland utilization gradient, at 100 m and 2 km distance from waterhole, were selected. The sites situated at 100 m from a waterhole, fall under a more disturbed area, whereas sites located at 2 km distance lie in the less disturbed area. A total of 100 trap stations, spread into a 1 ha (100 x 100 m) grid were placed at the two interval distances from the waterhole. The Sherman traps, along with the capture-mark-recaptured method were employed.

The Kruskal-Wallis test ( $H = 12$ ,  $df = 4$ ,  $p = 0.916$ ) indicated that there was no significant difference in the vegetation cover between the more disturbed and less disturbed area, particularly at Duitse post waterhole. The Mann-Whitney U test ( $U = 1.0$ ,  $p = 0.015$ ) indicated that there was a significant difference in the vegetation cover between the more disturbed and less disturbed area at Securidaca waterhole. A total of 146 individual small mammals, representing 12 species, were captured in 8000 trap nights. *Dendromus melanotis* was most commonly captured small mammal species followed by *Gerbillurus paeba*, *Tatera leucogaster* and *Thallomys nigricauda* being the least captured. The study revealed that species diversity was high in the more disturbed area, while species richness and composition was high in

the less disturbed area. The encountered high proportion of *Mastomys* spp and reduction of population density of *Tatera leucogaster* suggests a level of disturbance in the more disturbed areas. The Petersen method of capture-mark-recapture showed that there was no significant difference in population density of small mammals ( $U = 10.0$ ,  $p = 0.602$ ) between the more disturbed and less disturbed area. Minimum Number Alive (MNA) method showed that there was no significant difference in population size of small mammals ( $U = 62.5$ ,  $p = 0.579$ ) between more disturbed and less disturbed area. The present study was the first to record *Dendromus melanotis* at Waterberg Plateau Park.

**DEDICATION**

This thesis is dedicated to and in the memory of my beloved late parents, Mr. Andreas and Mrs. Emilia Erckie for their love, encouragement, and support that they generously extended to me throughout my formative years and helping to make me a person that I am today.

## ACKNOWLEDGEMENTS

First of all I give thanks to the Creator the most high for his blessings and wisdom. This project would not have been possible without assistance from the following institutions and individuals: The Wabi Game Lodge and Marula Game Lodge management, Namibia Nature Foundation and UNESCO, through the Ministry of Education, for financial assistance, which enabled me to enrol for the course and to conduct the research project.

The Permanent Secretary of Ministry of Environment and Tourism for granting me a study leave, permission to study small mammals at Waterberg Plateau Park and the use of official vehicle. My supervisors Dr. J.K. Mfunne (University of Namibia) and Prof U. Zeller (Museum für Naturkunde, Berlin) for their inspiration, guidance, constructive criticism, field guidance and the advice during the research and writing of the thesis. I'm grateful to the Humboldt University, especially Prof U. Zeller and Dr. A. Hoffmann, for allowing me to use the research materials.

The Deutscher Akademischer Austausch Dienst (DAAD) (Germany Academic Exchange Service) for generous financial assistance, which enabled me to do an internship at the Museum für Naturkunde in Berlin, Germany. Dr. P. Giere for supervision and assistance during identification of small mammals.

Mr. S. Eiseb from National Museum of Namibia, for his support and guidance, materials, field visits, transport and research materials. Mr. T. Kuivanen and Mr.

Augustinus for dissecting and mounting the small mammals. Dr. M. Hipondoka for his generous support, which included statistical software programs, advice and positive criticisms. My fellow students for providing a conducive study environment. Additional words of appreciation go to Saara S. Uusiku for being my research partner, for her advice and courage to work together. The staff members at Waterberg Plateau Park especially J. Ndiili, T. Kapia, D. Hamwele, K. Paulus, T. Kanime and M. Hangula for their assistance during the field work. Finally, to my family for their generous love, support, understanding, and encouragement during my study and research work.



## TABLE OF CONTENTS

	PAGE
TITLE.....	i
ABSTRACT.....	i
DEDICATION.....	iv
ACKNOWLEDGEMENT.....	v
DECLARATION.....	vii
LIST OF TABLES.....	xi
LIST OF FIGURES.....	xii
LIST OF APPENDICES.....	xiv
ABBREVIATIONS.....	xvi
CHAPTER 1 INTRODUCTION .....	1
1.1 Introduction.....	1
1.2 Justification for the study.....	6
1.3 Objectives.....	8
1.4 Research questions.....	9
1.5 Research hypothesis.....	10
1.6 Description of small mammals.....	11
CHAPTER 2 LITERATURE REVIEW.....	13
2.1 Effect of herbivores on small mammals.....	19
2.2 Effect of disturbance of large herbivores on the species diversity of small mammals.....	20
2.3 Ecological importance of small mammals.....	22

CHAPTER 3 MATERIAL AND METHODS.....	23
3.1 Study area.....	23
3.2 Park background.....	24
3.3 Human influence on the area.....	26
3.4 Geology and soil.....	28
3.5 Climate.....	30
3.6 Temperature.....	30
3.7 Wind.....	31
3.8 Precipitation.....	32
3.9 Fauna.....	34
3.10 Flora.....	35
3.11 Methods.....	38
3.11.1 Vegetation cover estimation.....	40
3.11.2 Field trapping of small mammals.....	41
3.11.3 Weight, marking and preservation.....	42
3.12 Data analysis.....	44
3.12.1 Trap nights and trap success of small mammals.....	45
3.12.2 Species diversity, species richness and heterogeneity of small mammals.....	46
3.12.3 Capture-Mark-Recapture of small mammals.....	47
3.12.4 Species composition of small mammals using the Hierarchical Cluster Analysis (HCA).....	49

CHAPTER 4 RESULTS.....	51
4.1 Variation in estimate of vegetation cover.....	51
4.2 Small mammals caught.....	53
4.3 Species diversity of small mammals.....	56
4.4 Estimated population density of small mammals using Petersen method of Capture-Mark-Recapture (CMR).....	61
4.5 Population size of small mammal species estimated from Minimum Number Alive (MNA).....	67
4.6 Species composition of small mammals.....	69
CHAPTER 5 DISCUSSION.....	72
5.1 Estimation of vegetation cover.....	72
5.2 Estimation of population density of small mammals species in terms of Minimum Number Alive (MNA).....	86
5.3 Species composition of small mammals.....	88
CHAPTER 6 CONCLUSION AND RECOMMENDATIONS.....	90
REFERENCES.....	93
APPENDICES.....	

## TABLES

- Table 4.1** Individual number of small mammal species captured in four different study areas at Waterberg Plateau Park during trapping session in December 2005, March, April, May and June 2006. (No. Ind. = Number of individual, M= male individual and F = female individual small mammal, % = relative abundance)..... 54
- Table 4.2** Total numbers of species of small mammals (species richness) captured over 4000 trap nights in the more disturbed and less disturbed area Waterberg Plateau Park during the trapping session of December 2005, March, April, May and June 2006. The table also revealed that less disturbed area has high species richness than the more disturbed area..... 55
- Table 4.3** Population size determined from Minimum Number Alive (MNA) of species of small mammals caught in the more disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park..... 67
- Table 4.4** Population size determined from Minimum Number Alive (MNA) of species of small mammals caught in the less disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park.....68

## FIGURES

- Figure 3.1** Showing the location of Waterberg Plateau Park (WPP) (Erckie, 2006). .... 23
- Figure 3.2** Rainfall isohyets of Namibia illustrating the effect of the Waterberg Plateau on the local climate (NMS, 2006) ..... 32
- Figure 3.3.** Annual rainfall amounts (mm) with the mean annual rainfall superimposed for Onjoka Office (WPP) for the period 1995 to 2005. .... 33
- Figure 3.4** The main plant communities at WPP as adapted from Jankowitz (1983) in MET (1985). ..... 36
- Figure 3.5.** Showing the location of the waterholes and the grid (plots) on the plateau in relation to the park. .... 37
- Figure 3.6** Illustrate the position of the Duitse post and Securidaca waterhole, plot A1 and B1 classified as more disturbed areas, whereas plot A2 and B2 classified to less disturbed area. .... 38
- Figure 4.1 (a)** Mean total vegetation (trees, shrubs/bushes, grasses and herbs) cover (%) at Duitse post waterhole in the more disturbed and less disturbed area at (Duitse post waterhole) during trapping session of December 2005, March, April, May and June 2006 at Waterberg Plateau Park. Error bars are the mean upper and lower 95% confident limits and represent the minimum and maximum values on the 95% confidence limits. Where the error bars are invisible the mean values were very small (0.09 to 0.22). ..... 50
- Figure 4.1 (b)** Mean total vegetation (trees, shrubs/bushes, grasses and herbs) cover % at Securidaca waterhole in the more disturbed and less disturbed area during trapping session of December 2005, March, April, May and June 2006 at Waterberg Plateau Park. Error bars are the mean upper and lower 95% confident limits and represent the minimum and maximum values on the 95% confidence limits. Where the error bars are invisible the mean values were very low (0.09 to 0.22). ..... 51
- Figure 4.2 (a)** Mean Shannon-Wiener index of species diversity ( $H'$ ) of small mammals in the more and less disturbed area during the five different trapping sessions from December 2005, March, April, May, and June 2006 at Waterberg Plateau Park. Error bars are the mean upper and lower 95% confident limits. .... 55
- Figure 4.2 (b)** Mean Shannon-Wiener index of species diversity ( $H'$ ) of small mammals in the more disturbed area (100m) and less disturbed area (2km) during the five different trapping sessions from December 2005, March, April, May, and June 2006 at Waterberg Plateau Park. Error bars are the mean upper and lower 95% confident limits. .... 57

- Figure 4.3** overall mean number of small mammal species captured in more disturbed and less disturbed area during the study period in December 2005, March, April, May and June 2006 at Waterberg Plateau Park. Error bars are the mean upper and lower 95 % confidence limits associated with the abundance of small mammal's estimates. .... 58
- Figure 4.4** Estimated population density (number/ha) of small mammal species recorded using the Petersen method of Capture–Mark–Recapture, in sample areas A1 and A2 which were 100m and 2km from Duitse post waterhole, designated as more disturbed and less disturbed area, respectively. Total of six small mammals species were caught during the session from December 2005, March 2006, April 2006, May 2006 and June 2006..... 61
- Figure 4.5** Estimated population density (number/ha) of small mammal species recorded using the Petersen method of Capture – Mark – Recapture, in sample areas B1 and B2 which was 100m and 2km from Securidaca post waterhole, designated more disturbed area. Total of five small mammals species were caught in B1 and eight small mammals species were caught in B2 during the session from December 2005, March 2006, April 2006, May 2006 and June 2006..... 63
- Figure 4.6** Overall estimated total population (number/ha) number of small mammals using Petersen method of Capture Mark-Recapture in the more disturbed and less disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park. The total population density in the more disturbed area was highest in April 2006 whereas the lowest was recorded in March 2006. In the less disturbed area the highest population density was highest in June 2006 whereas the lowest population density recorded in March 2006. .... 64
- Figure 4.7** Hierarchical Cluster Analysis (HCA) dendrogram indicating five (1-5) cluster groups of small mammal communities caught in the More Disturbed Area (MDA) and Less Disturbed Areas (LDA) at Duitse post and Securidaca waterholes, at Waterberg Plateau Park and during the months of December 2005, March, April, May, June 2005..... 68

## APPENDICES

- Appendix 1. Individual number of small mammals species captured in four different sites five different trapping sessions at Waterberg Plateau Park during trapping session in December 2005, March, April, May and June 2006..... 104
- Appendix 2. Individual number of small mammal species captured in four different sites five different trapping sessions at Waterberg Plateau Park during trapping session in December 2005, March, April, May and June 2006. (No Ind = Number of individual, M= male individual and F = female individual small mammal)..... 105
- Appendix 3. The number of male and female small mammals captured in the four different plots in five different trapping sessions at Waterberg Plateau Park during in December 2005, March , April, May and June 2006. (M = male and F = female small mammals captured )..... 106
- Appendix 4. Estimation of population size of small mammals using Petersen method of Capture Mark-Recapture in the more disturbed and less disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park..... 107
- Appendix 5. Population size in terms of MNA (Minimum Number Alive) of species of small mammals caught in the more disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park. .... 107
- Appendix 6 Population size in terms of MNA (Minimum Number Alive) of individual small mammals caught in the less disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park..... 108

**ABBREVIATIONS**

<b>A1:</b>	Sampling area or grid, 100m from Duitse post waterhole designated as more disturbed area
<b>A2:</b>	Sampling area or grid, 2km from Duitse post waterhole designated as less disturbed area
<b>ANOVA:</b>	Analysis of Variance
<b>Apr'06:</b>	April 2006
<b>B1:</b>	Sampling area or grid, 100m from Securidaca waterhole designated as more disturbed area
<b>B2:</b>	Sampling area or grid, 2km from Securidaca waterhole designated as less disturbed area
<b>CMR:</b>	Capture-Mark-Recapture
<b>DAAD:</b>	Deutscher Akademischer Austausch Dienst
<b>Dec'05:</b>	December 2005
<b>°C:</b>	Degree Celsius
<b>F:</b>	Female
<b>Gft:</b>	Grootfontein
<b>GIS</b>	Global Information System
<b>Ha:</b>	Hectare (s)
<b>HCA:</b>	Hierarchical Cluster Analysis
<b>IUCN:</b>	International Union for the Conservation of Nature and Natural Resources.
<b>Jun'06:</b>	June 2006

<b>Km:</b>	Kilometres
<b>LDA:</b>	Less disturbed area
<b>M:</b>	Male
<b>MA</b>	Millions years ago
<b>Mar'06:</b>	March 2006
<b>May'06:</b>	May 2006
<b><i>Mastomys spp:</i></b> <i>Mastomys</i> species	
<b>MDA:</b>	More disturbed area
<b>MET:</b>	Ministry of Environment and Tourism
<b>mm:</b>	Millimetres
<b>MNA:</b>	Minimum number alive
<b>NMS:</b>	Namibia Meteorological Services
<b>No. Ind:</b>	Number of individual (s)
<b>Otji:</b>	Otjiwarongo
<b>SE:</b>	Standard Error
<b>SWA:</b>	South West Africa
<b>UNESCO:</b>	United Nations Education Science and Culture Organization
<b>UNEP:</b>	United Nations Environment Program
<b>WPP:</b>	Waterberg Plateau Park.

## **CHAPTER 1 GENERAL INTRODUCTION**

### **1.1 INTRODUCTION**

The establishment of protected areas is essential for the conservation of biological diversity (Barnard *et al.*, 1998). At the same time the term biodiversity is commonly used as one of the criteria to justify the selection of protected areas. Sometimes biodiversity is being used for justification and without necessarily taking into consideration the possible impact of large herbivores on the environment. According to Avenant (2000), for example, most introductions of large herbivores into conservation areas are only based on the conservation status and economic values.

The introductions of mostly large herbivores into protected areas put pressure on the management to provide water, causing more intensive trampling and overgrazing around waterholes. At Waterberg Plateau Park, the introduced large herbivores are confined to plateau, where their natural migrations and emigrations are restricted. Their numbers are only manipulated through translocation and introduction. The high concentration and intensive grazing and browsing often reduces vegetation cover and causes a shift from palatable perennial shrubs to unpalatable perennials and annuals (Joubert & Ryan, 1999).

Overgrazing and trampling pressure around waterholes normally increases during the critical time or bottle neck period of June to October. At Waterberg Plateau Park, this is the normal pattern of water-dependent animals that concentrate close to the waterholes.

The concentrations of large herbivores, are putting more pressure on the land, especially through grazing and browsing of resources, which can lead to land degradation. Land degradation refers to the changing of vegetation layer in terms of structure and species composition (Joubert & Ryan, 1999; Hoffmann & Zeller, 2005). Changes of habitat structure including vegetation layer and its complexity influence small mammal's community structure and species richness (Els & Kerley, 1996; Joubert & Ryan, 1999; Hoffmann & Zeller, 2005).

In a natural environment, changes might be observed through indicators and the most obvious indicators of land degradation are the changes in soil, vegetation and production (Joubert & Ryan, 1999). According to Dean *et al.* (1995) in Joubert & Ryan (1999) overstocking of rangelands may negatively impact on biodiversity and on associated ecological processes, such as pollination, seed dispersal, seed germination and nutrient dispersion. As secondary productivity decreases, the cost and efforts to rehabilitate degraded land or habitats may be unaffordable. In addition, Laidlaw (2000) found that an area (about 600m<sup>2</sup>) close to waterholes was extremely trampled by the movements of the animals in such away that no vegetation could be found. The same applied to the walking path to and from the waterholes. The spacing between these paths narrow with increasing distance to water, indicating a degree of disturbance. The heavy movement that includes trampling may destroy small mammals' burrows, and therefore may decrease resting and nesting. Continued grazing and intensive trampling especially during the critical dry period may have negative impacted on biodiversity of small

mammals and these impacts might be associated with ecological processes such as pollination, seed dispersal, seed germination and nutrient dispersion (Joubert & Ryan, 1999). Overgrazing as disturbance factor leaves little or no grass canopy, which may affect the food and shelter of small mammals and the reduction of vegetation cover. This exposes small mammals to predation (Nyako-Lartey & Baxter, 1995; Joubert & Ryan, 1999).

Ecological disturbance to habitats of small mammals is often related to changes in diversity of small mammals such as decrease in species richness of small mammals (Els & Kerley, 1996; Avenant, 2000; Hoffmann & Zeller, 2005). Many studies have indicated that due to ecological disturbance, ecosystems may change, for example, where a particular species were formerly dominant they may be eliminated or debilitated. Such a disturbance demonstrated a scenario between losses in biodiversity and declines in ecosystem function (Els & Kerley, 1996; Avenant, 2000; Chase *et al.*, 2000). Further studies have also shown a connection between the presence/absence of small mammal indicator species and disturbance in natural ecosystems (Tasker *et al.*, 1991; Avenant, 2000; Chase *et al.*, 2000). Therefore, biodiversity of small mammals can be used as indicator of disturbance in an ecosystem.

According to Mendelsohn (1982), Kerley (1989), Kerley (1992a), Matson & Blood (1994), Avenant, (2000), Chase *et al.*, (2000) and Hoffmann & Zeller (2005) small mammals are important components in many ecosystems as they occupy important

positions as primary consumers in those ecosystems. They also play essential roles as predators, dispersers of seeds (Kerley, 2000), burrowers and as prey for carnivores and raptors (Hoffmann & Zeller, 1999; Avenant, 2000). Although small mammals play essential roles in the ecosystem, they are normally ignored or overlooked in both planning and management of conservation areas. It is therefore, essential to have an understanding of how small mammals relate to environmental features (Els & Kerley, 1996).

The protected areas can be assessed for multiple levels of biodiversity, including genetic diversity, species diversity and community diversity (Meffe & Carrol, 1997; Ricklefs & Miller, 1996; Chase *et al.*, 2000). These assessments can be simplified for both scientists and park managers to easily identify biological indicators (Bio- indicators) (Chase *et al.*, 2000). Chase *et al.*, (2000) defined bio-indicators as those species whose presence is correlated with species richness or with the presence of a threatened biological community or sub- association. However, not only is it the presence of a species that can be used as indicator but also the absence or disappearing of species can also be used as indicators of disturbed habitat. Single species can also be used as bio-indicators and important foci of conservation efforts because they are easier to identify and study than other levels of biodiversity and are more likely to be protected by law (Chase *et al.*, 2000).

According to Avenant (2000) and Chase *et al.*, (2000) there are some species of small mammals and birds that are sensitive to disturbance and there are those small mammals, birds and other species that can tolerate disturbance to certain levels. Because there are certain small mammal species that are sensitive to disturbance and some tolerate disturbance, they can be used directly for monitoring and accessing the changes in the species diversity, richness and composition. Therefore, using small mammals as bio-indicators may be a relatively quick and affordable method of indicating healthy/unhealthy ecosystem and may facilitate the management of nature reserve and future development of conservation area (Avenant, 2000). This study focused on the use of small mammals as bio-indicators to access the effect of high concentration, grazing and trampling intensity of large herbivores on the species diversity and abundance of small mammals at Waterberg Plateau Park (WPP).

Choosing WPP as the study area was based on the extra-ordinary features such as the topography, geology, and vegetation types. WPP is unique because of its historical importance, including as site of the oldest dinosaurs spoor (*Massospondylus*), the Bushman engravings, historical German control post, the introduction of rare and endangered game species and vulture feeding program (Jankowitz, 1983; Jankowitz & van Rensburg, 1985; Jankowitz & Venter, 1987). It has ideal habitats for various rare and specially protected game species, whose numbers have declined in the past. It is the only place in Namibia with both tree savannah and dry wood forest. It is also important for tourism activities such as game drives, guided and unguided wilderness trails. The

study aimed to evaluate whether the large herbivores which were introduced into WPP and especially their grazing intensity, have any effect on the species diversity of small mammals.

## **1.2 Justification for the study**

Namibia is a signatory to the International Union for the Conservation of Nature and Natural Resources (IUCN) and so must adhere to the global conservation goals as stated in the World Conservation Strategy, these being to:

- Maintain essential ecological processes and life support systems;
- preserve genetic diversity; and
- ensure the sustainable utilization of species and ecosystems (Du Preez, 2000) .

The conservation goals for the Waterberg Plateau Park were thus subject to global conservation goals and the relevant Namibian statutory laws. The conservation and management goals for WPP according to the WPP Master plan were set out as follows (MET, 1986):

### **Conservation goals:**

- Ensure the survival of certain rare and endangered Namibian species;
- keep the plant species and structural diversity within set limits;
- conserve the Etjo sandstone formation;

- conserve the archaeological- and cultural-historical heritage;
- conserve the ecological processes and survival mechanisms on the Omuverume Plateau without interference; and
- develop the Waterberg Plateau Park within the conservation goals for sustainable utilization.

**Management goals:**

- Establish populations of identified rare- and endangered animal species in accordance with carrying capacity estimates;
- maintain changes in the plant species diversity and structure within permissible limits;
- develop tourism wisely in accordance with the conservation goals;
- expose and educate people with regard to environmental issues;
- zone the WPP according to internationally accepted preservation and utilisation priorities; and
- adhere to the principles of Wilderness Management in the Wilderness area (Du Preez, 2000).

