A COMPARATIVE STUDY OF RODENT AND SHREW DIVERSITY AND ABUNDANCE IN AND OUTSIDE THE N'WASHITSHUMBE ENCLOSURE SITE IN THE KRUGER NATIONAL PARK

by

DUNCAN NEIL MACFADYEN

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MSc: Zoology

Department Zoology and Entomology

and

Department of Botany

University of Pretoria

Supervisor: Prof. Mac van der Merwe

Co-Supervisor: Prof. George Bredenkamp

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UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

DECLARATION

The compilation of this thesis “A comparative study of rodent and shrew diversity and abundance in and outside the N’washitshumbe enclosure site in the Kruger National Park” and the work reported on is the result of the author’s original work, unless specifically acknowledged, or stated to the contrary, in the text.

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ABSTRACT

Understanding the extent and cause of small mammal diversity and movement in an area is one of the major challenges in modern ecology. Rodents are a very successful group forming the largest Order of mammals, but monitoring trends in populations remains complicated, especially when populations are influenced by changes in vegetation structure, seasonal climate fluctuations and different management practices. This project aims to determine the biodiversity of rodent populations in the northern plains of the Kruger National Park and to investigate the possible role they may play as bio-indicators for different management practices. Movement of rodents from one area to the next is expected to be restricted due to changes in the habitat structure. This study describes the results of small mammal trapping in, surrounding and outside the N'washitshumbe enclosure site, an area enclosed since 1968 for the protection of endangered antelope species in the northern plains of the Kruger National Park, South Africa. The study refers to plant association, seasonal change, management practices (e.g. presence or absence of fire and elephant impact) and community dynamics of rodents. It is argued that progress in estimating rodent diversity to develop an understanding of small mammal community dynamics will be enhanced by building local inventories of fluctuations of species diversity and abundance, and in descriptive and experimental studies of the structure of the communities.

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CHAPTER 1

GENERAL INTRODUCTION

Small mammals have received the attention of man for thousands of years which many references in the Old Testament bear witness to (Elton 1943). The early scientific accounts of small mammals reflected their notoriety as agricultural pests and carriers of such diseases as bubonic plague, rabies and typhus (Davis 1942, 1948, 1953; Bouliere 1975; Myllymaki 1975; De Graaff 1981). While the pathological and agricultural importance of small mammals has not diminished, especially in less-developed countries (Davis 1966), their importance to science today has broadened and they have become subjects for medical (Davis 1963; Gordon & Rautenbach 1980), ecological (Lidicker 1966; Watts 1969; Hafner 1977), behavioural (Spencer & Cameron 1983; Ostfeld 1985) and physiological research (Pearson 1960; McNab 1963; Holleman & Dieterich 1973; Kenagy 1973).

This study is based on trapping of rodents and shrews in, outside and surrounding the N'washwitshumbe enclosure site in the northern Kruger National Park, with reference to plant association, seasonal change, veld management practices and community dynamics of rodents and shrews. A focal point was to establish the effect of fire and destruction of the vegetation by elephants and large ungulates on small mammal species richness and abundance under different habitat, veld management, and seasonal conditions.

In Africa the savanna biome is an extensive landscape covering 66% of the landmass (Mucina *et al.* 2005). Savanna ecosystems are co-dominated by two different life forms, trees and grasses. To gain useful understanding of associated small mammal assemblages, these spatial and temporal patterns need to be taken into account. The Northern Plains of the Kruger National Park (KNP) occur on a flat basaltic landscape (Gertenbach 1983). The upland areas are dominated by *Colophospernum mopane* shrubveld and the bottomland are characterized by seasonally inundated depressions or vleis (Harrington *et al.* 1999). Grasses dominate the vleis as seasonal inundation and saturation of soil does not support woody vegetation. At a broad scale the mopane matrix and vleis form two distinct patches. At a finer scale, a zone of transition, termed the vlei boundary, can be distinguished between the two patch types and was delineated by Kröger (2000).

Petersen (2006) investigated granivores as ecosystem regulators of woody plant increasers in semi-arid savannas of the lowveld in South Africa. Additional to this, small mammals have been pinpointed as ecosystem regulators in semi-arid Australia (Noble 1997) and USA (Weltzin *et al.* 1997). In both cases, small mammal species were largely eradicated and increases in woody vegetation subsequently occurred. Granivorous small mammals are abundant in South African semi-arid savannas and have high dietary nutritive demands which would encourage them to consume energy rich tree and shrub seeds, thus possibly acting as “regulators” of increasers in the ecosystem (Petersen 2006).

Anecdotal field observations suggest that woody patches are much taller and denser inside the enclosure. This observation led to the hypothesis that differences in small mammal diversity and assemblages inside the enclosure may result from differences in vegetation, the exclusion of browsing disturbance and differences in fire regime. The N'washitshumbe enclosure provides opportunity to test these hypotheses. The relationship between a landscape process and observation patterns can only be rigorously tested if the expected pattern in the absence of the process in known (Gardner *et al*. 1987).

The occasional burning of vegetation is a natural ecological phenomenon, occurring most often as a result of lightening (Komarek 1964). Accidental fires have resulted in the widespread appearance of "fire-climaxes" in vegetation (Tansley 1935). However, fires in major vegetation biomes of forest and grassland are genetically different (Daubenmire 1968a) both in terms of actual fire processors and of ecological effects. These are summarized by Ahlgren & Ahlgren (1960) for forest fires and by Daubenmire (1968b) for grassland fires. The emphasis on these summaries, and indeed on much of the available literature, is on the effects of burning on vegetation (e.g. Kucera & Koelling 1964; Hopkins 1965), and by comparison the effects of fire on animals is less well documented (Kern 1981).

Boundaries can be defined as the locations where the rates or magnitudes of ecological transfers change abruptly in relation to those within adjacent patch types (Holland 1988). They can be detected through changes in the physical, chemical and biological characteristics of the system (Forman 1997). Disturbance agents, such as large mammalian herbivores and fire, have the ability to physically alter the structure of landscape boundaries and influence them by altering the actions of vectors, such as water, which transport energy and materials in the system (Gosz 1991).

No other mammal group shows such a wide range of adaptations for successfully colonizing and inhabiting almost any type of habitat like the rodents. Consequently, they are important components of nearly all-terrestrial faunas. The life span and expectancy of rodents are short, but this is counterbalanced by the fact that they are prolific.

A plant community consists of a combination of plant species associated with each other and is restricted to a particular physical environment determined by climate, sunlight (energy), nutrients in the soil, geology, geomorphology and water availability for plants (Kent & Coker 2000; Bredenkamp 2001). Each plant community is unique in terms of plant species composition and their relative abundance (Bredenkamp 2001). Plant communities can be distinct, easily separable units or plant communities can occur in gradients as a result of continuity in environmental factors (Bredenkamp & Brown 2001). The vegetation and its abiotic environment form the habitat for animals and specific combinations of the plant species will determine the presence of specific animals. Vegetation is an easily recognisable expression of the ecology and the series of interactions and relationships among organisms and their environment and can be seen as the physical representation of the ecosystem (Bredenkamp 2001). Therefore it is important to know the vegetation before any conservation planning can be done. Because each plant community has its own floristic composition, physiognomy and habitat conditions, each community should be managed differently, as the different communities react differently to environmental conditions and utilisation by animals.

A vegetation type or plant community can be seen as an area in which the climate, landscape, soil and plant species composition are homogeneous to such a degree that it has the same grazing and browsing value and potential for plant biomass production (Van Rooyen 2002).

Although many studies have been conducted in the KNP on mammals, significantly few were conducted on rodent populations that play such an important role in the general ecology of the KNP. Of the 148 mammalian taxa known to occur in KNP, 25 taxa belong to the Order Rodentia. Rodents contribute significantly to the energy flow in nature and play a very important role in any biome in which they occur (Petersen 2006).

The aims of this study were:

1. To determine whether differences occur in biodiversity, assemblage composition and movement of small mammals in, outside and in the fire break protecting the N'washitshumbe enclosure site since its construction 38 years ago.
2. To compare diversity, abundance and movement patterns between these areas.
3. To investigates the effects that different management practices and herbivory patterns have on small mammal population structures in the northern plains of KNP. This is important since Type I herbivores such as zebra and buffalo have encroached into the area which has been historically inhabited by Type II herbivores such as

roan and sable (Staver 2004, unpublished).

CHAPTER 2

RODENT COMMUNITIES

2.1 Views on the rodent communities

Small mammal communities at a specific site are divided into different assemblages according to specific habitat resources. Establishing and identifying the correct scale in an accurate predication to be made for the conservation of the species or population which is dependent on a scale dependent resource (such as boundary). A scale dependent resource in general represents a resource which changes characteristics when observed at varying levels of scales. In this case, at a coarser scale of small mammal distribution when integrated with vegetation type, the population or species is not recognized as a unique entity. At too fine a scale, time may be wasted researching rodent species when not all are sensitive and effective indicators of environmental change.

Furthermore, the short life span allows relatively easy study of several generations which aids genetic (Krebs 1971; Smith *et al.* 1984) as well as ecological and behavioural studies. These characteristics plus the relative ease with which small mammal communities and their local habitats can be manipulated have made them increasingly important to ecologists for experimental examination of various current theories in population and community ecology (Rosenzweig 1973; Schroder & Rosenzweig 1975; Price 1978; Whitford *et al.* 1978; Geier & Best 1980; Parmenter & MacMahon 1983; Spencer & Cameron 1985; Bowers 1986). In a similar fashion, these characteristics make small mammal communities excellent indicators of habitat condition and their use in environments monitoring programmes is also increasing (Beatley 1976; Ghiselin 1980; Racey & Euler 1982; Steel *et al.* 1984).

Leopold (1933) and Odum (1971) recognized that biodiversity expressed at local species richness and abundance is relatively high in transition zones between plant communities. This is to be expected as boundaries or exclusions sites may contain small mammal species of the adjacent patch types and may be able to meet the physiological requirements of the two assemblages from both patches. At the same time, boundaries form patches of their own with a unique set of physical, chemical and biological characteristics that provide microhabitats to support greater species diversity (Gosz 1991).

Hansen *et al.* (1992) caution, however, that simple predications about species diversity and assemblages in boundaries are unlikely to be very widely applicable. Species and communities responses to landscape dynamics are a function of organism abundance relative to environmental dynamics. These relationships are likely to differ considerably across space and time scales. They suggest that more promising approaches to predicting community dynamics involve modeling the demography of individual species or functional groups of species based on their life histories in relation to landscape change.

Boundaries have become of interests to conservationists and scientists as a result of the apparent sensitivity to change over a wide range of scales (Neilson *et al.* 1992). These boundaries may be as a result of changes in landscape in the event of changes in vegetation structure. Landscapes are spatial and temporally heterogeneous mosaics of patch types (Levick 2001). Landscape boundaries or zones of transition separate these patches (Forman 1997). It is expected that with these boundaries or zones, separate assemblages of small mammals would occur.

The influence of boundaries on small mammal assemblages at the N'washitshumbe enclosure site are expected to vary to some degree as a result of a change in landscape due to intensive elephant and fire impact.

2.2 Rationale for this study

A number of studies on rodents in the KNP have been initiated over the past years (Kern 1977, Watson & Watson 1985), yet none have investigated small mammal assemblages at enclosure sites. These studies have also focused on small mammal populations elsewhere in the park and focused primarily from an ecological perspective. The need for comprehensive study investigating small mammal assemblages in, outside and surrounding an enclosure is overdue.

Large mammals have had numerous studies undertaken on them, yet the most abundant Order of all mammal species has had a limited amount of attention in comparison. This document will serve as the foundation for future studies involving small mammal population assemblages in and around enclosure sites. The present study investigates species richness, abundance and habitat preference of small mammals between June 2003 and April 2005. This study provides an estimate of the species richness of these animals on the northern plains for KNP. The N'washitshumbe enclosure experiences extreme variations in temperature, associated with seasonal change. This study also aims to identify trends in small mammal movements in response or absence of various management actions.

2.3 Objectives

Studies concerning woody vegetation, roan conservation and elephant and other large browsers on the northern plains have been conducted (Joubert 1970). Limited information regarding the impacts of changes in habitat and vegetation structure relating to small mammals is available.

The primary objective of this project is:

1. To identify and monitor the effect that different management actions have on small mammal populations in the KNP. The small mammal assemblages in, outside and in the fire break surrounding the N'washitshumbe enclosure site offer the ideal opportunity to study these populations under different management influences. Thus, an objective to determine the effects of large mammalian and fire impacts on vegetation and ultimately on small mammal assemblages. A further objective is to identify representative small mammal species in areas under three different management actions.

2. To also consider the grass and tree species component in and around the enclosure site and the fire break surrounding the enclosure during winter and summer. This allows for possible correlations between species of small mammal and different vegetation attributes to be identified. This information will expand the current knowledge on vegetation and rodent dependency. The plant communities in and outside the site are identified and described, indicating their floristic composition and habitat features.

3. A further objective was to quantify species richness and abundance of small mammal at the N'wshitshumbe enclosure on the northern plains of KNP. Thus, the study endeavours to predict those factors likely to affect the population densities of overall population in, outside and surrounding the enclosure, and to establish the distribution patterns of small mammal assemblages in, outside and in the fire break surrounding the N'washitshumbe enclosure site. Further, how small mammal communities are regulated in the interim between fires and exactly what their important ecological functions are in the park are questions so far unanswered.

4. To determine criteria from which the conservation of small mammal assemblages can be incorporated into the KNP management plan for enclosure sites throughout the park. Thus, considering the implications for small mammal assemblage research and conservation in KNP.

5. A further aim is to determine trends in small mammal movement in, outside and around enclosure sites, and to identify patterns of small mammal distribution in regard to differences in vegetation pattern in relation to small mammal capture success.

2.4 Hypotheses

The H_0 hypothesis is that small mammal diversity and abundance occurs independently of vegetation and time at the N'washitshumbe enclosure and that studies conducted at a small scale are necessary to determine species-specific responses to disturbance and the consequences that such responses hold to small mammal biodiversity and assemblages.

The H_1 hypothesis is that small mammal diversity and abundance occur dependently of vegetation and time at the N'washitshumbe enclosure.

CHAPTER 3

STUDY AREA

3.1 Kruger National Park

The Kruger National Park (KNP) occupies 1 948 528 ha in the Mpumalanga and Limpopo provinces in the north-east corner of the Republic of South Africa (Fig. 1.). It lies between 22^{o}20' to 25^{o}31' latitude south and 30^{o}50' to 32^{o}02' longitude east (Pienaar *et al.* 1980). Roughly 350 km long and 90 km wide, the KNP coincides with three international borders, that of Zimbabwe to the north, Mozambique to the east and the Republic of South Africa to the west. The western border has a discontinuous regional boundary with the Limpopo and Mpumalanga provinces. In ecological terms, the KNP has three natural borders. The Levuvhu and Limpopo rivers which delineate the northern border, the Lebombo mountains which lie along the eastern border and the Crocodile river which forms the southern border (Braack 1983). The western border is an arbitrary line which merely divides the KNP from private lands. Much of the land to the immediate west is used for game farming or as private nature reserves which tends to act as an ecological buffer separating the KNP from areas of agricultural land use further west.

Zoo-geographically, the KNP lies within both the Southern Savanna biotic zone of Moreau (Davis 1962) and the Tropical Arid Savanna region outlined by Huntley (1982). Rautenbach (1978) further classified the region as the Eastern Transvaal lowveld biotic zone. Though broadly classified into a single biotic zone, the KNP has many district ecological regions within it (Pienaar *et al.* 1980) and variations in rainfall, topography, geology and associated vegetation communities are apparent throughout the park.

The KNP lies in the summer rainfall region of southern Africa. The rainy season extends from October to April with rainfall peaking between December and February. Mean annual precipitation varies along a north/south gradient with 400 – 500mm/annum in the north and 600 – 700mm/annum in the south. Analysis of the annual rainfall data from the last 60 years suggests an 8 to 12 year cycle of wet and dry periods (Gertenbach 1980, Tyson 1986).

The topography ranges from undulating hills of granitic origin, with dolerite intrusions in the west, to the basaltic Lebombo plains in the eastern half, with the rhyolithic Lebombo Mountain range forming the eastern boundary (Van Wyk 1971). The interior of the park is generally flat with scattered small hills. Throughout the southern region and along the eastern and northern perimeters mountains and large hills predominate.

The major geological substrates are rhyolites in the far east, basalts in the central east and granites in the west. In the transition from basalt to granite is a unique strip of Ecca shales which runs longitudinally through the centre of the southern region of the park (Gertenbach 1983).

Due to different combinations of the rainfall, topography and geology, the vegetation is quite diverse. Gertenbach (1983) divided the vegetation into 35 distinct landscape types for the purpose of practical conservation management. He defines a landscape as "an area with a specific geomorphology, macroclimate, soil and vegetation pattern and associated fauna".

3.2 N'washitshumbe enclosure site

The N'washitshumbe roan enclosure is situated in the central part of the Vlakteplaas region in the northern plains of the KNP in the Limpopo Province of South Africa (Fig. 1.).

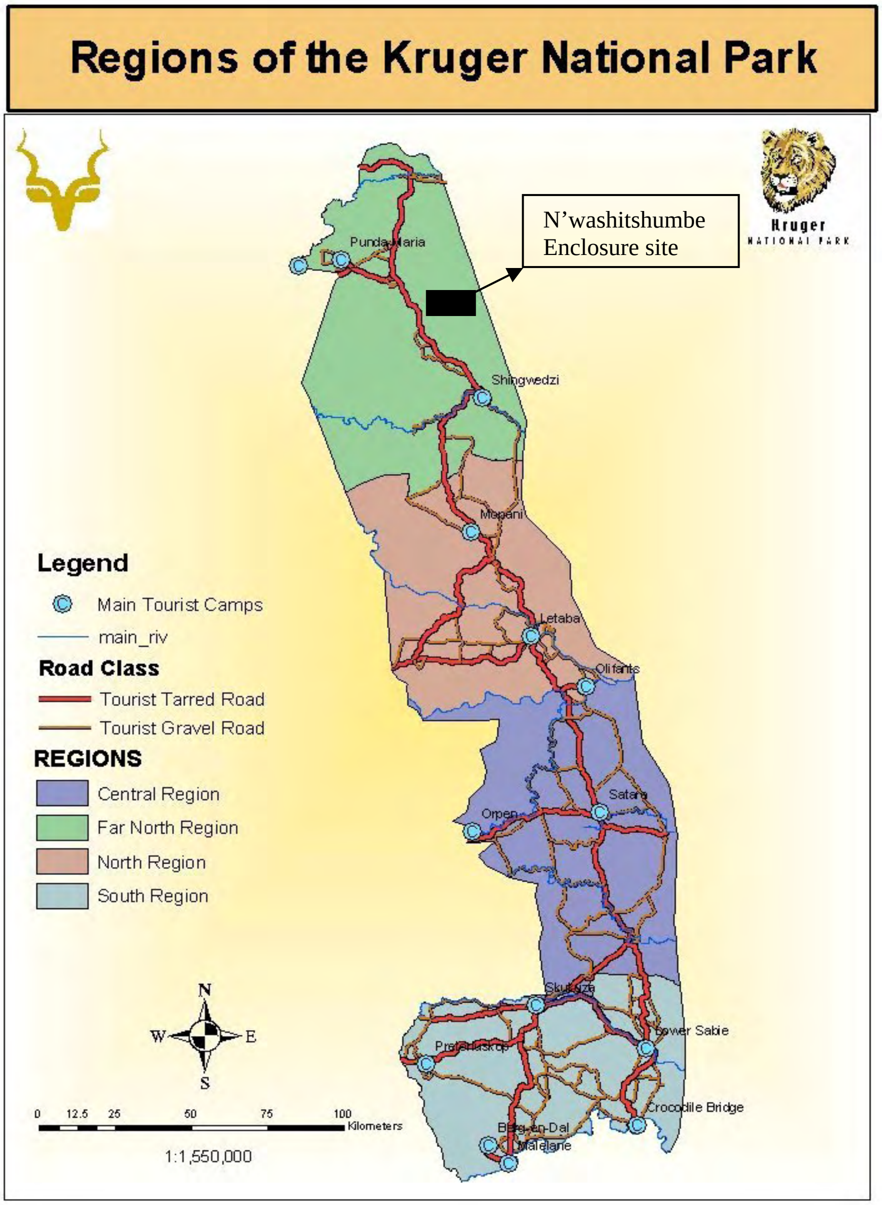


Figure 1. A schematic representation of Kruger National Park (22˚ S-26˚ S, 31˚E-32˚E), showing the northern plains and the appropriate location of the N’washitshumbe enclosure site.

The enclosure lies on olivine-rich basalt in the Karoo geologic sequence and receives between 350 and 450 mm rain per year. The landscape is classified as Basaltic Plains with *Colophospermum mopane* shrub savanna (Solomon *et al.* 1999). These plains are drained by seasonally flooded depressions referred to as vleis, within the plain upland areas are dominated by Mopane/Combretum woodland. Grasses dominate the low-lying, seasonally inundated vlei. The total enclosure encompasses 302 ha today, although when the enclosure was erected in 1967 the total area was 254 ha of upland landtype.

The N'washitshumbe enclosure provided a suitable site to perform a detailed study on small mammal abundance, their movements and vegetation requirements. The differences between inside and outside the enclosure site are significant (Figs. 2, 3 & 4).

Figure 2. A photograph illustrating the difference between inside (area to the left of fence indicated with arrows) and outside at the mid-slope of the catena at the N'washitshumbe enclosure site.

Figure 3. A photograph illustrating the difference between the inside (area to the right of the fence indicated with arrows) and outside at the bottom slope of the catena at the N'washitshumbe enclosure site.

Figure 4. A photograph illustrating the difference in the density of the vegetation on the inside (area to the left of the fence indicated with arrows) and outside the N'washitshumbe enclosure site.

The enclosure (which excludes large predators and large herbivores) was erected roughly in the centre of the roan antelope (*Hippotragus equinus*) study area in 1967 (Joubert 1976). In 1994, 48 ha were added in order to include the adjacent watercourse and associated ecotone vegetation hence forth termed the bottomlands. The enclosure is protected from fire by a network of fire breaks and controlled rotational burning that takes place inside the enclosure. The average fire return period has been four years outside the enclosure site (Trollope *et al.* 1998).

According to the working definitions of the MAB/SCOPE working group (Holland *et al.* 1990), the definition of an ecotone is a zone of transition between adjacent ecological systems having a set of characteristics uniquely defined by space and time scales and by strength of the interaction between ecological systems. The definition of a vlei that best describes the conditions at the N'washitshumbe enclosure site comes from Rogers (1995). "…floodplain vleis comprise a riverine area (either reed bed or a reed swamp) and a grassy floodplain of varying width on either side. The riverine area may be permanently flooded or seasonally inundated but the grassy floodplain is only inundated by occasional floods". Rainfall in the Vlakteplaas region of the Kruger National Park occurs predominantly in the summer months (Fig. 5.).

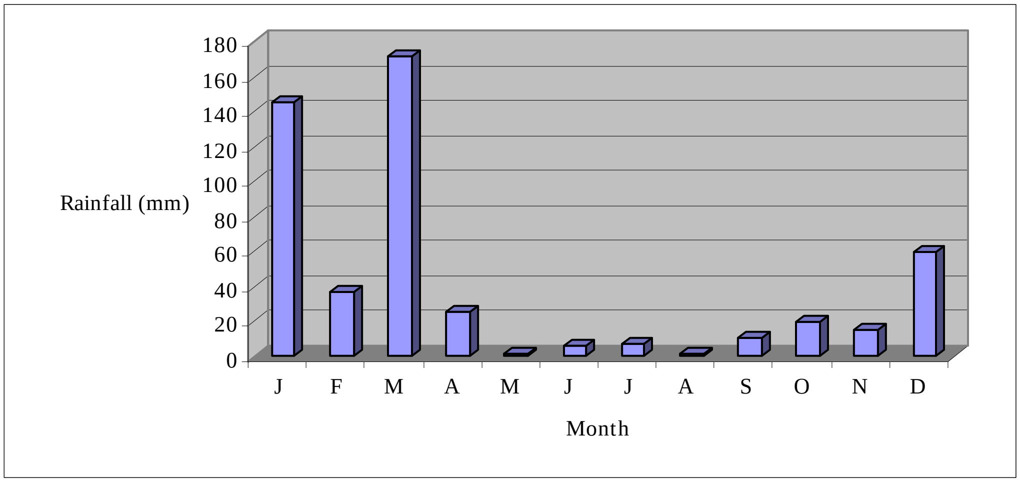


Figure 5. A graph illustrating mean monthly rainfall in the Vlakteplaas Region of the Kruger National Park for 2004.