Over the years WPP management pays more attention to large herbivores such as black rhino (*Diceros bicornis bicornis*), white rhino (*Ceratherium simum*), roan antelope (*Hippotragus equinus*) and sable antelope (*Hippotragus niger*) (Joubert & Moster, 1975) because they are either threatened with extinction or rare in Southern African region

(Fuggle & Rabie, 1983). Most of these large herbivores have attractive value, together with its rarity (tourism), makes them economically very valuable. Little or no attention has been given to small mammals.

At WPP large herbivores are confined to the main Plateau and the park management embarked upon activities including the provision of water. Water is pumped onto the plateau and without which the plateau would not support water dependent herbivores during the dry season. The plateau is surrounded by farmlands and escarpment making it effectively an ecological island. Numbers of large herbivores are regulated by means of translocation and introduction. Therefore, provision of water leads to high concentration of game, causing trampling and overgrazing at water points. These activities cause a reduction of ground cover, leading to dry conditions, increase soil temperature and soil erosion. Both trampling and overgrazing are likely to affect the diversity of plants and small organisms including small mammals.

### 1.3 Objectives

The aim of the study was to assess the influence of different levels of large herbivores grazing intensity on species diversity, composition and abundance of small mammals at Waterberg Plateau Park (WPP).

The specific objectives of the study were to:

- (a). Determine and compare species diversity and richness of small mammals along a large herbivore disturbance gradient.
- (b). Determine and compare species composition of small mammals along a large herbivore disturbance gradient.
- (c). Estimate population size of small mammals along large herbivore disturbance gradient.

### 1.4 Research questions

Accordingly an intensive study will be initiated to answer these questions:

- (a) What is the species diversity, richness and composition of small mammals along disturbance gradient of the large herbivores?
- (b) Is there a difference in species diversity, richness and composition of small mammals along the large herbivores disturbance gradient?

- (c) Does disturbance of large herbivores influence population size of small mammals species along the large herbivores disturbance gradient?

### **1.5 Research hypothesis**

- (a) On the effect of trampling and grazing on diversity of small mammals, it is hypothesized that the species diversity, richness and composition of small mammals would decrease towards the waterhole due to an increase in the level of disturbance (high trampling and grazing intensity by large herbivores). Due to these activities of large herbivores there would be less shelter and food for small mammals towards the waterhole.
- (b) It is hypothesized that large herbivores, through trampling and overgrazing (disturbance) change the habitat and hence alter community structure of small mammals.
- (c) It is hypothesized that the estimated population size of small mammals along the large herbivore disturbance gradient would be lower closer to waterhole because of the increase in the level of disturbance (high concentration, trampling and grazing intensity).

## 1.6 Description of small mammals

It seems that within ecological literature the term “small mammal” always brings out a debate regarding what it means. In fact, it usually has a very special meaning and certainly it does not embrace all kinds of small mammals. One could try to include all small mammals for example bats would undoubtedly be included, which in this case is not intended. In this study, the term is intended to include the free-living rodents and insectivores (Delany, 1974).

The lower size limit set was based on the weight of Etruscan (*Crocidura etruscus*), the smallest known mammals, and weighing as little as 2g. The upper or higher limit is more difficult to define as there is gradation in size to the very large species. According to Bourlière (1975) and Fleming (1979) the upper limit of the weight of a small mammal is 5kg. This approximates the largest size that can be regularly caught in a commercially produced break-back rat trap. There is a considerable range of species within these size limits, including many shrews and moles among the insectivores and most rats, mice, gerbils, dormice and some of the smaller squirrels among the rodents (Delany, 1974).

Small mammals are represented in each of the major lines of mammalian evolution (Monotremes, marsupials, and placental). The diversity of their ecological adaptations is impressive, ranging from fossorial herbivores (mole rats) to aerial carnivores (bats) (Southern, 1979). Most small mammals are herbivorous (rodents) and they exist in great

abundance in almost all of the world ecosystems. They create a broad basic layer of primary consumers in the pyramid (Southern, 1979).

However, there are exceptional insectivores that include the hedgehogs, golden moles and shrew that are primarily carnivorous and are widely spread among the habitats of the world, though their numbers do not rival those of herbivores (Southern, 1979; Stuart & Stuart, 1991 & Delany, 1974).

## **Chapter 2 Literature review**

While the vegetation characteristics of the Park and population dynamics of some large herbivores have been extensively studied (Jankowitz, 1983; Jankowitz & Rensburg, 1985; Jankowitz & Venter, 1987) no detailed study on the effects of large herbivores on the species diversity of the resident small mammal populations has been done to date at Waterberg Plateau Park (Griffin pers. comm. 2005). Very few studies (Perrin & Boyer, 2000; Hoffmann & Zeller, 2005; Muck & Zeller, 2006; Ruthbun & Ruthbun, 2006) have been conducted on the ecology of small mammals in Namibia.

However, at a global and regional scale, numerous studies were conducted in this context particularly in South Africa (Mendelsohn, 1982; Rowe-Rowe & Meester 1982; Gliwicz, 1985; Bronner & Meester; 1987; Perrin & Swanepoel 1987; Kerley *et al.* 1990; Kerley, 1991; Nyako-Lartey, 1995; Joubert & Ryan, 1999; Monadjem, 1999; Chase *et al.*, 2000; Laidlaw, 2000; Hoffmann & Zeller, 2005). At global level, Chase *et al.* (2000) conducted an intensive study on single species as indicators of species richness and composition on the California Coastal Sage Scrub Birds and small mammals. Based on their results, they recommended that efforts to conserve the biodiversity of birds and small-mammals in coastal sage scrubs should not focus exclusively on rare species or on locations with the highest species richness. Instead focus should be directed at a diverse suite of species that are representative of range of variation in communities found in coastal sage scrub habitats. Laidlaw (2000) also conducted a general study on the effects of habitat disturbance and protected areas on mammals (including small mammals) of

Malaysia peninsular. Laidlaw (2000) examined the effects of disturbance caused by logging in the forest on the species richness and composition of the mammal communities in seven protected areas.

At the regional level, Mendelsohn (1982) described the composition and dynamics of small mammal community on the Springbok flats in South Africa. This study formed part of a wider investigation into the effects of the availability, as prey, of small mammals on blackshouldered kites (*Elanus caeruleus*). Additionally, Perrin & Swanepoel (1987) conducted a study in the Arid Sweet Bushveld type (South Africa) on the breeding biology of the bushveld gerbil *Tatera leucogaster* in relation to diet, rainfall and life history theory. Their results show that *Tatera leucogaster* is a selective feeder, but seasonally may feed on the available insects and seeds. They also found that *Tatera leucogaster* feeds on herbage when preferred foods are unavailable.

Nyako-Lartey & Baxter (1995) conducted a study of the effects of different grazing regimes on the population dynamics of small mammals along a feeding gradient in the Eastern Cape. They predicted that species diversity and population diversity of small mammals on the grids might be affected by the grazing habits and stocking rates of livestock. They predicted that seasonal recruitment and breeding of small mammals was affected by grazing, whereas sex ratio appeared unaffected. They concluded that cattle grazing, whether it is continuous or rested, allows small mammal species to coexist, but with reduced species diversity of small mammals. Sheep grazing on the other hand is

unfavourable to population growth and diversity of small mammals. Nyako-Lartey & Baxter (1995) found that sheep feeding habits of grazing close to the soil surface and removing peripheral leaves (reduced foliage cover) made small mammals particularly vulnerable to predation. Consequently, most individual small mammal emigrated from the site or just survived in what must be regarded as marginal habitat.

Joubert & Ryan, (1999) engaged in an investigation on differences in mammal and bird assemblages between commercial and communal rangelands at Paulshoek, in the Succulent Karoo, South Africa. During their investigation they found that diurnal mammals were scarce in communal rangelands, apparently due to a lack of cover for predator avoidance and herbivory. They also found few birds' species, particularly granivores, were more abundant on communal rangelands, probably because of the increase in annual plant cover. Based on their findings they recommended to management that it is essential to ensure that a minimum vegetation cover is maintained in a habitat in order to conserve the diversity of small mammals.

Avenant (2000) conducted a study of small mammal community characteristics as indicators of ecological disturbance in the Willem Pretorius Nature Reserve, Free State, South Africa. The author found that low species richness and diversity of small mammals, and the high proportion of *Mastomys coucha* in all habitats, indicate a high level of disturbance in the reserve

In Namibia few studies have been conducted on small mammals, especially on the effect of large herbivores on small mammal communities. However, Muck & Zeller (2006) conducted a study on the small mammal communities on cattle and game grazing areas in Namibia on the farm Omatako and Erichsfelde in the Otjozondjupa region. They compared two different management practices (game and cattle farming) by comparing the data of species diversity, density, vegetation parameters, and on grazing and trampling effects by large herbivores. They concluded that the abundance of small mammals was dependent on the vegetation cover. They also concluded that cattle farms supported more and different species, and had a more stable evenness than the game farm.

Other studies merely focused on species diversity, distribution and conservation in general (Meester, 1958; Coetzee, 1969; Matson & Blood, 1994; Griffin, 1990 & 1998). For example, Griffin (1990) conducted a review of taxonomy and ecology of *Gerbilline* rodents of the Central Namib Desert, with keys to the species (Rodentia: Muridae). Most of all current bio-geographical reviews of Central Namib gerbils have presented limited or incorrect information on the presence and distribution of some species. A review of present knowledge concerning the taxonomy and ecology of Central Namib gerbils, which is intended to serve as a basis for future studies on their biology and ecology in the Central Namib (Griffin, 1990).

Griffin (1998) investigated the species diversity, distribution and conservation of Namibian mammals. Griffin reported that the distribution of small mammal has probably not changed significantly over the last 200 years, while other species such as lions and plain zebras have undergone range reduction of up to 95% or more. Griffin (1998) also suggested that the major threat to mammals in Namibia are invasive alien species, including the risks of genetic pollution, and habitat alteration, especially wetland degradation.

Perrin & Boyer (2000) conducted a study on seasonal changes in the population dynamics of hairy footed gerbils in the Namib Desert. They found that although the gerbils were primarily insectivores, they occasionally consumed some green plant materials. They concluded that precipitation drove the system, regulated primary production and hence determined gerbil's population dynamics.

Eiseb (2004) conducted a survey of small mammals on the request of the Namib Spreetshoogte Nature Reserve management (Namibia). Small mammal species trapped, were identified and added to the reserve's biodiversity database. Other studies on small mammals were on the ectoparasites of small mammals. For example Eiseb (2002) conducted a study on fleas (Insecta: *Siphonaptera*) of small mammals occurring at Gella-Ost and Nabaos, Keetmanshoop District in southern Namibia. Eiseb found that the predominant flea species *Xenopsylla piriei* and *Xenopsylla trifaria* were both found on both plots and were recorded from four species of small mammals, namely *Desmodillus*

*auricularis*, *Gerbillurus vallinus*, *Saccostomus campestris* and *Tatera leucogaster*. Eiseb concluded that the prevalence of infested hosts generally increased from February to August. *Xenopsylla piriei* and *Xenopsylla trifaria* were found throughout the study in comparison to *Xenopsylla versuta* which was found in May and August, while *Macrosclidopsylla albertyni* was found only in August. Kangombe (2005) conducted a short study on host specificity of flea's of some small mammals in selected areas around Windhoek. Kangombe's study investigated the prevalence, intensity of infestation and species diversity of fleas on small mammals..

Muck & Zeller (2006) conducted a study on small mammal communities on cattle and grazing areas in Namibia. They found that there was a reduction in the abundance of small mammal over the course of one year on farmland in Namibia independent of whether cattle or wild ungulates were kept on the farm. They also found that reduction of small mammal was correlated with a decline of vegetation cover in the study areas. They concluded that the area on which the cattle were confined supported more and different species, and had a more stable evenness than the wild ungulate grazing ground.

## 2.1 Effect of herbivores on small mammals

Nyako-Lartey and Baxter (1995) conducted a study on effects of different grazing regimes on the population dynamics of small mammal in the Eastern Cape. They compared the two areas, one area was grazed by cattle and the other area was grazed by sheep. Their results show that grazing pattern and behaviour of sheep was probably the most important factor in causing small mammals numbers to be lower on sheep, than cattle grazing plots.

Tasker *et al.* (1991) conducted a study on the small mammal diversity and abundance in relation to fire and grazing in a Eucalypt Forest of Northern New South Wales. They concentrated on the impacts of grazing on small mammals in grazed and un-grazed areas. They concluded that there was no difference in the species richness or diversity of grazed and un-grazed forests. The abundance of small mammals was significantly different between grazed and un-grazed forests. The un-grazed forests had a higher abundance of small mammals.

Hoffmann & Zeller (2005) and Akhtar- Schuster (2002) conducted similar studies on the influence of variations in land use intensity on species diversity and abundance of small mammals. Hoffmann & Zeller (2005) for example found that intensive and uncontrolled grazing by livestock in the communal area had a negative impact on small mammal richness, diversity and survival.

Mahlaba & Perrin (2003) conducted a study on population density and composition of small mammal community in an *Acacia nigrescens* savanna in the Mlawula Nature Reserve, north-eastern Swaziland. They concluded that alien invasive species (which excluded competing local grasses, shrubs and forbs) and overgrazing by medium- to large size ungulates have negative impact on the reproduction and communities of small mammals.

## **2.2 Effects of disturbance of large herbivores on the species diversity of small mammals.**

According to Muck & Zeller (2006) small mammals diversity and abundance are closely linked to vegetation cover and plant species composition, and inter-specific and intra-specific competition. Plants provide food to rodents and other small mammals; they also provide protective cover against predators and extreme environmental conditions (Nyako-Lartey & Baxter, 1995; Muck & Zeller, 2006).

In this study, large herbivores are regarded as the main threats to biodiversity particularly of small mammals. This is because large herbivores may directly compete among themselves for food, space, change soil structure and chemical composition, and impact on the vegetation through their diet, dietary pattern and trampling. In so doing disturbance activities such as overgrazing might cause reduction of ground cover, which would make small mammals particularly vulnerable to predation. Consequently, those small mammals that are sensitive to disturbance would have emigrated from the area or

they might just survive in what is termed as marginal habitat. Intensive trampling on the other side may destroy burrows of small mammal and therefore decrease the nesting and nesting possibilities for these animals. The removal of ground cover due to overgrazing and trampling may lead to dry conditions, increase in soil temperature and soil erosion. The long term effects are impacting on the small mammal species diversity, richness and composition.

According to Chase *et al.* (2000), Laidlaw (2000) and Hoffmann & Zeller (2005) the disturbance of habitat structure are associated with changes in small mammal community structure and species richness. Large herbivores modify vegetation layers in terms of structure and composition to a level where small mammals can be affected (Kerley, 1992b; Hoffmann & Zeller, 2005). Hartebeest, roan and sable antelope are selective feeders and do not feed near the ground (Smithers, 1983). They predominantly remove central tillers but not leaves at the periphery. Consequently, small mammals have adequate grass cover that enable them make runaways and nests (Nyako-Lartey & Baxter, 1995). White rhino and buffalo are bulk feeders (Smithers, 1983), they feed on the leaves around the edges of the tussocks leaving little or no grass canopy cover (Nyako-Lartey & Baxter, 1995). Trampling and overgrazing also affects the food supply. It reduces shelter of small mammals and vegetation cover and exposes them to predation (Nyako-Lartey & Baxter, 1995; Joubert & Ryan, 1999; Avenant, 2000; Hoffmann & Zeller, 2005).

### 2.3 Ecological importance of small mammals

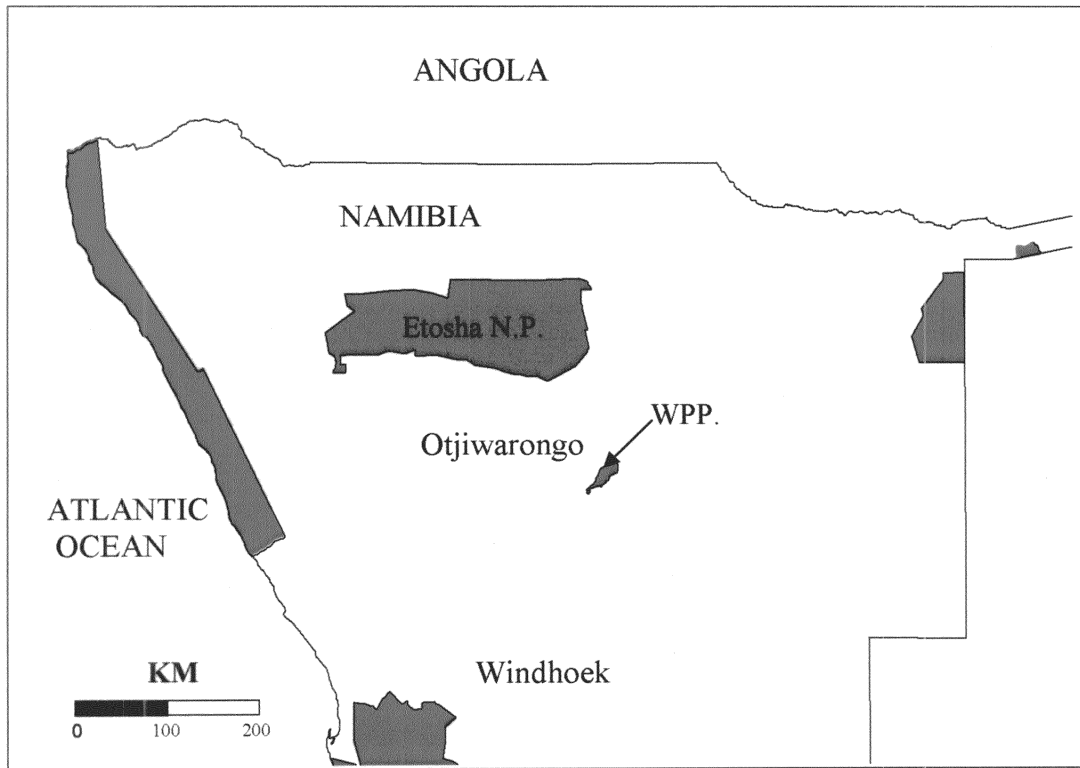
Small mammals play essential ecological roles as consumers, predators, dispersers of seeds, burrowers and as prey for carnivores and raptors. Many small mammals act as indicators of status of the ecosystems (Kerley, 1992b; Avenant, 2000; Hoffmann & Zeller, 2005). There are some small mammals that are able to successfully tolerate and exploit the disturbance that occur in their physical and biological environment, while other small mammals communities are unable to control changes in their environment (Nyako-Lartey & Baxter, 1995). Overgrazing and trampling are such a disturbance in the environment (Avenant, 2000; Muck & Zeller, 2006), that it influence stratification of grass, plant species composition and the standing crop biomass of grassland ecosystem.

Activities of large herbivore such as overgrazing and trampling reduce vegetation cover, leads to changes in soil structure, and soil temperature and these portray rangelands and areas close to waterholes as being unproductive and irreversibly degraded (Joubert & Ryan, 1999). Overgrazing and trampling of habitats may negatively impact on biodiversity (Hoffmann & Zeller, 2005). On which is on associated ecological processes such as pollination, seed dispersal, seed germination and nutrient dispersion (Joubert & Ryan, 1999; Chase *et al.* 2000; Laidlaw, 2000). There are some small mammal species for example, *Tatera leucogaster*, which are regarded as being sensitive to disturbance (Hoffmann & Zeller, 2005). While *Gerbillurus vullinus* and *Mastomys* spp are the first species to dominate after disturbances occur such as drought, fire, overgrazing and cultivation (Avenant, 2000; Hoffmann & Zeller, 2005).

## CHAPTER 3 MATERIALS AND METHODS

### 3.1 Study area

The WPP is situated in north-central Namibia between 20° 30' S and 17° 15' E (Figure 3.1) and approximately 80 km east of the town of Otjiwarongo. It forms a table mountain with a prominent plateau of about 40 000 hectares. The highest point on the plateau lies at 1930 m above sea level (Schneider, 2004). The lowest point of the plateau lies at 1550 m above sea level and between 100 m to 300 m above the surrounding plains (MET, 1986). The Park measures about 50 km in length and 16 km in width. On the north-west, the south-west and the south-east, the mountain is surrounded by steep escarpment or steeply rising slopes. Towards north-east the plateau altitude decreases gradually due to the dips of the plateau where the mountain eventually merges with the Kalahari Sandveld to the east (Schneider, 2004). Along the northern western edge of the WPP lies the Okarukuvisa Mountains, which are approximately 2000m higher than the plateau. These mountains protect the area in the southeast against erosion (Du Preez, 2000).



**Figure 3.1** Showing the location of Waterberg Plateau Park (WPP) (Erckie, 2006).

### 3.2 Park background

The Waterberg Plateau was first proclaimed as a Natural monument by the Historical Monument Commission decision G.K. 133 – O.K. 2003 on 15 June 1956. Ten years later (May 1966) the Parks board of the then Administration of South West Africa, visited the Waterberg plateau and decided on the following:

- The feasibility of renovating the old German Police station known as the “Rasthaus” for tourism, and
- The possibility of creating an eland reserve on the plateau.

Mr. K.C. Tinley, who was the ecologist of the Nature Conservation Branch, was tasked to produce an ecological report, with recommendations on the feasibility of creating an eland reserve on Waterberg (MET, 1986). Tinley (1966) recommended the following:

- a. During 1967 commercial farmers were granted ownership over wildlife in Namibia as preventative measure and to ensure the future of eland (*Taurotragus oryx*), and in addition the saving of rare, wild ungulates from extinction.
- b. The two key farm areas for the Plateau, Onjoka (333 ha) and Bergtuine (455 ha) should be bought and added to the North Western Monument areas on the Plateau.
- c. The Directorate of Water Affairs has planned to construct a dam for the Waterberg Plateau in the Karakuwisa Mountain Range. A game proof fence should be build along the northern boundary of the Plateau.
- d. When (c) and (d) are completed, the Nature Conservation should begin stocking the Plateau with rare game species such as Sable antelope, Roan antelope, Tsessebe and black rhino.
- e. Nature Conservation staff were appointed to administer the Nature Reserve (Monument Areas) of the Waterberg Plateau; especially as there is much poaching on the Plateau.

In 1970 some farms adjusted to the park where bought and incorporated into the park which in extent makes up 40545 ha. On 16 June 1972, the WPP was officially

proclaimed according to Article 38 of the Ordinance of Nature Conservation of 1967 with the following justification (Jankowitz 1983):

The aesthetical value of the sandstone formations;

The historical importance of the area;

The suitable habitat for rare and endangered animal species;

The only area in Namibia where the “Tree savanna and Kalahari dry woodland” are Conserved; and the need for a tourism Centrum in the north, central area of Namibia.

### **3.3 Human influence on the area**

Of all the ethnic groups known, the San were the earliest ethnic group to occupy Waterberg Plateau, followed by the Damara (Jankowitz 1983; MET 1986). The influence of these ethnic groups was mostly concentrated in the vicinity of the natural fountains at the foot of the mountain where tobacco, calabashes and pumpkins were grown on a small scale. The San were responsible for veld fires that were used to entice animals to burned areas for hunting purposes (Jankowitz 1983, MET, 1986).

According to MET (1986), the Herero were the third ethnic group to reside in the area. However, MET stated that “Herero were semi nomadic, cattle herders and hunters”, thus without permanent shelters and they never stayed or used the plateau as pasture for their cattle and only used the fountains in the eastern side of the plateau and only in cases of drought as the water of the Waterberg were too “fresh” (not enough salt in the water). It does not give a true reflection of the Herero community. Because some of the Herero

community who were residing at the Waterberg area were involved in small scale cultivation of land (personal observation). However their impacts on the vegetation were caused by the large cattle herds and the burning of veld to control ticks. This most likely had an influence on the plant growth.

The impact of the white farmers at Waterberg started in 1910. By approximately 1960-1961 they had a lot of cattle on the plateau (Jankowitz 1983). According to Du Preez (2000), one farmer, Mr. Von Boetinger, started in 1920 to burn the entire plateau every third or fourth year, depending on the rainfall received. Burning was done between August and September with strong north winds resulting in a crown fire with little damage to the grass strata, thus resulting in an open savanna. By 1953/54 the plateau was open grassland with low shrubs and trees (MET, 1986). Hot fires and ten years drought (1959/1969) are two natural and human induced factors that possibly influenced the present plant community structure on the plateau (Jankowitz, 1983).

The outbreak of foot and mouth disease in Otjiwarongo district in 1961/62 also led farmers in the area of Waterberg search for emergency grazing on the plateau. This resulted in almost total devastation of the grass layer and large scale erosion on the plateau.

### 3.4 Geology and Soil

Geology is one of the features that make Waterberg Plateau a unique place. According to Schneider (2004) the geological history of Waterberg started 300 Ma ago, when thin tillites were deposited on pre-Damaran basement by the retreating Dwyka ice sheet. Thereafter, shales, mudstone and sandstones of the Eccca group were poured, but only locally. Another event followed about 220 Ma ago, a half-graben, the Omingonde Basin, developed in the Waterberg and Mount Etjo region and the sedimentation of the Omingonde Formation started in this half-graben under semi-arid climate conditions. Equal to 700 m of conglomerates, sandstones, and mudstones accumulated, and some limestone layers occurred. These sediments were derived from the surrounding highlands, where the basement rocks were exposed to weathering. The eroded materials were then transported into the lakes in the half-graben, but they probably flowed only intermittently after periodic rains, as evidence from the re-working within individual sediment layers (Schneider, 2004).

Over time, the climate became more arid and about 180 Ma ago, where the lithified dunes known as aeolianite covered the entire area. These dunes belong to the Etjo Formation overlying the Omingonde Formation. It is believed that the dunes were at least 100 m thick. It consisted of typical Kalahari dune veld with sandstone cliffs of up to 100 m high in northwestern and southwestern boundary. At the Waterberg itself, the Dwyka and Eccca Groups do not crop out. The Omingonde Formation consists mainly of

massive, red-brown, fine-grained sandstone and siltstone with subordinate mudstone (Schneider, 2004).

The texture of the soil on the WPP is sandy loam, which forms 89.4 % of the A and B horizons based on 225 samples analyzed by Jankowitz (1983). Jankowitz (1983) described the soil as “very poor”, since it was derived from the red quartzite sand, which is mainly leached out. Sand sampled on the plateau indicated that the clay content was relatively low, with 93%, of 225 samples having a clay content of less than 20%. The pH in the sand ranged between 3.6 and 6 with an average value of 4.4 for 77 samples taken (Jankowitz 1983).

Jankowitz (1983) found the following values for some soil nutrients from 77 samples taken from WPP:

Phosphate (P) - For A and B-horizon it was found that between 80 % and 96, 6 % of the sand taken, the phosphate content values were lower than 15 parts per million (ppm). Only 5,7 % of all samples analyzed were higher than 40 ppm.

Potassium (K) - The potassium values in the A and B-horizons were also low with 89,8 % in the A-horizon and 9,6 percent in the B-horizon.

Calcium (Ca) - For 81,2 % in the A and 91,4 percent in the B-horizon Ca values of all samples were below 200 ppm.

### **3.5 Climate**

WPP falls within the climatic region known as “Hot steppe” climatic zone according to the Köppen system of classification (Erb, 1993; Du Preez, 2000). “Hot steppe” is a dry region with a deficiency in rainfall, an annual mean temperature above 18° C and receives summer rainfall (Jankowitz, 1983, Erb, 1993). Meaning that during the winter months (May to August) high-pressure cells move south and contribute to the formation of the Kalahari high-pressure system over Botswana. As a consequence, not much humid airflows into northern Namibia and rain during these months are an exception on WPP (Du Preez, 2000). According to Du Preez (2000) the topography of the WPP is an influencing factor on the local climate of the plateau. This is because the plateau is about 150m higher than the surrounding areas.

### **3.6 Temperature**

WPP temperature tends to follow the typical summer high and winter low pattern of the Southern Hemisphere (Du Preez, 2000). The average daily minimum temperature for the coldest month is between 4 °C and 5 °C and during June, the temperatures can go as low as -5 °C (Jankowitz, 1983; Erb, 1993). The average daily maximum temperature ranges in the hottest month between 31 °C to 32 °C and during October to December and January temperatures rises up to 39.4° C (Jankowitz, 1983; Erb; 1993; Du Preez, 2000; NMS, 2006). Sachse and Bonthuys (1990) in Du Preez (2000) recorded high temperatures of 40 °C in Otjiwarongo over November and December.

Intensive efforts were made to obtain daily mean temperatures from the Namibia Meteorological Services (NMS) for Waterberg Plateau Park. The available temperature data, that gave an indication of the expected temperatures on WPP are for Grootfontein (1968- 1985) and Otjiwarongo (1907-1982) which were situated about 80 km east and west of WPP respectively. The lowest temperature of  $-9.5\text{ }^{\circ}\text{C}$  ever was recorded at WPP by Jankowitz (1983).

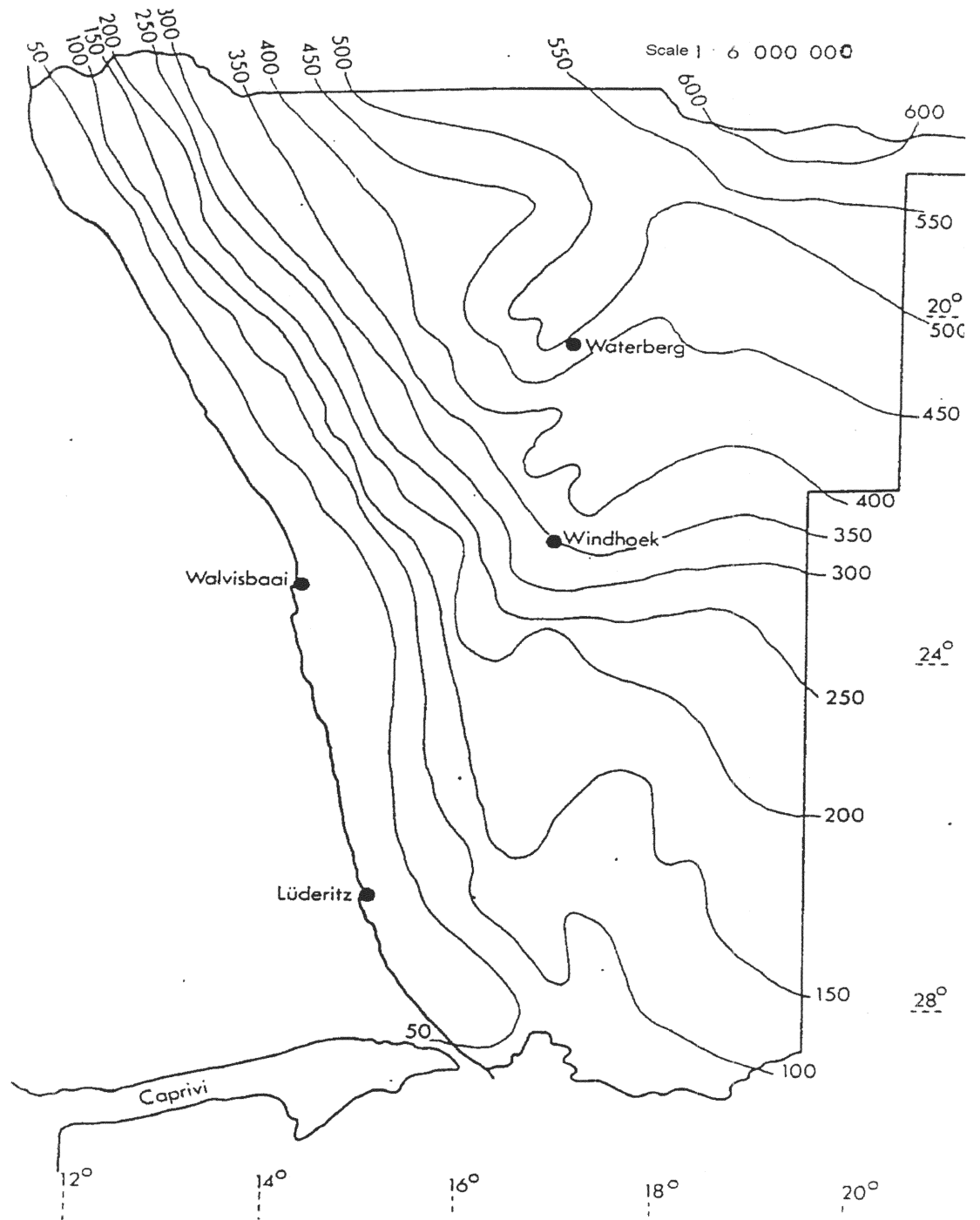
### **3.7 Wind**

According to Jankowitz (1983), the wind regimes are influenced by the prevailing high and low-pressure systems. The winds that are predominant throughout the year and blow from the east being windiest between June and December. In April and October the north winds turn to west winds in the late afternoons, and south and southeast winds blow usually during September and October. These prevailing wind patterns influence the rain and usually the rain occurs with the north, northeast and east winds, which brings humid air from those directions (Jankowitz 1983; Du Preez, 2000).

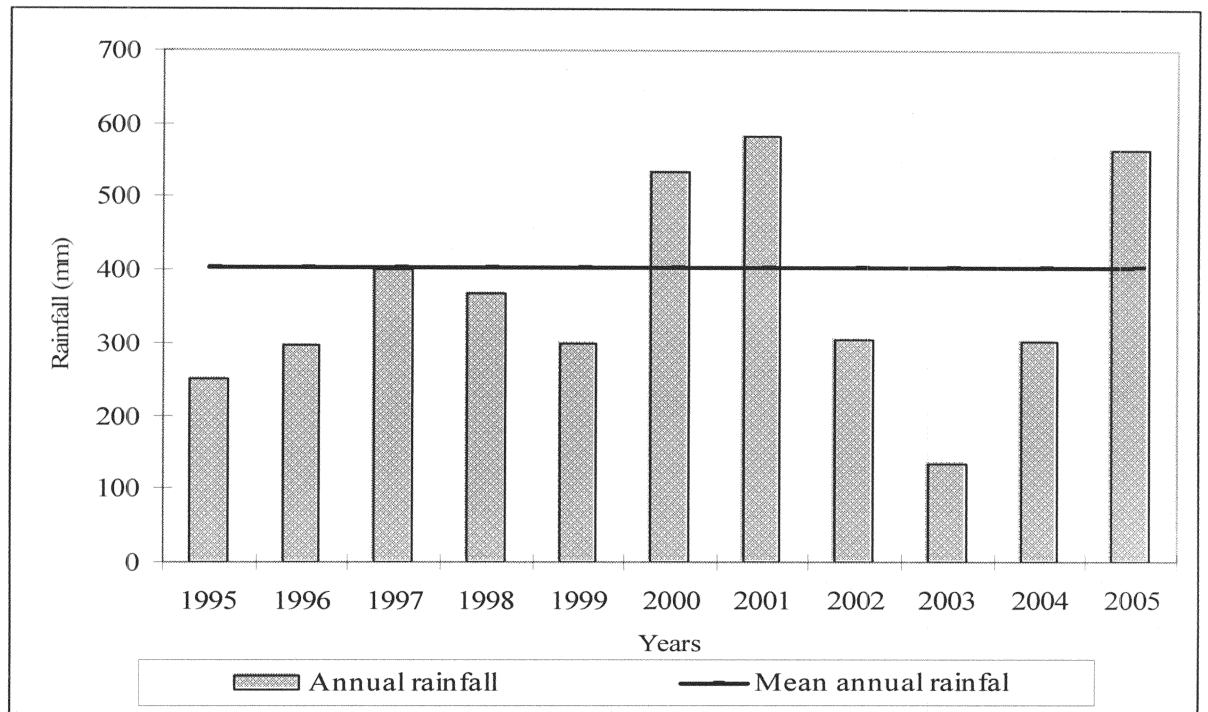
### 3.8 Precipitation

Dew and mist occur during summer and autumn respectively. Frost occurs in the winter months with a definite influence on the structure of the plant communities, and therefore directly impact on the small mammal's habitat. Frost is associated with the topography of the mountain with a higher incidence of lower temperatures in the more low-lying areas.

Waterberg Plateau Park falls within the 450-500 mm rainfall isohyets (Figure 3.2), with mean annual rainfall which is not normally distributed and therefore the median as a statistical parameter can also be used to describe the rainfall distribution. The median is a good statistical parameter to describe the "normal" rainfall in particular the monthly "normal" in Namibia where the temporal variability is great (Katsiambirtas, 1988). But in this study to be able to compare the different climatic parameters the mean, and not the median, was used.



**Figure 3.2** Rainfall isohyets of Namibia illustrating the effect of the Waterberg Plateau on the local climate (NMS, 2006)



**Figure 3.3.** Annual rainfall (mm) with the mean annual rainfall super-imposed for Onjoka Office (WPP) for the period 1995 to 2005 (Erckie, 2006).

### 3.9 Fauna

Waterberg Plateau Park (WPP) was proclaimed in 1972 as a sanctuary for rare and endangered game species with the objective of breeding and to provide stock for the reintroduction of species within selected areas in Namibia where they naturally occurred.

Some of the herbivores such as Tsessebe (*Damaliscus lunatrus*) introduced at WPP were threatened due to habitat destruction, others such as black rhino (*Diceros bicornis*) were threatened with extinction due to illegal hunting and trading of their

products. A few others like white rhino (*Ceratotherium simum*) were introduced due to economical reasons whereas some game species such as roan antelope (*Hippotragus equine*) and sable antelope (*Hippotragus niger*) were considered as rare in Southern Africa (Erb, 1993). However, game species such as African buffalo (*Syncerus caffer*) were introduced for multi purposes such as breeding, trophy hunting, and tourism and live selling.

The following game species were present before the proclamation and were kept on the plateau due to their conservation status: Eland (*Taurotragus oryx*), Giraffe (*Giraffe camelopardalis*) and Red Hartebeest (*Alcelaphus buselaphus*) (MET, 1986).

### **3.10 Flora**

According to Jankowitz (1983) and Jankowitz & Venter (1987), WPP falls within the “Tree Savanna and Kalahari Woodland” vegetation type of Namibia and consists mainly of variety of deciduous trees and shrubs and “hard” grasses.

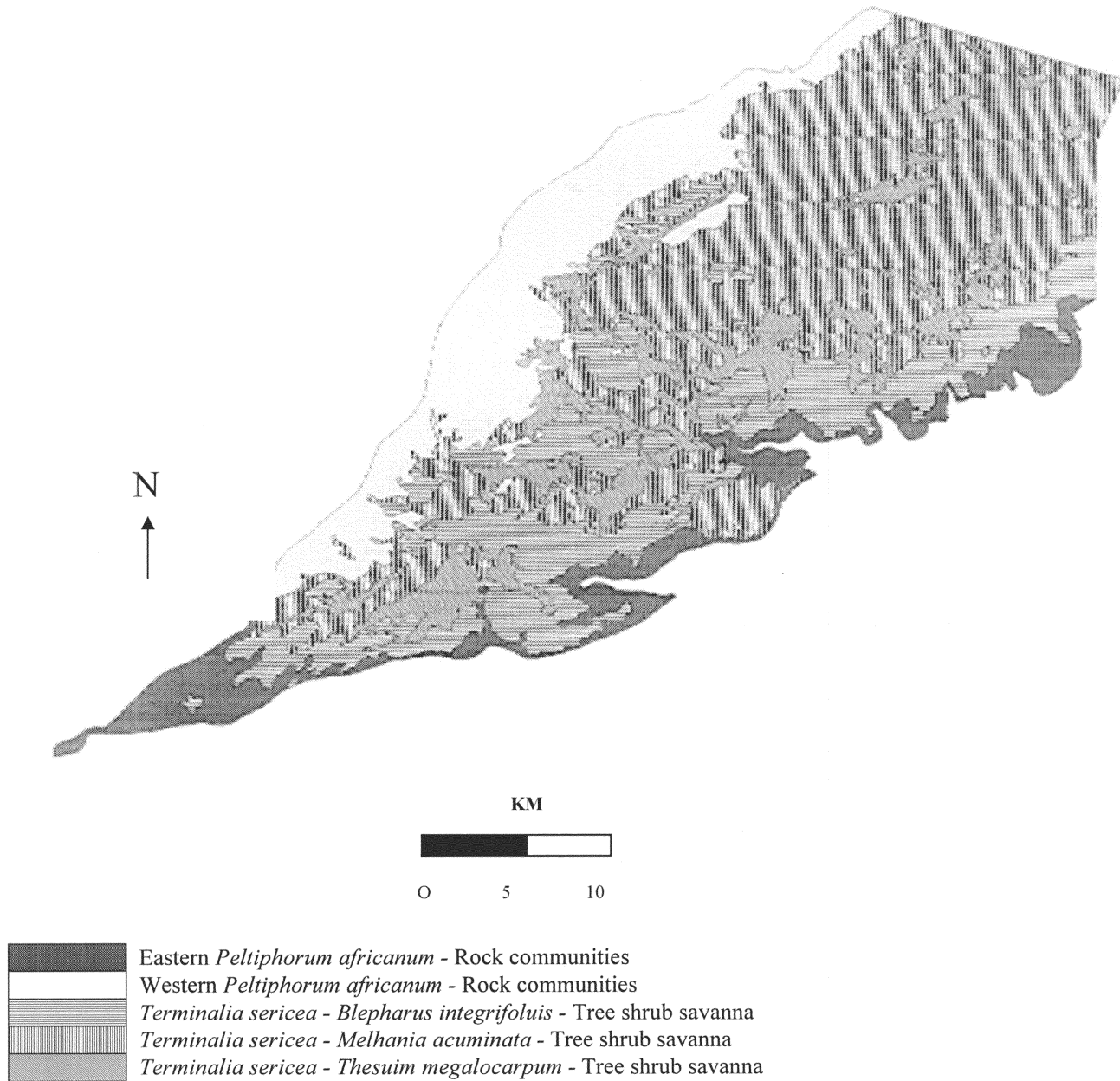
The vegetation types on the main plateau are associated with vegetation in the Kalahari basin (Erb, 1993). In contrast, the vegetation below the plateau is of the common thorn bush savanna, dominated by *Acacia mellifera*, *Dichrostachys cinerea* and *Acacia erioloba* (Jankowitz, 1983; Jankowitz & van Rensburg, 1985; Jankowitz & Venter,

1987). All the mentioned plant communities represent about 1600 ha of the main plateau (Jankowitz, 1983) (Figure 3.4).

Jankowitz (Jankowitz 1983; Jankowitz and Venter 1987) carried out a complete vegetation survey of WPP. They found ten different plant communities and classified them in four different vegetation types as:

- *Terminalia sericea*–*Thesium megalocarpum* (tree/ shrub savanna), which is widespread on the deep sandy soil of the plateau resulting in a complex mosaic distribution. This habitat type was related with low-lying depressions, which are susceptible to frost.
- *Terminalia sericea*–*Melhania acuminata* (tree/shrub savanna), the largest (16000 ha) and widespread plant community on the plateau with *Antheplora pubescens*–*Eragrostis superba* dominant grass species (grass savanna).
- *Peltophorum africanum* (rock communities) that include all rocky areas of the WPP
- *Terminalia sericea*-*Blepharus intergrifoluris* tree shrub savanna on the dune crests (Jankowitz, 1983; Jankowitz & van Rensburg, 1985; Jankowitz & Venter, 1987).

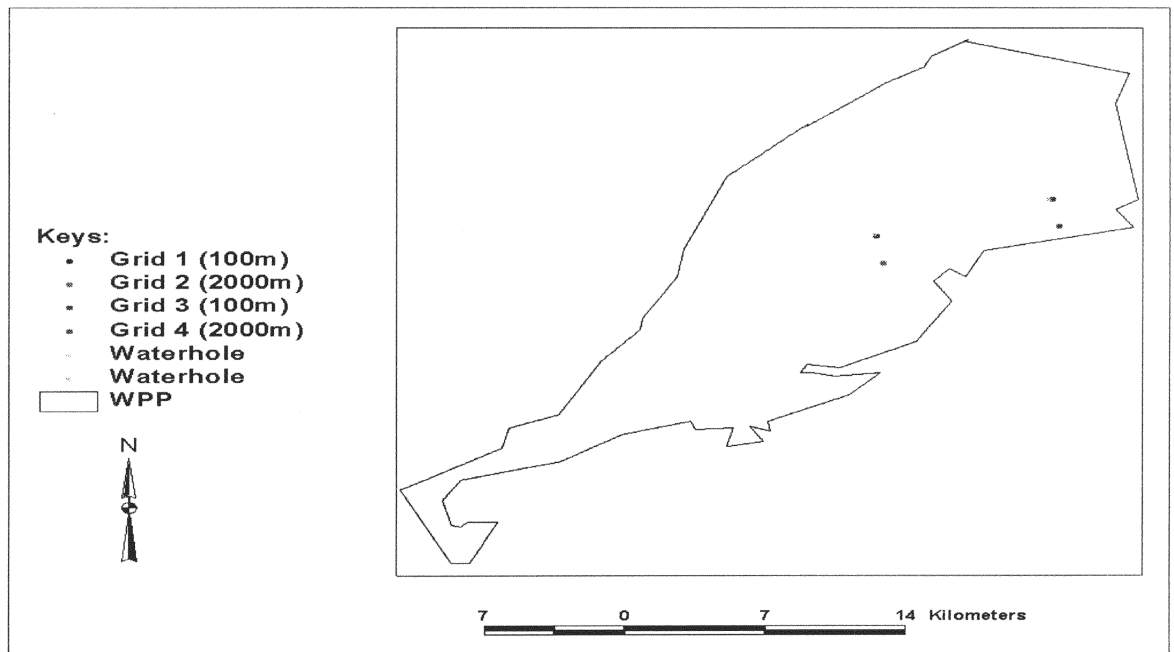
The study areas fall within the tree shrub savanna but between the *Terminalia sericea* – *Melhania acuminata* and *Terminalia sericea* and *Blepharus intergrifoluis* vegetation types.