The Marula *Sclerocarya birrea* section is now very obviously different from the area outside the enclosure, where most of the large Marula trees have disappeared (Fig. 6.).

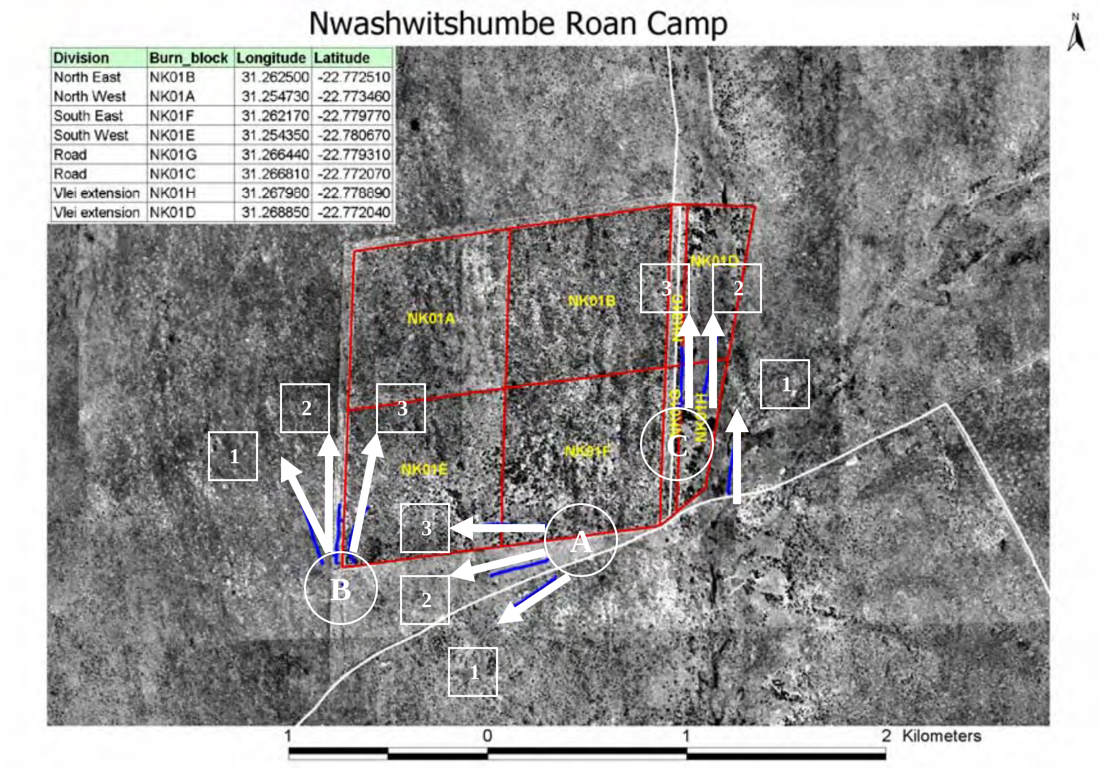
Figure 6. An illustration of broad vegetation structure at the N’washitshumbe enclosure site.

CHAPTER 4

METHODOLOGY

4.1 Rodent capture methodology

The experiment was initiated in the Northern Plains of the Kruger National Park at the N'washitshumbe enclosure S22˚ 43'-S22˚ 59'; E31˚12'-E31˚22'. Three grids each comprising three transect lines of 30 Sherman traps each were placed to incorporate the top, middle and bottom slopes within, surrounding and inside the N'washitshumbe enclosure site (Fig. 7.). Markers were placed along each transect line and around each trap to ensure the same site was surveyed each month.



Division	Burn_block	Longitude	Latitude
North East	NK01B	31.262500	-22.772510
North West	NK01A	31.254730	-22.773460
South East	NK01F	31.262170	-22.779770
South West	NK01E	31.254350	-22.780670
Road	NK01G	31.266440	-22.779310
Road	NK01C	31.266810	-22.772070
Vlei extension	NK01H	31.267980	-22.778890
Vlei extension	NK01D	31.268850	-22.772040

Figure 7. An aerial photograph illustrating trap coordinates and placement of transects lines (A_1, A_2, A_3; B_1, B_2, $B_{3;}$ C_1, C_2, C_3) at the N'washitshumbe enclosure site.

The three grids (direction indicated with arrows) at the N'washitshumbe enclosure site were placed at the top (Figs. 8, 9 & 10), middle (Figs.11, 12 & 13) and bottom slope (Figs. 14, 15 & 16) of the catena. These grids were further divided into nine transects, inside the enclosure (Figs. 10, 13, 15 & 16), outside the enclosure (Figs. 8, 11 & 14) and in the fire breaks (Figs. 9 & 12) surrounding the enclosure.

Figure 8. A photograph illustrating transect A1 (direction indicated by arrows) outside on the mid-slope of the catena at the N'washitshumbe enclosure site.

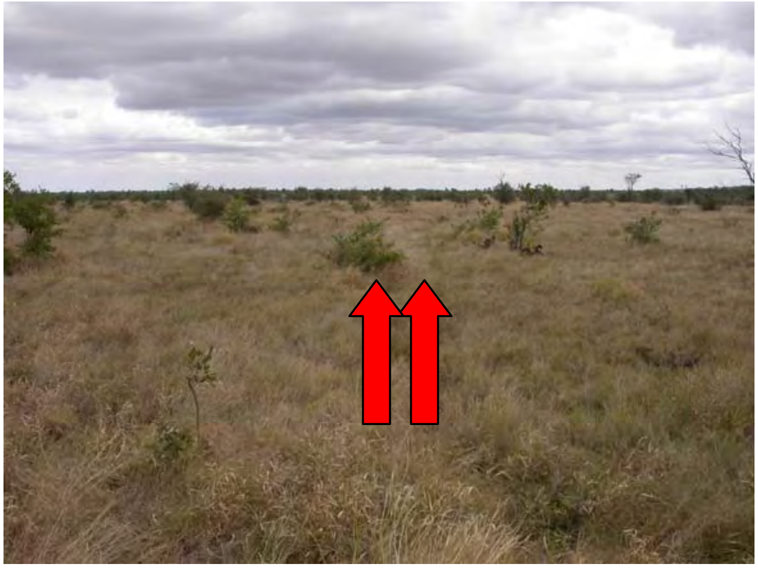


Figure 9. A photograph illustrating transect A2 (direction indicated by arrows) in the fire break on the mid-slope of the catena at the N'washitshumbe enclosure site.

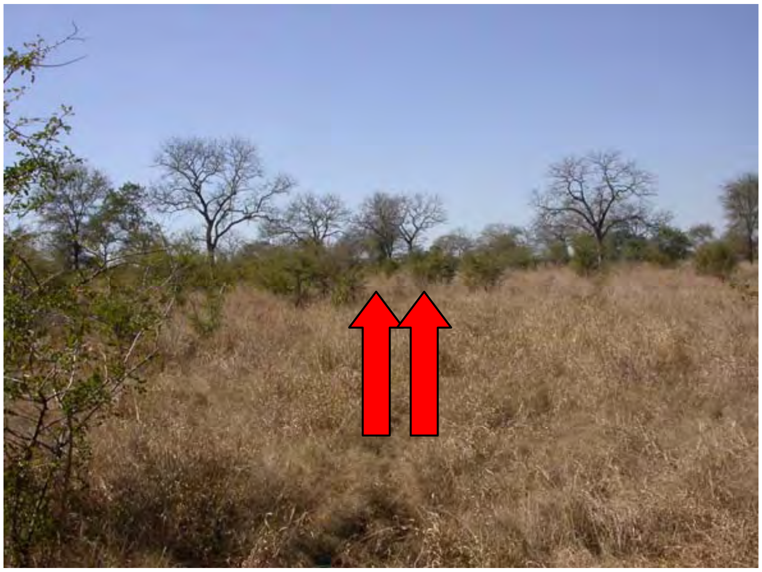


Figure 10. A photograph illustrating transect A3 (direction indicated by arrows) inside on the mid-slope of the catena at the N'washitshumbe enclosure site.

Figure 11. A photograph illustrating transect B1 (direction indicated by arrows) outside on the top-slope of the catena at the N'washitshumbe enclosure site.

Figure 12. A photograph illustrating transect B2 (direction indicated by arrows) in the fire break on the mid-slope of the catena at the N'washitshumbe enclosure site.

Figure 13. A photograph illustrating transect B3 (direction indicated by arrows) inside on the top-slope of the catena at the N’washitshumbe enclosure site.

Figure 14. A photograph illustrating transect C1 (direction indicated by arrows) outside on the bottom-slope of the catena at the N’washitshumbe enclosure site.

Figure 15. A photograph illustrating transect C2 (direction indicated by arrows) inside on the bottom-slope of the catena at the N'washitshumbe enclosure site.

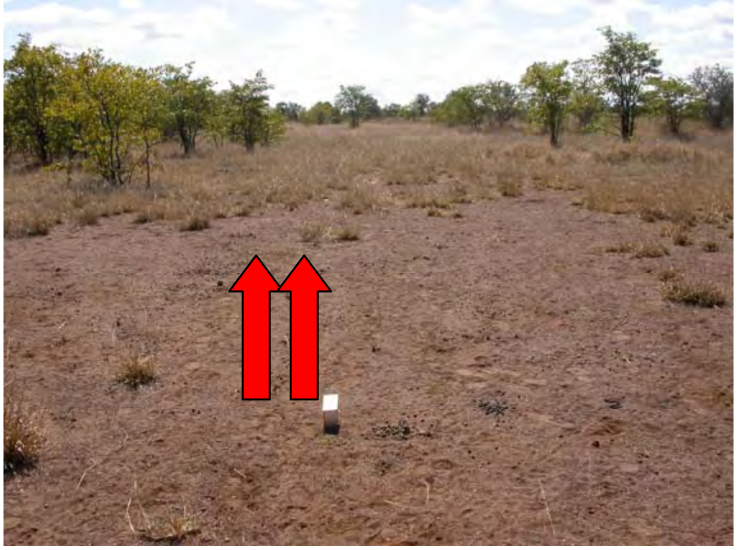


Figure 16. A photograph illustrating transect C3 (direction indicated by arrows) inside at the sodic area on the bottom-slope of the catena at the N'washitshumbe enclosure site.

The starting point was plotting three grids at each level on the catena in, outside and in the fire break surrounding the N’washitshumbe enclosure site. Sherman traps are placed at ten meter intervals and checked and re-baited daily. Ten meter spacing was adopted in, outside and surrounding the enclosure with the available traps. According to De Wit (1972), however, twenty meter spacing gives a higher capture rate.

All captured animals are removed from the traps using a sturdy plastic bag and removed from the bag by hand after being anesthetized using ethyl acetate. Upon first capture, specimens were identified, sexed, measured and weighed. Specimens were measured using callipers and weighed with a Pesola pull-scale. All specimens were recorded by toe clipping (American Society of Mammalogists 1998) and marked using the 1-2-4-7 toe-clipping system (DeBlase & Martin 1981). Only the last phalange/s were removed during toe clipping procedure. Recapture numbers and new specimen information were recorded electronically on a Cyber Tracker.

All new specimens marked by toe clipping were released at the same site where captured. Recaptured specimen numbers were documented and animals released where they were captured. Care was taken to ensure each visit followed exactly the same procedure. Trapping was undertaken 2-3 days each month between June 2003 and April 2005.

During each survey, small mammals were live-trapped using Sherman traps so that dispersal, relative distance and assemblage composition could be assessed (Johnson *et al.* 2002). Sampling during each survey consisted of setting 270 traps (30 traps x three lines x three management sections). Each trap was uniquely identified in order to document animal movement between and within the grids. Traps were placed relative to permanent markers spaced every ten meters along the transect line. Traps were baited with rolled oats, peanut butter and cooking oil mixed very approximately as two volumes of oats to one of peanut butter (Johnson *et al*. 2002). Oil was added to give the desired consistency. Traps were shaded with vegetation, inspected and baited daily between 0600 and 1400 h. It was generally found to be necessary to re-bait the Sherman traps every morning because of ant activity (eat the bait). Each grid was trapped for two to three days.

Species diversity was calculated using the following formula:

$$D = 1 - \Sigma \{[n^1 (n^1 - 1)] / [N (n – 1)\}$$

Where D is species diversity, n^1 is the number of individuals of one species caught during the trapping session; N is the total number of individuals of all species caught during the trapping session (Pielou 1969). A further indication of species diversity was obtained by an examination of the mean body weights of each species present at any trapping session, as utilized Brown (1975). Since the samples sizes for individual species in any one trapped session were very low, an average weight over the whole study period was calculated for each species.

Home ranges were calculated using the Exclusive Boundary Strip method of Stickel (1954), for those individuals with a minimum of three captures in different traps in any one trapping session.

4.2 Vegetation survey methodology

Data was collected during the dry season in July 2004 and in the wet season April 2005.

4.2.1 Vegetation sampling method:

For sound management purposes it is imperative to distinguish between different plant communities, as each will need separate management (Bredenkamp & Brown 2001). This is the reason a plant community approach has been chosen as the preferred method for this study.

The Zürich-Montpellier or Braun-Blaunquet approach to the study of vegetation has proved to be efficient and reliable method for vegetation survey and classification (Werger 1974). It is commonly used in South Africa and has been applied with great success (Bredenkamp 1975; Bezuidenhout 1988; Kooij 1990; Eckhardt 1993; Perkins 1997). A variation of the Braun-Blanquet cover-abundance scale (Westhoff & Van der

Maarel 1973; Mueller-Dombois & Ellerberg 1974; Werger 1974) was used as the sampling technique in this study.

A list of observations of a sample plot with all its floristic and associated environmental data is called a relevé (Eckhardt 1993).

4.2.2 Reconnaissance

A reconnaissance is the preliminary inspection or familiarization of the study area prior to sampling which has the object of estimating floristic and environmental variation, familiarization with the flora and to obtain permission from authorities for later work and accommodation possibilities (Westfall 1992; Westfall *et al*. 1996). This exercise was completed in January 2001 during which time three quadrats were placed randomly in different major vegetation types.

4.2.3 Baseline data

A general impression of the habitat will give an indication of the abiotic characteristics of the plot, which can later help in describing the plant communities. Vegetation is dependent on its physical habitat (Daubenmire 1968a; Gauch 1982). Notes on the following were made:

- Geology

- Rockiness of soil surface percentage
- Aspect (N, NE, E, SE, S, SW,W, NW)
- Gradient in degrees
- Soil texture
- Soil colour

- Management activity: inside, around, outside enclosure

- GPS points for location of the plots on a map

- Other characteristics of note in the plot were recorded such as erosion, trampling, animal activities and any other notable characteristics.

- A floristic survey of all the plant species and their Braun-Blanquet cover abundance were noted in each sample plot. The following Braun-Blanquet cover abundance scales were used (Mueller-Dombois & Ellerberg 1974):

r - one individual with a very small cover

+ - present, but not abundant with a crown cover of less than 1% of the plot

1- any amount of individuals with a crown cover between 1% and 5% of the plot

2a - any amount of individuals with a crown cover between 5.1% and 12% of the plot

2b- any amount of individuals with a crown covers between 12.1% and 25% of the plot

3 - any amount of individuals with a crown cover between 25.1% and 50% of the plot

4 - any amount of individuals with a crown cover between 50.1% and 75% of the plot

5 - any amount of individuals with a crown cover between 75.1% and 100% of the plot

- A photograph of each transect was taken for broad visual representation of the vegetation in each sample plot.

4.2.4 Species Identification

All the species at every sample plot were identified as far as possible. The plant species were identified in the veld or at the H.G.W.J Schweickerdt Herbarium at the University of Pretoria. Various references were consulted including Van Wyk & Malan (1997), Van Wyk & Van Wyk (1997), Pooley (1998) and Van Oudtshoorn (2002). The names of the taxa are in accordance with Germishuizen & Meyer (2003).

4.2.5 Data collection

Sample plots were placed around each of the 270 rodent traps in the nine transect lines. The number of vegetation sample plots corresponds directly with rodent capture methodology. The 270 plots were surveyed in July 2004 and again in April 2005. The size of each plot was 4m² placed at each trap, with the trap in the centre of the plot. Disc pasture meter (Bransby & Tainton 1977) readings were taken at each corner of the plot to record standing mass of the herbaceous layer. $0.25m^2$ grids were placed in the two diagonal corners of the plot to determine the density of each grass species, and the height of each grass plant present. A 10m radius at each trap, with the trap in the centre was used to record all trees and shrubs, placed into height classes.

4.2.6 Classification

The floristic data from each sample plot were captured in the vegetation database, TURBOVEG for Windows (Hennekens 1996a; Hennekens & Schaminee 2001). The database was exported as a Cornell Condensed Species File (CC-file) into a working directory in MEGATAB (Hennekens 1996b). MEGATAB is a DOS based programme used to analyse vegetation data and compile the floristic table.

One of the classification methods, the Two-Way Indicator Species Analysis (TWINSPAN) uses an ordination method, Correspondence Analysis (CA), as the basis of the classification methods (Hill 1979a). The groups of samples are split based on the results of a CA. Each of these groups is then split repeatedly up to a significant level (community or sub-community level). This method was applied to the dataset. The TWINSPAN table was refined by Braun-Blanquet procedures as described by Werger (1974) and Kent & Coker (2000).

The final phytosociological table indicates the different identified plant communities. The phytosociological table was divided into separate tables to give a more accurate and easily representable analysis of the plant communities.

A synoptic table was complied for all the communities to indicate their relationship which cannot be recognised from the three separate tables. The entries in the synoptic table represent the constancy of the species in each community.

In the synoptic table the entries represent the constancy of the species as follows:
1: 1 - 20%
2: 21 - 40%
3: 41 - 60%
4: 61 – 80%
5: 81 – 100%

All entries indicating a consistence less than 20% have been omitted from the table.

4.2.7 Ordination

A Detrended Correspondence Analysis (DECORANA) ordination (Hill 1976b) was conducted on the data set, using the ordination programme PCOrd (McCune & Mefford 1999), to confirm the identification of plant communities and to illustrate the floristic gradients within and between the different communities.

4.2.8 Describing Communities

The communities with the sub-communities were then described in terms of distribution, brad habitat, diagnostic species, species with significant indicator value and dominant species. The plant community names are based on the representative and diagnostic species and dominant species of each community.

4.3 STATISTICAL ANALYSIS

Once the data has been tabulated, statistical techniques were use to analyse the data to determine trends in species association. In this work three kinds of statistical analysis were used, Chi-square analysis, analysis of variance (ANOVA), and Tukey's test (Fowler *et al.* 1998).

CHAPTER 5

DESCRIPTION OF VEGETATION COMMUNITY STRUCTIRE AND DYNAMICS

5. 1 Introduction:

The upland areas of the northern plains are dominated by mopane (*Colophospermum mopane*), marula (*Sclerocarya birrea)*, knob thorn (*Acacia nigrescens)* and *Combretum* veld. This matrix is interdigitated with lower lying drainage depressions or vleis. These vleis are seasonally inundated with water and primarily support wetland grasses and sedges. Dominant woody species occurring near the vlei include *Hyphaene petersiana*, *Lonchocarpus capassa, Dalbergia melanoxylon, Dichrostachys cineria*, *Albizia harveyi*, *Combretum imberbe, Combretum hereroense* and *Lannea schweinfurthii*.

In areas of undulating topography, the continuing process of rainfall runoff and soil transport from ridge tops to valley bottoms create horizontal soil sequences called catenas (Belsky 1995). These soil sequences are vegetated by different plant communities, creating vegetation zones that vary from the top of the catenas to the bottom. The shallow sandy soils that dominate the top areas are vegetated by short, shallowly rooted species, while the heavy clay soils that accumulate in the more mesic valley bottoms are vegetated by taller and more deeply rooted species (Morison *et al.* 1948). The density, height and growth form characteristics of both woody and grassy components vary considerably within the biome. In southern Africa two distinct savanna types are recognized – arid eutrophic savannas and moist dystrophic savannas (Booysen & Tainton 1984), which are alternatively described as sweet and mixed veld (Acocks 1953). Bothma (2004) described succession is savannas as multidimensional, occurring over different time scales and consisting of multiple stable points in the same locality. Walter (1979) highlights that climatic savannas (such as those of the Lowveld region) are comprised of antagonistic grass and shrub species, which through various allelopathic and resource portioning actions, actively attempt to exclude each other from the landscape.

The horizontal vegetation bands associated with catenas have been shown to strongly influence the movements of mammalian herbivores (Duncan 1975; Sinclair 1975, Sinclair 1977; Joubert 1976).

A vegetation survey, based on placement of rodent traps, was conducted at the N’washitshumbe enclosure site. The aim of the survey was to describe and classify plant communities in which traps were located, and interpret them ecologically.

The floristic composition and habitat information were recorded at 270 traps. The data were captured in the TURBOVEG database and classified using TWINSPAN numerical classification algorithm. The resulting physiological tables were compiled and organized using the MEGATAB computerized table management programme according to Braun-Blaunquet procedures. The data were also subjected to a Detrended

Correspondence Analysis (DECORANA), processed by the PCOrd numerical ordination programme, to confirm the results of the classification. The results of the floristic ordination could also be linked to any environmental gradients controlling the existence and distribution patterns of the different plant communities. Thirteen plant communities were identified, described, and ecologically interpreted. The plant communities at the enclosure are distributed in a mosaic of woodlands, grasslands and wetlands, based on the heterogeneous habitats created by variations in topography and resulting soil type.

The distribution of plant communities is closely related to environmental conditions (Daubenmire 1968b; Gauch 1982). To understand the distribution of plant communities, it is inevitable to consider the environmental variables such as geology, topography and climate. Aerial photographs of the enclosure were obtained from the geographic information systems lab in Skukuza. Climatic data was obtained from the South African Weather Bureau.

5.2 Classification and Ordination

Two broad types of data analysis are used for the analysis of vegetation data, namely classification and ordination (Kent & Coker 2000). Classification is based on the Clementsian view that plant communities are clearly recognisable and definable entities, which repeat themselves over a given region of the earth. In classification it is assumed that there are distinct communities present at a site and that each of these communities is clearly defined in the phytosociological table (Kent & Coker 2000). The aim of classification is to group together a set of individuals (quadrats or vegetation samples) on the basis of their attributes (their floristic composition). The end product should be a set of groups derived from the individuals where every individual within a specific group is more similar to other individuals in that group than to any individuals in any other group (Kent & Coker 2000). Ordination follows Gleason's viewpoint that the distributions of plant species change gradually along an abiotic gradient, such as soil moisture. The ordination arranges the vegetation samples in relation to each other, in terms of their similarity in species composition and their associated environmental conditions (Kent & Coker 2000). Present day viewpoints see vegetation as a complex mosaic of continuity and discontinuity, therefore classification and ordination are complementary. Methods for classification and ordination are techniques for data reduction and data exploration. They are used to look for a pattern and order in a set of data. Classification and ordination can be performed on the same data set (Kent & Coker 2000). The data analysis in this study includes both classification and ordination of the vegetation data.

5.3 Descriptions of the N'washitshumbe enclosure site communities

5.3.1 Classification

The vegetation data was classified using TWINSPAN, as discussed in methodology to produce a first approximation of the plant communities at the enclosure site. The large phytosociological table was divided into separate tables to give a more accurate and easily representable analysis of plant communities. The communities and their species group composition are shown in a phytosociological table (Table 1a & 1b).

Thirteen plant communities composing fifteen species groups have been identified. These communities are:

A. *Acacia* mixed veld

1. *Schmidtia pappophoroides* - *Heteropogon contortus* community

2. *Schmidtia pappophoroides* - *Setaria incrassata* community

3. *Panicum coloratum* - *Setaria incrassata* community

4. *Schmidtia pappophoroides* - *Urochloa mosambicensis* community

5. *Panicum maximum* - *Panicum coloratum* community

B. *Colophospermum mopane* veld

6. *Aristida bipartita* - *Colophospermum mopane* community

7. *Panicum coloratum* - *Colophospermum mopane* community

8. *Cenchrus ciliaris* - *Colophospermum mopane* community

C. *Dalbergia melanoxylon* veld

9. *Setaria incrassata – Dalbergia melanoxylon* community

10. *Panicum maximum - Urochloa mosambicensis* community

D. Sodic site vegetation

11. *Sporobolus ioclados - Sporobolus nitens* community

E. Vlei vegetation

12. *Cyperus textilis - Andropogon* vlei community

13. *Sporobolus pyramidalis - Andropogon* vlei community

5.3.2 Description of plant communities

5.3.2.1 *Schmidtia pappophoroides - Heteropogon contortus* community

This plant community was represented by 14 relevés and is situated outside the enclosure site and fire break in grid A1. This plant community is represented on the middle slope of the catena.

The *Schmidtia pappophoroides - Heteropogon contortus* community is situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community is characterized by species groups A and F, with the absence of species group G.

Dominant woody plants are *Acacia nigrescens.* Other woody species were represented by *Ehretia amoena, Capparis* spp.., *Combretum imberbe* and *Albizia harveyi. Combretum hereroense, Maytenus senegalensis* and *Grewia monticola*.

Dominant grasses represented included *Schmidtia pappophoroides* and *Heteropogon contortus. Themeda triandra, Panicum coloratum, Urochloa mosambicensis, Cenchrus ciliaris, Enneapogon cenchroides* and *Eragrostis superba* were often present.

Diagnostic forbs include *Sesbania sesban* and *Heliotropium steudneri.* Other forbs recorded included *Vernonis poskeana, Merremia palmata, Kyphocarpa angustifolia* and *Ceratotheca triloba.*

5.3.2.2 *Schmidtia pappophoroides - Setaria incrassata* community

This plant community was represented by 14 relevés and is situated outside the enclosure site and fire break in grid A1. This plant community is represented on the middle slope of the catena.

The *Schmidtia pappophoroides* - *Setaria incrassata* community is situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community is characterized by the simultaneous presence of species groups A, C, F and G. This community differed from community 5.3.2.1 with the inclusion of species group G.

Dominant woody species are *Acacia nigrescens* and *Dalbergia melanoxylon.* Other woody species were represented by *Ehretia amoena*, *Capparis* spp. and *Albizia harveyi.*

Dominant grasses represented included *Schmidtia pappophoroides and Setaria incrassata. Enneapogon cenchroides, Themeda triandra, Heteropogon contortus, Panicum coloratum, Urochloa mosambicensis, Cenchrus ciliarus* and *Eragrotis superba* were often present.

Forb species recorded included *Sesbania sesban*, *Merremia palmate*, *Kyphocarpa angustifolia*, *Heliotropium steudneri* and *Vernonia poskeana.*

5.3.2.3 *Panicum coloratum - Setaria incrassata* community

This plant community was represented by 17 relevés situated inside and in the fire break surrounding the enclosure site in grids A3 and A2 respectively. This plant community was represented on the middle slope of the catena.

The *Panicum coloratum - Setaria incrassata* community was situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community was characterized by the simultaneous presence of species groups A, C and G, with the absence of species group F.

The dominant woody species is *Dalbergia melanoxylon* in this community. Other woody species were represented by *Acacia nigrescens, Sclerocarya birrea, Acacia nigrescens and Ehretia amoena.*

Dominant grasses represented included *Panicum coloratum and Setaria incrassata. Urochloa mosambicensis, Cenchrus ciliarus* and *Eragrotis superba* were often present.

Forb species recorded included *Sesbania sesban, Merremia palmate, Kyphocarpa angustifolia, Heliotropium steudneri* and *Vernonia poskeana.*

5.3.2.4 *Schmidtia pappophoroides - Urochloa mosambicensis* community

This plant community was represented by 11 relevés situated in the fire break surrounding the enclosure site in grid A2. This plant community was represented on the middle slope of the catena.

The *Schmidtia pappophoroides - Urochloa mosambicensis* community was situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community was characterized by the presence of species groups A and C, but species groups F and G are absent.

Few woody species were recorded. *Ehretia amoena, Capparis* spp., *Ormocarpum trichocarpum, Pterocarpus rotundifolius* and *Lonchocarpus capassa* were present.

Dominant grasses represented included *Schmidtia pappophoroides* and *Urochloa mosambicensis. Enneapogon cenchroides, Cenchrus ciliarus, Panicum coloratum* and *Eragrotis superba* were often present.

Forb species recorded included *Sesbania sesban, Merremia palmata, Kyphocarpa angustifolia, Heliotropium steudneri, Vernonia poskeana* and *Indigofera* spp.

5.3.2.5 *Panicum maximum - Panicum coloratum* community

This plant community was represented by seven relevés situated inside the enclosure site in grid A3. This plant community was represented on the middle slope of the catena.

The *Panicum maximum - Panicum coloratum* community was situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community was characterized by species group I.

Few woody species were recorded. *Acacia nigrescens, Ehretia amoena*, *Capparis* spp.. and *Lonchocarpus capassa, Pterocarpus rotundifolius* were present.

Dominant grasses represented included *Panicum maximum* and *Panicum coloratum*. *Schmidtia pappophoroides, Urochloa mosambicensis. Enneapogon scoparius, Cenchrus ciliarus* and *Eragrotis superba* were often present.

Forb species recorded included *Sesbania sesban, Kyphocarpa angustifolia, Heliotropium steudneri* and *Vernonia poskeana*.

5.3.2.6 *Aristida bipartita - Colophospermum mopane* community

This plant community was represented by 21 relevés situated in the fire break surrounding the enclosure site in grid B2. This plant community was represented on the top slope of the catena.

The *Aristida bipartita - Colophospermum mopane* community was situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community was characterized by species group D, with *Aristida bipartita* the only diagnostic species. This community differed from the former community with the inclusion of species group B and D, and with the exclusion of species group A.

Woody species were dominated by *Colophospermum mopane*. *Dalbergia melanoxylon*, *Combretum imberbe*, *Ormocarpum trichocarpum* and *Lonchocarpus capassa* were also present.

Dominant grasses represented included *Aristida bipartita* and *Urochloa mosambicensis. Panicum coloratum*, *Schmidtia pappophoroides*, *Enneapogon cenchroides*, *Cenchrus ciliarus* and *Eragrotis superba* were often present.

Forb species recorded included *Merremia palmata, Kyphocarpa angustifolia, Heliotropium steudneri, Vernonia poskeana* and *Rhynchosia* species.

5.3.2.7 *Panicum coloratum - Colophospermum mopane* community

This plant community was represented by 30 relevés and was situated outside the enclosure site and fire break in grid B1. This plant community was represented on the top slope of the catena.

The *Panicum coloratum - Colophospermum mopane* community was situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community was characterized by species group E, while species group C is also present in low quantities.

Woody species were dominated by *Colophospermum mopane*. *Dalbergia melanoxylon*, *Combretum imberbe*, *Ormocarpum trichocarpum* and *Lonchocarpus capassa* were also represented.

Dominant grasses represented included *Panicum coloratum* and *Themeda triandra. Schmidtia pappophoroides, Heteropogon contortus, Cenchrus ciliarus, Urochloa mosambicensis, Aristida adscensionis, Eragrostis rigidior*, *Setaria incrassata* and *Eragrotis superba* were often present.

Forb species recorded included *Kyphocarpa angustifolia, Heliotropium steudneri, Vernonia poskeana, Ceratotheca triloba* and *Rhynchosia* spp.

5.3.2.8 *Cenchrus ciliaris* - *Colophospermum mopane* community

This plant community was represented by seven relevés and was situated inside the enclosure site in grid B3. This plant community was represented on the top slope of the catena.

The *Cenchrus ciliaris* - *Colophospermum mopane* community was situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community was characterized by species group E, with the absence of species group C. Very high cover values for *Colophospermum mopane* are present.

The dominant woody species is *Colophospermum mopane*. *Dalbergia melanoxylon*, *Combretum imberbe* and *Lonchocarpus capassa* are also present.

The dominant grasses are *Cenchrus ciliarus. Heteropogon contortus, Aristida adscensionis, Urochloa mosambicensis, Aristida adscensionis, Eragrostis rigidior, Setaria incrassata* and *Eragrotis superba* were often present.

Limited forb species were recorded within this community.

5.3.2.9 *Setaria incrassata – Dalbergia melanoxylon* community

This plant community was represented by 30 relevés and was situated inside, outside and in the fire break surrounding the enclosure site in grid A1, A2, A3, B2 and B3. This plant community was represented on the top and middle slope of the catena.

The *Setaria incrassata – Dalbergia melanoxylon* community was situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community was characterized by species group H, but with the exclusion of species groups E and J.

The dominant woody species is *Dalbergia melanoxylon. Combretum imberbe* and *Lonchocarpus capassa* are present.

Dominant grasses represented by *Cenchrus ciliarus. Heteropogon contortus, Aristida adscensionis, Urochloa mosambicensis, Aristida adscensionis, Eragrostis rigidior*, *Setaria incrassata* and *Eragrotis superba* were often present.

Few forb species were recorded within this community.

5.3.2.10 *Panicum maximum – Urochloa mosambicensis* community

This plant community was represented by 29 relevés and was situated inside and in the fire break surrounding the enclosure site in grid A2, A3, B2 and B3. This plant community was represented on the top and middle slope of the catena.

The *Panicum maximum – Urochloa mosambicensis* community was situated on the North-Western side of the enclosure site (31.254730 Long; -22.773460 Lat). This community was characterized by species group J.

The dominant woody species is *Dalbergia melanoxylon. Colophospermum mopane*, *Acacia nigrescens*, *Lonchocarpus capassa* and *Capparis* species were also represented.

Dominant grasses represented by *Panicum maximum and Urochloa mosambicensis*. Other species present included *Themeda triandra, Heteropogon contortus*, *Aristida adscensionis*, *Setaria incrassata*, *Enneapogon scorparius, Cenchrus ciliaris* and *Eragrostis superba.*

Forbs present included *Sesbania sesban, Kyphocarpa angustifolia* and *Vernonia poskeana.*

5.3.2.11 *Sporobolus ioclados - Sporobolus nitens* community

This plant community was represented by 30 relevés and was situated inside the enclosure, restricted to grid C3. This plant community was represented on the bottom slope of the catena in a sodic depression.

The *Sporobolus ioclados - Sporobolus nitens* community was situated on the South-Eastern side of the enclosure site (31.262170 Long; -22.779770 Lat). This community was characterized by species group L. This community differed significantly from the former community with the exclusion of all other species groups.

Few woody species were represented within this community. *Colophospermum mopane* was recorded on the verges of the sodic depression.

Grasses were limited to *Sporobolus ioclados* and *Sporobolus nitens*.

A *Limeum* species was the only forb species recorded within this community type.

5.3.2.12 *Cyperus textilis - Andropogon* species community

This plant community was represented by 39 relevés and was situated inside and outside the enclosure site in grids C1 and C2. This plant community was represented on the bottom slope of the catena, in the vlei.

The *Cyperus textilis* - *Andropogon* species community was situated in the vlei extension to the South (31.267980 Long; -22.778890 Lat). This community was characterized by species group M where two diagnostic species were identified. This community differed significantly from community 5.3.2.13 with the absence of species group N.

Limited woody species were recorded within this plant community. *Combretum imberbe* and *Albizia harveyi* were recorded at low numbers.

Andropogon spp. was the dominant grass species recorded within this community. Other species present included *Sporobolus pyramidalis*, *Chloris gayana* and *Chloris virgata*. *Cyperus textilis* dominated this vlei community.

An *Ipomoea* species was the only forb species recorded within this community type.

5.3.2.13 *Sporobolus pyramidalis - Andropogon* species community

This plant community was represented by 21 relevés and was situated inside the enclosure site in grid C2. This plant community was represented on the bottom slope of the catena.

The *Sporobolus pyramidalis - Andropogon* species community was situated in the vlei extension to the South (31.267980 Long; -22.778890 Lat). This community was characterized by species group N and where several diagnostic species were identified. This community differed significantly from the former community with the absence of species group M.

No woody species were recorded.

Sporobolus pyramidalis and *Andropogon* species were the dominant grass species recorded. Other recorded species included *Setaria incrassata*, *Chloris gayana* and *Panicum maximum*. *Cyperus textilis* was absent from this vlei community.

Forbs within the community were represented by *Sesbania punicea* and *Rhynchosia* species.

5.3.2 Ordination and habitat interpretation

The classification is supported by the results of the DECORANA ordination done by using the programme PCOrd. The ordination provides a further understanding of the vegetation and associated habitat gradients between plant communities. The results of an ordination indicate the position of the relevés in a multi-dimensional space, with the relevés that are floristically most similar projected close to each other, while relevés that are very different projected far from each other. The result is therefore a gradient of relevés, with the most different relevés positioned at the poles of the axes and all the other relevés positioned somewhere in between.

Although the different communities were largely restricted to specific areas in the ordination diagram, the clustering towards the left hampered interpretation of floristic relationships, and also relationships between plant communities and environmental factors. Due to the strong discontinuity shown in the ordination diagram, between bottom slope communities (*Sporobolus ioclados* and *Sporobolus nitens* community, *Cyperus textilis* - *Andropogon* vlei community, *Sporobolus pyramidalis* – *Andropogon* vlei community) and the rest of the communities indicated that these communities were floristically quite different, and that the communities were divided according the slope of the catena. (Fig.17.).

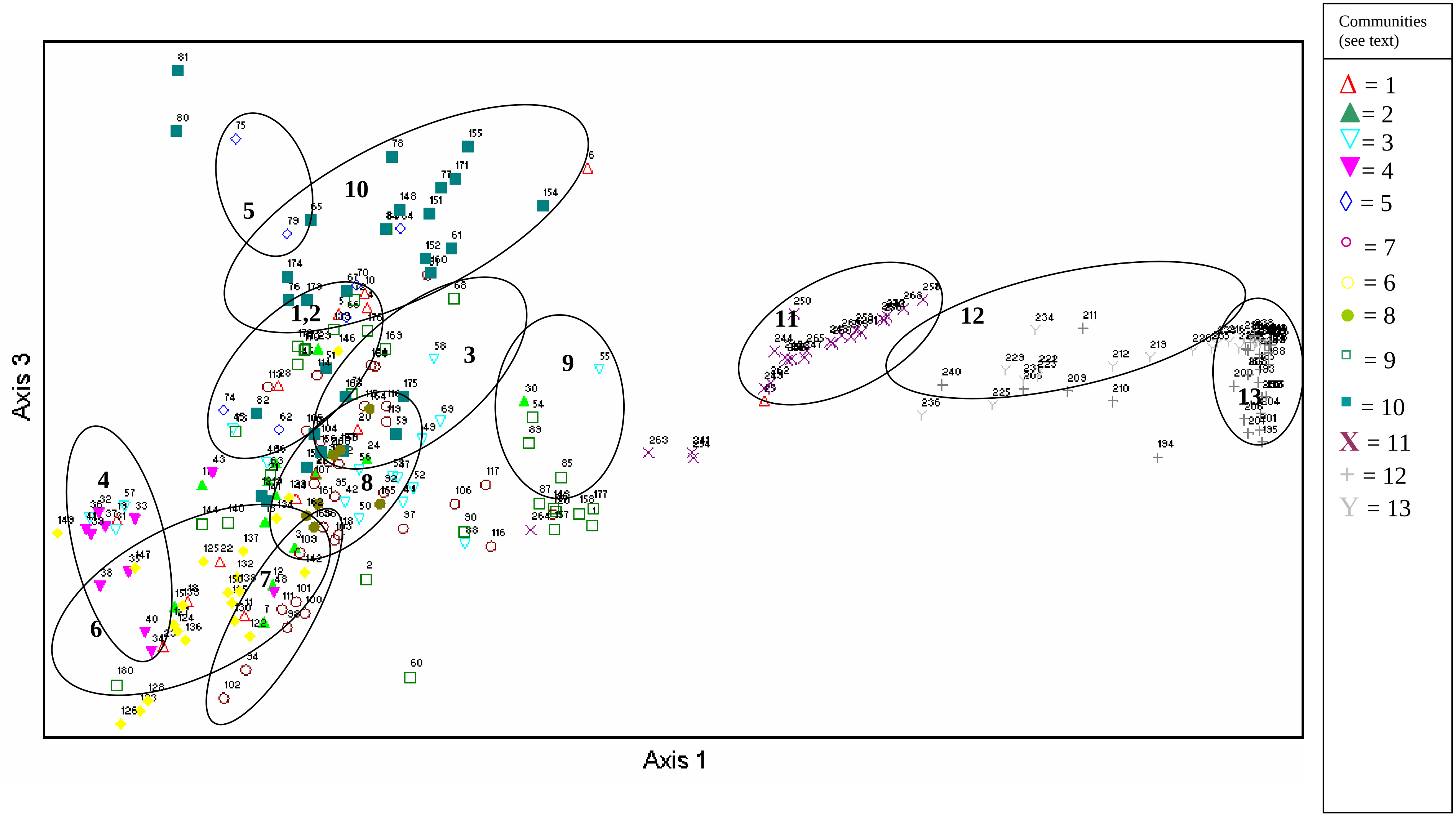


Figure 17. Ordination of vegetation communities at the N’washitshumbe enclosure

5.3.2.1 Top-slope Vegetation Communities

The top-slope of the catena at N'washitshumbe enclosure site was dominated by three communities. *Colophospermum mopane* was recorded as the dominant woody plant in all of these communities.

The three communities found exclusively on the upper slope of the catena included:

6. *Aristida bipartita* - *Colophospermum mopane* community

7. *Panicum coloratum* - *Colophospermum mopane* community

8. *Cenchrus ciliaris* - *Colophospermum mopane* community

The location of these three communities is located in the left bottom areas of the scatter diagram (Fig. 17.).

Continuity could be observed between these three plant communities, and in general these *Colophospermum mopane* dominated communities are related to communities 1, 2, 3 and 4, the Acacia mixed veld, where *Colophospermum mopane* may occur with lower constancy.

5.3.2.2 Vegetation communities shared between top and mid-slope

The top and mid-slope of the catena at N'washitshumbe enclosure site were shared by two plant communities. In both these communities *Dalbergia melanoxylon* is prominent, and the plots of these communities repeat soils towards the more sodic sites.

9. *Setaria incrassata – Dalbergia melanoxylon* community

10. *Panicum maximum – Urochloa mosambicensis* community

Some discontinuity could be observed between these plant communities, however community 9 towards the bottom of the gradient tends to be more related to the *Colophospermum mopane* and the *Acaci*a mixed veld.

4.3.2.3 Mid-slope Vegetation Communities

The mid-slope of the catena at N'washitshumbe enclosure site was dominated by five communities. These repeat the *Acacia* mixed veld, with all the communities situated towards the left of the scatter diagram (Fig. 17.).

1 *Schmidtia pappophoroides - Heteropogon contortus* community

2 *Schmidtia pappophoroides - Setaria incrassata* community

3. *Panicum coloratum* - *Setaria incrassata* community

4. *Schmidtia pappophoroides* - *Urochloa mosambicensis* community

5. *Panicum maximum* - *Panicum coloratum* community

Community 4 indicates some relationship with *Colophospermum mopane* communities, whereas communities 1, 2, 3 and 5, situated towards the centre of the diagram, indicate a possible relationship to the *Dalbergia* community.

5.3.2.4 Bottom-slope Vegetation Communities

The bottom-slope of the catena at N'washitshumbe enclosure site was dominated by three communities. The *Sporobolus ioclados* and *Sporobolus nitens* community was found in a sodic depression. The two vlei communities differed predominantly due to the presence or absence of *Cyperus textilis*.

11. *Sporobolus ioclados* and *Sporobolus nitens* community

12. *Cyperus textilis* - *Andropogon* species community

13. *Sporobolus welwitschii* - *Andropogon* species community

Some discontinuity could be observed between the plant communities, indicating unique differentiated composition and separate habitat conditions.

The relationship between plant communities and the distribution of small mammal species are given in Chapter 10.

CHAPTER 6

OVERALL SMALL MAMMAL COMMUNITY STRUCTURE AND DYNAMICS AT N'WASHITSHUMBE ENCLOSURE SITE

6.1 Introduction

By means of capture and recapture programs, the rodent population on both sides of the fence was monitored to establish whether there was a difference in the composition of species, population numbers and species diversity. The enclosure provided the opportunity of surveying areas of similar habitat, allowing for significant differences between three groups of management (inside, outside and in the fire break surrounding the enclosure). This method should provide a clear indication of any negative effects elephants and use of fire may have on fauna and therefore on rodents and all other animals depending on rodents for survival. A significant shift in community composition between the populations on the inside of the fence, in the fire break and outside will provide important information for managing biodiversity in the KNP.

The two species of multimammate mouse, *Mastomys coucha* and *Mastomys natalensis* were recorded as *Mastomys* spp. as identifications are not reliably diagnosed without genetic characteristics (Smithers 1971).

Vegetation was categorized according to plant communities, species, height, canopy diameter and distance to the neighboring trees (Chapter 5).

All rodents and shrews were sampled in all three areas in, around and outside the enclosure site. The study comprised nine treatments: three upland survey lines (three 100m lines of 30 traps each in, outside and in the fire break surrounding the enclosure at the top of the catena; three midlands survey lines (three 100 m lines of 30 traps each in, outside and in the fire break in the middle of the catena; and three bottomlands survey lines (three lines of 30 traps each in, outside and in a sodic site inside the enclosure.

Trap disturbance is often a common unpublished problem in many small mammal studies (Watson & Watson 1985). The degree of traps disturbance can range from an occasional irregular happening to a more regular occurence. The consequences of serious trap disturbances can bring a study to a complete halt for several reasons: trap unavailability due to closure, damage or loss, cost in time and money for repair or replacement of traps and capture mortality. According to Watson & Watson (1985) damage to traps can be usually attributed to four categories: jackal, squirrels, large mammals and environmental factors, while mortality was limited to two categories: jackal and environmental factors. Necessary precautions were taken to minimize trap loss and disturbance, resulting in very few trap disturbances during the entire study.

6.2 Descriptions of species collected at the N'washitshumbe enclosure site

6.2.1 Natal multimammate mouse (*Mastomys natalensis)* (Fig. 18.)

Females have up to 12 pairs of mammae in two more or less continuous rows from the chest to the inguinal area. The possession of so many mammae is unique among murids and is a useful character in the identification of females. Gordon (1984), using a series of *M. natalensis* (2n = 32) and *M. coucha* (2n = 36), could detect no significant differences in size between the two species, except that the ears in the former appeared to be slightly shorter than those of the latter, although an overlap in size occurs. The adults of this species have a total length of about 224 mm, with tails of 119 mm and a mass of 63.5 g (Skinner & Chimimba 2005).