**Figure 3.4** The main plant communities at WPP as adapted from Jankowitz (1983) in MET (1985).

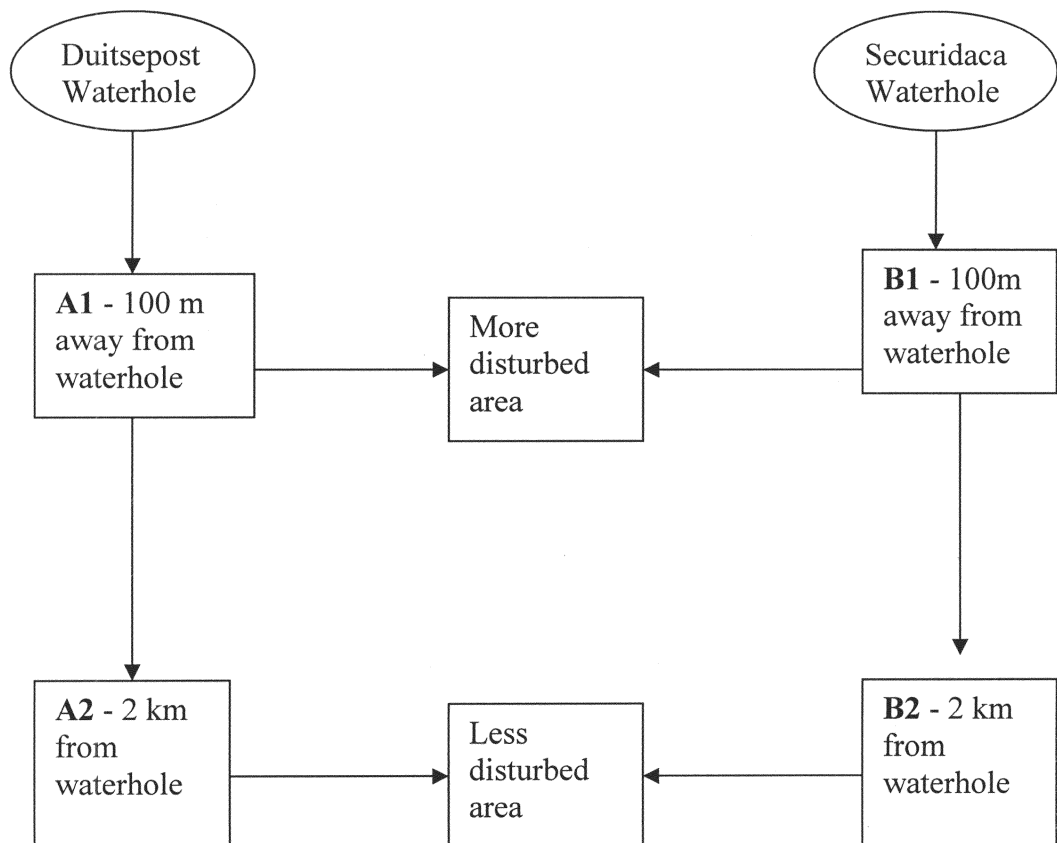
### 3.11 Methods

In order to determine species diversity of small mammals, two water points, Duitse post (S 20° 23' 40.7" and E 017° 18' 09.6") and Securidaca (S 20° 21' 44.2" and E 017° 22' 50.9) were selected for this study. Both waterholes are located on a level landscape of the plateau (Figure 3.5). The grids were placed at each waterhole at a distance of 100m and 2km from the artificial waterholes. The grids (plots) were demarcated with binding wire droppers.



**Figure 3.5.** Showing the location of the waterholes and the grid (plots) on the plateau in relation to the Park (Erckie, 2006).

The four plots were named A1, A2, B1 and B2. A1 and A2 were plots at Duitse post waterhole, whereas B1 and B2 were plots at Securidaca waterhole. In this study, the plots (A1 and B1), which were 100 m away from the waterholes, were classified as more disturbed areas and the plots (A2 and B2) which were 2km away from the waterholes, were classified as less disturbed areas (Figure 3.6).



**Figure 3.6** Illustrate the position of the Duitse post and Securidaca waterhole, plot A1 and B1 classified as more disturbed areas, whereas plot A2 and B2 classified to less disturbed area.

### 3.11.1 Vegetation cover estimation

The estimation of vegetation cover was conducted during the trapping session of December 2005 (hot and dry); March, April (warm and wet), May and June 2006 (cold and dry). This estimation was conducted at 100m and 2km from the waterhole and these were designated as more disturbed area and less disturbed area, respectively. At each grid the grass cover was assessed in order to ascertain the existence of significant gradient in the level of disturbance from the waterhole outwards. The projected ground vegetation cover of each study area was estimated within 10m<sup>2</sup>, which were marked with poles. Plants were first categorized as trees, grasses, shrubs, herbs and bare ground. Every square (10m x 10m) was given a fixed point and cover for each category was estimated. Four vegetation variables were sampled at each square (10mx10m) (Muck & Zeller, 2006) : (a) maximum height of trees, (b) percentage grass cover, (c) percentage herb cover, (d) total ground cover. The total projected ground cover was percentage trees, grass, herb and bush cover. By looking at all plants of one category, imaginary shade was added (in %) in relation to the whole square. All plant cover was estimated by summing up percentage cover and comparing to estimated bare ground.

Tree species were identified using the Field Guide to Trees of Southern Africa (Van Wyk & Van Wyk, 1997), Grasses were identified using the Grasses of South West Africa/ Namibia (Muller, 1984) and Guide to grasses of Southern Africa (Van Oudtshoorn, 1999).

### 3.11.2 Field trapping of small mammals

Trapping of small mammals was conducted every second week of December 2005 (hot and dry) and in 2006 in the months of March (hot and wet), April (hot and wet), May (cold and wet), and June (very cold and dry). Data were collected over four consecutive nights. A total of five trapping sessions was carried out (on the four plots) on the plateau. Each trap grid covered an area of 1ha (100 m x 100 m) and each grid had 100 trap stations (Sherman live traps) (Leirs, 1995, Nyako-Lartey & Baxter, 1995). These grids consisted each of 10 parallel rows and, 10 columns and with 10m-space interval (Deblase & Martin, 1981), resulting in 100 trapping stations per grid. Each trap was placed at the centre of the grid. For recording purposes each trap was identified by coordinates or grids of A to J, 1 to 10 (Leirs, 1995, Nyako-Lartey & Baxter, 1995). At each area the two grids were situated 2 km apart.

Traps were baited with a fresh mixture of oats and peanut butter. The bait mixture was used on the basis of strong smell of peanut butter, which attracts small mammals to the traps. Small mammal traps were baited or set before sunset between 17h00 and 18h00 and checked in the morning between 07h00 and 11h00. This timing allowed access for diurnal day living animals because small mammals that are active during the day have their movement limited to a period between sunrise and midday, and again from late afternoon until sunset (Smith *et al.*, 1975). A total of 2000 trap nights were conducted at each plot during the study of December 2005, March, April, May and June 2006.

### 3.11.3 Weighing, Marking and Preservation

Captured small mammals were placed in a plastic bag and weighed to the nearest gram, using a 200g and 300g Pesola spring balance. The tail and hind foot lengths were measured to the nearest 1mm after immobilizing the animals using transparent plastic tubes as restrainers. Small mammals were weighed, measured (head-body length), sexed, and assigned to relative age classes (juveniles, sub adults and adults (Nyako-Lartey & Baxter, 1995). Relative age was assigned to individual small mammal species based on comparison with other individuals in the sample areas. The category for adult generally refers to the large and potentially breeding members of a population. The category for sub-adult individual generally a young and may or may not be in breeding condition. This individual is typically smaller than an adult, but otherwise is similar to the adult. A juvenile individual is smaller than a sub-adult and often (but not always) has a pelage coloration that is distinct from that of sub-adult and adults (Nyako-Lartey & Baxter, 1995).

The reproductive status of small mammals was assessed. Females were considered reproductively active when the nipples were enlarged or engorged, or the vulva was perforate, plugged or blood, and the lower abdomen swollen. Males were considered reproductively active when enlarged testes had descended to the scrotum (Perrin & Boyer, 2000). A diagnostic morphological features were used and standard identification

measurements were taken to identify the animals to species level using the characteristics of De Graaff (1981) and Smithers (1983).

The Capture Mark Re-capture (CMR) method was used (Krebs, 1989; Hoffmann & Zeller, 2005; Muck & Zeller, 2006). Marking allows each individual to be identified whenever it is caught again in subsequent sessions. Captured small mammals were released immediately to reduce stress from hypothermia and possible predations and increase capture opportunity (Perrin & Boyer, 2000). Before release, small mammals were individually marked (tattooed) with unique subcutaneous (underside of the tail) marks (using PRIMAcryl paint). The tattooing or marking allowed the identification of each individual upon recapture. The marking method requires that three fundamental assumptions be met (Smith *et al.*, 1975; DeBlase & Martin, 1981):

1. That the small mammals captured and marked do not lose their marks
2. That the small mammals captured and marked are correctly recorded as marked or unmarked individuals.
3. That marking does not affect the probability of survival of the marked individuals compared with that of unmarked individuals.

From each species of small mammals two samples were taken for verification. Those small mammals were killed using chloroform and the specimen placed in formalin (Formadehyde solution) for 24 hours in order to harden them. They were finally preserved in 75% ethanol as “wet specimen”. Museum labels were attached to the specimens; these voucher specimens were kept for later identification. The specimens

were dissected, and taxonomically identified using standard keys including the mammals of the Southern African sub region (Skinner and Smithers, 1990), Field Guide to the Mammals of Southern Africa (Stuart & Stuart, 1991) and a manual of Mammalogy with keys to families of the world (DeBlase & Martin, 1981) small mammals manual.

### **3.12 Data analysis**

Statistical Software packages, GenStat for Windows Discovery Edition 2 Release 4.24DE and Statistical Package for the Social Sciences 11.5 for Windows (SPSS) were used to analyze the data pertaining to small mammals. Trapping of small mammals was done for 4 consecutive days in each trapping site during each month (December 2005, March, April, May and June 2006) when data was collected. A Kolmogorov-Smirnov (K-S) test for normality test was calculated using SPSS and a Kruskal-Wallis test was calculated using GenStat. A Kolmogorov-Smirnov test was used to determine whether the data for species diversity, richness and species composition of small mammals follows a normal distribution. The data referred to was the total number of individual small mammal species collected during each trapping session in each month. The Kolmogorov-Smirnov test of normality showed that the following data obtained in this study were not normally distributed ( $p < 0.000$ ), species diversity ( $D = 0.181$ ,  $df = 80$ ,  $P < 0.000$ ), richness ( $D = 0.181$ ,  $df = 80$ ,  $P < 0.000$ ) and abundance ( $D = 0.152$ ,  $df = 80$ ,  $P < 0.000$ ).

A Kruskal-Wallis test is a nonparametric equivalent of the one-way analysis of variance and has a null hypothesis that all samples are taken from population with the same median (Dytham, 1999). A Kruskal-Wallis test was used to test for significant difference for species diversity, richness and abundance of small mammals that were not normally distributed. Mann-Whitney test showed that there was no significant difference ( $U = 9.0$ ,  $P < 0.000$ ) between the more disturbed and less disturbed area.

Hierarchical Cluster Analysis (HCA) was used to determine and compare species composition of small mammals. Cluster analysis was also used to generate dendrograms that show similarities and dissimilarities among the groups in the more disturbed and less disturbed area.

### **3.12.1 Trap nights and trap success of small mammals**

The term “trap night or trap units” is a term used to describe the number of traps used multiplied by the number of nights (DeBlase & Martin, 1981; Nyako-Lartey & Baxter, 1995; Avenant, 2000; Hofmann & Zeller, 2005). Trap success was given as the percentage of the traps that captured small mammals (DeBlase & Martin, 1981). Trap success (or percentage success) was indicated as the number of small mammals captured/100 trap nights (DeBlase & Martin, 1981; Avenant, 2000).

### 3.12.2 Species diversity, species richness and heterogeneity of small mammals

There are many different indices in which biological diversity can be measured. These include species richness, evenness and heterogeneity (Schulders & Ricklefs, 1993; Mfunne, 2005). In this study species diversity was presented as species richness which is the number of species that occur within a sampling area (Schulders & Ricklefs, 1993; Mfunne, 2005). Heterogeneity encompasses both species richness and species evenness (Schulders & Ricklefs, 1993; Mfunne, 2005). Therefore, high species diversity might occur where there is combination of more different species and where the number of individuals in the total population are more equitably distributed among species (Mfunne, 2005).

Species diversity of small mammals in each area was calculated using excel programme and the Shannon-Wiener species diversity index ( $H'$ ) measure for biological diversity (Nel, 1975; Zar, 1999).

$$H' = -\sum_{i=1}^s (p_i) (\ln p_i)$$

Where  $H'$  is the information content of sample (value of Shannon-Wiener diversity index = Index of species diversity),  $p_i$  was the proportion of individuals found in the  $i^{\text{th}}$  species;  $\ln$  is the natural logarithm of the  $p_i$ . The Shannon–Wiener index takes into account species richness as well as evenness, which are good indications of species diversity (Krebs, 1989).

Species richness of small mammals was calculated as the number of species that were captured within the sample areas during the trapping period of five months (December 2005, March, April, May and June 2006).

### 3.12.3 Capture-Mark-Recapture of small mammals

In this study abundance of small mammals was presented as: (a) numbers captured, (b) population density using (i) minimum number known to be alive (ii) Petersen method of Captured-Mark-Recaptured.

Population density was estimated using the Petersen method of Capture-Mark-Recapture (CMR) because it was based on a single episode of marking animals and a second single episode of recapturing individuals (Krebs, 1989; Southerland, 1996). The idea was to calculate the proportion of marked animals in a recapture sample which are equal to the proportion of all marked animals in the whole population. According to Krebs (1989) the “Petersen estimation” of population density has been widely used because it is intuitively clear. However, the formula below may also produce a biased estimator of population size, tending to overestimate the actual population. This bias can be large for small, and several formulas have been suggested to reduce this bias. Seber (1982) in Krebs (1989) recommends the estimator

$$\frac{N = (M+1)(C+1)-1}{R+1}$$

where  $N$  is the number of animals in the population at the time of marking,  $M$  is the number of animals marked in the first sample and released,  $C$  is the number of animals caught in the second sample and  $R$  is the number of marked animals caught in the second sample. For the Petersen method of Capture-Mark-Recapture to be an accurate estimation of population density there are five assumptions that must hold (Krebs, 1989):

- (i) The population is closed, so  $N$  is constant. In closed population it is assumed that population do not change in size; for example, gain (births or immigration) or losses (deaths or emigration) during the course of the study.
- (ii) All animals have the same chance of getting caught in the first sample.
- (iii) Marking individuals does not affect their catchability. This assumption is that marked and unmarked animals have equal chance of being captured
- (iv) Animals do not lose marks (tattoos) during trapping sessions, because the tattoos are subcutaneous (under the skin).
- (v) All marks are reported on discovery in each sample.

The Minimum Number Alive (MNA) method estimates the minimum number of small mammals alive (Bronner & Meester, 1987; Armstrong & Hensbergen, 1996; Monadjem & Perrin, 1998). The number of individuals on each grid was estimated using the minimum number known to be alive method (MNA: Krebs, 1989). Minimum number of small mammals alive includes all individuals caught during the trapping session in

December 2005, March, April, May and June 2006 from four plots at Waterberg Plateau including those marked previously which were recaptured at a later date.

#### **3.12.4 Species composition of small mammals using the Hierarchical Cluster Analysis (HCA).**

Hierarchical Cluster Analysis is a multivariate test that groups observations by similarity and provides insight into data. It is also another way of summarizing species data into groups to generate dendrogram that show putative phylogenetic relationships or at least divide individuals into groups that might have taxonomic meaning (Dytham, 1999). Cluster analysis is based on the idea that community types exist, that each can be characterized by characteristic species combinations. Cluster analysis for the purpose of describing community types thus attempts to form groups of sites in such a way that the community-composition of sites varies most between groups and varies least within groups (Jongman, 1987). According to Jongman (1987) cluster analysis is often used in the early exploratory phase of an ecological investigation.

The results may suggest relations to be studied in more detail in subsequent research. Ideally, similarities of small mammals in the two areas (more disturbed and less disturbed area) expressed their ecological relation or resemblance of the dissimilarities of small mammals of two areas and are the complement of their similarities. The basis of all similarity indices for qualitative characters is that two sites are more similar if they

share more species and that they are dissimilar if there are more species unique for one of both area (s) (two species are more similar if their distribution over the areas is more similar (Tongeren, 1987)).

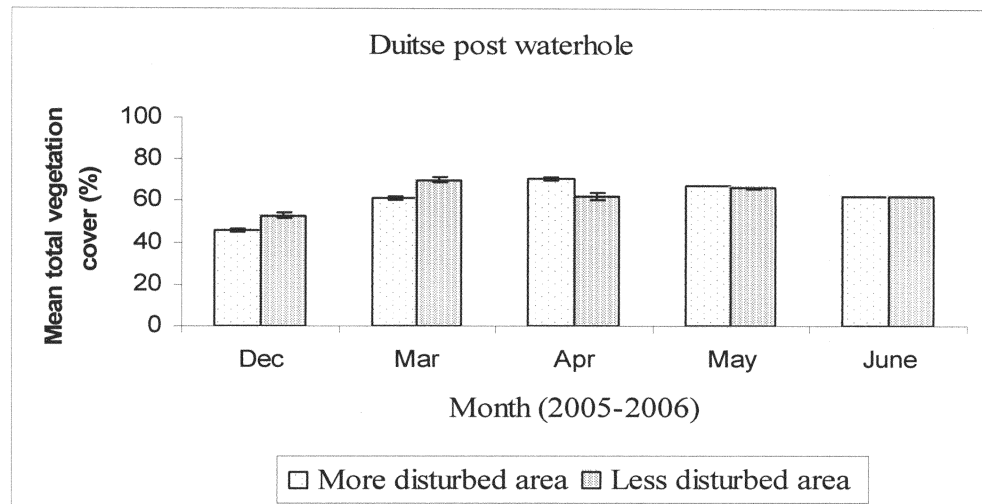
## CHAPTER 4 RESULTS

### 4.1 Variation in estimate of vegetation cover

The study area at Duitse post waterhole falls within the *Terminalia sericea* –*Blepharus integrifolius* (Tree shrub savanna) vegetation type. The dominant trees species in more disturbed area at Duitse post waterhole were *Terminalia sericea*, *Grewia flavescens* and *Ziziphus mucronata*. Whereas the dominant tree species in less disturbed area at Duitsepost were *Terminalia sericea*, *Grewia flavescens*, *Philenoptera nelsii* and *Burkea africana*. The study area at Securidaca waterhole fall between the *Terminalia sericea*-*Melhania acuminata* and *Terminalia sericea*-*Blepharus integrifoluris* (Tree shrub savanna) (Jankowitz, 1983). The dominant trees species in the more disturbed area at Securidaca were *Combretum collinum*, *Philenoptera nelsii* and *Burkea Africana*. Whereas the dominant tree species in less disturbed area at Securidaca were *Grewia flavescens*, *Terminalia sericea* and *Ochna pulchra*.

At Duitse post waterhole the estimated vegetation cover in the more disturbed and less disturbed area ranged from 46% to 71% and 53% to 70% respectively. In the more disturbed area the highest (71%) estimated vegetation was recorded in April 2006 whereas the lowest (46%) was recorded in December 2005. In the less disturbed area the highest (70%) vegetation cover was in March, while the lowest (53%) was recorded in December 2006 (Figure 4.1a). Kruskal-Wallis test ( $H = 12.0$ ,  $df = 4$ ,  $p = 0.916$ ) indicated that there was no significant difference in estimated vegetation cover at Duitse

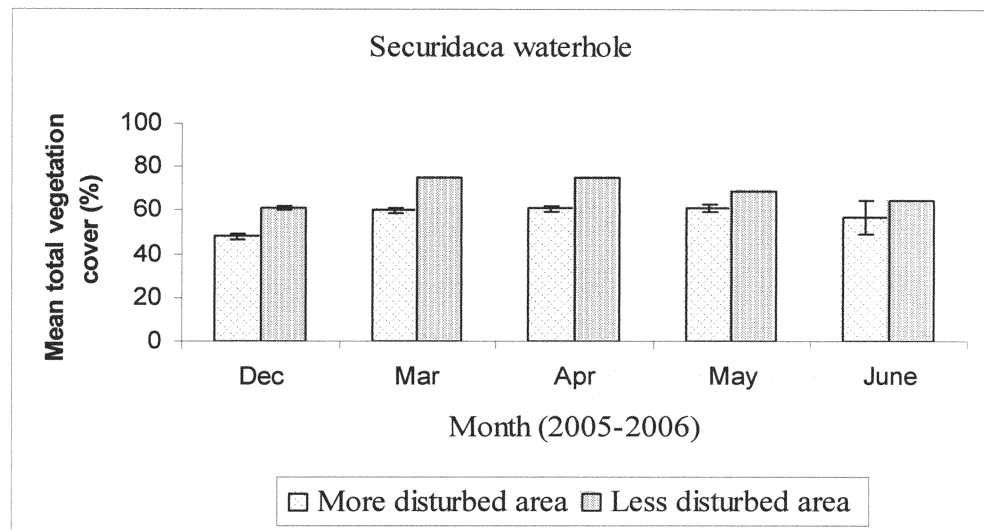
post waterhole between more disturbed and less disturbed area, throughout the study period.