Figure 18. A photograph of *Mastomys natalensis* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

There appears to be considerable range in colour variation, which Roberts (1951) believed might be related to their habitat. The base of the hair on the upper parts is broadly pale grey to dark grey or nearly black, the hairs of the guard coat either very narrowly tipped with buffy-yellow, in which case the upper parts are dark in colour, or more broadly tipped, in which case they are paler in colour, giving an overall more buffy appearance to the individual (Skinner & Chimimba 2005). The flanks are paler in colour than the upper parts and tinged yellowish or fawn, often being clearly yellowish or buffy at the junction of the colour of the upper and under parts. The colour of the under parts is quite characteristic. In adult females each mamma is surrounded by a sprinkling of whitish-tipped hair so that they stand out from the general greyish colour of the background.

The limits of the distribution of this species are questionable, although it is believed to be dominant in the east and north-eastern parts of the country. They are nocturnal and predominantly terrestrial. In their association with man they use secluded corners of dwellings in which to construct their nests, cutting holes in the floors to gain access to warm shelter or using interstices of brickwork (Skinner & Chimimba 2005). In the field they use shelters under the roots of trees and fallen logs, in piles of rocks or debris and cracks in the soil, or they excavate their own burrows or use the holes of other species. This species was recorded using the holes of *T. leucogaster* at the enclosure site.

Multimammate mice are omnivorous. Under field conditions they subsist mainly on the seeds of grass and other plant, the dried pods of *Acacia* spp. and the dry pulpy exterior of wild fruits, augmented with a smaller proportion of insect material including grasshoppers, termites and beetles (Skinner & Chimimba 2005). Multimammate mice were recorded to be cannibalistic and regularly ate each other in traps during this study. Breeding activity in the Subregion peaks during the wet season, and densities increase markedly following rainfall (Watson 1987). Although *M. natalensis* have their young at any time of the year, this declines during the colder, drier months of June and July. At birth the altricial young are naked, bright pink, with a tinge of grey on the back, marking the area where the fur on the upper parts later develops, and darker grey on the head with their eyes closed. Oliff (1953) recorded a mean litter size over a four year period of 7.3, while Meester (1960) found the average number was 8.5 (n = 19), the average time between litters being 33.1 days. Population explosions of multimammate mice are well known in the Sub-region. They appear to correlate with climatic conditions which lead to an increase in food supplies, although other factors, not presently recognised may play a part in triggering off this phenomenon (Ellison 1990).

6.2.2 Multimammate mouse (*Mastomys coucha)*

It is assumed the majority of the information provided for *M. natalensis* is valid for *M. coucha*, except for chromosome differences and with the latter species being predominant in the central, north-western regions of the country. Both *M. coucha* and *M. natalensis* are recorded at the enclosure site during this study.

6.2.3 Pouched mouse *(Saccostomys campestris)* (Fig. 19.)

They are called pouched mice as they have cheek pouches like their close relative the giant rat, *Cricetomys gambianus*. Adults have a total length of about 160 mm; the males have a mean mass of 48.5g, and the female's 42.2 g. In any large series of adults it is very noticeable that there is an even run of size, but with a small percentage of very large males or females that are larger than the mean size of the general series. With larger male specimens in breeding condition, with enlarged scrotal testes and gravid females with young, it was found that much smaller males may also be in breeding condition and smaller females also gravid with young (Skinner & Chimimba 2005). Characteristic features are the robust body, thick-set head and noticeably short, pinkish tail, which is less than a third of the total length. The colour of the upper part of the body is grey, or grey tinged brown. The under parts are white or off-white. The fur is thick, soft and silky. The unscaled tail is thinly haired, slightly darker on the top than underneath, and in lighter coloured specimens the pink of the skin shows through the thin coat of hair (Skinner & Chimimba 2005).

Figure 19. A photograph of *Saccostomys campestris* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

They are distributed widely in the Subregion, occurring in Botswana, Zimbabwe, and Mozambique, south of the Zambezi. They occur in Kwa-Zulu Natal, Northern Cape, Mpumalanga, Limpopo and Gauteng provinces (Skinner & Chimimba 2005). Pouched mice are catholic in their habitat requirements, occurring in such diverse associations as the short grass fringes of pans in the Kalahari, open *Acacia* spp. bushveld in the Limpopo province (Ellison 1990), in rocky koppies and fringes of lowland forest. They are commoner, nevertheless, in areas where there is a sandy substrate with scrub or cover of open woodland. They are nocturnal and terrestrial and they will excavate their own burrows in sandy soils, but in hard ground use established holes such as those termitaria or burrows open by other species. They also inhabit piles of rocks, holes, under fallen logs and roots of trees exposed by erosion. Pouched mice are solitary, with only a single occupant inhabiting each burrow, although in the breeding season a female will be together with her young (Ellison *pers. comm.*). *S. campestris* is a partially insectivorous granivore (Kerley 1989) with bunodont molars having transverse lophs. Although grass seeds are taken, it appears to form only a small percentage of the food which consists predominantly of the large seeds of forbs, bushes and trees. Five to ten young are born during the warm, wet summer months within the next chambers of their burrows (Skinner & Chimimba 2005). The young are born fully haired with a mean mass of 2.8 g.

6.2.4 Bushveld gerbil *(Tatera leucogaster)* (Fig. 20.)

They are so called as they are commonly associated with savanna grassland and woodland. There is no sexual dimorphism in bushveld gerbils. Both sexes have a head and body length of about 130 mm, a tail slightly longer, about 150 mm, and a mass of about 70 .0 g. The hairs are broad and long, with typical large chevron scales in a mosaic pattern (Keogh 1985). Generally they are reddish-brown to orange-buffy on the upper parts and pure white on the chin, throat and remainder of the under parts, with white hands and feet. The sides of their muzzles are white and they have a white mark above and behind the eyes, their ears being dark brown. The upper part of the tail has a distinct dark band down its entire length, sometimes with a poorly developed tuft of hair at the tip. The under parts are white. The hind foot reminiscent of a small kangaroo. They are common throughout Botswana, Zimbabwe and Mozambique, south of the Zambezi River, extending eastwards to Swaziland and southwards into north-eastern Kwa-Zulu Natal. They are distributed widely in Mpumalanga, Limpopo and Gauteng provinces (Skinner & Chimimba 2005).

Figure 20. A photograph of *Tatera leucogaster* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

They are predominantly associated with light sandy soils or sandy alluvium, but are not confined entirely to this type of substrate as they have been taken on hard ground. They are absent from areas of heavy red clay soil, which may be due to their inability to excavate burrows for themselves (Skinner & Chimimba 2005). Where they occur on hard ground, they sue termitaria or under tree roots and do not appear to excavate burrows themselves. Apparently they are independent of any one type of vegetational association, as they have been taken in a wider variety of associations ranging form open grassland to savanna woodland. They are nocturnal, terrestrial and they excavate burrows, about 40 mm to 45 mm in diameter in sandy soils, the entrances usually being at the base of small bushes or grass clumps. The burrows in use can be recognised by the fresh ramp of sand found at the entrances in the morning, on which their spoor may be seen. It appears that the burrows are cleaned up nightly. These are occupied by a pair, but warrens are found with many entrances which may be interconnected underground.

Their gut morphology is typical of an omnivorous diet and there are no special adaptations. They are gramnivorous insectivores and Perrin & Swanepoel (1987), in a sample of 360 stomachs from Limpopo province; found that they contained 41.1% insects, 26.4% seeds and 32.2% herbage, insects and seeds. Four to five altricial young are born in late summer and again in winter in a grass-lined chamber within the burrow system (Skinner & Chimimba 2005).

6.2.5 Single-striped mouse (*Lemniscomys rosalia)*

The colloquial name is appropriate as the conspicuous feature of the species is the single dark line down the mid-back. The adults have a total length of about 270 mm, with tails slightly longer than the length of the head and body and a mass of about 58.0 g (Skinner & Chimimba 2005). Hairs are deeply grooved and scales “snake-skin”- like (Keogh, 1985). The upper parts vary in colour geographically. Colour varies from pale buffy to reddish-orange on the upper parts of the body. The sides of the head and limbs are grizzled with dark brown and the stripe on the mid-back is dark brown. The lips, chin and around the gape of the mouth, the throat, belly and inner surfaces of the limbs are rusty white. The feet are yellowish, the muzzle a rusty orange-yellow, and the eyebrows and ears reddish-orange (Skinner & Chimimba 2005).

While they occur in a wide variety of different vegetational associations from savanna woodland to the dry open scrub of the Kalahari, the common factor is grassland areas within these diverse associations (Skinner & Chimimba 2005). They occur in dry grassland in the ecotone of vleis and woodland and in the stands of high grass surrounding agricultural lands, preferring areas where there is good cover of grass and avoiding parts where the grass is short. They are diurnal and terrestrial. Burrows are occupied by a solitary individual, a pair or family parties, and are excavated where there is a good overhead cover of tall or matted grasses. They form runs from the burrow entrances to feeding grounds (Skinner & Chimimba 2005). Swanepoel (1972) found the home range of males exceed that of the females.

In a sample of 11 stomachs from *L. rosalia* taken in the wet season in the Kruger National Park, Watson (1987) found 50% seeds, 48% herbage and 2% insects. The young are born during the warm, wet summer months from September to March (Swanepoel 1972; Kern 1977; Scott & Meester 1988). At birth pups are altricial, naked, with toes fused, eyes closed and ear flaps folded down, but development is rapid.

6.2.6 Red veld rat *(Aethomys chrysophilus)*

The colloquial name refers to the colour of the body which has a reddish tinge, often accentuated towards the rump. Red veld rats have a mean total of about 280 mm, with tails that are longer than the length of the head and body. They have broad hairs with a scooped-out appearance of the groove and flattened. Petal scales (Keogh 1985).The colour is reddish-fawn, with a sprinkling of black hairs; individual hairs on the upperparts are dark grey at the base and tipped with reddish fawn. Some individuals are darker reddish fawn on the rump. The flanks are lighter in colour than the upper parts and the under parts are greyish, with the individual hairs having grey bases and white tips.

They are recorded from Namibia, excluding the western desert regions, widely distributed throughout Zimbabwe; Mozambique, Mpumalanga, Limpopo province and Gauteng (Skinner & Chimimba 2005). Red veld rats are catholic in their habitat requirements occurring both in grassland, with some scrub cover, and savanna woodland. They are associated especially with some form of cover in the form of rocky crevices, piles of boulders and debris, fallen trees or holes in termitaria, thick scrub or clumps of grass. They are nocturnal and terrestrial. They excavate their burrows under the cover of bushes, but more commonly use more substantial cover. They are not gregarious and the shelters are used, at most, by a pair or a family group. From the stomach contents in the wet season in the Kruger National Park, Watson (1987) found that they eat 21% insects, 32% vegetable matter and 47% seeds. Red veld rats breed throughout the year. The young are born naked and pink, with their eyes closed, and are apparently not nipple clingers (Skinner & Chimimba 2005).

6.2.7 Pygmy Mouse *(Mus minutoides)* (Fig. 21.)

The colloquial name is appropriate as *M. minutoides* is among the smallest of the murids.

The adults of this species have a total length of about 97 mm, with tails of 41 mm and a mass of 5.5 g (Skinner & Chimimba 2005). The upper parts of the body are brownish-buff. The brownish colour is imparted to the pelage by the presence of black-tipped hairs which become fewer on the flanks; these are orange-buffy in colour. The border between the colour of the flanks and the white of the under parts is sharply defined. The tail is brown above and buffy below, the ears brownish, the hands and feet buffy-white.

Figure 21. A photograph of *Mus minutoides* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

They occur in the Cape Macchia Zone as well as in the savanna grassland and woodland areas to the east and northeast and in areas with a mean annual rainfall from about 100 mm in the southwest to 1000 mm in the Drakensberg (Skinner & Chimimba 2005).

Pygmy mice are nocturnal and terrestrial. They are not a communal species, and the burrows are used only by a pair or a family group. In soft ground they construct shallow burrows, but much more commonly use existing shelter under fallen logs, piles of debris, boulders or holes in termite mounds. They apparently forage singly at night and may not be tied closely to a single shelter, as an effective way of catching them is to lay a tarpaulin or sheets of corrugated iron on the ground which they will use as temporary diurnal shelters (Skinner & Chimimba 2005). The main diet is grass seeds, insects and termites; Wilson (1975) recorded the seeds of couch grass *Cynodon dactylon* in stomach contents.

The altricial young are bright pink at birth and their eyes are closed, while the skin is translucent, the abdominal viscera visible through it. Pigmentation on the shoulders is noticeable by the third or fourth day and by the fifth day the whole head, back and tail is pigmented (Skinner & Chimimba 2005). They are weaned by the 17th day.

6.2.8 Woodland dormouse *(Graphiurus murinus)*

Throughout their wide distributional range they are associated with woodland. This is the larger of the two smaller species of dormice that are recorded from the Subregion. Adults have a range of head and body lengths from 84 mm to 117 mm, and skulls from 28.6 mm to 30.8 mm and are, therefore larger than the lesser savanna dormouse (Genest-Villard 1978). The colour of the upper parts of the body is a uniform grey or a buffy grey, the hair short, about 6 mm long on the shoulders, and soft and woolly. The under parts are buffy-white, the individual hairs dark slate at the base with buffy-white tips. The bushy tail is shorter that the length of the head and body, whilst the hair on the upper surface graduates in length from the base, where it is the same length as on the upper parts of the body, to about 18 mm long towards the tip. The cheeks are buffy-white and have a dark suffusion from the base of the whiskers which extends to and broadens out under the eyes (Skinner & Chimimba 2005).

This species is well distributed in South Africa, from Kwa-Zulu Natal, Mpumalanga, Gauteng and Limpopo provinces. They are found in woodland, amongst rocks and trees, where they use holes in trees or crevices in which to rest during daylight hours. They have also been taken in piles of debris deposited by high floods near seasonal rivers (Skinner & Chimimba 2005). They are nocturnal and arboreal, but to a lesser extent terrestrial. At night they forage singly on the trees in search of insects and other food items. They feed primarily on herbage, insects and grass seeds. Young are born in the summer months between February and March in crevices or holes in trees.

6.2.9 Fat mouse *(Steatomys pratensis)*

Fat mice have a total length of about 130 mm, with short tails about 50 mm long and a mass of about 26.0 g. They have comparatively short hair with a definite groove in the chevron pattern (Keogh 1985). Their colour varies throughout their wide distribution range, being lighter or darker shades of rusty-brown on the upper parts of the body, brownish on the flanks. The under parts, hands and feet are white. The individual hairs on the upper parts have slatey bases and the pelage has a distinct sheen. They are recorded from the northern and northeaster parts of Namibia, northern Botswana, widely through

Zimbabwe and Mozambique. They occur widely in Kwa-Zulu Natal, Mpumalanga, Limpopo and Gauteng provinces (Skinner & Chimimba 2005).

Where the species occurs in generally arid terrain, they are associated with the fringes of rivers and swamps and, throughout their range, with sandy substrate. They are nocturnal and terrestrial, occupying burrows singly or in pairs. They construct several burrows sloping downwards to a chamber about 250 mm below the surface (de Graaff 1981). In the state of hibernation during cold dry months of the year they dig themselves in, shallowly, under clumps of grass. In a sample of 11 stomachs taken in the wet season in the Kruger National Park, Watson (1987) found their diet consisted of 83% seeds, 4% herbage and 13% insects, indicating that they are essentially omnivorous granivores. Three to four young are born during the warm, wet summer months from about October to May (Kern 1977). Females have up to 16 mammae arranged in two irregular rows from the pectoral to the inguinal region.

6.2.10 Tree squirrel (*Paraxerus cepapi*)

They are so named for their association with woodland and their use of holes in trees and resting places. Tree squirrels vary greatly in colour and size throughout their distribution range in the Subregion. Colour in particular is very variable. The colour varies from an overall pale grey to a darker, buffy or rusty colour. The under parts vary from yellowish to buffy in colour. Tree squirrels have an overall length of some 350 mm and a tail of about half this length (Skinner & Chimimba 2005). Adult males are slightly heavier than females with an average mass of about 200 g. The tree squirrel is confined in its distribution to the southern part of the continent, from south-western Tanzania to southern Mozambique, and westwards to south-eastern Angola. They are recorded from extreme northern parts of eastern Namibia. They also occur in the northern, north-eastern and eastern parts of Botswana, Zimbabwe and Mozambique. They are found in large numbers in Mpumalanga and Limpopo provinces in the eastern parts of South Africa (Skinner & Chimimba 2005).

Their occurrence is not dependent on any particular type of woodland and they are found in a wide variety of types, including in particular mopane *C. mopane*. Their frequent association with mopane has led them to be known as “mopane squirrels”. While the tree squirrel is observed to be generally solitary, pairs or small family groups of a female with two or three young may be seen. Tree squirrels vocalise with a long, drawn out chuck-chuck-chuck which increases in intensity, the interval between the individual syllables decreasing until it becomes a rattle (Skinner & Chimimba 2005).

Tree squirrels are predominantly vegetarians, although insects are an important secondary component of their diet during certain times of the year. Vegetable matter consists of flowers, leaves, seeds, berries, fruits and the bark of a wide variety of plants and grasses. Both sexes bury hard foods such as seeds and nuts. The mating behaviour of tree squirrels involves much vocalisation, chasing and mounting. The two to three young may be born at any time throughout the year, but a far higher percentage is born during the warm, wet summer months October to April (Viljoen 1975).

6.2.11 Lesser red musk shrew *(Crocidura hirta)*

Names lesser to distinguish them from the greater musk shrew, *Crocidura flavescens*, to which they are closely related. Musk shrews, *C. hirta*, have a total length of about 130 mm with tails that are about half the length of the head and body and a mass of about 16.0 g. Lesser musk shrews are cinnamon-brown on the upper parts of the body, lightly grizzled with fawn, there being some variation, however from a pale reddish-fawn to a dark brown. The individual hairs are slate-grey at the base with a fawn subterminal band and a brown or buffy-brown tip (Skinner & Chimimba 2005).

They are recorded from northern Namibia and they occur widely throughout Botswana, Zimbabwe, and Mozambique, throughout Gauteng, Mpumalanga, Limpopo and northern Kwa-Zulu Natal. The lesser musk shrew is catholic in its habitat requirements being found in forests, damp situations along rivers and streams, and in a wide range of habitats in the savanna zone. They appear to require cover in the form of low branches, dense undergrowth, piles of debris, fallen logs and are recorded using holes in termitaria (Skinner & Chimimba 2005). They are not reliant of water supply and probably rely in dew for their moisture requirements.

They appear to be active on and off throughout at 24 hour period, being caught in traps both during the day and at night. Normally the forage solitary but Meester (1963) has shown that they will live together amicably in groups of two or more. Meester (1963) recorded that they will eat earthworms, insects, and termites and that they will feed on carcasses of rodents and bats and are at times cannibalistic. Average litter size being 3.6 (n = 5) with a range between one and nine in Limpopo province. The gestation period is 18 days and females can have two litters in the course of a breeding season (Meester 1963).

6.3 Total small mammal abundance and diversity recorded at the N'washitshumbe enclosure site

6.3.1 Introduction

Data was recorded between June 2003 and April 2005 from 15 sampling trips covering 45 trap nights, where a total number of 2326 individuals belonging to eleven small mammal taxa were captured. The difference in percentage of small mammals collected differed significantly. The N'washitshumbe enclosure site was divided into three sampling grids based on slope of the catena. Grids were recorded according to slope, top (grid B), middle (grid A) and lower (grid C). Two transect lines in grid C were in the vlei wetland and the third in a sodic area inside the enclosure. These grids were further divided into place (inside, outside, around the enclosure). The frequency of rodent captures differed significantly between top slope grid B (n = 814), mid slope A (n = 878) and bottom slope C (n = 634). The grids were divided into three sampling transects based on management activity. The frequency of rodent captures different significantly between outside 1 (n = 970), in the fire break surrounding the enclosure 2 (n = 631) and inside the enclosure site 3 (n = 589). A single transect was placed in a sodic area within the enclosure to assess abundance and species richness in such an area (n = 136).

6.3.2 Trap results

Tapping success varied seasonally and with climatic conditions. Winter months harbored close to 80% success rate due to a population explosion of *Mastomys* spp. Trapping success dropped (< 30%) over summer months. This could be a result of food being more readily available. Eleven species were collected: *Mastomys natalensis, Mastomys coucha, Saccostomys campestris, Tatera leucogaster, Lemniscomys rosalia, Aethomys chrysophilus; Mus minutoides, Graphiurus murinus, Steatomys pratensis, Crocidura hirta* and *Paraxerus cepapi* (Table 2).

Table 2. List of species collected at the N'washitshumbe enclosure site over the duration of this study period.

Species	Number
Mastomys species	1878
Saccostomys campestris	282
Tatera leucogaster	106
Lemniscomys rosalia	32
Aethomys chrysophilus	12
Mus minutoides	12
Graphiurus murinus	1
Steatomys pratensis	1
Crocidura hirta	1
Paraxerus cepapi	1
Total	2326

Mastomys was recorded the dominant genus at the enclosure site (n = 1878). Fluctuations in species diversity occurred monthly, *Mastomys* being dominant between May and August due to a population explosion. Fluctuations in species richness and abundance occurred monthly in the open field outside the fire break, in the fire break around the enclosure and inside the enclosure. In certain winter months, only *Mastomys* were collected. The population grew rapidly in response to late rains in April. *Saccostomys campestris* (n = 282) and *Tatera leucogaster* (n = 99) were the next most common species and they were collected more frequently in periods when *M. natalensis* numbers had decreased in summer.

The following frequencies were recorded during the study period: *Mastomys* species (n = 1878); *Saccostomys campestris* (n = 282), *Tatera leucogaster* (n = 106), *Lemniscomys rosalia* (n = 32), *Aethomys chrysophilus* (n = 12), *Mus minutoides* (n = 12), *Graphiurus murinus* (n = 1), *Steatomys pratensis* (n = 1), *Crocidura hirta* (n = 1) and *Paraxerus cepapi* (n = 1) (Appendix A).

The following percentages of the total captures were recorded during the study period: *Mastomys* spp. (80.74%), *Saccostomys campestris* (12.12%), *Tatera leucogaster* (4.56%), *Lemniscomys rosalia* (1.38%), *Aethomys chrysophilus* (0.52%), *Mus minutoides* (0.52%), *Graphiurus murinus* (0.04%), *Steatomys pratensis* (0.04%), *Crocidura hirta* (0.04%) and *Paraxerus cepapi* (0.04%) (Appendix B)

6.3.3 Sex ratio of the total population of small mammals recorded at the N’washitshumbe enclosure site

The sex of individual specimens was recorded during the duration of the study. Differences in sex ratio occurred seasonally and noticeably between species. The assessment of sex ratio is significant in determining increases in population, population structure and dynamics. Disproportional sex ratio’s can result in increased competition for mates and ultimately affect breeding performance.

The sex ratio between different species and individuals was recorded at the study site over the study period.

The following ratios were recorded during the study period: *Mastomys* spp. (♂ = 970; ♀= 905; u = 3), *Saccostomys campestris* (♂ = 137; ♀= 145), *Tatera leucogaster (*♂ = 49; ♀= 57), *Lemniscomys rosalia* (♂ = 18; ♀= 14), *Aethomys chrysophilus* (♂ = 6; ♀= 6), *Mus minutoides* (♂ = 5; ♀= 7), *Graphiurus murinus* (♂ = 1; ♀= 0), *Steatomys pratensis* (♂ = 1; ♀= 0), *Crocidura hirta* (♂ = 0; ♀= 1) and *Paraxerus cepapi* (♂ = 1; ♀= 0) (Appendix C). The sex ratio percentage for the individual species was recorded per species (Appendix D).

6.3.3.1 Sex ratio of the total population of *Mastomys* spp. recorded at the N’washitshumbe enclosure site (Fig. 22.)

Multimammate mouse (*Mastomys* spp.) has a recorded litter size of 24 young with three to four litters per season. The proportion of females to males is therefore important in determining population growth. Monthly sex ratio data was recorded for *Mastomys* spp. at the enclosure site. The frequency of male animals (n = 970) to female animals (n = 905) differed insignificantly. The following monthly frequency between male and female specimens were recorded for *Mastomys* spp.: January (♂ = 24; ♀ = 23), February (♂ = 17; ♀ = 37), March (♂ = 34; ♀ = 45), April (♂ = 117; ♀ = 118), May (♂ = 73; ♀ = 81), June (♂ = 141; ♀ = 104), July (♂ = 175; ♀ = 133), August (♂ = 242; ♀ = 232), September (♂ = 38; ♀ = 32), October (♂ = 45; ♀ = 45) and December (♂ = 64; ♀ = 55).

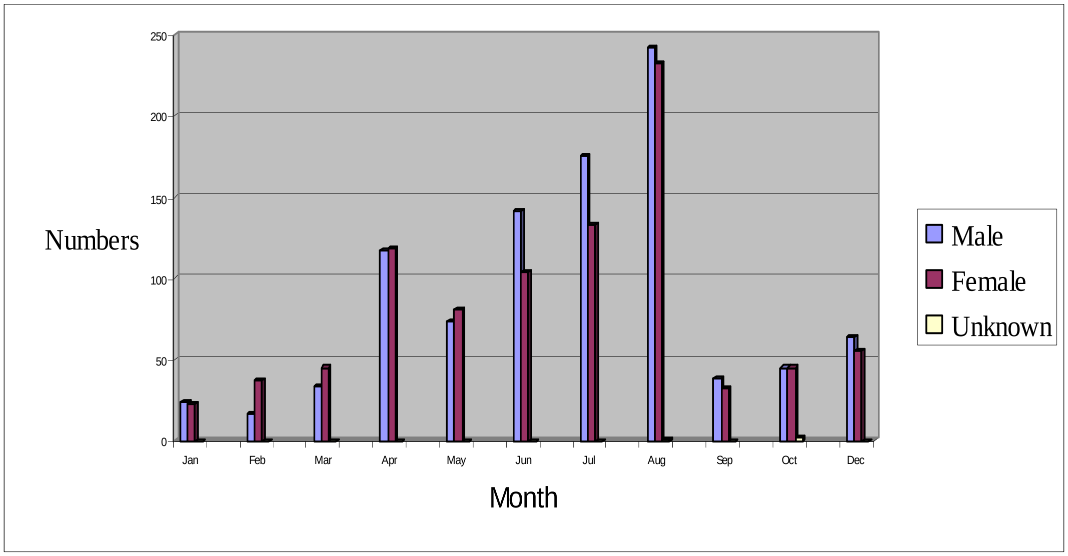


Figure 22. Graph illustrating the total monthly recorded sex ratio of *Mastomys* spp. collected at the N’washitshumbe enclosure site, northern plains, Kruger National Park

The ratio between male and female specimens appeared similar during the summer months (September – January). During late summer to early autumn female animals were caught more frequently, possibly due to breeding and increased food requirement. The winter months (June – August) resulted in more male animals being collected. Over the study period similar male to female ratios were recorded (♂ = 51.65%; ♀ = 48.19%). Interestingly, larger numbers of females were collected during February and March, possibly due to an increased appetite and nutrient intake when feeding young.

6.3.3.2 Sex ratio of the total population of *S. campestris* recorded at the N'washitshumbe enclosure site (Fig. 23.)

Monthly sex data were recorded on *Saccostomys campestris* at the site. The frequency of males animals (n = 137) to female animals (n = 145) differed insignificantly. The following monthly frequencies between male and female specimens were recorded for *S. campestris;* January (♂ = 10; ♀ = 11), February (♂ = 21; ♀ = 26), March (♂ = 17; ♀ = 19), April (♂ = 13; ♀ = 13), May (♂ = 1; ♀ = 1), June (♂ = 11; ♀ = 18), July (♂ = 4; ♀ = 2), August (♂ = 22; ♀ = 20), September (♂ = 10%; ♀ = 9), October (♂ = 13; ♀ = 11%) and December (♂ = 15; ♀ = 5).

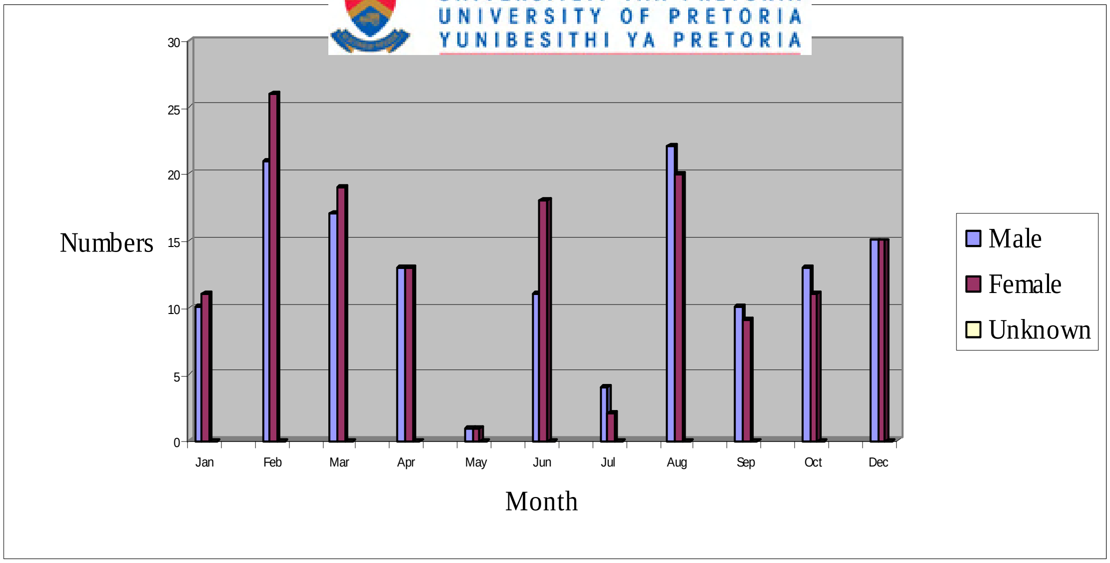


Figure 23. Graph illustrating the total monthly recorded sex ratio of *S. campestris* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

The ratio between male and female specimens appeared similar throughout the year, except for a greater number of females present in February and March, possibly due to increased appetite and nutrient intake when feeding young. Generally over the study period similar male to female ratio were recorded (♂ = 48.58%; ♀ = 51.42%).

6.3.3.3 Sex ratio of the total population of *T. leucogaster* recorded at the N'washitshumbe enclosure site (Fig. 24.)

Monthly sex ratio data were recorded on *Tatera leucogaster* at the enclosure site. The frequency of males animals (n = 49) to female animals (n = 57) differed significantly. The following monthly frequencies between male and female specimens were recorded for *T. leucogaster*: January (♂ = 0; ♀ = 0), February (♂ = 0; ♀ = 2), March (♂ = 4; ♀ = 4), April (♂ = 19; ♀ = 15), May (♂ = 1; ♀ = 2), June (♂ = 3; ♀ = 5), July (♂ = 2; ♀ =

3), August (♂ = 4; ♀ = 17), September (♂ = 0; ♀ = 4), October (♂ = 4; ♀ = 3) and December (♂ = 12; ♀ = 2).

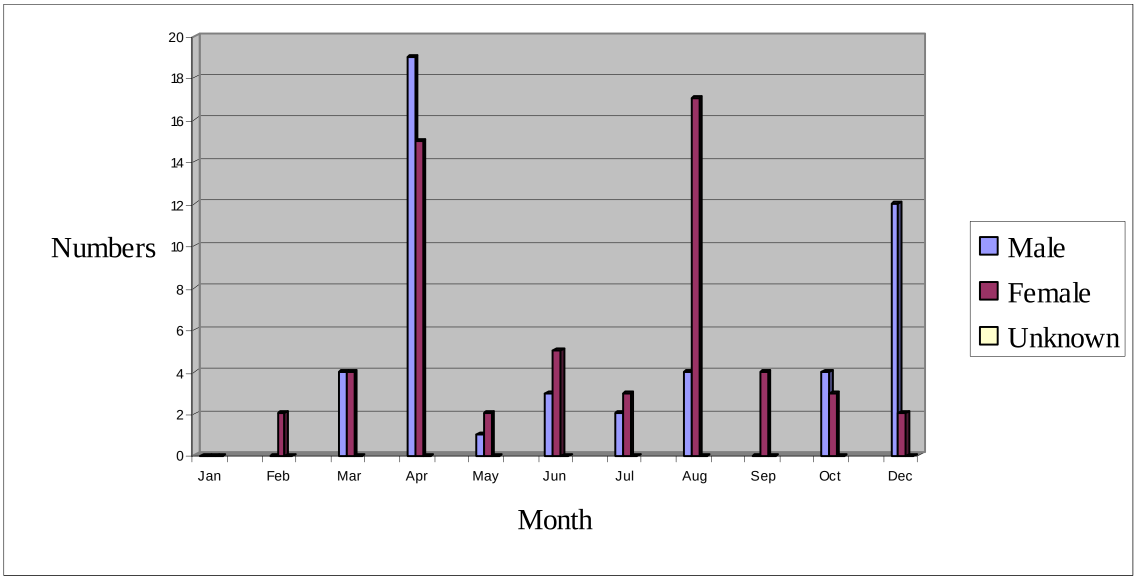


Figure 24. Graph illustrating the total monthly recorded sex ratio of *T. leucogaster* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

The ratio between male and female specimens appeared similar except for August and December. A higher number of females (n = 17) than males (n = 4) were recorded in August. The inverse relationship was recorded in December, with male numbers (n = 12) recorded in greater numbers than females (n = 2). Over the study period similar male to female ration was recorded (♂ = 46.23%; ♀ = 53.77%). A large percentage of males were present during at the beginning of autumn, compared with a large percentage of female's animals present at the beginning of spring, possibly as a result of increased forage prior to breeding, thus building body fat sustaining condition through pregnancy.

6.3.3.4 Sex ratio of the total population of *L. rosalia* recorded at the N'washitshumbe enclosure site (Fig. 25)

Monthly sex data were recorded on *Lemniscomys rosalia* at the site. The frequency of male animals (n = 18) to female animals (n = 14) differed insignificantly.

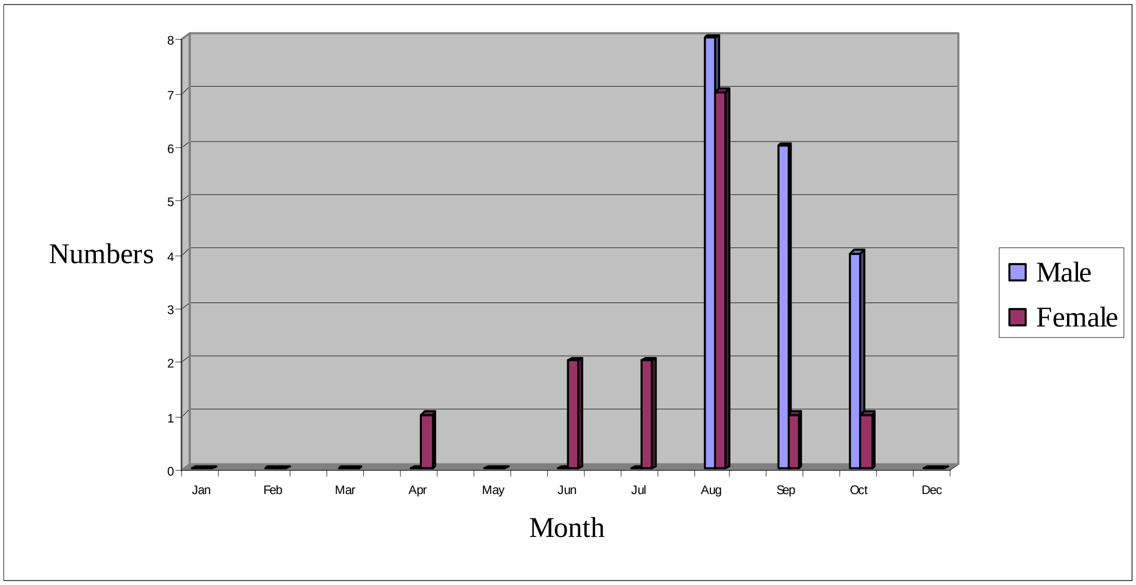


Figure 25. Graph illustrating the total monthly recorded sex ratio of *L. rosalia* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

The following monthly percentages between male and female specimens were recorded for *L. rosalia*: January (♂ = 0; ♀ = 0), February (♂ = 0; ♀ = 0%), March (♂ = 0; ♀ = 0), April (♂ = 0; ♀ = 1), May (♂ = 0; ♀ = 0), June (♂ = 0; ♀ = 2), July (♂ = 0; ♀ = 2), August (♂ = 8; ♀ = 7), September (♂ = 6; ♀ = 1), October (♂ = 4; ♀ = 1) and December (♂ = 0; ♀ = 0). The ratio between male and female specimens appeared inconsistent. Insufficient numbers of animals were collected to determine trends in the population, however significantly greater numbers of males (n = 18) were collected cumulatively in August, September and October. Over the study period a greater percentage of males to females were recorded (♂ = 56.25%; ♀ = 43.75%). No male animals were collected over the winter months, possibly due to local movements. A sudden increase in male animals occurred at the beginning of spring through summer.

6.3.3.5 Sex ratio of the total population of *A. chrysophilus* recorded at the N'washitshumbe enclosure site (Fig. 26.)

Monthly sex data were recorded on *Aethomys chrysophilus* at the site. The frequency of males animals (n = 6) to female animals (n = 6) did not differ significantly. The following monthly frequencies between male and female specimens were recorded for *A. chrysophilus*: January (♂ = 0; ♀ = 0), February (♂ = 0; ♀ = 0), March (♂ = 0; ♀ = 0), April (♂ = 0; ♀ = 0), May (♂ = 1; ♀ = 1), June (♂ = 2; ♀ = 2), July (♂ = 0; ♀ = 0), August (♂ = 0; ♀ = 1), September (♂ = 1; ♀ = 1), October (♂ = 1; ♀ = 0) and December (♂ = 1; ♀ = 1).

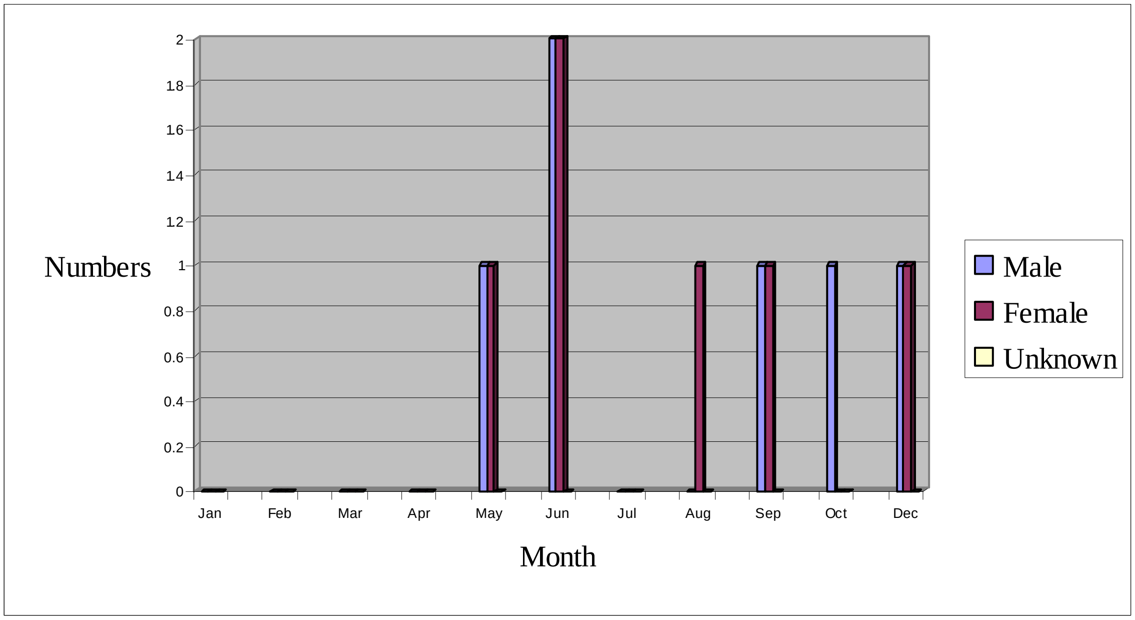


Figure 26. Graph illustrating the total monthly recorded sex ratio of *A. chrysophilus* collected at the N’washitshumbe enclosure site, northern plains, Kruger National Park

The ratio between male and female specimens appeared similar with low numbers of both sexes being recorded. Over the study period similar male to female ratio were recorded (♂ = 50%; ♀ = 50%). These numbers indicate a balance between sex ratio, although this species occurs in low numbers at the site.

6.3.3.6 Sex ratio of the total population of *M. minutoides* recorded at the N’washitshumbe enclosure site (Fig. 27.)

Monthly sex data were recorded on *Mus minutoides* at the site. The frequency of male animals (n = 5) to female animals (n = 7) did not differ significantly. The following monthly frequencies between male and female specimens were recorded for *M. minutoides*: January (♂ = 0; ♀ = 0), February (♂ = 0; ♀ = 0), March (♂ = 0; ♀ = 0), April (♂ = 0; ♀ = 0), May (♂ = 0; ♀ = 0), June (♂ = 0; ♀ = 0), July (♂ = 0; ♀ = 0), August (♂ = 3; ♀ = 3%), September (♂ = 1; ♀ = 1), October(♂ = 1; ♀ = 3) and December (♂ = 0; ♀ = 0). The ratio between male and female appeared similar during the three months in which the specimens were recorded (August - October).

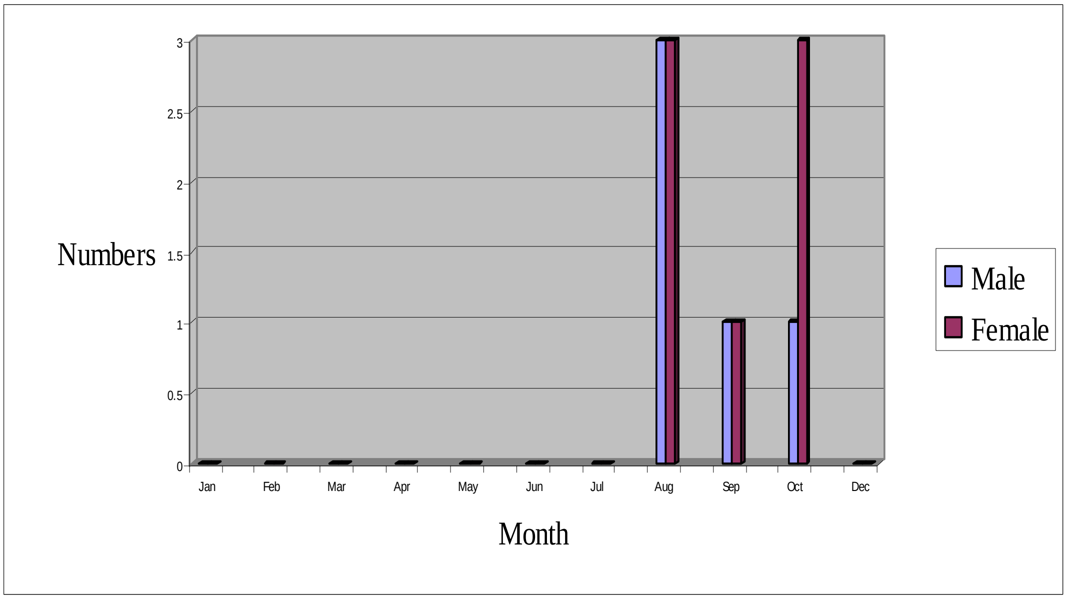


Figure 27. Graph illustrating the total monthly recorded sex ratio of *M. minutoides* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

Over the study period similar male to female ratio were recorded (♂ = 41.67%; ♀ = 58.33%). No animals were present January – July, with the first animals being recorded in August.

Insufficient numbers of *Graphiurus murinus* (♂ = 1), *Steatomys pratensis* (♂ = 1), *Crocidura hirta* (♀ = 1) and *Paraxerus cepapi* (♂ = 1) were recorded to determine meaningful trends in sex ratio from these species.

6.3.4 Capture – recapture ratio of the total population of small mammals recorded at the N'washitshumbe enclosure site

5.3.4.1 Introduction

The frequency of new and recaptured animals recorded during this study provided valuable information regarding the population dynamics and abundance of these species. The frequency of new and recaptured animals differed seasonally as well as between species (Appendix E). The assessment of data was important in determining immigration, emigration and breeding structure. Frequency was represented by the total number of animals captured during the three nights, excluding recaptures (Johnson *et al.* 2002). The percentage of captured and recaptured animals was recorded per species collected (Appendix F). Trapping rates among different survey months were calculated. Because of the relatively small samples sizes of certain species, interpretation of recaptured data was restricted to individuals recaptured within the same trap grid during a particular survey. As trapping at each grid was performed over two or three nights, recaptures occurred in the first and/or second night after marking an individual.

6.3.4.2 Total capture–recapture results recorded at the N'washitshumbe enclosure site

Six species were captured and recaptured: Animals recaptured included *Mastomys* spp. (n = 755), *Saccostomys campestris* (n = 151), *Tatera leucogaster* (n = 45), *Lemniscomys* *rosalia* (n = 21), *Aethomys chrysophilus* (n = 5) and *Mus minutoides* (n = 4). New animals recorded for the various species included *Mastomys* spp. (n = 1106), *Saccostomys campestris* (n = 129), *Tatera leucogaster* (n = 61), *Lemniscomys rosalia* (n = 11), *Aethomys chrysophilus* (n = 6); *Mus minutoides* (n = 8), *Graphiurus murinus* (n = 1), *Steatomys pratensis* (n = 1), *Crocidura hirta* (n = 1) and *Paraxerus cepapi* (n = 1).

6.3.5.1 Capture-recapture ratio of the total population of *Mastomys* spp recorded at the N'washitshumbe enclosure site (Fig. 28.)

Capture-recapture data were recorded for *Mastomys* spp at the enclosure site. The frequency of new captures (n = 1106) to recaptures (n = 755) differed significantly. Furthermore large numbers of new specimens were born and entered the system, further explaining the many new captures. Preliminary results indicate that almost half of the animals recaptured were caught more than once.

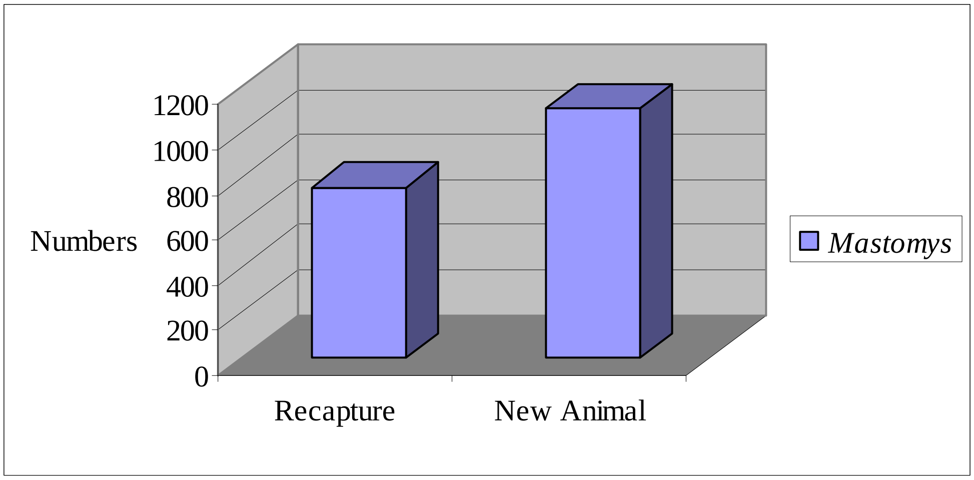


Figure 28. Graph illustrating the recorded capture-recapture ratio of *Mastomys* spp. collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

This result is clearly indicated by the percentage of new captures (59.43%) to recaptures (40.57%). The large percentage of the overall recaptures (76.96%) and overall new captures (83.47%) recorded during this study were *Mastomys* spp.