**Figure 4.1a** Mean total vegetation (trees, shrubs/bushes, grasses and herbs) cover (%) at Duitse post waterhole in the more disturbed and less disturbed area during trapping session of December 2005, March, April, May and June 2006 at Waterberg Plateau Park. Error bars are the mean upper and lower 95% confident limits and represent the minimum and maximum values on the 95% confidence limits. Where the error bars are invisible the mean values were very small (0.09 to 0.22).

The mean total vegetation cover (%) at Securidaca waterhole in the more disturbed and less disturbed area ranged from 48 % to 61 % and 61 % to 75 % respectively (Figure 4.1b). In the more disturbed area the highest estimated vegetation cover was recorded in April and May 2006 with the same percentage of (61%), whereas the lowest (48%) estimated vegetation cover was recorded in December 2005. In the less disturbed area the highest vegetation cover was recorded in March and April 2006 with the same percentage of (75%), whereas the lowest (61%) estimated vegetation cover was recorded in December 2006 (Figure 4.1b). Mann-Whitney U test ( $U = 1.0$ ,  $p = 0.015$ ) indicated

that there was a significant difference at Securidaca waterhole between more disturbed and less disturbed area. At Securidaca waterhole the less disturbed area has higher vegetation cover than more disturbed area.



**Figure 4.1b** Mean total vegetation cover (trees, shrubs/bushes, grasses and herbs) in the more disturbed and less disturbed area during March, May and June 2006 at Waterberg Plateau Park. Error bars are the mean upper and lower 95% confident limits and represent the minimum and maximum values on the 95% confidence limits. Where the error bars are invisible the mean values were very low (0.09 to 0.22).

#### 4.2 Small mammals caught

A total of 146 individual small mammals belonging to 12 species were captured in four sampling areas (Table 4.1). These 12 different small mammal species represented 11 rodents and 1 insectivore. *Dendromus melanotis* represented 28% (n=41) and dominated the catches, followed by *Gerbillurus paeba* 23% (n=33) and *Tatera leucogaster* 16% (n=24). The least caught small mammals species was *Thallomys nigricauda* 1% (n=1)

(Table 4.1). Of the 146 individual small mammals caught, 51 %, (n = 75) were males and 49% (n=71) were females (49 %, n = 71). *Gerbillurus paeba* and *Mastomys spp* dominated the male small mammals captured with 21 % (n = 16) followed by *Dendromus melanotis* with 16% (n=12). *Dendromus melanotis* dominated the female catches 41% (n=29) followed by *Gerbillurus paeba* 24% (n=17). Very few female *Crocidura hirta*, *Aethomys namaquensis* and *Mastomys spp* 3% (n=2) (Table 4.1), were captured.

**Table 4.1** Individual number of small mammal species captured in four different study areas at Waterberg Plateau Park during trapping session in December 2005, March, April, May and June 2006. (No. Ind. = Number of individual, M= male individual and F = female individual small mammal, % = relative abundance).

Taxon	No. Ind.	%	M	%	F	%
<b>Soricidea</b>						
<i>Crocidura hirta</i> (Peters, 1852)	3	2	1	1	2	3
<b>Muridae: Gerbillinae</b>						
<i>Dendromus melanotis</i> (Smith, A., 1834)	41	28	12	16	29	41
<i>Gerbillurus paeba</i> (Smith, A., 1836)	33	23	16	21	17	24
<i>Gerbillurus vullinus</i> (Thomas, 1918)	1	1	1	1	0	0
<i>Tatera leucogaster</i> (Peters, 1852)	24	16	8	11	16	23
<b>Muridae: Murinae</b>						
<i>Aethomys chrysophilus</i> (De Winton, 1897)	2	1	2	3	0	0
<i>Aethomys namaquensis</i> (Smith, A., 1834)	10	7	8	11	2	3
<i>Mastomys spp</i> (Thomas, 1915)	18	12	16	21	2	3
<i>Mus indutus</i> (Thomas, 1910)	9	6	6	8	3	4
<i>Thallomys nigricauda</i> (Thomas, 1882)	1	1	1	1	0	0
<b>Muridae: Cricetomynae</b>						
<i>Saccostomus campestris</i> (Peters, 1852)	2	1	2	3	0	0
<b>Gliridae</b>						
<i>Graphiurus murinus</i> (Desmarest, 1882)	2	1	2	3	0	0
<b>Total</b>	<b>146</b>	<b>100</b>	<b>75</b>	<b>100</b>	<b>71</b>	<b>100</b>

During the trapping session of December 2005, March, April, May and June 2006 sixteen trapping session per plot were conducted. A total of 2000 trap nights were conducted at each plots. Out of a total of 8000 trap nights, 146 individuals representing 12 species (1 insectivore and 11 rodents) were caught and marked. A total of 67 and 79 individuals were captured in more disturbed and less disturbed area respectively. The species richness was higher (10) in less disturbed area and lower in more disturbed area (Table 4.2)

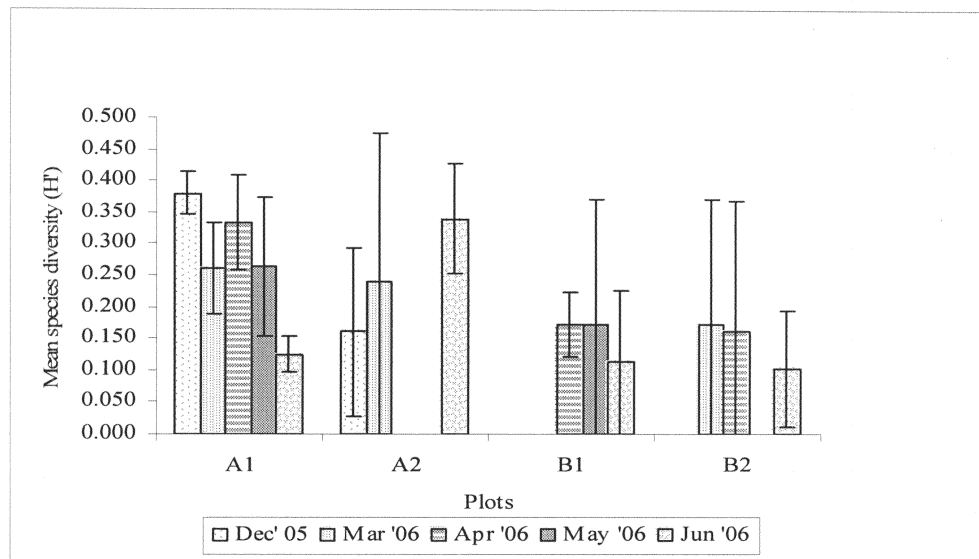
**Table 4.2** Total numbers of species of small mammals (species richness) captured over 4000 trap nights in the more disturbed and less disturbed area Waterberg Plateau Park during the trapping session of December 2005, March, April, May and June 2006. The table also revealed that less disturbed area has high species richness than the more disturbed area.

Species	More disturbed area	Less disturbed area
	Individual (n)	Individual (n)
<b>Soricidea</b>		
<i>Crocidura hirta</i>	0	3
<b>Muridae: Gerbillinae</b>		
<i>Dendromus melanotis</i>	14	27
<i>Gerbillurus paeba</i>	21	12
<i>Gerbillurus vallinus</i>	2	0
<i>Tatera leucogaster</i>	10	14
<b>Muridae: Murinae</b>		
<i>Aethomys chrysophilus</i>	2	0
<i>Aethomys namaquensis</i>	2	7
<i>Mastomys spp</i>	11	7
<i>Mus indutus</i>	5	4
<i>Thallomys nigricauda</i>	0	1
<b>Muridae: Cricetomyinae</b>		
<i>Saccostomus campestris</i>	0	2
<b>Gliridae</b>		
<i>Graphiurus murinus</i>	0	2
<b>Sum of captures</b>	<b>67</b>	<b>79</b>
<b>Specie richness</b>	<b>8</b>	<b>10</b>

### 4.3 Species diversity of small mammals

Kruskal-Wallis test revealed that there was a significant difference ( $H = 17.56$ ,  $df = 3$ ,  $p < 0.001$ ) in the species diversity ( $H'$ ) of small mammals among the four plots (Figure 4.2 (a)). The Mann-Whitney U test also revealed significant difference between plot A1 and plot B1 (more disturbed area) ( $U = 55.0$ ,  $p < 0.001$ ) and between plot A2 and plot B2 (less disturbed area) ( $U = 65.0$ ,  $p < 0.001$ ). More disturbed areas were more diverse than less disturbed areas.

Mean species diversity of small mammals caught in more disturbed (A1) and less disturbed areas (A2) ranged from 0.125 to 0.380 and 0.00 to 0.340 respectively. In the more disturbed area (B1) and less disturbed area (B2) the mean diversity of small mammal caught ranged from 0.000 to 0.173 and 0.000 to 0.173 respectively (Figure 4.2a).

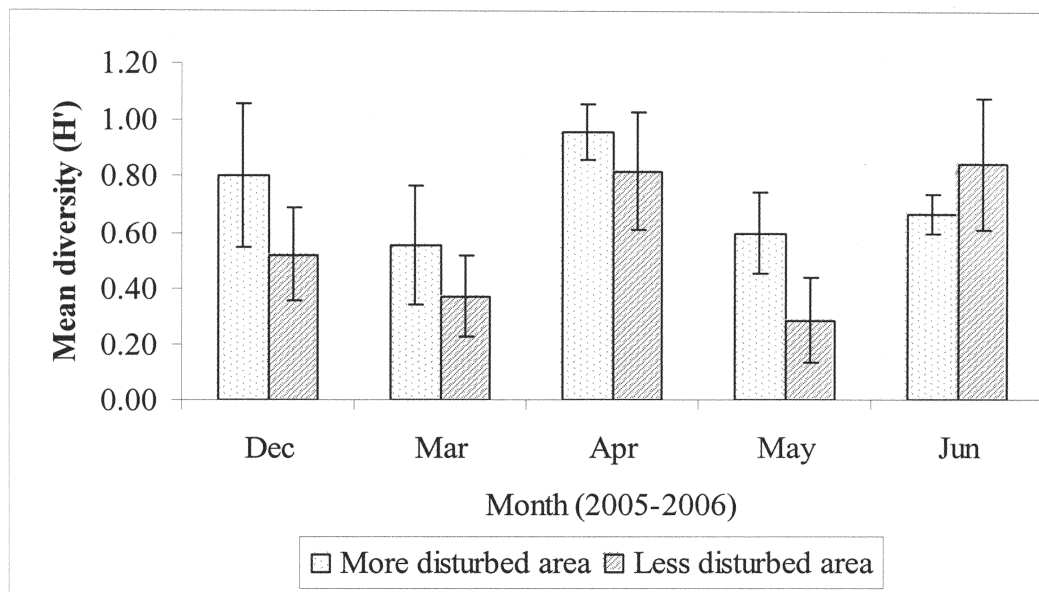


**Figure 4.2a** Mean Shannon-Wiener index of diversity ( $H'$ ) of small mammal species between the four study areas (A1, A2, B1 and B2) during five different trapping sessions from December 2005, March, April, May, and June 2006 at Waterberg Plateau Park. Plus error bars represent the maximum values on the 95% limits associated with the species diversity of small mammals. Study area A1 and B1, and A2 and B2 designated as more disturbed and less disturbed area respectively at Duitse post (A1, A2) and Securidaca (B1, B2) waterholes. Where there are no bars and error bars, it shows that no small mammal species were caught during that specific month at the given sample area.

The highest mean species diversity ( $H' = 0.380$ ) in more disturbed area (A1, 100 m from Duitse post waterhole) was recorded in December 2005 and the lowest ( $H' = 0.125$ ) was recorded in June 2006. The highest mean species diversity ( $H' = 0.340$ ) in less disturbed area (A2, 2km from Duitse post waterhole) was recorded in June 2006 and the lowest ( $H' = 0.000$ ) was recorded in April 2006 and May 2006 respectively. The highest mean species diversity ( $H' = 0.173$ ) in more disturbed area (B1, 100m from Securidaca waterhole) was recorded in April 2006 and May 2006 and lowest mean species diversity ( $H' = 0.000$ ) was recorded December 2005 and March 2006.

A Kruskal-Wallis test revealed that there was a significant difference ( $H = 12.24$ ,  $df = 4$ ,  $p = 0.012$ ) in the species diversity of small mammal among the five months between the more and less disturbed area during the study period. The Mann Whitney U test ( $U = 514.0$ ,  $p = 0.005$ ) showed that the more disturbed area has higher diversity of small mammals than less disturbed area. Mean diversity of small mammals caught in the more disturbed and less disturbed area ranged from 0.56 to 0.96 and 0.29 to 0.85 respectively (Figure 4.2b).

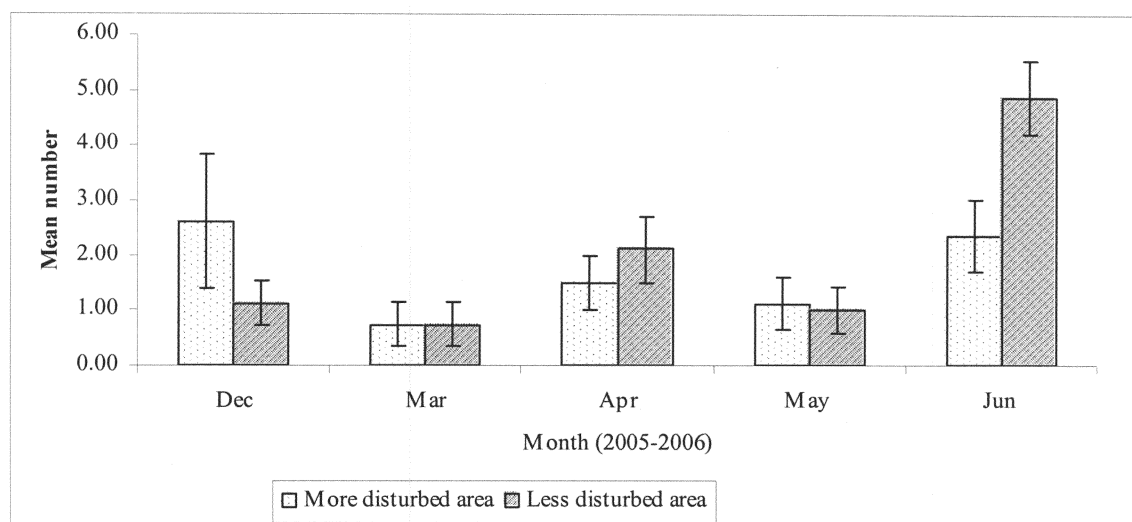
The mean species diversity of small mammals in more disturbed areas (A1 and B1) and in less disturbed areas (A2 and B2) were pooled together respectively, to give a overall mean diversity of small mammals. The overall mean species diversity of small mammal was higher in more disturbed area than in less disturbed area. In more disturbed area, the highest ( $H' = 0.82$ ) diversity was recorded during April 2006 while the lowest ( $H' = 0.29$ ) diversity was recorded in March 2006. In the less disturbed area, the highest ( $H' = 0.96$ ) diversity was recorded during June 2006 while the lowest ( $H' = 0.56$ ) recorded during May 2006 (Figure 4.2b)



**Figure 4.2b** Overall mean Shannon-Wiener index of species diversity ( $H'$ ) of small mammals in the more (100m from waterhole) and less disturbed area (2,000m from waterhole) during the five different trapping sessions from December 2005, March, April, May, and June 2006 at Waterberg Plateau Park. Error bars are the mean upper and lower 95% confident limits.

The most dominant small mammal species in the more disturbed area was *Gerbillurus paeba* 31.8% (n=21) followed by *Dendromus melanotis* 21.2% (n=14) and *Mastomys spp* 16.7% (n=11). The most dominant species in the less disturbed area was *Dendromus melanotis* 34.2% (n=27) followed by *Tatera leucogaster* 17.7 % (n=14) and *Gerbillurus paeba* 15.2% (n=12).

The mean numbers of small mammals in the more disturbed area ranged from 0.75 to 2.63 whereas in the less disturbed area mean number ranged from 1.00 to 4.88 (Figure. 4.3). Kruskal-Wallis test showed that there was no significant difference ( $H = 1.997$ ,  $df = 3$ ,  $p = 0.548$ ) in the abundance of small mammals between four study areas.



**Figure 4.3** Mean number of small mammal species captured in more disturbed and less disturbed area during the study period in December 2005, March, April, May and June 2006 at Waterberg Plateau Park. Error bars are the mean upper and lower 95 % confidence limits associated with the estimates of abundance of small mammals.

In the less disturbed area the mean number of small mammals was higher (4.88) during the month of June 2006, and the lowest (0.75) during the month of March 2006. In the more disturbed area, the mean abundance was higher (4.88) during the month of June 2006 and lowest (0.75) during the month of March 2006 (Figure 4.3).

#### 4.4 Estimated population density of small mammals using Petersen method of Capture-Mark-Recapture (CMR).

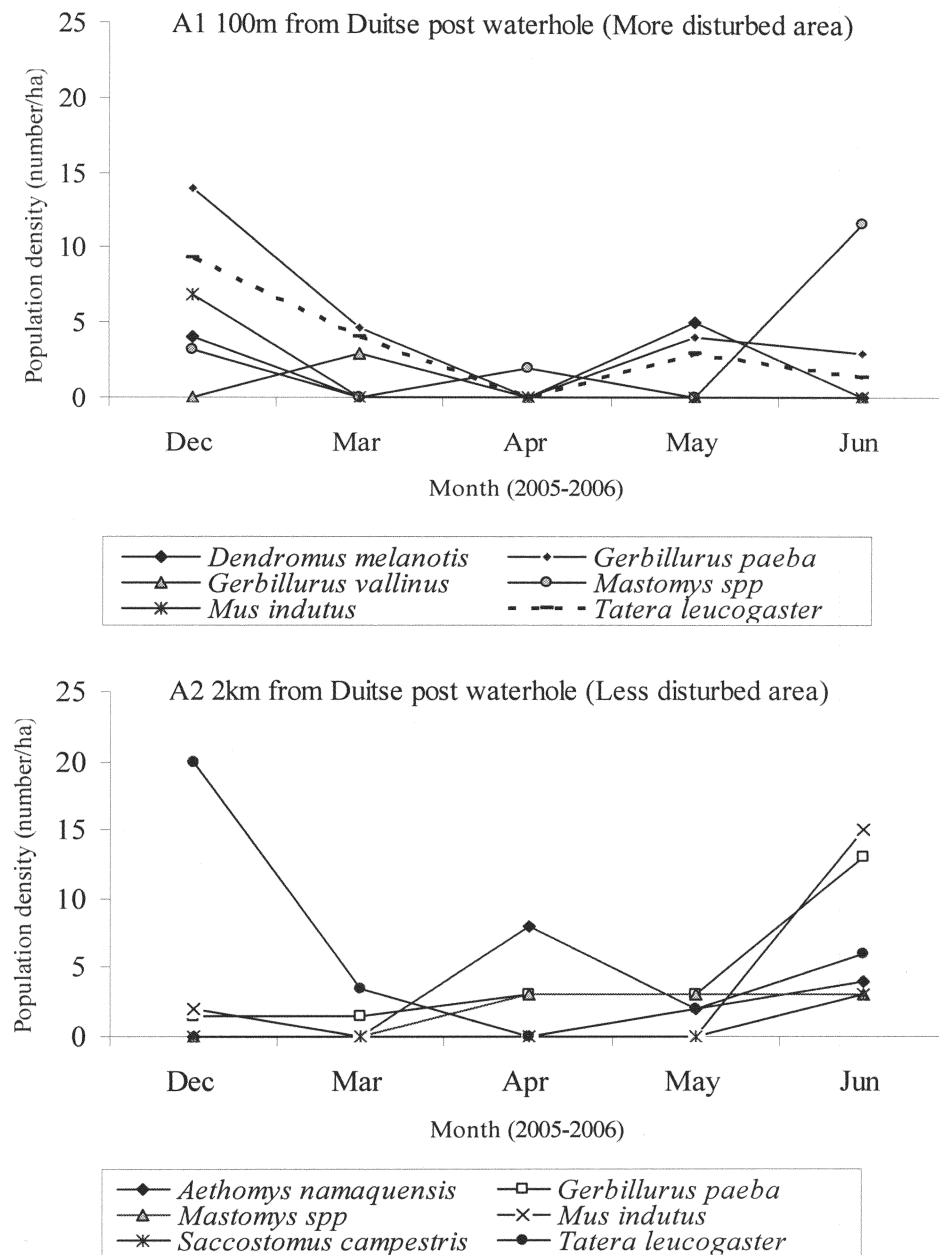
Kruskal-Wallis test showed that there was no significant difference ( $H=1.997$ ,  $df=3$ ,  $p=0.548$ ) in population density between the more disturbed and less disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park (Figure 4.4 and 4.5).

A total of 6 small mammal species were caught in the more disturbed area (A1) of Duitse post (Figure 4.4). During the trapping session of December 2005 five of the six small mammal species were captured. The population density of *Gerbillurus paeba* was highest (14) in more disturbed area (area A1) during the trapping session of December 2005, the population density of the *Gerbillurus paeba* declined in March 2006 but were not recorded in April 2006 and recorded in May and June 2006 respectively (Figure 4.4). The population density of *Dendromus melanotis* was the highest (9) in May 2006 and the lowest (3) was *Tatera leucogaster*. The population density of *Mastomys spp* was the highest (11) in June (Figure 4.4).

A total of 6 small mammal species were caught in the less disturbed area of Duitse post (study area A2, 2 km) (Figure 4.4). In December 2005 population density of *Tatera leucogaster* was the highest (20) and the population density of *Mastomys spp* was the

lowest (2.5). In March 2006, the highest population density was *Tatera leucogaster* (3.5) and lowest was *Gerbillurus paeba* (1.3).

Three species of small mammals were recorded in April 2006, of which the population density of *Aethomys namaquensis* was highest (8) while both *Gerbillurus paeba* and *Mastomys spp* (3) had lowest population density respectively. Four small mammal species were recorded in May 2006, population density for *Gerbillurus paeba* and *Mastomys spp* was the highest (3) and both *Aethomys namaquensis* and *Tatera leucogaster* had the lowest (3) population density (Figure 4.4).



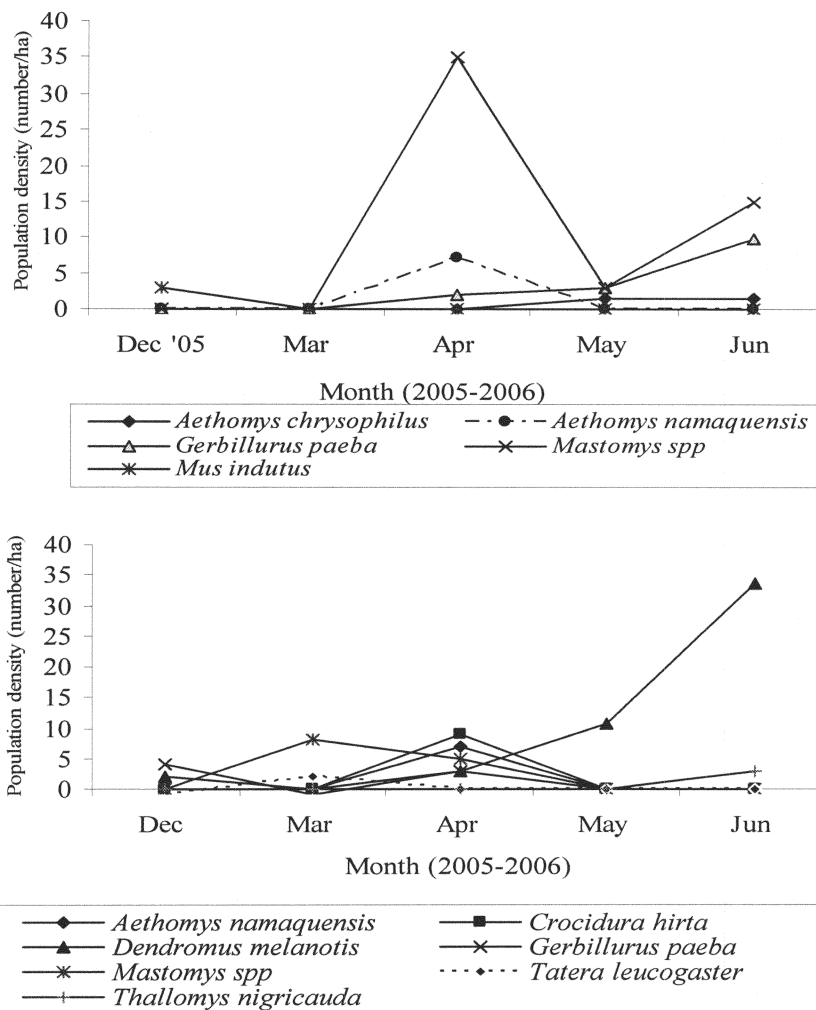
**Figure 4.4** Estimated population density (number/ha) of small mammal species recorded using the Petersen method of Capture–Mark–Recapture, in sample area A1 which was 100m and 2 km from Duitse post waterhole, designated as more disturbed area. Total of six small mammals species were caught in A1 and A2 during the session from December 2005, March 2006, April 2006, May 2006 and June 2006. In A1 and A2 the highest population density of small mammal species was recorded during December 2005, followed by June 2006. In A1 *Gerbillurus paeba* was the species with a highest population density, while *Mus indutus* had the lowest population density. In A2 *Tatera leucogaster* was a species with population density recorded for all months but highest in December 2005. *Saccostomus campestris* was the one with lowest population density for all months except in June 2006.

A total of 5 small mammal species were caught in the B1 (more disturbed area) at Securidaca waterhole (Figure 4.4). Of the five small mammal species only one was recorded in December 2005, with population density of (3). There were no small mammals species captured in the more disturbed area (at Securidaca waterhole) in March 2006 (Figure 4.5).

In April 2006 the highest ( $n = 35$ ) population density was *Mastomys spp*, followed by ( $n = 7$ ) *Aethomys namaquensis* and the lowest (2) population density was *Gerbillurus paeba*. During the trapping session of May 2006 the highest (3) population density were *Mastomys spp* and *Gerbillurus paeba* and lowest (1.5) was *Aethomys chrysophilus*. Three small mammals species were recorded in June 2006, the highest (15) population density *Mus indutus*, followed by *Gerbillurus paeba* (9.3) and the lowest *Aethomys chrysophilus* (1.5) (Figure 4.5).

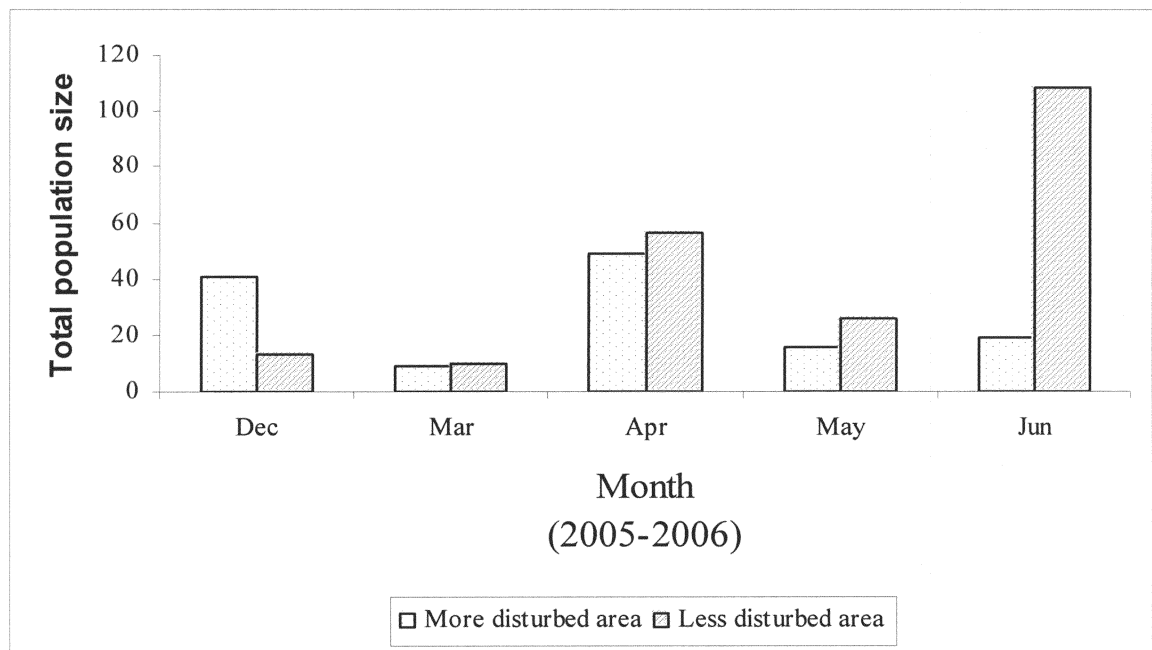
Figure 4.5 also indicates that a total of 7 small mammal species were caught in the less disturbed area of Securidaca waterhole (B2, 2km). Two of the 7 small mammal species recorded in December 2005, with highest population density (4) was *Gerbillurus paeba* and the lowest (2) was *Dendromus melanotis*. The population density of *Dendromus melanotis* was highest in June 2006 (Figure 4.5). During the trapping session of May 2006 the highest (3) were *Mastomys spp* and *Dendromus melanotis*. During the trapping session of May 2006 only one small mammal (*Dendromus melanotis*) with population density of (10.7) was recorded. The highest (33.6) small mammals population density of

*Dendromus melanotis* was recorded in June 2006 and the lowest (3) was *Mastomys spp* (Figure 4.5).



**Figure 4.5** Estimated population density (number/ha) of small mammal species recorded using the Petersen method of Capture – Mark – Recapture, in sample area B1 which was 100m from Securidaca post waterhole, designated more disturbed area. Total of five small mammal species were caught during the session from December 2005, March 2006, April 2006, May 2006 and June 2006. *Mastomys spp* was the species recorded with the highest population density where as *Mus indutus* had the lowest population density overall. In B2 a total of eight small mammals species were caught during the session from December 2005, March 2006, April 2006, May 2006 and June 2006. *Dendromus melanotis* has population density recorded for all months except March 2006. Population density for *Dendromus melanotis* increased from March to June 2006. *Thalломys nigricauda* and *Mus indutus* had the lowest opulation density for all months except in June 2006 for *Thalломys nigricauda*

The mean estimated population density of small mammals in more disturbed areas (A1 and B1) and in less disturbed areas (A2 and B2) were pooled together respectively, to give a overall mean population density of small mammals. In general the population density of small mammals in the more disturbed area ranged from 9.2 to 49 individuals/ha and 9.7 to 108.3 individuals/ha in the less disturbed area (Figure 4.6). In the more disturbed area the population density was higher in April 2006 (48.8) and lower in March 2006 (9.2). In the less disturbed area population density was higher in June 2006 (108.3) and lower in March 2006 (9.7) (Figure 4.6).



**Figure 4.6** Overall estimated total population (number/ha) number of small mammals using Petersen method of Capture Mark-Recapture in the more disturbed and less disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park. The total population density in the more disturbed area was highest in April 2006 whereas the lowest was recorded in March 2006. In the less disturbed area the highest population density was highest in June 2006 whereas the lowest population density recorded in March 2006.

#### 4.5 Population size of small mammal species estimated from Minimum number Alive (MNA)

Kruskal-Wallis test revealed that there was no difference ( $H=1.89$ ,  $df=3$ ,  $p=0.462$ ) on population size of small mammals between more disturbed and less disturbed area.

**Table 4.3** Population size determined from Minimum Number Alive (MNA) of species of small mammals caught in the more disturbed area (A1 and B1) during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park.

More disturbed area						
Small mammal species	Dec '05	Mar '06	Apr '06	May '06	Jun '06	Total
<i>Aethomys chrysophilus</i>				1	1	2
<i>Aethomys namaquensis</i>			3			3
<i>Dendromus melanotis</i>	2	1	2	3	10	18
<i>Gerbillurus paeba</i>	7	4	3	3	7	24
<i>Gerbillurus vullinus</i>		1	1			2
<i>Mastomys spp</i>	2	1	8	3	1	12
<i>Mus indutus</i>	5					5
<i>Tatera leucogaster</i>	5	2	1	3	1	12
<b>Total</b>	<b>21</b>	<b>9</b>	<b>18</b>	<b>11</b>	<b>19</b>	<b>78</b>

Minimum number alive of individual small mammals caught was low ( $n=78$ ) in more disturbed area compare to higher ( $n=97$ ) population size of small mammals in the less disturbed area (Table 4.3 and 4.4). The highest ( $n=21$ ) MNA was recorded in December 2005 and the lowest ( $n=9$ ) MNA was recorded in March 2006. The highest MNA recorded was for *Gerbillurus paeba* ( $n=24$ ), followed by *Dendromus melanotis* ( $n=18$ ), *Mastomys spp* ( $n=12$ ) and *Tatera leucogaster* ( $n=12$ ) and the lowest MNA was for *Aethomys chrysophilus* and *Gerbillurus vullinus* each ( $n=2$ ). The more disturbed area

had lower (8) species richness and estimated population density in terms of MNA (n=79) of small mammals (Table 4.3). The less disturbed area had higher (10) species richness and estimated population density in terms of MNA (n=97) of small mammals (Table 4.4).

**Table 4.4** Population size in terms of MNA (Minimum Number Alive) of individual small mammals caught in the less disturbed area (A2 and B2) during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park.

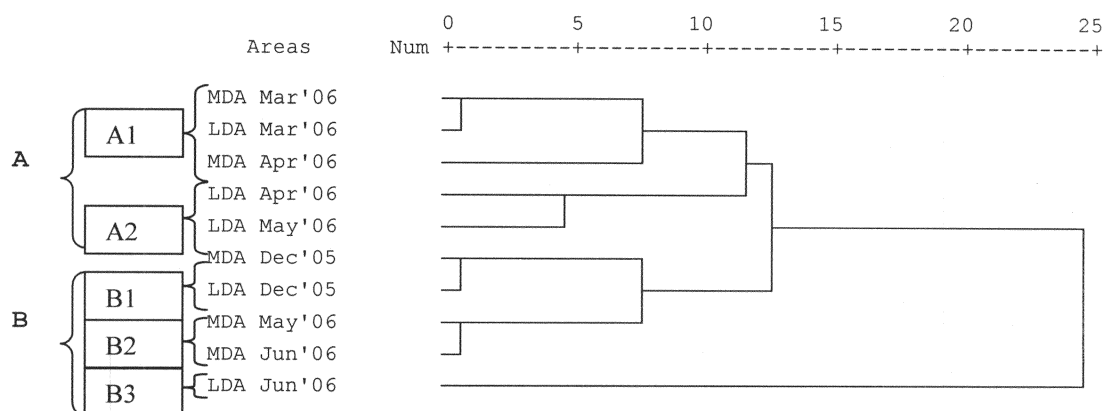
Less disturbed Area						
Small mammals species	Dec '05	Mar '06	Apr '06	May '06	Jun '06	Total
<i>Aethomys namaquensis</i>			5	1	1	7
<i>Crocidura hirta</i>			3			3
<i>Dendromus melanotis</i>	1			4	25	30
<i>Gerbillurus paeba</i>	2	1	2	1	8	14
<i>Graphiurus murinus</i>					2	2
<i>Mastomys spp</i>		2	4	1	1	8
<i>Mus indutus</i>	1				3	4
<i>Saccostomus campestris</i>			1		1	2
<i>Tatera leucogaster</i>	5	6	5	3	7	26
<i>Thallomys nigricauda</i>					1	1
<b>Total</b>	<b>9</b>	<b>9</b>	<b>20</b>	<b>10</b>	<b>49</b>	<b>97</b>

Minimum number alive of individual small mammals caught was higher (n=97) in more disturbed area than in less disturbed area (n=78). The highest (n=49) MNA of small mammals was recorded in June and the lowest (n=9) MNA was each recorded in December 2005 and March 2006. The highest MNA recorded was for *Dendromus melanotis* (n=30), followed by *Tatera leucogaster* (n=26) and the lowest MNA was for *Thallomys nigricauda* (n=1) followed by *Saccostomus campestris* and *Graphiurus murinus* each (n=2) (Table 4.4).

#### 4.6 Species composition of small mammals

Hierarchical Cluster Analysis (HCA) separated the species of small mammals caught in both, more disturbed and less disturbed area during trapping session of December 2005, March, April, May and April 2006 into five clusters. Two predominant clusters (**A** & **B**) with five sub clusters (A1, A2) and (B1, B2, B3) were generated using absence and presence data of the twelve small mammal species captured in the disturbed areas and less disturbed areas and during the trapping months (December 2005, March, April, May and June 2006) (Figure 3.9). The two predominant clusters were further subdivided into two season patterns namely (**A**) hot and wet season (March and April 2006) and (**B**) dry and cold (December 2005, May and June 2006).

The HCA revealed that similar small mammal species were captured in the more disturbed and less disturbed areas during the trapping session of December 2005, March, April, May, June 2006 (Figure 4.7). However, the HCA also showed that sub cluster B3 was unique sample cluster because only one species (*Crocidura hirta*) was captured in less disturbed area during the trapping session of June 2006 (Figure 4.7).



**Figure 4.7** Hierarchical Cluster Analysis (HCA) dendrogram indicating five (1-5) cluster groups of small mammal communities caught in the More Disturbed Area (MDA) and Less Disturbed Areas (LDA) at Duitse post and Securidaca waterholes, at Waterberg Plateau Park and during the months of December 2005, March, April, May, June 2005.

### Cluster A1

This cluster formed a compact and larger cluster. Three species, *Tatera leucogaster*, *Gerbillurus paeba* and *Mastomys spp.* were common, captured in both MDA and LDA throughout the study period except in March 2006. These species were also captured in both the more disturbed and less disturbed area

### Cluster A 2

In this cluster, *Aethomys namaquensis* and *Dendromus melanotis* were most common species captured. These species were only captured in LDA during the trapping period of April and May 2006. The difference in this cluster (different from cluster A14) was the presence of *Crocidura hirta* and *Saccostomus campestris*. Other common species,

which were also present, were *Gerbillurus paeba*, *Tatera leucogaster* and *Mastomys* species as discussed in Cluster A1.

#### **Cluster B1**

This cluster indicates that *Mus indutus* species were most common in LDA and MDA during the trapping session of December 2005 only. Notable features which were generated by this cluster indicated that *Gerbillurus paeba*, *Tatera leucogaster* and *Mastomys* species were most common as discussed in cluster A1.

#### **Cluster B2**

This cluster demonstrates that *Aethomys chrysophilus* and *Dendromus melanotis*, were commonly caught in MDA during the trapping session of May and June 2006. Other notable features are presence of the common *Gerbillurus paeba*, *Tatera leucogaster* and *Mastomys* species as discussed in cluster A1.

#### **Cluster B3**

This cluster was grouped together because *Graphiurus murinus* and *Thallomys nigricauda* were captured once while *Saccostomus campestris* were captured twice in the LDA. *Graphiurus murinus* and *Thallomys nigricauda* were captured during the trapping session of June 2006. *Saccostomus campestris* were captured during the trapping session of May and June 2006.

## CHAPTER 5 DISCUSSION

This study investigated effects of disturbance of large herbivores on species diversity, richness and abundance of small mammals at Waterberg Plateau Park. It was assumed that the high concentration of large herbivores around waterholes especially during the early and mid-winter months (May and June 2006) caused intensive grazing, browsing and trampling which reduced vegetation cover (Personal observation). It was further assumed that the results of severe trampling and intensive grazing around the waterholes negatively affected the food supply, reducing shelters of small mammals and vegetation cover. This would lead small mammals to be exposed to predation (Nyako-Lartey & Baxter, 1995; Joubert & Ryan, 1999; Avenant 2000). It was found that the decrease of vegetation covers around the waterholes (more disturbed area) through trampling and overgrazing (disturbance) affected population size of small mammal. This was supported by results in Figures 4.1 and 4.2

### 5.1 Estimation of vegetation cover.

By using a Kruskal-Wallis test, this study showed that at Duitse post waterhole the vegetation cover did not differ significantly ( $H=12.0$ ,  $df=4$ ,  $p=0.916$ ) between the more disturbed area (A1) and less disturbed area (A2) (Figure 4.1a). However, Mann-Whitney ( $U = 1.0$ ,  $p =0.015$ ) revealed that at Securidaca waterhole vegetation cover was significantly higher in the more disturbed area (B1) than the less disturbed area (B2) (Figure 4.1b). The high vegetation cover and low concentration of large herbivores was

observed during the months of March and April 2006 in both more disturbed and less disturbed areas (Figure 4.1a and 4.1b) at both trapping sites (Duitse post and Securidaca waterholes). The low concentration of large herbivores was due to availability of water in the rocky terrain and feeding pattern (personal observation). The feeding patterns of large herbivores are influenced by the rainfall and availability of water. During the rainy season most of the large herbivores are scattered throughout the park. They move closer to the artificial water as the water dries up with the high concentration during the dry months. These dry months are the critical period or bottle neck period with a high concentration of large herbivores at the artificial waterholes.

Therefore, the availability of water and food influence the movement of water-dependent large herbivores. During the rainy season water accumulates in pools, where the large herbivores drink, instead of going to the artificial waterholes. In the process, this allows the area closer to the waterholes to recover and only grazed during the dry period. The high concentrations of large herbivores around the water holes are normally observed when the water in the pools has dried up and herbivores are forced to go to artificial waterholes.

The high concentration of large herbivores was observed in more disturbed areas during the trapping session of December 2005 and June 2006 (Figure 4.1a and 4.1b). The high concentration of large herbivores has resulted in intensive grazing and tremendous trampling at Securidaca waterhole. As at Duitse post waterhole there was no significant

difference in vegetation cover. The intensive grazing and trampling at Securidaca waterhole (more disturbed area) also reduced the vegetation cover during the month of December 2005 and June 2006 (Figure 4.1a and 4.1b). Low diversity of small mammal were recorded in the more disturbed area at Securidaca waterhole (Figure 4.1a).

Alternatively, the high concentration of large herbivores at waterholes might have been one of the factors that affected the diversity of small mammals. It was observed that vegetation cover in the more disturbed area was reduced through grazing and trampling (Figure 4.1a and b). This can be quantified by the high concentration of large herbivores (buffalo, elands, rhinos, giraffes, roan and sable antelope) spending a lot of time grazing in the more disturbed area (Personal observation). According to Nyako-Lartey & Baxter (1995) and Joubert & Ryan (1999) cattle and ungulates can negatively influence the vegetation structure by reducing vegetation cover, leaving little or no grass canopy and allowing little cover for small mammals. Overgrazing also reduces availability of food (Lack, 1954 in Nyako-Lartey & Baxter, 1995), shelters for small mammals (Bowland & Perrin, 1989). Reduction of vegetation cover exposes small mammals to predation (Pearson, 1971 in Nyako-Lartey & Baxter, 1995).

Despite the high concentration of large herbivores in the more disturbed area it was reported that the highest mean ( $H' = 0.380$ ) diversity of small mammals was recorded in the more disturbed area during the trapping session of December 2005 (Figure 4.2a). It was expected that the low vegetation cover could make the area less attractive or less

suitable for most of the small mammals. However, this was not the case; a lot of small mammals were also caught in the more disturbed area (Figure 4.2.a). The explanation for this is that successional small mammals species often tend to coexist for short period. This was also supported by Smith, *et al.* (1975) that small mammals are able to adapt to certain habitats as long as their needs such as food, shelter, moisture etc., are met. Although the more disturbed areas seemed to be heavily trampled and overgrazed, it might be that certain small mammals were able to adapt in the marginal areas. Alternatively, the vegetation cover attracted some small mammals to live close to the waterhole.

The study revealed that there was a weak positive correlation ( $r = 0.24$ ) and a very weak negative correlation ( $r = -0.21$ ) between diversity of small mammals and vegetation cover in more disturbed and less disturbed area, respectively. In this study the vegetation cover might not be the only variable that influences the diversity of small mammals. There might be other variables such as availability of water, moisture, food (seeds, insects etc), that might have influenced the diversity of small mammals. Bond (1980) maintained that microhabitat features such as vegetation structure, cover and height, relative humidity, litter depth, and foliage height diversity are directly related to the life form and growth pattern of plant species within a plant community and these factors are important floristic variables affecting small mammals community structure.