6.3.5.2 Capture-recapture ratio of the total population of *S. campestris* recorded at the N'washitshumbe enclosure site (Fig. 29.)

Capture - recapture data were recorded for *Saccostomys campestris* at the enclosure site. The frequencies recorded of new captures (n = 129) to recaptures (n = 151) were similar. In comparison, significantly more recaptures were recorded when compared with *Mastomys* spp. recaptures.

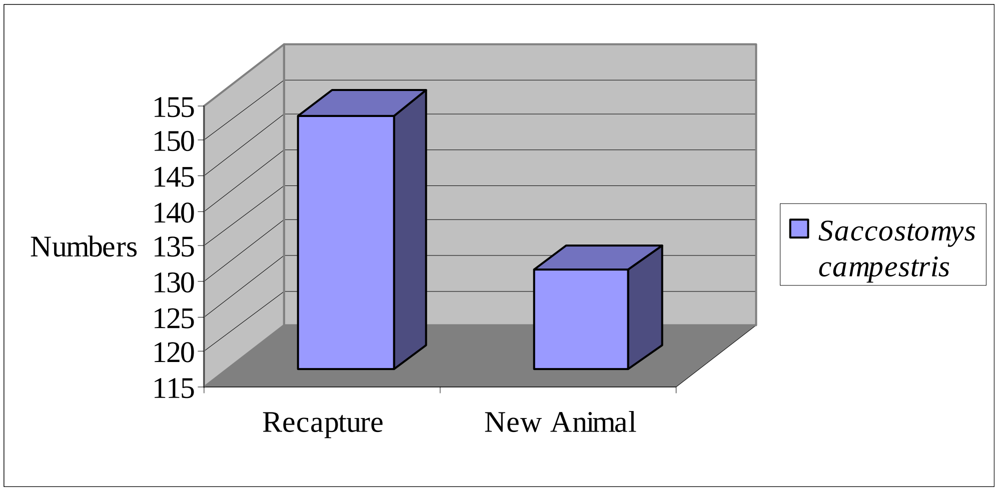


Figure 29. Graph illustrating the recorded capture-recapture ratio of *S. campestris* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

This result is clearly indicated by the percentage of new captures (46.07%) to recaptures (53.93%). The representative percentage of the overall recaptures (15.39%) and overall new captures (9.74%) recorded during this study were *S. camprestris*. Local movements appear restricted resulting in specific individuals being recorded repeatedly.

6.3.5.3 Capture-recapture ratio of the total population of *T. leucogaster* recorded at the N'washitshumbe enclosure site (Fig. 30.)

Capture-recapture data were recorded for *Tatera leucogaster* at the enclosure site. The frequency of new captures (n = 61) to recaptures (n = 45) indicated fewer animals were recaptured when compared with new animals recorded.

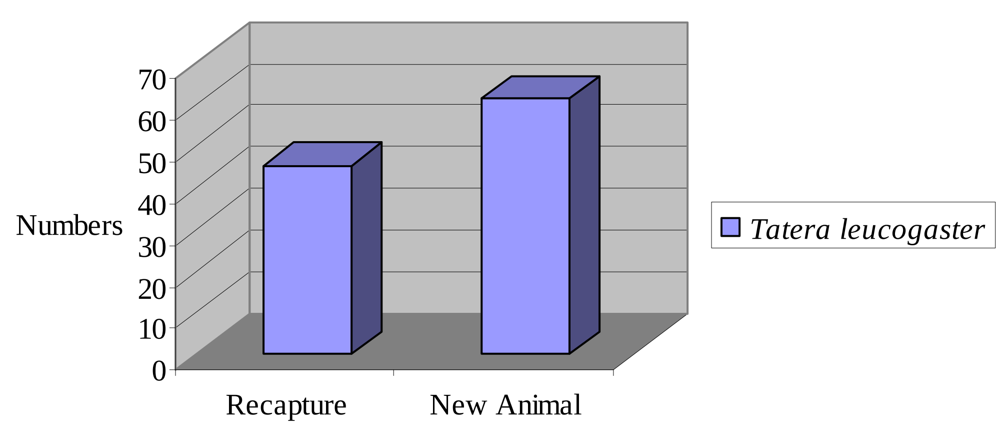


Figure 30. Graph illustrating the recorded capture-recapture ratio of *T. leucogaster* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

This result indicated by the percentage of new captures (57.55%) to recaptures (42.45%), shows that a large percentage of the population was recaptured during the study period. The representative percentage of the overall recaptures (4.59%) and overall new captures (4.6%) recorded during this study were *T. leucogaster*.

6.3.5.4 Capture-recapture ratio of the total population of *Lemniscomys rosalia* recorded at the N'washitshumbe enclosure site (Fig. 31.)

Capture - recapture data were recorded for *Lemniscomys rosalia* at the enclosure site. Disproportional frequencies of new captures (n = 11) to recaptures (n = 21) were recorded. In comparison, significantly more recaptures were recorded. A large number of animals were recaptured when compared with new animals collected, possibly as a result of low numbers of individuals in the trapping areas.

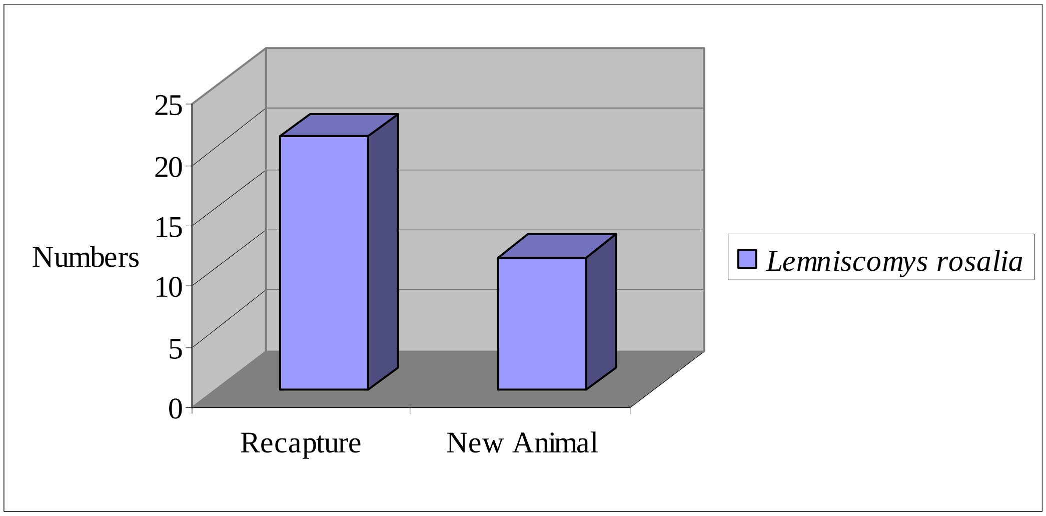


Figure 31. Graph illustrating the recorded capture-recapture ratio of *L. rosalia* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

This result is clearly indicated by the percentage of new captures (34.37%) to recaptures (65.63%). The representative percentage of the overall recaptures (2.14%) and overall new captures (0.82%) recorded during this study were *L. rosalia.*

6.3.5.5 Capture-recapture ratio of the total population of *Aethomys chrysophilus* recorded at the N'washitshumbe enclosure site (Fig. 32.)

Capture - recapture data were recorded for *Aethomys chrysophilus* at the enclosure site. Similar frequencies of new captures (n = 6) to recaptures (n = 5) were recorded. In comparison, similar numbers of new animals to recaptures were recorded.

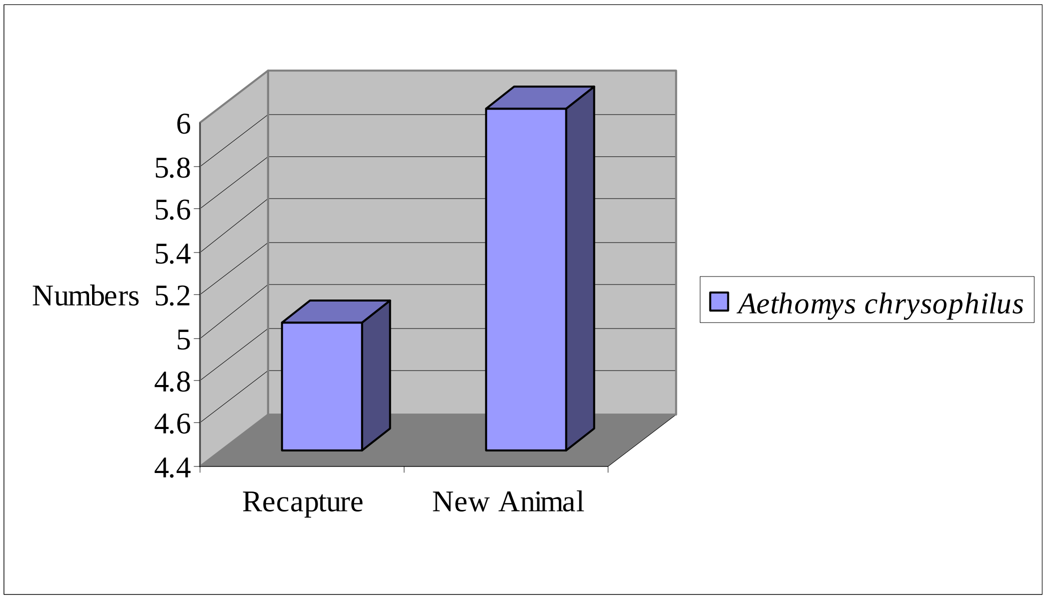


Figure 32. Graph illustrating the recorded capture-recapture ratio of *A. chrysophilus* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

This result is clearly indicated by the percentage of new captures (54.5 %) to recaptures (45.5%). The representative percentage of the overall recaptures (0.51%) and overall new captures (0.45%) recorded during this study were *A. chrysophilus.*

6.3.5.6 Capture-recapture ratio of the total population of *Mus minutoides* recorded at the N'washitshumbe enclosure site (Fig. 33.)

Capture - recapture data were recorded for *Mus minutoides* at the enclosure site. The frequency of new captures (n = 8) to recaptures (n = 4) indicated fewer animals were recaptured when compared with new animals recorded.

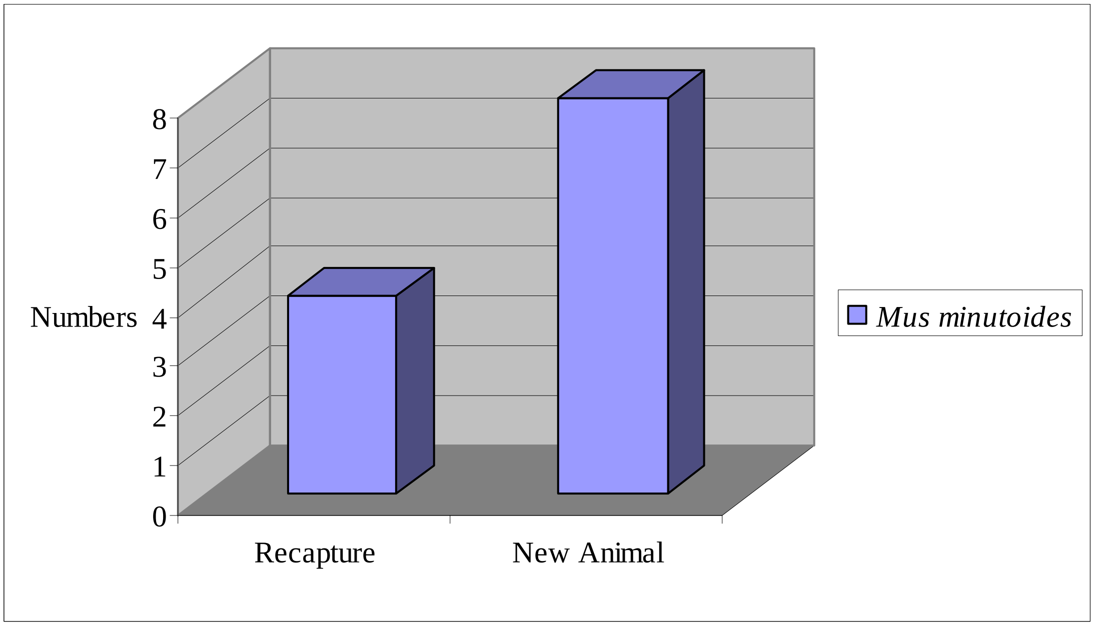


Figure 33. Graph illustrating the recorded capture-recapture ratio of *M. minutoides* collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

This result, indicated by the percentage of new captures (66.7%) to recaptures (33.3%), shows a large percentage of the population was not recaptured during the study period. The representative percentage of the overall recaptures (0.41%) and overall new captures (0.6%) recorded during this study was composed of *M. minutoides*.

Insufficient numbers of *Graphiurus murinus* (n = 1), *Steatomys pratensis* (n = 1), *Crocidura hirta* (n = 1) and *Paraxerus cepapi* (n = 1) were recorded to determine meaningful trends in capture-recapture data from these species.

Trap mortality was minimal, with the exemption of mid-winter trapping. During this time large numbers of animals were trapped, causing an extended time period to process all trapped animals, thus resulted in traps being occupied after mid day. A few animals died, probably due to heat.

6.3.5.7 Capture ratio of non-mammalian species recorded at the N'washitshumbe enclosure site (Fig. 34.)

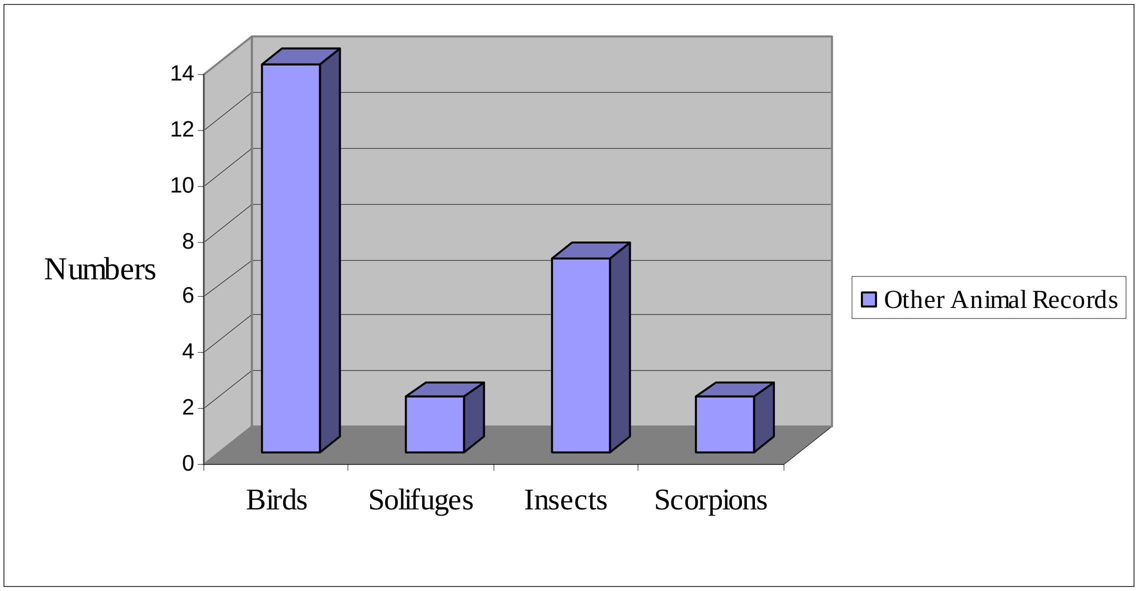


Figure 34. Graph illustrating the capture ratio of other animals collected at the N'washitshumbe enclosure site, northern plains, Kruger National Park

Watson & Watson (1985) classified disturbance of traps into three broad means of disturbance. These included predators, such as jackal, food competitors such as squirrels, birds and insects, and a random type which includes the large mammals, reptiles, amphibians and environmental factors. The season and state of the environment, especially food supply is also an important factor.

Birds regularly disturbed traps at N'washitshumbe survey site and records included Greater Blue-eared Glossy Starling (*Lamprotornis chalybaeus*), Kurrichane Buttonquail (*Turnix sylvatica*), White Browed Shrub-Robin (*Erythropygia leucophrys*) and Arrowmarked Babbler (*Turdoides jardineii*). Invertebrates, including solifuges, scorpions and large beetles also played an important role in disturbing traps at the survey site. The level of physical disturbance caused by fire and elephants outside the enclosure was noticeable. Consequently, it was expected that large differences in microhabitat (e.g. in shade and cover) existed between areas located outside and inside the enclosure.

CHAPTER 7

SMALL MAMMAL RECORDS ON THE CATENA AT THE N'WASHITSHUMBE ENCLOSURE SITE

7.1 Introduction

The catena was divided into three broad categories, top, middle and bottom slope (Fig. 35.). Data on small mammals were recorded at grids placed at different slopes on the catena (Appendix G). The landscapes resulted in significant differences in soil, geology, hydrology and associated vegetation. The assessment of small mammal diversity on the catena results in significant differences as a result of species niche separation. The N'washitshumbe enclosure site occurs on a gradient including vlei, the vlei boundary and an upland region. The eastern section of the enclosure site is the floodplain vlei area and the vlei boundary. It is collectively referred to as the bottomlands as this area occurs at the lowest point of the catenal gradient within the enclosure. The western area of the enclosure lies higher up on the landscape gradient and is referred to as middlelands. The top section of the enclosure been the highest point on the catenal gradient is referred to as uplands. All of the data collected in these areas were marked accordingly. The vlei ecotone region marked the upper boundary of the bottomlands and was clearly feinable by a band of *Sporobolus ioclados* that grew exclusively in the vlei ecotone (Kröger 2000). This ecotone forms a sodic area which interfaces with the vlei inside the enclosure.

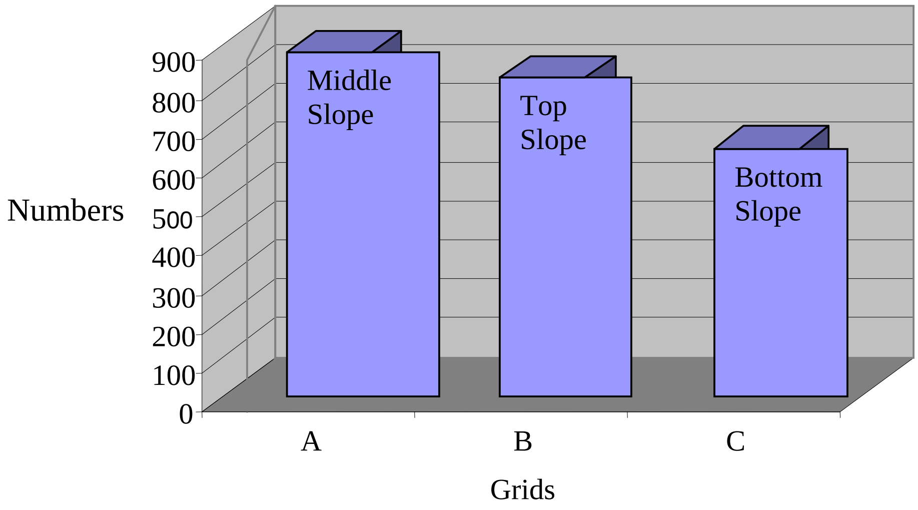


Figure 35. Graph illustrating the comparison of small mammal abundance between three grids on the top, middle and bottom slopes of the catena at the N'washitshumbe enclosure site

7.2 Small mammal records from the top slope of the catena at the N'washitshumbe enclosure site

7.2.1 Introduction

The top slope is referred to as grid B. The top slope at the enclosure site was represented by relatively flat, dry ground, covered by low, stunted mopane (*Coloshospermum mopane*) and zebrawood (*Dalbergia melanoxylon*) (See Chapter 5). The area is sparsely covered by herbaceous material with a high percentage of bare ground.

The frequency of rodent captures differed significantly at grid B (n = 814). The top slope was divided into three sampling transects based on management area. The frequency of rodent captures differed significantly between outside B1 (n = 310), in the fire break surrounding the enclosure B2 (n = 298) and inside the enclosure site B3 (n = 206) (Table 3).

Table 3. The frequency of rodent captures recorded on the top slope of the catena at the N'washitshumbe enclosure site

Species	1B	2B	3B	Total
Mastomys species	250	235	174	659
Saccostomys campestris	34	36	15	85
Tatera leucogaster	21	12	12	45
Lemniscomys rosalia	1	11	0	12
Aethomys chrysophilus	4	0	0	4
Mus minutoides	0	4	4	8
Graphiurus murinus	0	0	1	1
Steatomys pratensis	0	0	0	0
Crocidura hirta	0	0	0	0
Paraxerus cepapi	0	0	0	0
Total	310	298	206	814

7.2.2 Top-slope trapping results recorded in and outside the N'washitshumbe enclosure site (Fig. 36.)

Trapping success varied seasonally and with climatic conditions. Winter months harbored close to 90% success rate due to a population explosion of *Mastomys* spp. Trapping success dropped (> 25%) over summer months (Table 4). This could be a result of food being more readily available.

Table 4. Percentage of total rodent captures for four mid-summer and mid-winter months at the N'washitshumbe enclosure site

Winter months	%	Summer months	%
May	6.9	Oct	5.87
Jun	11.95	Nov	7.2
Jul	13.8	Dec	2.95
Aug	24.08	Jan	4.54
Total %	56.73		20.56

Eight species were collected on the top slope of the catena at the enclosure site: *Mastomys natalensis, Mastomys coucha, Saccostomys campestris, Tatera leucogaster, Lemniscomys rosalia, Aethomys chrysophilus, Mus minutoides and Graphiurus murinus. Mastomys* was recorded the dominant genus on the top slope (n = 659). *Graphiurus murinus* (n = 1) was recorded exclusively on the top slope. Fluctuations in species diversity occurred with *Mastomys* being dominant between May and August due to a population explosion.

The following frequencies were recorded on the top slope of the catena during the study period: *Mastomys* spp. (n = 659), *Saccostomys campestris* (n = 85), *Tatera leucogaster* (n = 45), *Lemniscomys rosalia* (n = 12), *Aethomys chrysophilus* (n = 4), *Mus minutoides* (n = 8) and *Graphiurus murinus* (n = 1). No record of *Steatomys pratensis*, *Crocidura hirta* or *Paraxerus cepapi* was recorded at the grid site.

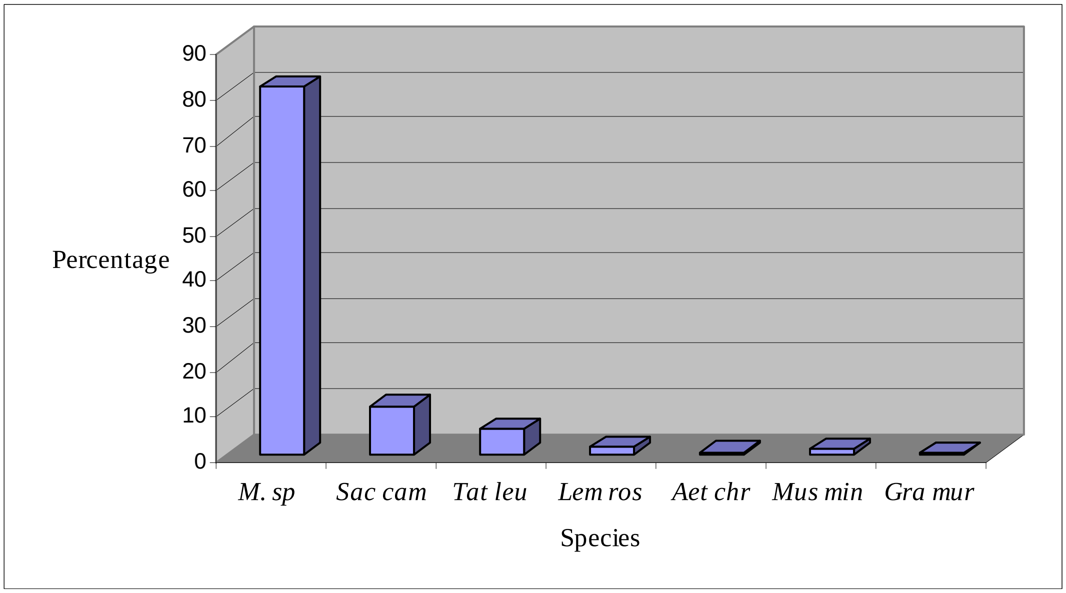


Figure 36. Graph illustrating the comparison of small mammal abundance and diversity on the top slope of the catena at the N'washitshumbe enclosure site

The total number of other species, other than *Mastomys* spp., amounted to a mere 155 specimens, with the pouched mouse *Saccostomys campestris* second with 85 specimens, and the bushveld gerbil *Tatera leucogaster* third with 45 specimens. These two species were collected more frequently during periods when *M. natalensis* numbers had decreased.