It was expected that species diversity should be high during the rainy season in both areas because rainfall is generally associated with the increase in supply of seed and insects. These are a source of food for small mammals and hence could contribute to higher diversity of small mammals. Heaney (2001) reported a similar pattern in the Phillipines, where the availability of a particular resource, for example soft bodied soil invertebrates, earthworms, larva of insects forms a resource that is heavily utilized by distinctive subsets of small mammal communities. However, it seems that the rain did not positively influence or help increase the high diversity of small mammals as expected. Similarly, it was also expected that diversity should decrease in the more disturbed area as the food resources declined. It was found that the diversity of small mammals decreased as the vegetation cover and food resources declined.

In this study a high mean diversity of small mammals was recorded in the more disturbed site (A1, at Duitse post waterhole) ( $H' = 0.260$ ) and low mean diversity of small mammals was recorded in the less disturbed (B1, at Securidaca waterhole) ( $H' = 0.199$ ) area during the month of March 2006, respectively. This was supported by the weak negative ( $r = -0.38$ ) correlation between rainfall and diversity of small mammals in more disturbed and also a weak negative correlation ( $r = -0.39$ ) between rainfall and diversity of small mammals in the less disturbed area. There was also a weak positive and weak negative correlation between species diversity of small mammals and monthly temperature in more disturbed ( $r = 0.27$ ) and less disturbed area ( $r = -0.26$ ) respectively. However, the impact of large herbivores on the diversity, richness and abundance of

small mammals at Waterberg Plateau Park requires further investigations. It was found that impact of large herbivores might not be the only ones that affected the diversity of small mammals as other parameters such as relative humidity, availability of water, altitudes, trapping periods, soil etc, could have also exerted significant impacts.

Alternatively, the dominance of nocturnal species in the more disturbed areas suggests that ecological disturbance (s) is, or has taken place. This view is strengthened by the fact that one of the dominant nocturnal species found was the indicator species *Mastomys* spp. A number of studies (Mendelsohn, 1982, Rowe-Rowe, 1995, Avenant, 1996 Avenant, 2000) have reported *Mastomys* spp to often be the first to dominate after disturbance such as drought, fire, overgrazing and cultivation. Therefore, the impact of large herbivores on the diversity of small mammals requires further investigations.

Species richness of small mammals was expressed as the number of species that were caught within the sample sites during the trapping period of five months (December 2005, March, April, May and June 2006). It was expected that species richness of small mammals would be low in the more disturbed area and higher in the less disturbed area. On the contrary, this study revealed that there was higher species richness in the less disturbed area and low species richness in the more disturbed area. The total number of species recorded in the more disturbed and less disturbed area was 8 and 10 respectively (Table 4.2). These results (Table 4.2) of species richness of small mammals were supported by similar study of Muck and Zeller (2006). They stated that a change in vegetation structure caused changes in the species composition and abundance.

Further investigation was conducted to determine which vegetation characteristics might have led to the differences in the composition of small mammal's composition at the two study areas. In the more disturbed area *Gerbillurus paeba*, *Dendromus melanotis* and *Mastomys* spp were the dominant species caught (Table 4.2). All these species are nocturnal (Skinner & Smithers, 1990). *Gerbillurus paeba* is widely distributed and is associated with the South West Arid Zone, extending marginally into the southern savanna grassland and prefer sandy soil with grass (Skinner & Smithers, 1990).

*Gerbillurus paeba*, the hairy-footed gerbil was dominant (in terms of number) in the more disturbed area (with less vegetation cover) and was captured in all trapping sessions. This is also supported by studies that *Gerbillurus paeba*, nocturnal species favours "open edge microhabitats for foraging" (Kerley *et al.*, 1990; Joubert & Ryan, 1999; Perrin & Johnson, 1999; Perrin & Boyer, 2000 and Avenant & Kuyler, 2002). Kerley, (1989) and White, *et al.* (1997) described *Gerbillurus paeba* as an opportunistic omnivore. This was also supported by Skinners & Smithers (1990) and White *et al.* (1997) who described the diet of *Gerbillurus paeba* to consist of seed, pods and insects.

In order for species to be dominant in more disturbed habitat it must be highly aggressive, competent with agonistic behaviour (Skinner & Smithers, 1990). It must be able to compete with other species and be able to migrate if food becomes scarce or other environmental condition become unfavourable. The other factor that might

influence the dominance in the more disturbed areas is water availability and diet composition (Skinner & Smithers, 1990).

*Dendromus melanotis* is associated with many parts of habitats, ranging from riverine conditions (wet areas) to dry areas, such as the Kalahari Desert. The present study is the first to record *Dendromus melanotis* at Waterberg Plateau Park. In the present study *Dendromus melanotis* was recorded in both in the more disturbed and in the less disturbed. This grey climbing mouse, was the second most dominant species in the more disturbed area, it has been suggested that it favours tall, dense grass cover (Skinner & Smithers, 1990, De Graaff, 1981; Rowe-Rowe & Meester, 1982; Rowe-Rowe & Lowry, 1982). This was supported by the findings of this study, when the number of *Dendromus melanotis* increased in the less disturbed area during the trapping session of June 2006. This might have been influenced by the adequate vegetation cover because it is one of the principal or major factors which allow the number of species to increase (Kerley *et al.*, 1990).

*Mastomys* spp, multimammate mouse, were third dominant species in the more disturbed area because they are described as opportunistic and coloniser species and become dominant after disturbances (Leirs *et al.*, 1994; Joubert & Ryan, 1999; Avenant & Kuyler, 2002). The results from this study as well as other studies (Leirs *et al.*, 1994; Wandrag *et al.*, 2002; Avenant & Kuyler, 2002) showed that *Mastomys* spp. preferentially occupies areas with low vegetation cover. But in natural habitats, animals

including small mammals will only occupy or colonise areas even with low vegetation cover if an adequate supply of food is available. Also in natural habitats, disturbed areas (because of reduced vegetation cover) might not necessarily contain adequate food as this might depend on the degree of disturbance. *Mastomys* spp. are omnivores, relying heavily on seeds and insects (De Graaff, 1981; Skinner & Smithers, 1990; Monadjem & Perrin, 1998). In this study it was difficult to show that low vegetation cover supported more seeds or insects which form part of the *Mastomys* spp. diet. Experimental study (Monadjem & Perrin, 1998) and other studies (Rivers-Moore & Samways, 1996; Muck & Zeller 2006) have shown that open patches supported a lower abundance of insects than more densely vegetated areas, which might influence the presence of small mammals on such habitats. From this study it seems that *Mastomys* spp. generally select areas with low vegetation cover or there might also be other unknown factors that influence such selection.

In this study small mammal species such as *Gerbillurus paeba*, *Dendromus melanotis* and *Mastomys* spp were probably not affected by the disturbance caused by large herbivores because they rely more on seeds, which are likely to be less in more disturbed area. *Gerbillurus paeba* and *Mastomys* spp might have decreased in both the population density and size in the less disturbed area due to the high vegetation cover (A2 and B2).

Other species which were caught in the more disturbed areas were *Mus indutus*, *Aethomys chrysophilus*, *Aethomys namaquensis*, and *Gerbillurus vullinus*. Skinners & Smithers (1990) described *Mus indutus* (Desert pygmy mouse) as terrestrial and nocturnal animals and prefer substantial cover. In this study these small mammals were caught in the traps close to or in the shrubs/bushes thickets and they were caught during the dry hot (December 2005) and dry and cold (June 2006) weather conditions. They were caught in those traps close or in the shrubs/bushes because the scrubs/bushes have higher vegetation cover in which the small mammals may take refuge.

*Aethomys namaquensis* (Namaqua rock mouse) also has a wide-ranging habitat tolerance and mostly associated with rocky habitat (Jooster & Palmer, 1982 and Skinner & Smithers, 1990). Despite this type of wide-ranging habitat preference, in this study only three (male) individuals were caught in the more disturbed area and each individual was only caught once. Seven other individuals were caught in less disturbed area and this might be an indication of habitat tolerance. Similar study by Armstrong & Hensbergen (1996) also recorded few or low number of individual of *Aethomys namaquensis* which were caught in the bare patches, plains and the few caught were either rare or caught only once. The highest (n =7) number of *Aethomys namaquensis* were caught in the less disturbed area; this might be contributed to the availability of food and ground vegetation cover. In contrast, a study in Nama Karoo by Hoffmann & Zeller (2005) revealed that more *Aethomys namaquensis* individuals were caught in more disturbed

area (Gellap-Ost). Therefore, disturbance variable might not be the only factor influencing the occurrence and distribution of *Aethomys namaquensis*.

Although *Aethomys chrysophilus* (Red veld rat) was only recorded twice in more disturbed area (Figure 4.4), Skinner & Smithers (1990) described them as catholic (wide-ranging), ranging from grassland with shrub cover to savanna woodland but strongly associated with rocky crevices, piles of boulders of debris, fallen trees, scrubs or clumps of grass and enter houses. But in this study, only two *Aethomys chrysophilus* individual were caught in a the plot B1 (more disturbed area). This plot had the lowest species diversity, richness and abundance. As previously described by Skinner & Smithers (1990), they preferred a wide-range of habitats. Therefore, they are able to tolerate more disturbed areas.

*Gerbillurus vallinus* (Namaqua bush-tailed gerbils) has a relatively restricted distribution. Its distribution stretches from the northern-western Cape northwards to Solitaire on the southern eastern edge of the central Namib Desert (Griffin, 1990). Only one individual was caught in B1 (more disturbed area). In the less disturbed area (B2, Securidaca) the dominant small mammal species were *Dendromus melanotis*, *Tatera leucogaster* and *Gerbullurus paeba* (Table 4.2). *Dendromus melanotis* was the most dominant in the less disturbed area due to vegetation cover (dense and tall grass cover) and availability of food. The preferential occupation of these habitats might be

associated with high vegetation cover for nesting, avoiding predators and the abundance of food supplies (personal observation).

*Tatera leucogaster*, bushveld gerbil is omnivorous, with much of their diet comprising arthropods and plant materials but few seeds (Perrin & Boyer, 2000). However, De Graaff (1981) and Perrin & Swanepoel (1987) described them as colonial, nocturnal, burrowing rodents, preferring sandy soil and areas widely distributed from the savannas, open woodlands, the Kalahari and parts of Southwest Arid biotic zone of Southern Africa with mean annual rainfall of 250 mm and over 1600 mm (Skinner & Smithers, 1990). In the Karoo it was predicted that *Tatera leucogaster* depends much on an adequate vegetation cover and not necessarily on food availability but it was found that they depend on the other resources such as availability of water (Hoffmann & Zeller, 2005). In Namibia *Tatera leucogaster* as widely distributed including the Namib Desert (Perrin & Boyer, 2000). Despite the wide distribution, it was found that *Tatera leucogaster* was captured in all trapping sessions but was less dominant in the more disturbed area (A1, Duitse post waterhole) (Table 4.2). Some studies described *Tatera leucogaster* as being sensitive to changes in vegetation cover (Hoffmann & Zeller, 2005; Muck & Zeller, 2006). In the present study most burrows were excavated in sandy soil and their entrances were situated at the base of small bushes and grass clumps. This location in the more disturbed area might have exposed the burrows to severe trampling and might also explain their lower number in the more disturbed area.

Other species which were less abundant in the less disturbed area were *Crocidura hirta*, *Graphiurus murinus*, *Saccostomus campestris* and *Thallomys nigricauda*. It was not surprising, then, that *Crocidura hirta*, (Lesser red musk shrew), were only caught in the less disturbed area. According to Skinner & Smithers (1990) and Monadjem (1999) *Crocidura hirta* were not restricted to certain habitat and that they have wide ranging habitat selection. They were caught during the trapping session of April 2006. One individual was found dead in the trap and it is suspected that its death resulted from the cold weather that was experienced during the previous night. The area where the shrews were trapped was covered with low bushes but dense undergrowth piles of debris and unused burrows similar to what was described by Skinner & Smithers (1990). It is not known what was responsible for rarity of the shrew because the rainfall for the entire plateau was above average and it was the key period of sufficient insects. Alternatively, the cold weather at night might be the factor, which decreased the trap success.

Insufficient data were collected on *Graphiurus murinus*, *Saccostomus campestris* and *Thallomys nigricauda* for any conclusion to be draw. In the case of *Graphiurus murinus* (woodland dormouse) both specimens were caught in the plot A2, *Philenoptera nelsii* and *Terminalia serice* communities. This is probably their favoured habitat because they depend on large trees for nesting ( Jooster & Palmer, 1982; Rowe-Rowe & Lowry, 1982 and Skinner & Smithers, 1990). *Graphiurus murinus* were only captured in the less disturbed area (A2). This might have been contributed by the tall trees that are searched after for nesting purposes. According to Skinner & Smithers (1990), they forage at night

searching for insects and other food items. The fact that they forage most of the time on trees, made it difficult to trap them because the Sherman traps were set on the ground.

*Thallomys nigricauda* (Black-tailed rat) depend on tree for nesting and foraging. This species is poorly studied because of its nocturnality and arboreality (Skinner & Smithers, 1990; Eccard and others 2000). Both *Graphiurus murinus* and *Thallomys nigricauda* might not be directly affected by the trampling of large herbivores as they depend on tall trees for foraging and nesting.

According to Skinner & Smithers (1990) *Saccostomus campestris* (Pouched mouse) are catholic in their habitat requirements, favouring diverse areas which are associated with the open short grass. In the Kalahari they preferred outskirts of pans while in the Transvaal they are found in open *Acacia* spp bushveld (Skinner & Smithers, 1990). In this study it was caught in the *Philenoptera nelsii* and *Terminalia sericea* communities; however only two individuals were obtained which is also insufficient for making tangible conclusion.

## 5.2 Estimation of population density of small mammal species in terms of Minimum Number Alive (MNA).

Considering all the individuals small mammal species which were trapped in more disturbed and less disturbed area, lower (n = 78) population density was recorded in more disturbed area and higher (n = 97) population density was recorded less disturbed area. Kruskal-Wallis test was used to test difference in population density of small mammal species between the more disturbed and less disturbed area. The Kruskal-Wallis test showed that there was no significant difference ( $H= 1.879$ ,  $df = 3$ ,  $p= 0.462$ ) in terms of population density between the more disturbed and less disturbed areas.

MNA of individual small mammals caught was lower (n = 78) in a more disturbed area, the highest (n = 21) was recorded in December 2005 and the lowest (n = 9) MNA was recorded in March 2006 (Table 4.3). *Dendromus melanotis* had the highest (n = 24) estimated population size, followed by *Mastomys* spp and *Tatera leucogaster* each (n = 12). The low appearance of *Tatera leucogaster* in the more disturbed area and the dominance of the *Dendromus melanotis* was noticeable. Skinner & Smithers, (1990) described *Dendromus melanotis* as agile climbers, nocturnal and largely terrestrial, foraging in the low bushes and in tall grass. In this study, *Dendromus melanotis* dominated the catch with (n=30) in the less disturbed area which was dominated by tall (> 1 m) grass and shrubs/bushes (Table 4.4). *Mastomys* spp were also dominating (n=24) in the more disturbed area (Table 4.4). The dominance of small mammal communities

also varied significantly in the less disturbed area (Table 4.4). The dominant species in the less disturbed area was *Dendromus melanotis* (n = 30), followed by *Tatera leucogaster* (n = 26). *Tatera leucogaster* increased noticeably in the less disturbed area (Table 4.4). Meaning that they might have been affected by the changing of habitat structure in the more disturbed area through trampling and overgrazing caused by large herbivores.

During this study the highest number of *Tatera leucogaster* was found in the less disturbed area which was dominated by shrubs/bushes and grass. According to De Graaff (1981) and Skinner & Smithers (1990) *Tatera leucogaster* is found in wide ranges of savanna and open woodlands of the Southern African sub-region. In Namibia they occur mostly in areas with a mean rainfall of less than 100 mm, whereas in the Southern African sub-region they occur in the areas with a mean annual rainfall of 250 mm and upwards (De Graaff, 1981; Skinner & Smithers, 1990).

The high monthly and overall similarity between MNA estimate and numbers caught supported these methods and reflecting a high degree of trapability, which represented population density most accurately. Bronner and Meester (1987) noted in simulation studies that MNA is generally 10-20% lower than absolute population size. Flowerdew (1976) suggested that MNA estimates are usually accurate when trapping is intensive and recapture rates are high. These conditions were fulfilled during the present study but the recapture rates were high during each monthly trapping but low between months.

### 5.3 Species composition of small mammals

Five clusters were generated using twelve small mammal species in more disturbed and less disturbed area (Figure 4.7). Three small mammal species, *Tatera leucogaster*, *Gerbillurus paeba* and *Mastomys* spp were more common in the more disturbed and less disturbed area and throughout the trapping sessions. *Gerbillurus paeba* was one of the most common and most abundant species of small mammal species in the more disturbed and less disturbed area, whereas *Tatera leucogaster* and *Mastomys* spp were more common in more disturbed and less disturbed area but not abundant. Small mammal species such as *Aethomys namaquensis*, *Crocidura hirta*, *Saccostomus campestris*, *Graphiurus murinus* and *Thallomys nigricauda* were only captured in the less disturbed area but were less common. *Dendromus melanotis* was the most common and abundant of small mammals in the less disturbed area.

According to Jongman (1987), the species composition of species usually covaries in a more or less systematic way, because they react to the various environmental variables in a similar way. The impact on vegetation cover in the more disturbed area might be one variable that influences the abundance of some small mammal and create favourable conditions for some species. According to Kerley *et al.*, (1990) and Avenant & Kuyler, (2002) *Gerbillurus paeba* “favoured open microhabitats” for foraging and in this study the more disturbed area provided such conditions. Hoffmann & Zeller (2005) described *Tatera leucogaster* as being sensitive to disturbance, in this study presence of *Tatera*

*leucogaster* in the more disturbed area might be an indication of coexistence of small mammals as described by Muck and Zeller (2006). In a similar way the absence of some species such as *Aethomys namaquensis*, *Crocidura hirta*, *Saccostomus campestris*, *Graphiurus murinus* and *Thallomys nigricauda* in the more disturbed area might be signalling the degree of the disturbance created by large herbivores leaving a more unfavourable vegetation cover for small mammals.

Finally, rainfall may provide surface water, allow seeds to germinate, vegetation to grow which provide adequate food source. Therefore absence of rain can be a limiting factor for dwelling rodents because of lack of food source. This study found that there was a weak negative correlation between diversity, richness, abundance, vegetation cover and actual rainfall events. This maybe due to the occurrence of low vegetation cover, scarcity of seeds which reduced the dietary of seed resulting in limiting alternative resources and thus reflecting a period of food shortage (White *et al.*, 1997).

## CHAPTER 6 CONCLUSION AND RECOMMENDATIONS

Although it was predicted that the areas close to the waterhole (more disturbed area) should have low vegetation cover because of the high concentration of large herbivores which lead to a lot of trampling and causes overgrazing, this study found that that was not always the case. At site 1 (Duitse post waterhole) there was no significant difference in estimated vegetation cover between the more disturbed and less disturbed area (Figure 4.1a). At site (Securidaca waterhole) that there was a significant difference in estimated vegetation cover between the more disturbed and less disturbed area (Figure 4.1b). Although the area closer to waterhole was designated as more disturbed area, it supported the highest diversity of small mammals. The results of the present study suggests that diversity of small mammal species was not affected by the trampling and intensity of grazing by large herbivores. In addition, the diversity of small mammals did not correlate with the difference of the vegetation cover in the study areas.

However, the less disturbed area supported the highest species richness of small mammals than the more disturbed area. These differences remain unclear and therefore, it is important to conduct a similar study, to see if these findings are going to be supported by studies in other habitats and over longer periods where no ecological disturbances have taken place.

The estimation of population size of small mammals using Petersen method of Capture-Mark-Recapture (CMR) and population size of small mammal species estimated from

Minimum number Alive (MNA) showed that there was no significant difference between the more disturbed areas and less disturbed areas during the trapping session in December 2005, March, April, May and June 2006.

In conclusion, the presence of *Mastomys* spp as one of the dominant species and decrease of *Tatera leucogaster* in the more disturbed area may suggest a degree of disturbance. Alternatively, the lack of dominance of *Mastomys* spp in terms of abundance in the more disturbed area is a characteristic that indicates ecosystem integrity (Avenant, 2000). Numerous studies (Leirs *et al.*, 1994; Monadjem & Perrin, 1998; Avenant, 2000; Chase *et al.*, 2000; Avenant & Kuyler, 2002 and Wandrag *et al.*, 2002) have described the dominance of *Mastomys* spp in more disturbed area as indicator species indicated that this area was disturbed. Although *Mastomys* spp was the only small mammal species associated as indicator species. *Mastomys* spp can be used as a single small mammal species indicators of environmental disturbance or change, for example, to detect habitat changes evaluate the effects of changes in habitat overtime and monitor population trends of other species (Chase *et al.*, 2000).

It is essential to include the conservation of small mammal species (including individual species) in the planning and management of protected areas because they are part of biodiversity and play vital roles in the ecosystem equally as do the large herbivores (Hayward & Phillipson, 1979). It is equally important to create awareness on the importance of small mammals in protected areas, on the treats of habitat threats (land

degradation), pollution, overgrazing, increasing fire frequency and the introduction or invasion of exotic flora and fauna. These threats are not only affecting small mammals but also biodiversity in particular.