The total species percentage recorded on the top slope during the study period: *Mastomys* spp. (80.96%), *Saccostomys campestris* (10.44%), *Tatera leucogaster* (5.53%), *Lemniscomys rosalia* (1.47%), *Aethomys chrysophilus* (0.49%), *Mus minutoides* (0.99%) and *Graphiurus murinus* (0.12%). Species representative percentage of overall animals collected on the top slope represented 34.98% of overall animals captured during the survey. Of all *Mastomys* spp. individuals captured during the survey, 35.09% were on the top slope. The percentages for the other species are 30.14% for *Saccostomys campestris,* 42.45% for *Tatera leucogaster*, 37.5% for *Lemniscomys rosalia*, 33.33% for *Aethomys chrysophilus*, 66.67% for *Mus minutoides* and 100% for *Graphiurus murinus.* These results indicated that *T. leucogaster, M. minutoides* and *G. murinus* occurred in higher densities on the top slope of the catena.

7.3 Small mammal records from the middle-slope of the catena at the N'washitshumbe enclosure site (Fig. 37.)

7.3.1 Introduction

The middle slope is referred to as grid A. The middle slope at the enclosure had substantial grass cover, with apple leaf (*Lonchocarpus capassa*) and marula (*Sclerocarya birrea*) prominent (See Chapter 5).

The frequency of rodent captures differed at grid A (n = 878). The middle slope was divided into three sampling transects based on management activity. The frequency of rodent captures differed outside A1 (n = 342), in the fire break surrounding the enclosure A2 (n = 333) and inside the enclosure site A3 (n = 203) (Table 5).

Table 5. The frequency of rodent captures recorded on the middle slope of the catena at the N'washitshumbe enclosure site

Species	1A	2A	3A	Total
Mastomys species	249	289	154	692
Saccostomys campestris	62	43	33	138
Tatera leucogaster	28	1	11	40
Lemniscomys rosalia	0	0	0	0
Aethomys chrysophilus	1	0	1	2
Mus minutoides	1	0	3	4
Graphiurus murinus	0	0	0	0
Steatomys pratensis	1	0	0	1
Crocidura hirta	0	0	0	0
Paraxerus cepapi	0	0	1	1
Total	342	333	203	878

7.3.2 Mid-slope trapping results recorded in and outside the N'washitshumbe enclosure site

Trapping success varied seasonally and with climatic conditions. Winter months harbored close to 90% trapping success rate due to a population explosion of *Mastomys* spp. Trapping success dropped significantly (> 40%) over the summer months (Table 6).

Table 6. Comparison of *Mastomys* trapping between winter and summer months at the N'washitshumbe enclosure site.

Winter months		Summer months	
May	6.9	Oct	5.87
Jun	11.95	Nov	7.2
Jul	13.8	Dec	2.95
Aug	24.08	Jan	4.54
Total %	56.73		20.56

This could be a result of food being more readily available. Movement was recorded between low-lying areas and middle slopes. Recapture data indicates that animals appeared to move from the middle slope to the bottom slope in winter months. This is expected to be as the result of less cover on the middle slope in winter months.

Eight species were collected on the middle slope of the catena at the enclosure site: *Mastomys natalensis*, *Mastomys coucha*, *Saccostomys campestris*, *Tatera* *leucogaster, Aethomys chrysophilus, Mus minutoides, Paraxerus cepapi and Steatomys pratensis* (Fig. 37.). *Mastomys* was recorded the dominant genus on the middle slope (n = 659). *S. pratensis* (n = 1) and *P. cepapi* (n = 1) were recorded exclusively on the middle slope. Fluctuations in species diversity occurred monthly, with *Mastomys* being dominant between May and August due to a population explosion. In certain months, only *Mastomys* were collected. The population grew rapidly in response to late rains in April. *Saccostomys campestris* (n = 138) and *Tatera leucogaster* (n = 40) were collected more frequently in periods when *M. natalensis* numbers had decreased.

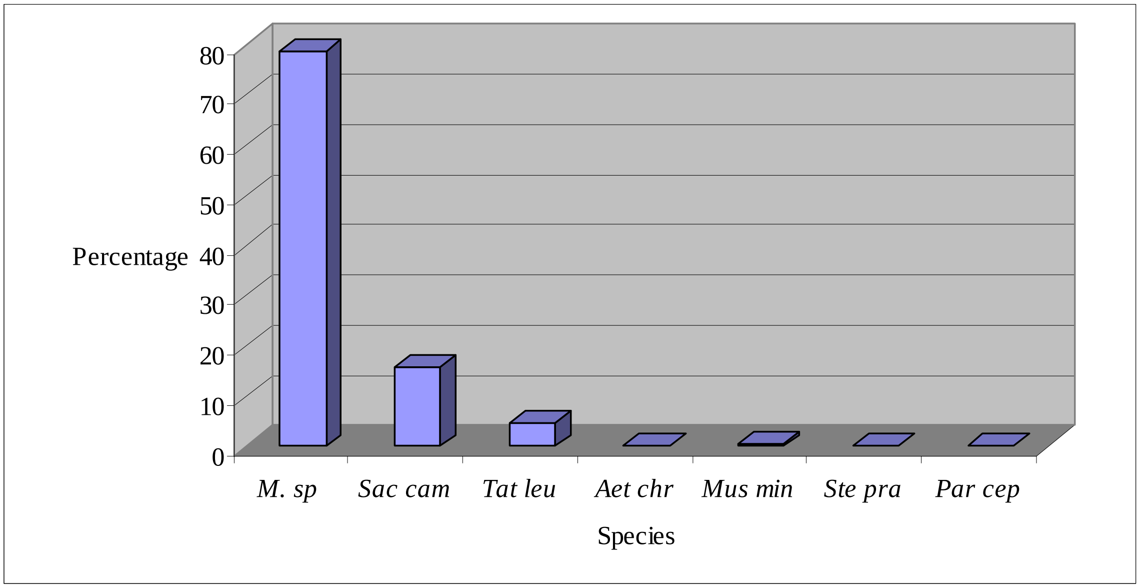


Figure 37. Graph illustrating the comparison of small mammal abundance and diversity at grid A on the middle slope of the catena at the N’washitshumbe enclosure site

The following frequencies were recorded on the mid-slope during the study period: *Mastomys* spp. (n = 692), *Saccostomys campestris* (n = 138), *Tatera leucogaster* (n = 40), *Aethomys chrysophilus* (n = 2), *Mus minutoides* (n = 4), *Steatomys pratensis* (n = 1) and

Paraxerus cepapi (n = 1). The total number of species other than *Mastomys* amounted to 186 specimens.

The total species percentage recorded on the middle slope recorded during the study period: *Mastomys* spp. (78.82%), *Saccostomys campestris* (15.72%), *Tatera leucogaster* (4.56%), *Aethomys chrysophilus* (0.23%), *Mus minutoides* (0.45%), *Steatomys pratensis* (0.11%) and *Paraxerus cepapi* (0.11%). Species representative percentage of overall animals collected on the middle slope was 37.74% of overall animals captured during the survey. Of all *Mastomys* spp. individuals captured during the survey, 36.85% were on the middle slope. The percentages for the other species are 48.94% for *Saccostomys campestris*, 37.74% for *Tatera leucogaster*, 16.67% for *Aethomys chrysophilus*, 33.33% for *Mus minutoides*, 100% for *Steatomys pratensis* and 100% for *Paraxerus cepapi*. The results indicated that S. *campestris*, *S. pratensis* and *P. cepapi* occurred in higher densities at the middle slope of the catena.

7.4 Small mammal records from the bottom-slope of the catena at the N'washitshumbe enclosure site

7.4.1 Introduction

The bottom slope is referred to as grid C. The bottom slope at the enclosure site was represented by relatively flat, seasonally inundated vlei, and covered by tall grass and sedge. Woody vegetation was represented by lala palm (*Hyphaene petersiana*) in these low-lying areas. The area was densely covered by herbaceous material with a high basal cover percentage. The bottom slope was divided into three sampling transects based on management activity. The frequency of rodent captures differed significantly between outside C1 (n = 318), inside the enclosure C2 (n = 180) and the sodic area inside the enclosure site C3 (n = 136) (Table 7).

Table 7. The frequency of rodent captures recorded on the bottom slope of the catena at the N’washitshumbe enclosure site

Species	1C	2C	3C	Total
Mastomys species	264	159	104	527
Saccostomys campestris	23	13	23	59
Tatera leucogaster	12	0	9	21
Lemniscomys rosalia	15	5	0	20
Aethomys chrysophilus	3	3	0	6
Mus minutoides	0	0	0	0
Graphiurus murinus	0	0	0	0
Steatomys pratensis	0	0	0	0
Crocidura hirta	1	0	0	1
Paraxerus cepapi	0	0	0	0
Total	318	180	136	634

7.4.2 Bottom-slope trapping results recorded in and outside the N'washitshumbe enclosure site

Trapping success varied seasonally and with climatic conditions. The winter months harbored close to 70% trapping success rate due to a population explosion of *Mastomys* spp.. Trapping success dropped significantly (> 30%) over the summer months. This could be a result of food being more readily available and an increase in vegetation biomass. Seven species were collected at the bottom slope: *Mastomys natalensis*, *Mastomys coucha*, *Saccostomys campestris*, *Tatera leucogaster*, *Lemniscomys rosalia*, *Aethomys chrysophilus* and *Crocidura hirta*. *Mastomys* was the dominant genus in the low-lying areas (n = 527). Fluctuations in species diversity occurred monthly, with *Mastomys* being dominant between May and August due to a population explosion. Relatively few specimens were collected in the sodic area and it is assumed to be the result of limited shelter from predators as grass cover was very low. The diversity of grass seeds was noticeably lower.

The following frequencies were recorded on the bottom slope of the catena during the study period: *Mastomys* spp. (n = 527), *Saccostomys campestris* (n = 59), *Tatera leucogaster* (n = 21), *Lemniscomys rosalia* (n = 20), *Aethomys chrysophilus* (n = 6) and *Crocidura hirta* (n = 1). There were no records of *Steatomys pratensis*, *Mus minutoides*, *Graphiurus murinus* or *Paraxerus cepapi* at the grid site. The total number of species other than *Mastomys* amounted to 15% (Fig. 38.).

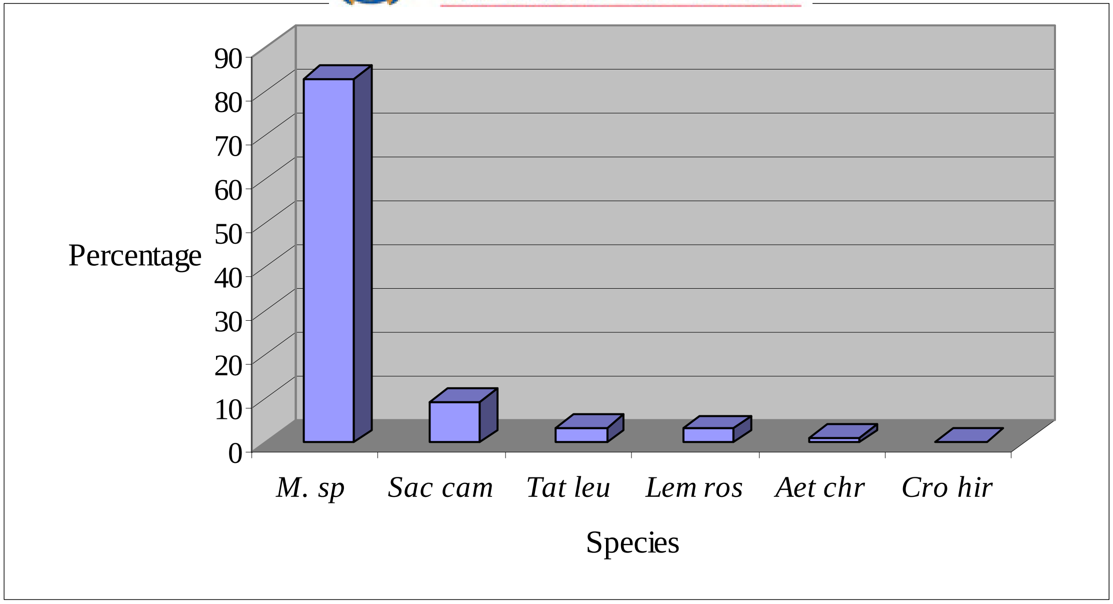


Figure 38. Graph illustrating the comparison of small mammal abundance and diversity at Grid C on the middle slope of the catena at the N’washitshumbe enclosure site

The total species percentage recorded on the bottom slope during the study period was: *Mastomys* spp. (83.12%), *Saccostomys campestris* (9.31%), *Tatera leucogaster* (3.31%), *Lemniscomys rosalia* (3.15%), *Aethomys chrysophilus* (0.95%) and *Crocidura hirta* (0.16%). Species representative percentage of overall animals collected on the bottom slope represented 27.26% of animals captured during the survey. Of all *Mastomys* spp. individuals captured during the survey, 28.06% were on the bottom slope. The percentages for the other species are 20.92% for *Saccostomys campestris*, 19.81% for *Tatera leucogaster*, 62.50% for *Lemniscomys rosalia*, 50% for *Aethomys chrysophilus*, and 100% for *Crocidura hirta*. Results indicated that *L. rosalia*, *A. chrysophilus* and *C. hirta* occurred in higher densities on the bottom slope of the catena, although in low numbers.

CHAPTER 8

SMALL MAMMAL RECORDS ON THE MANAGEMENT AT THE N’WASHITSHUMBE ENCLOSURE SITE

8.1 Introduction

Data on small mammals were recorded in transects placed at different areas according to management action at the N’washitshumbe enclosure site (Appendix H). The management of the site resulted in significant differences in vegetation diversity, density and height. The assessment of small mammal diversity at these management units resulted in differences as a result of altered habitat (Appendix I). These management units were divided into three broad categories, outside, around and inside the enclosure site (Fig. 39.).

Mastomys specimens collected in different management areas at N’washitshumbe enclosure included outside (n = 40.63%), in the fire break (n = 36.37%) and inside (n = 23%).

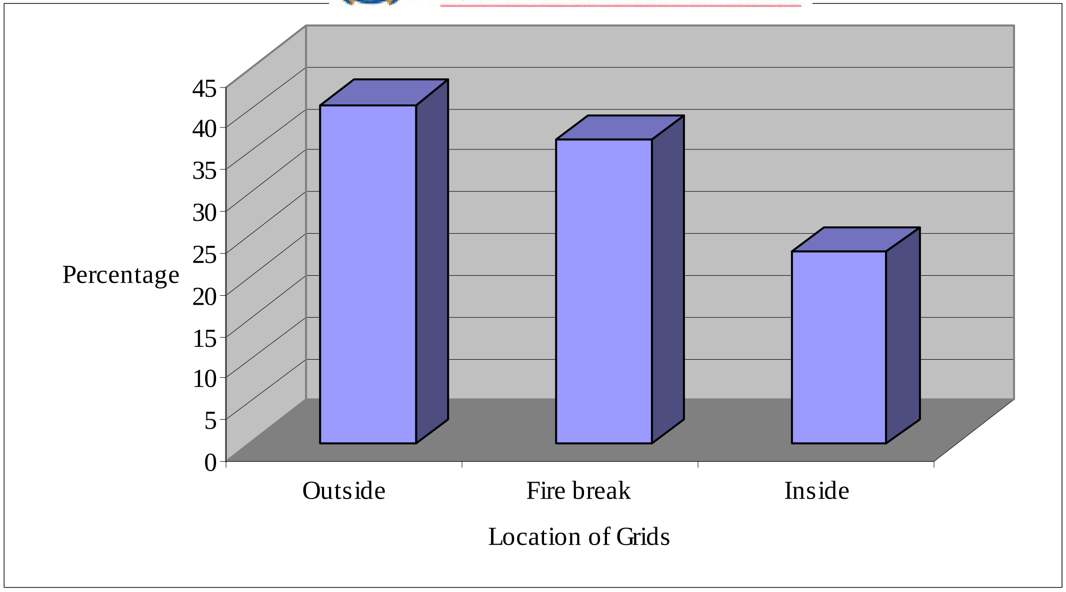


Figure 39. Graph illustrating the comparison of small mammal capture success between the different management areas at the N'washitshumbe enclosure site

These differences are possibly a result of restricted movement in and outside the enclosure. This may result in restricted influxes of animals from neighboring populations from outside into the enclosure. Preliminary results from Nkuhlu enclosure near Skukuza indicate that a larger number of animals are present inside the enclosure than outside (Wilson *pers comm.* 2007). This is a newly constructed enclosure which may influence numbers of small mammal due to grass cover not reaching moribund proportions.

8.2 Small mammal records from outside the N'washitshumbe enclosure site

8.2.1 Introduction

Data were recorded outside the enclosure site and referred to as transects A1, B1 and C1. Outside the site was represented by top, middle and bottom slope habitats. The primary difference in management being the influence of fire, elephant and buffalo impact on the vegetation density and diversity outside, when compared with the inside. These sites were subjected to ad hoc fire, elephant and buffalo impact and representative of veld conditions in the region. Outside sites were divided into three sampling transects based on management activity. The frequency of rodent captures differed between the top slope outside B1 (n = 310), in the fire break surrounding the enclosure A1 (n = 342) and inside the enclosure site C1 (n = 318) (Table 8).

Table 8. The frequency of rodent captures recorded outside the N'washitshumbe enclosure site

Species	Transects			
	A1	B1	C1	Total
Mastomys species	249	250	264	763
Saccostomys campestris	62	34	23	119
Tatera leucogaster	28	21	12	61
Lemniscomys rosalia	0	1	15	16
Aethomys chrysophilus	1	4	3	8
Mus minutoides	1	0	0	1
Graphiurus murinus	0	0	0	0
Steatomys pratensis	1	0	0	1
Crocidura hirta	0	0	1	1
Paraxerus cepapi	0	0	0	0
Total	342	310	318	970

8.2.2 Outside enclosure trapping results recorded at the N'washitshumbe enclosure site

Trapping success varied seasonally and with climatic conditions. Winter months harbored close to 100% success rate due to a population explosion of *Mastomys* spp. Trapping success dropped drastically (<70%) during the summer months. This could be a result of food being more readily available.

Preliminary analysis of recapture data indicates a seasonal movement occurred between transects C1 and A1. Nine species were collected at sites outside the enclosure: *Mastomys natalensis*, *Mastomys coucha*, *Saccostomys campestris*, *Tatera leucogaster*, *Lemniscomys rosalia* (Fig. 40a.) and *Aethomys chrysophilus*, *Mus minutoides*, *Crocidura hirta* and *Steatomys pratensis* (Fig. 40b.).

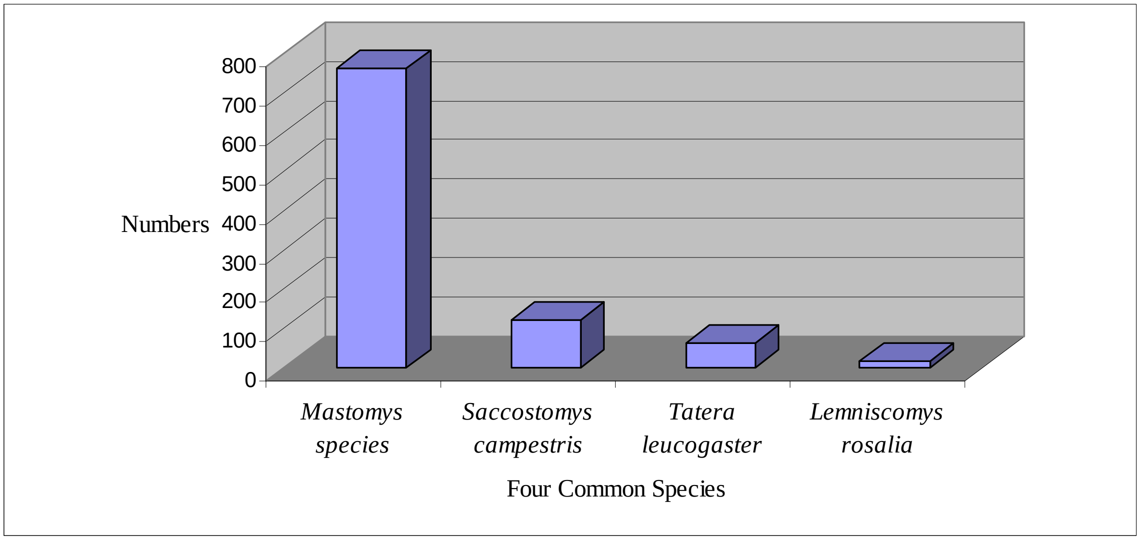


Figure 40a. Graph illustrating the comparison of the four most abundant small mammal species collected in the open field outside the fire break around the N'washitshumbe enclosure site

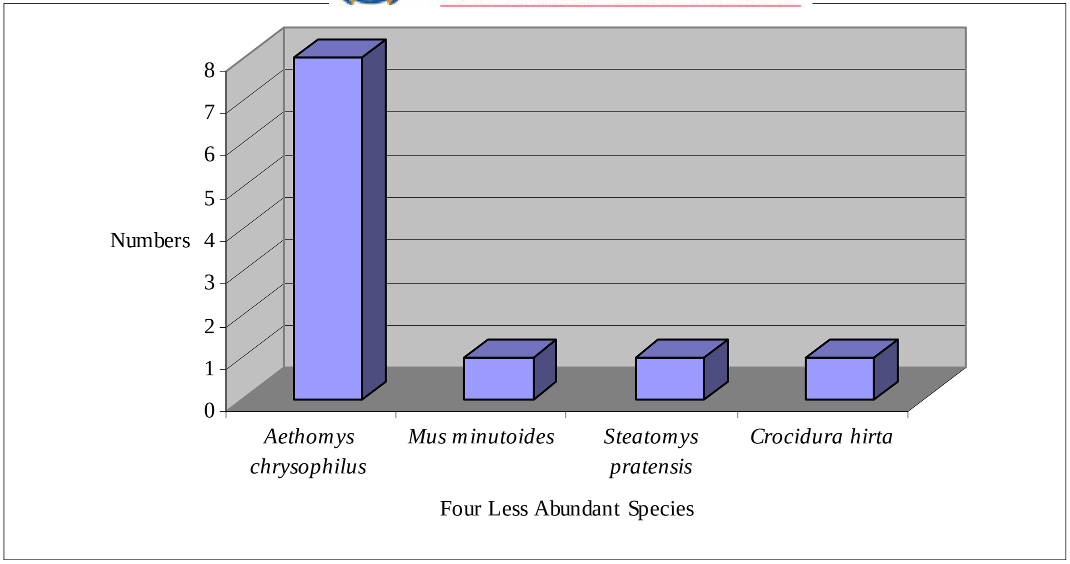


Figure 40b. Graph illustrating the comparison of the four less abundant small mammal species collected in the open field outside the fire break around the N'washitshumbe enclosure site

Mastomys was the dominant genus on the top slope (n = 763). *S. pratensis* (n = 1) was recorded outside the enclosure site. This species is relatively common in the central Satara area of the Kruger National Park, favouring open, grassy areas.