## CHAPTER 6 REFERENCES

- 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** (1): 11-18
- Avenant, N.L. (1996). Identification and distribution of two *Mastomys* spp in Lesotho and part of South Africa. *Navorsing Nasionale Museum*. Bloemfontein. **12**: 49-58
- Avenant, N.L. (2000). Small mammal community characteristics as indicators of ecological disturbance in the Willem Pretorius Reserve, Free State, South Africa. *South African Journal of Wildlife Research*. **30** (1): 26-33.
- Avenant, N.L. & Kuyler, P. 2002. Small mammal diversity in the Maguga Dam inundation area, Swaziland. *South African Journal of Wildlife Research* **32** (2): 101-108.
- Barnard, P., Bethune, S. & Kolberg, H. (1998). Barnard, P. (Ed.) *Biological Diversity in Namibia: a Country Study*. Windhoek: Ministry of Environment and Tourism/National Biodiversity Task Force. 57-187.
- Bond, W.J. (1980). Fire and senescent fynbos in the Swartberg, Southern Cape. *South African Forestry Journal* 114: 68-71
- Bourlière, F. (1975). Mammals, small and large: the ecological implications of size. In: Golley, F.B., Petruszewicz, K. & Ryszkowski, L. (Eds.): *Small mammals:*

- their productivity and population dynamics.* International Biological Programme 5. Cambridge University Press. 1-8.
- Bowland, A.E & Perrin, M.R. (1989). The effect of overgrazing on small mammals in Umfolozi Game Reserve. *Zeitschrift für Säugetierkunde*, **54**: 251-260.
- Bronner, G. & Meester, J. (1987). Comparison of methods for estimating rodent numbers. *South African Journal of Wildlife Research*, **17** (2): 59-63.
- Chase, K.M., Kristan III, B.W., Lynam, J.A., Price, V.M. & Rotenberry, T.J. (2000). Single species as indicators of species Richness and Composition in California Coastal Sage Scrub Birds and small mammals. *Conservation Biology*. **14**: 2. 474-487.
- Coetzee, C.G. (1969). The distribution of mammals in the Namib Desert and adjoining inland escarpment. *Scientific Paper of Namib Desert Research Station*. **40**, 23-36.
- DeBlase, A.F. & Martin, R.E. (1981). A manual of Mammalogy with Keys to Families of the World. Wm.C. Brown Company Publishers. Dubuque, Iowa.
- De Graaf, D. (1981). *The Rodent of Southern Africa*. Butterworth, Durban.
- Delany, M.J. (1974). *The Ecology of small mammals*. The Institute of Biology's studies in Biology. 51: 1-60. Edward Arnold. London.
- Du Preez, P. (2000). *Analysis of the reproduction, population characteristics and the use of space of Black rhino *Diceros bicornis bicornis* (Linnaeus 1758) in the Waterberg Plateau Park, Namibia*. MSc Thesis, Department of Biological Sciences, University of Zimbabwe. (Unpublished).

- Dytham, C. (1999). *Choosing and Using Statistics. A Biologist's Guide*. Blackwell Science. Great Britain.
- Eiseb, S.J. (2002). *Fleas (Insecta: Siphonaptera) of small mammals occurring at Gellap-Ost and Nabaos, Keetmanshoop District in southern Namibia*, A thesis for Masters in tropical Entomology, Department of Biological Sciences, University of Zimbabwe. Unpublished.
- Eiseb, S.J. (2004). Field report on the small mammals trapping at the Namib Sprietshoogte Nature Reserve. Unpublished
- Els, L.M. & Kerley, G.I.M. (1996). Biotic and abiotic correlates of small mammal community structure in the Groendal Wilderness Area, Eastern Cape, South Africa. *Koedoe*: **39/2**. 121-130
- Erb, K.P. (1993). *The Roan Antelope (Hippotragus equinus, Desmarest 1804), its ecology in the Waterberg Plateau Park*. MSc Thesis, Department Nature Conservation, University of Stellenbosch. (Unpublished).
- Fleming, H.T. (1979). Life history strategies. In: Stoddart, D. .M. (Ed). *Ecology of small mammals*. Chapman and Hall. London.1-5.
- Flowerdew, J.R. (1976). Ecological methods. *Mammalian Rev.* **6**: 123-159.
- Fraser, M.W. (1990). Small mammals, birds and ants as seed predators in post-fire mountain fynbos. *South African Wildlife Research.* **20** (2). 52-55.
- Fuggle, R.F. & Rabie, M.A. (Eds.) (1983). *Environmental concerns in South Africa*. Juta & Co: Cape Town.

- Gliwicz, J. (1985). Rodent community of dry African Savanna: population study. *Mammalia*. **49** (4): 509-516.
- Griffin, M. 1990. Review of taxonomy and ecology of *gerbiline* rodent of the Central Namib Desert, with keys to the species (Rodentia: Muridae). In: Seely, M.K., (Ed) *Namib ecology: 25 years of Namib research*, pp. 83-98. Transvaal Museum Monograph No. 7, Transvaal Museum, Pretoria
- Griffin, M. (1998). The species diversity, distribution and conservation of Namibian mammals. *Biodiversity and Conservation* **7**: 483-494.
- Heaney, L.R. (2001). Small mammal diversity along elevational gradients in the Phillipines: an assessment of patterns and hypotheses. *Global Ecology & Biogeography*. **10**: 15-39.
- Hoffmann, A. & Zeller, U. (2005). Influence of variations in land use intensity on species diversity and abundance of small mammals in Nama Karoo, Namibia.
- Jankowitz, W.J. (1983). Die plant ekologie van die Waterberg – Plato park. D.Sc Thesis, University of the Orange Free-State.
- Jankowitz, W.J. & van Rensburg, W.L.J. (1985). Die basale en die dra vermoë van die sleutelgrasse palntgemeenskappe in die Waterberg –Plato park. *Madoqua* **14** (3): 305-313.
- Jankowitz, W.J. & Venter, H.J.T. (1987). Die plantgemeenskappe van die Waterberg Plato park. *Madoqua*. **15** (2): 97-146.

- Jongman, R.H.G. (1987). Introduction. In: Jongman, R.H.G, ter Braak, C.J.F & Tongeren. (Eds). *Data analysis in community and landscape ecology*. Pudoc Wageningen. 1-9.
- Jooster, J.F & Palmer, N.G. (1982). The distribution and habitat preference of some small mammals in the Rolfontein Nature Reserve. *South African Journal of Wildlife Research*. **12**:
- Joubert, E. & Moster, P.K.N. (1975). Distribution patterns and status of some mammals in South West Africa. *Madoqua* **9**:5-44
- Joubert, D. F. & Ryan, P.G. (1999). Differences in mammal and bird assemblages between commercial and communal rangelands in the Succulent karoo, South Africa. *Journal of Arid Environments*. **43**: 287-299.
- Kangombe, F.N. (2005). Host specificit of fleas of selected small mammals in selected areas around Windhoek. Unpublished.
- Katsiambirtas, E.E. (1988). *Climate of South West Africa/Namibia*. Series No. 2. South West Africa/Namibia Meteorological Service. Windhoek: Department of Transport, Namibia.
- Kerley, G.I.H. (1989). Diet of small mammals from the Karoo, South Africa. *South African Journal of Wildlife Researc*. **19**: 67-72
- Kerley, G.I.H, Knight, M.H. & Erasmus, T. (1990). Small mammal microhabitat use and diet in the southern Kalahari, South Africa. *South Africa Journal Wildlife Research*. **20**:123-126

- Kerley, G.I.H. (1991). Seed removal by rodents, birds and ants in the semi-arid Karoo, South Africa. *Journal of Arid environment*. **20**: 63-69.
- Kerley, G.I.H. (1992a). Ecological correlates of small mammal community structure in the semi-arid Karoo, *South African Journal of Zoology*. London. **227**: 17-27.
- Kerley, G.I.H. (1992b). Small mammal seed consumption in the Karoo, South Africa: further evidence for divergence in desert biotic processes. *Oecologia*. **89**: 471-475.
- Krebs, C.J. (1989). *Ecological Methodology*. University of British Columbia. Harper Collins.
- Lack, D. (1954). *The natural regulation of animals numbers*. Oxford, Clarendon Press.
- Laidlaw, R.K. (2000). Effects of habitat disturbance and Protected Areas on mammals of Peninsular Malaysia. *Conservation Biology*. **14**: 6. 1639-1648.
- Leirs, H, Verhagen, R & Verheyen, W. (1994). The basis of reproductive seasonality in *Mastomys* rats (Rodentia: Muridae) in Tanzania. *Journal of Tropical Ecology*. **10**: 55-66.
- Leirs, H. (1995). Population ecology of *Mastomys natalensis*: *Implications for rodent control in Africa*. Agricultural Edition Nr. 35. Belgian administration for development Cooperation Brussels.
- Mahlaba, T.A.M. & Perrin, M.R. (2003). Population dynamics of small mammals at Mlawula, Swazilan. *African Journal of Africa*. **41**. 317-323. Available from:

<[http://uniswa.sz/academics/science/bio/staff/tmahlab/a/mlawula\\_rodents.pdf](http://uniswa.sz/academics/science/bio/staff/tmahlab/a/mlawula_rodents.pdf)>.[Accessed 2005October 6].

- Matson, J.O. & Blood, B.R. (1994): A report on the distribution of small mammals from Namibia. *Z. Säugetierk.* **59**: 289-298.
- Meffe, G.K. & Carrol, C.R. (1997). *Principals of Conservation Biology*. Sinaure Associates. INC. Sunderland.
- Mendelsohn, J.M. (1982). Notes on small mammals on the Springbok Flats, Transvaal. *South African Journal of Zoology.* **17**, 197-20.
- Meester, J. 1958. Some mammal from the Namib Desert. *Annals of the Transvaal Museum.* **24**:241-248
- MET. (1986). Waterberg Plato Park Konsep Meestersplan. Ministry of Environment and Tourism, Namibia, N11/2/5, unpublished. Report.
- Mfunne, J.K. (2005). Module: Assessing Biodiversity. Lecturer notes. University of Namibia. Unpublished.
- Monadjem, A. & Perrin, M.R. (1998). 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** (3).173-177
- Monadjem, A. (1999): Geographic distribution patterns of small mammals in Swaziland in relation to abiotic factors and human land-use activity. *Biodiversity and Conservation.* **8**: 223-237.
- Muck, C. & Zeller, U. (2006). Small mammal communities on cattle and game grazing areas in Namibia. *African Zoology* **41**(2): 1-8 (October 2006).

- Müller, M.A.N. (1984). Grasses of South West Africa/Namibia. Directorate of Agriculture and Forestry, Department of Agriculture and Nature Conservation, South West Africa/ Namibia.
- NMS. (2006). *Rainfall data*. Unpublished.
- Nel, J.A.J. (1975). Species Density and Ecological Diversity of South African Mammal Communities. *South African Journal Of Science*. 17: 168-170.
- Nyako-Lartey, Q. & Baxter, R.M. (1995): The effects of different grazing regimes on the population dynamics of small mammals in the Eastern Cape. *Transvaal Royal Society of Southern Africa*. 50 (2): 143-151.
- Perrin, M.R. & Boyer, D.C. (1999). Seasonal changes in the population dynamics of hairy-footed gerbils in the Namib Desert. *South African Journal of Wildlife Research* 30 (2). 73-83.
- Perrin, M.R. & Johnson, S.J. (1999). The effect of supplemental food and cover availability on a population of the striped mouse. *South African Journal of Wildlife Research*. 29 (1) 15-18
- Perrin, M.R. & Swanepoel, P. (1987). Breeding biology of the bushveld gerbil *Tatera leucogaster* in relation to diet, rainfall and life history theory. *South African Journal of Zoology*. 22 (3):218-227
- Rathbun, G.B & Rathbun, C.D. (2006). Social structure of the bushveld sengi (*Elephantulus intufi*) in Namibia and the evolution of monogamy in the Macroscelidea. *Journal of Zoology*. 269 (2006) 391-399.

- Ricklefs, R.E. & Miller, G.L. (1996). *Ecology 4<sup>th</sup> Edition*. Freeman, W.H and Company. New York.
- Rivers-Moore, N.A & Samways. (1996). Game and cattle trampling, and impacts of human dwellings on arthropods at a game park boundary. *Biodiversity and Conservation*. **5**: 1545-1556.
- Rowe-Rowe, D.T. & Lowry, P.B. (1982). Influence of fire on small mammal populations in the Natal Drakensberg. *South African Journal of Wildlife Research*. **17**: 202-209.
- Rowe-Rowe, D.T. & Meester. (1982). Habitat preferences and abundance relations of small mammals in the Natal Drakensberg. *South African Journal of Zoology*: **17** (4):202-209.
- Rowe-Rowe, D.T. (1995). Small-mammal recolonization of a fire-exclusion catchment after unscheduled burning. *South African Journal of Wildlife Research*. **25** (4) 133-137
- Sachse, B. and Bonthuys, A. 1990 'n Voorgestelde bewaringsplan vir die Otjiwa-wildplaas. Stellenbosch: Univ. of Stellenbosch, unpubl. B.Sc (Agric) project report.
- Schluter, D. & Ricklefs, R.E. (1993). Species Diversity, an introduction to the problem. In: Ricklefs, R.E. & Schluter, D. (Eds). *Species Diversity in Ecological Community. Historical and Geographical Perspectives*. University of Chicago Press. 1-10.

- Schneider, G. (2004). *The Roadside Geology of Namibia*. Gebrueder Borntraeger, Berlin- Stuttgart.
- Skinner, D.J & Smithers, R.H.N. (1990). *The mammals of the South Africa Subregion*, University of Pretoria, Pretoria, South Africa.
- Smith, M.H., Gardner, R.H., Gentry, J.B., Kaufman, D.W.; O' & Farrell, M.H. (1975). Density estimations of small mammal's populations. In: Golley, F.B., Petrusiewicz, K. & Ryszkowski, L. (Eds.). *Small mammals: their productivity and population dynamics*. International Biological Programme 5. Cambridge University Press. 25-55.
- Smithers, R.H.N. (1983). *The mammals of southern African sub-region*. Pretoria, University of Pretoria.
- Southernland, J.W. (1996). Why Census ?. In: Southernland, J.W. (Ed). *Ecological Census Techniques. A Handbook*. Cambridge University Press 1-10.
- Southern, H.N. (1979) Population processes in small mammals. In: Stoddart, D. M. (Ed). *Ecology of small mammals*. Chapman and Hall. London. 63-101.
- Stuart, C & Stuart, T. (1991). *Field guide to the Mammals of Southern Africa*. Struik.
- Tasker, E. Bradstock, R, & Christopher Dickman, C. (1991). Small Mammal Diversity and Abundance in Relation to Fire and Grazing History in the Eucalypt Forests of Northern New South Wales. School of Environmental Information Science. Available from:

- <http://www.csu.edu.au/special/bushfire99/papers/tasker/>>. [Accessed 2005 October 6].
- Tinley, K.K. (1996). *Waterberg Plateau, South West Africa*. Ministry of Environment and Tourism, Namibia, N50/2. Unpublished Report. 7 pp.
- Tongeren, O.F.R. (1987). Cluster analysis. In: Jongma, R.H.G, ter Braak, C.J.F & Tongeren. (Eds). *Data analysis in community and landscape ecology*. Pudoc Wageningen. 174-213.
- arid Karoo, South Africa. *Journal of Arid Environment*. **37**: 529-549.
- Van Oudtshoorn, F.P. (1999). *Guide to Grasses of Southern Africa*. Briza Publications, Arcadia.
- Van Wyk, B. & Van Wyk, P. (1997). *Field Guide to Trees of Southern Africa*. Struik Publishers.
- 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**: (2): 137-143.
- White, R.M., Kerley, G.I.H & Bernard, R.T.F. (1997). Pattern and control of reproduction of the southern African rodent *Gerbillurus paeba* in the semi-arid Karoo, South Africa. *Journal of Arid Environment*. **37**: 529-549
- Zar, J.H. (1999). *Biostatistical Analysis*. Fourth Edition. Department of Biological Sciences Northern Illinois University. Prentice Hall. Upper Saddle River, New Jersey.

## APPENDICES

**Appendix 1.** Individual number of small mammals species captured in four different sites five different trapping sessions at Waterberg Plateau Park during trapping session in December 2005, March, April, May and June 2006.

<b>Taxon</b>	<b>No. Individual</b>	<b>Percentage</b>
<b>Soricidea</b>		
<i>Crocidura hirta</i> (Peters, 1852 )	4	1.2
<b>Muridae: Gerbillinae</b>		
<i>Dendromus melanotis</i> (Smith, A., 1834)	89	27.4
<i>Gerbilurus paeba</i> (Smith, A., 1836)	80	24.6
<i>Gerbilurus vallinus</i> (Thomas, 1918)	3	0.9
<i>Tatera leucogaster</i> (Peters, 1852)	69	21.2
<b>Muridae: Murinae</b>		
<i>Aethomys chrysophilus</i> (De Winton, 1897)	8	2.5
<i>Aethomys namaquensis</i> (Smith, A., 1834)	18	5.5
<i>Mastomys spp</i> (Thomas, 1915 )	34	10.5
<i>Mus indutus</i> (Thomas, 1910)	16	4.9
<i>Thallomys nigricauda</i> (Thomas, 1882)	1	0.3
<b>Muridae: Cricetomynae</b>		
<i>Saccostomus campestris</i> (Peters, 1852)	2	0.6
<b>Gliridae</b>		
<i>Graphiurus murinus</i> (Desmarest, 1882)	2	0.6
<b>Total</b>	<b>326</b>	<b>100</b>

**Appendix 2.** Individual number of small mammal species captured in four different sites five different trapping sessions at Waterberg Plateau Park during trapping session in December 2005, March, April, May and June 2006. (No Ind = Number of individual, M= male individual and F = female individual small mammal)

<b>Taxon</b>	<b>No. Ind.</b>	<b>%</b>	<b>M</b>	<b>%</b>	<b>F</b>	<b>%</b>
<b>Soricidea</b>						
<i>Crocidura hirta</i> (Peters, 1852 )	3	2	1	1	2	3
<b>Muridae: Gerbillinae</b>						
<i>Dendromus melanotis</i> (Smith, A., 1834)	41	28	12	16	29	41
<i>Gerbilurus paeba</i> (Smith, A., 1836)	33	23	16	21	17	24
<i>Gerbilurus vallinus</i> (Thomas, 1918)	1	1	1	1	0	0
<i>Tatera leucogaster</i> (Peters, 1852)	24	16	8	11	16	23
<b>Muridae: Murinae</b>						
<i>Aethomys chrysophilus</i> (De Winton, 1897)	2	1	2	3	0	0
<i>Aethomys namaquensis</i> (Smith, A., 1834)	10	7	8	11	2	3
<i>Mastomys spp</i> (Thomas, 1915 )	18	12	16	21	2	3
<i>Mus indutus</i> (Thomas, 1910)	9	6	6	8	3	4
<i>Thallomys nigricauda</i> (Thomas, 1882)	1	1	1	1	0	0
<b>Muridae: Cricetomynae</b>						
<i>Saccostomus campestris</i> (Peters, 1852)	2	1	2	3	0	0
<b>Gliridae</b>						
<i>Graphiurus murinus</i> (Desmarest, 1882)	2	1	2	3	0	0
<b>Total</b>	<b>146</b>	<b>100</b>	<b>75</b>	<b>100</b>	<b>71</b>	<b>100</b>

**Appendix 3.** The number of male and female small mammals captured in the four different plots in five different trapping sessions at Waterberg Plateau Park during in December 2005, March , April, May and June 2006. (M = male and F = female small mammals captured )

Species	Dec '05		Mar '06		Apr '06		May ' 06		Jun '06		Total
	M	F	M	F	M	F	M	F	M	F	
<i>Aethomys chrysophilus</i>							1		1		2
<i>Aethomys namaquensis</i>					7	1	1			1	10
<i>Crocidura hirta</i>					1	2					3
<i>Dendromus melanotis</i>		3				1	5	1	24	7	41
<i>Gerbilurus paeba</i>	6	3	1	3	1	2	3	1	5	8	33
<i>Gerbilurus vullinus</i>			1								1
<i>Graphiurus murinus</i>									2		2
<i>Mastomys spp</i>	1	1	3		11	1	2				19
<i>Mus indutus</i>	4	2							1		7
<i>Saccostomus campestris</i>					1				1	1	3
<i>Tatera leucogaster</i>	6	4		5	1			3	1	4	24
<i>Thallomys nigricauda</i>									1		1
<b>Total</b>	<b>17</b>	<b>13</b>	<b>5</b>	<b>8</b>	<b>22</b>	<b>7</b>	<b>12</b>	<b>5</b>	<b>36</b>	<b>21</b>	<b>146</b>

**Appendix 4.** Estimation of population size of small mammals using Petersen method of Capture Mark-Recapture in the more disturbed and less disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park.

Areas	Total population size of small mammals per month (year: 2005-2006)					
	Dec '05	Mar '06	Apr '06	May '06	Jun '06	Total
<b>More disturbed area</b>	40.2	9.2	48.4	16	19	<b>133</b>
<b>Less disturbed area</b>	13.3	9.7	56.5	25.7	108.3	<b>213.5</b>

**Appendix 5.** Population size in terms of MNA (Minimum Number Alive) of species of small mammals caught in the more disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park.

More disturbed area						
Small mammals species	Dec '05	Mar '06	Apr '06	May '06	Jun '06	Total
<i>Aethomys chrysophilus</i>				1	1	<b>2</b>
<i>Aethomys namaquensis</i>			3			<b>3</b>
<i>Dendromus melanotis</i>	2	1	2	3	10	<b>24</b>
<i>Gerbilurus paeba</i>	7	4	3	3	7	
<i>Gerbilurus vullinus</i>		1	1			<b>2</b>
<i>Mastomys spp</i>	2	1	8	3	1	<b>12</b>
<i>Mus indutus</i>	5					<b>5</b>
<i>Tatera leucogaster</i>	5	2	1	3	1	<b>12</b>
<b>Total</b>	<b>21</b>	<b>9</b>	<b>18</b>	<b>11</b>	<b>19</b>	<b>78</b>

**Appendix 6.** Population size in terms of MNA (Minimum Number Alive) of individual small mammals caught in the less disturbed area during the trapping session in December 2005, March, April, May and June 2006 at Waterberg Plateau Park.

<b>Less disturbed Area</b>						
<b>Small mammals species</b>	<b>Dec '05</b>	<b>Mar '06</b>	<b>Apr '06</b>	<b>May '06</b>	<b>Jun '06</b>	<b>Total</b>
<i>Aethomys namaquensis</i>			5	1	1	7
<i>Crocidura hirta</i>			3			3
<i>Dendromus melanotis</i>	1			4	25	30
<i>Gerbilurus paeba</i>	2	1	2	1	8	14
<i>Graphiurus murinus</i>					2	2
<i>Mastomys spp</i>		2	4	1	1	8
<i>Mus indutus</i>	1				3	4
<i>Saccostomus campestris</i>			1		1	2
<i>Tatera leucogaster</i>	5	6	5	3	7	26
<i>Thallomys nigricauda</i>					1	1
<b>Total</b>	<b>9</b>	<b>9</b>	<b>20</b>	<b>10</b>	<b>49</b>	<b>97</b>