Fluctuations in species diversity occurred monthly following the general trend with *Mastomys* being dominant between May and August due to a population explosion. An inverse relationship occurred between *Mastomys* and other species in the area (Figs. 41.a, b.).

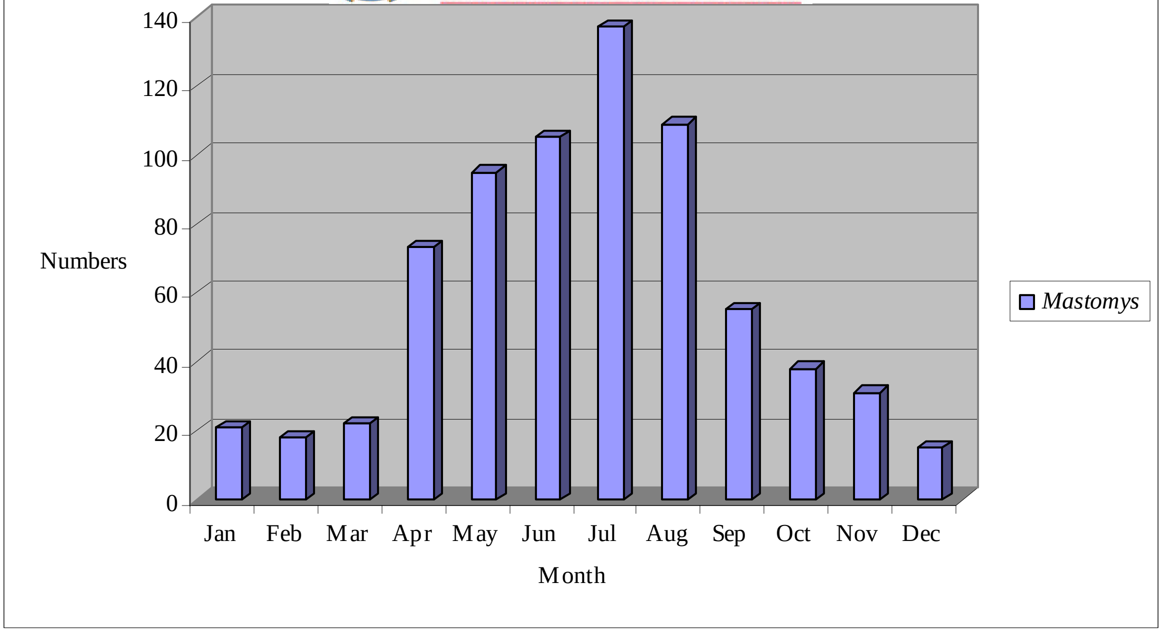


Figure 41a. Graph illustrating the comparison of *Mastomys* species collected monthly in the open field outside the fire break around the N'washitshumbe enclosure.

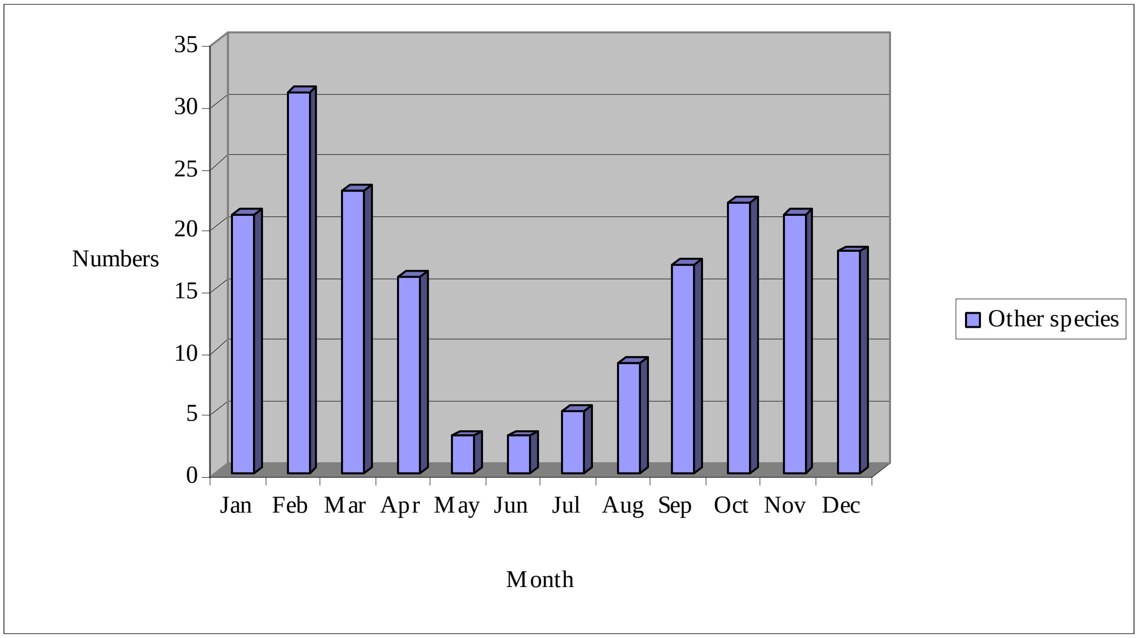


Figure 41b. Graph illustrating the comparison of all other species collected monthly in the open field outside the fire break around the N'washitshumbe enclosure site in the absence of *Mastomys*

The following frequencies were recorded outside the enclosure site during the study period: *Mastomys* spp. (n = 763), *Saccostomys campestris* (n = 119), *Tatera leucogaster* (n = 61), *Lemniscomys rosalia* (n = 16), *Aethomys chrysophilus* (n = 8), *Mus minutoides* (n = 1), *Crocidura hirta* (n = 1) and *Steatomys pratensis* (n = 1). No records of *Graphiurus murinus* or *Paraxerus cepapi* were recorded outside the enclosure site. This probably indicates that changes in habitat affect species diversity. Certain species preferring wooded areas may have a reduced distribution range as a result of uncontrolled elephant, buffalo and fire impact. This may favour other species which prefer open, less wooded, grassy areas. The total number of species other than *Mastomys* amounted to 207 specimens.

The total species percentage recorded outside the enclosure during the study period was: *Mastomys* spp. (78.66%), *Saccostomys campestris* (12.27%), *Tatera leucogaster* (6.25%), *Lemniscomys rosalia* (1.6%), *Aethomys chrysophilus* (0.82%), *Mus minutoides* (0.1%), *Crocidura hirta* (0.1%) and *Steatomys preatensis* (0.1%). Species representative percentage of overall animals collected outside the enclosure site was 41.69% of overall animals captured during the survey. Of all *Mastomys* spp. individuals captured during the survey, 40.63% were collected outside the enclosure. The percentages for the other species are 42.2% for *Saccostomys campestris*, 57.55% for *Tatera leucogaster*, 50% for *Lemniscomys rosalia*, 66.67% for *Aethomys chrysophilus*, 8.34% for *Mus minutoides*, 100% for *Steatomys pratensis* and 100% for *Crocidura hirta.*

Results indicated that *Mastomys* spp., *Saccostomys campestris*, *Tatera leucogaster*, *Lemniscomys rosalia*, *Aethomys chrysophilus*, *Steatomys preatensis* and *Crocidura hirta* occurred in higher densities outside the enclosure site when compared with the fire break and inside the enclosure sites.

8.3 Small mammal records from the fire break surrounding the N'washitshumbe enclosure site

8.3.1 Introduction

Data were recorded in the fire break around the enclosure site and referred to as transects A2 and B2. The fire breaks surrounding the enclosure site were represented by top and middle slope habitats. No fire break was present at the bottom slope as a result of the vlei being an effective fire barrier. The primary difference of the frequency of fire impact on the vegetation was compared on the outside and inside of the enclosure. These sites were subjected to regular fire impact as a result of the annual burning of fire breaks as well as elephant and buffalo impact similar to outside the enclosure. The frequency of rodent captures were insignificant in the fire break area (n = 631) when compared with outside sites. Fire break sites were divided into two sampling transects based on slope. The frequency of rodent captures were insignificant between top slope fire break B2 (n = 310) and middle slope fire break A2 (n = 333) (Table 9).

Table 9. The frequency of rodent captures recorded in the fire break around the N'washitshumbe enclosure site

Species	A2	B2	Total
Mastomys species	289	235	524
Saccostomys campestris	43	36	79
Tatera leucogaster	1	12	13
Lemniscomys rosalia	0	11	11
Aethomys chrysophilus	0	0	0
Mus minutoides	0	4	4
Graphiurus murinus	0	0	0
Steatomys pratensis	0	0	0
Crocidura hirta	0	0	0
Paraxerus cepapi	0	0	0
Total	333	298	631

8.3.2 Fire-break trapping results recorded around the N'washitshumbe enclosure site

Trapping success varied seasonally and with climatic conditions. Winter months harbored close to 110% trapping success due to a population explosion of *Mastomys* spp. Trapping success dropped (< 70%) over the summer months. Six species were collected at sites in the fire break surrounding the enclosure: *Mastomys natalensis*, *Mastomys coucha*, *Saccostomys campestris*, *Tatera leucogaster*, *Lemniscomys rosalia and Mus minutoides*. *Mastomys* is the recorded dominant genus in the fire break area (n = 526). No species were recorded exclusively in the fire break surrounding the site. This could be as a result of this being a volatile habitat, constantly growing out after the previous fire, thus favoured by pioneer species of animals.

Fluctuations in species diversity occurred monthly following the trend with *Mastomys* being dominant between May and August (Fig. 42a.).

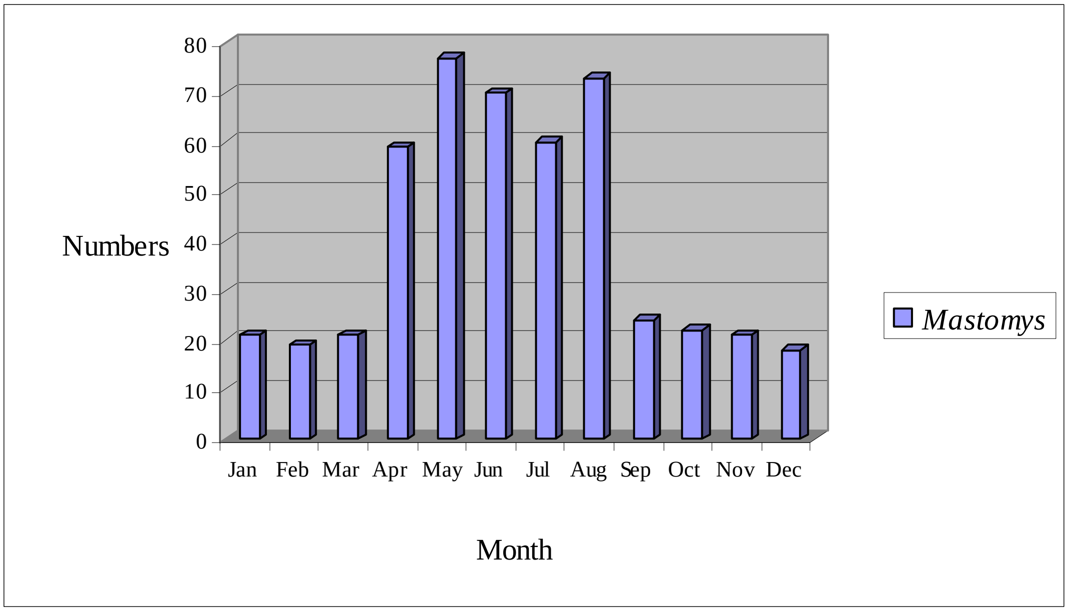


Figure 42a. Graph illustrating the comparison of *Mastomys* species collected monthly in the fire break around the N'washitshumbe enclosure site

The following frequencies were recorded in the fire breaks during the study period: *Mastomys* spp. (n = 524), *Saccostomys campestris* (n = 79), *Tatera leucogaster* (n = 13), *Lemniscomys rosalia* (n = 11) and *Mus minutoides* (n = 4)). An inverse relationship occurred between *Mastomys* and other species in the area (Fig. 42b.).

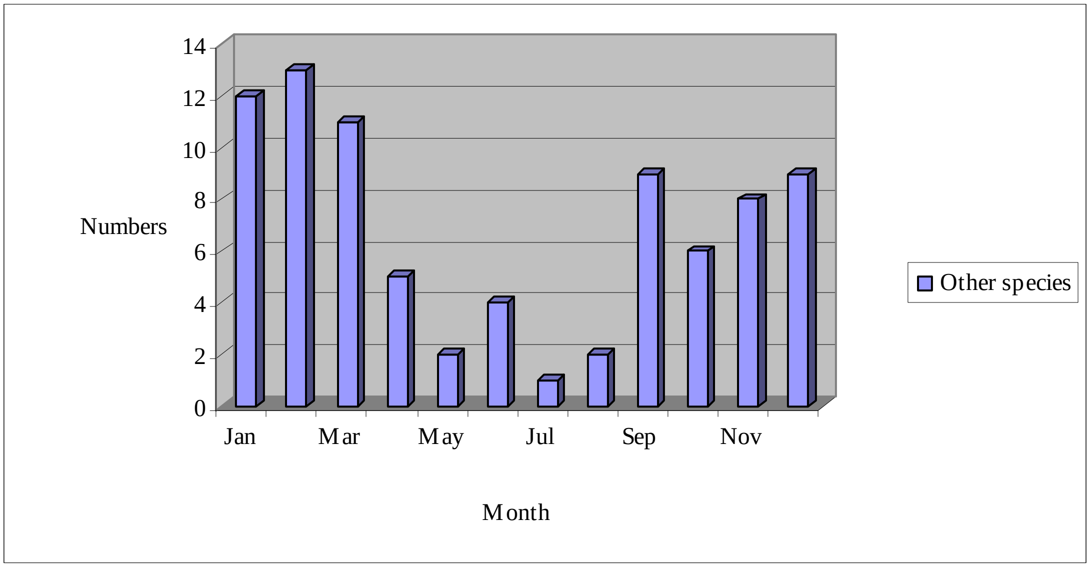


Figure 42b. Graph illustrating the comparison of less abundant species collected monthly in the the fire break around the N'washitshumbe enclosure site in the absence of *Mastomys*

No record of *Aethomys chrysophilus, Steatomys pratensis, Graphiurus murinus* or *Paraxerus cepapi* were recorded in the fire break sites. This is a clear indication of the influences of regular fire which result in low, scrub-like wooded vegetation and limited herbaceous material. The total number of species excluding *Mastomys* amounted to 107 specimens. The total species percentages recorded in the fire breaks surrounding the enclosure during the study period were: *Mastomys* spp. (83.04%), *Saccostomys campestris* (12.52%), *Tatera leucogaster* (2.06%), *Lemniscomys rosalia* (1.75%) and *Mus minutoides* (0.63%). Species representative percentage of overall animals collected in the fire breaks surrounding the enclosure site was 27.13% during the survey. Of all *Mastomys* spp. individuals captured during the survey, 27.9% were in the fire breaks surrounding the enclosure. The percentages for the other species are 28.01% for *Saccostomys campestris*, 12.26% for *Tatera leucogaster*, 34.38% for *Lemniscomys* *rosalia,* for and 33.33% for *Mus minutoides.* The results indicated that no species occur in higher densities in the fire break when compared with the outside and the inside of the enclosure.

8.4 Small mammal records from inside the N'washitshumbe enclosure site

8.4.1 Introduction

Data were recorded inside the enclosure site and referred to as transects A3, B3 and C2. The sites inside the enclosure were represented by top, middle and bottom slope habitats. The primary difference being the absence of fire, elephant and buffalo impact on the vegetation, compared with the outside and fire break sites. This has resulted in a substantially greater amount of herbaceous material and a greater abundance of larger woody plants. The frequency of rodent captures were significant lower inside the enclosure (n = 589) compared with the outside sites. These sites were divided into three sampling transects based on slope. The frequency of rodent captures were insignificant between the top B3 (n = 206) and middle slope A3 (n = 203) on the inside. However fewer animals were collected at the bottom slope C2 (n = 180) on the inside.

8.4.2 Inside enclosure trapping results recorded at the N’washitshumbe enclosure site

Trapping success varied seasonally and with climatic conditions. Winter months harbored close to 90% success rate due to a population explosion of *Mastomys* spp. Trapping success dropped significantly (< 60%) over summer months. Nine species were collected inside the enclosure site: *Mastomys natalensis*, *Mastomys coucha*, *Saccostomys campestris*, *Tatera leucogaster*, *Lemniscomys rosalia*, *Aethomys chrysophilus*, *Mus minutoides*, *Graphiurus murinus* and *Paraxerus cepapi* (Fig. 43a.).

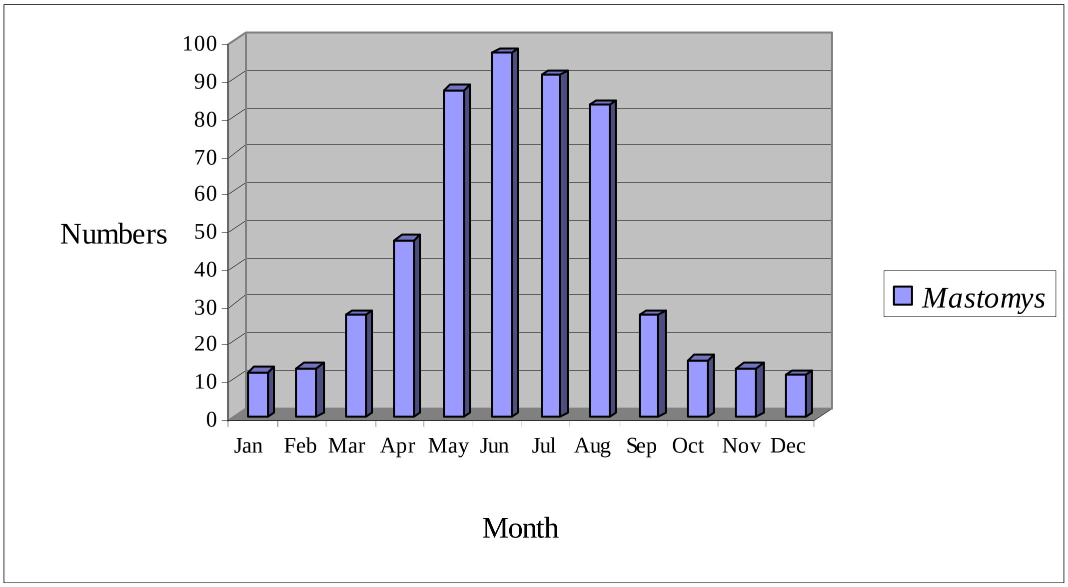


Figure 43a. Graph illustrating the comparison of *Mastomys* species collected monthly inside the N’washitshumbe enclosure site

Mastomys was the dominant genus inside the enclosure site (n = 487). *Graphiurus murinus* and *Paraxerus cepapi* were recorded exclusively inside the enclosure site. This could be as a result of a mature habitat, dominated by denser vegetation and large trees.

This habitat is favoured by more arboreal species. Fluctuations in species diversity occurred monthly following the trend with *Mastomys* being dominant between May and August.

The following frequencies were recorded inside the enclosure during the study period: *Mastomys* spp. (n = 487), *Saccostomys campestris* (n = 61), *Tatera leucogaster* (n = 23), *Lemniscomys rosalia* (n = 5), *Aethomys chrysophilus (n = 4)*, *Mus minutoides* (n = 7), *Paraxerus cepapi* (n = 1) and *Graphiurus murinus* (n = 1). No records of *Steatomys pratensis* or *Crocidura hirta* were recorded inside the enclosure site. Vegetation was denser in the absence of fire and large herbivore impact, resulting in a habitat less favourable for species that prefer less dense habitat. The total number of species excluding *Mastomys* amounted to 102 specimens. An inverse relationship occurred between *Mastomys* and other species in the area (Fig. 43b.).

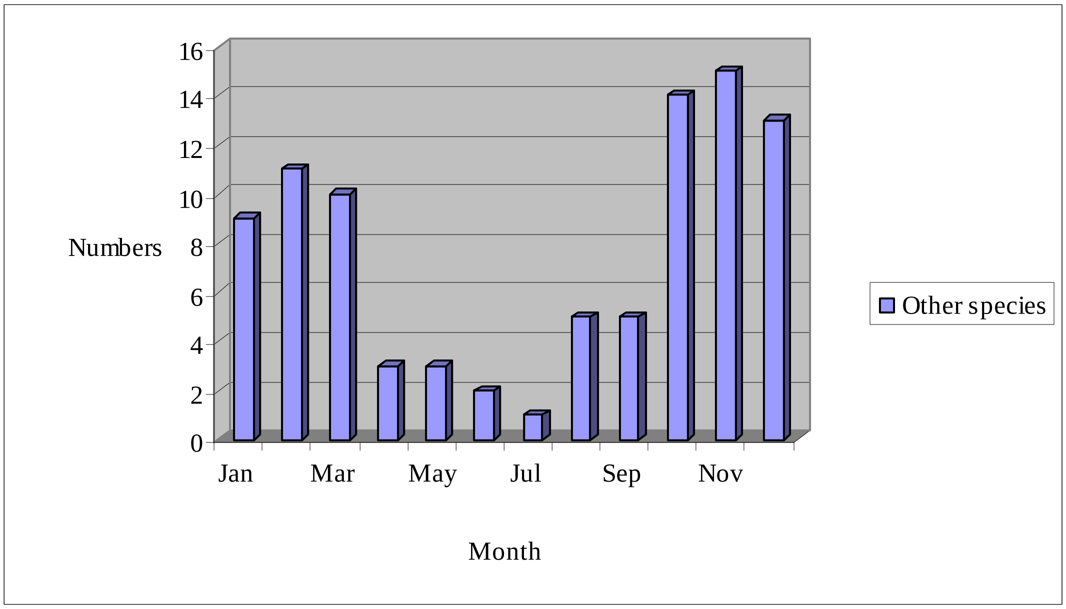


Figure 43b. Graph illustrating the comparison of less abundant species collected monthly inside the N'washitshumbe enclosure site in the absence of *Mastomys*

The total percentages recorded inside the enclosure site during the study period were: *Mastomys* spp. (82.18%), *Saccostomys campestris* (10.4%), *Tatera leucogaster* (4.9%), *Lemniscomys rosalia* (0.48%), *Aethomys chrysophilus* (0.68%), *Mus minutoides* (1.19%), *Paraxerus cepapi* (0.17%) and *Graphiurus murinus* (0.17%). Species representative percentage of overall animals collected inside the enclosure site was 25.31% during the survey. Of all *Mastomys* spp. individuals captured during the survey, 25.93% were present inside the enclosure. The percentages for the other species are 21.63% for *Saccostomys campestris*, 21.7% for *Tatera leucogaster*, 15.62% for *Lemniscomys rosalia*, 33.33% for *Aethomys chrysophilus*, 58.33% for *Mus minutoides*, 100% for *Graphiurus murinus* and 100% for *Paraxerus cepapi*.

Results indicated that *M. minutoides*, *G. murinus* and *P. cepapi* occurred exclusively or in higher densities inside the enclosure site than on the outside and in the fire break.

8.5 Small mammal records from the sodic site inside the N'washitshumbe enclosure site

8.5.1 Introduction

Data were recorded from a sodic site inside the enclosure referred to as transect C3. This site was chosen as a representative of a sodic area on the bottom slope of the catena. This site was not compared with other such sites outside the enclosure but rather as a stand alone in the survey area. This area was represented by sparse grass cover in an absence of woody plants. The frequency of rodent captures were significant lower (n = 136) in the sodic area when compared with other transect lines at the site.

8.5.2 Sodic site trapping results recorded at the N'washitshumbe enclosure site

Trapping success varied seasonally and with climatic conditions. Winter months harbored close to 60% success rate due to a population explosion of *Mastomys* spp. Trapping success dropped (> 75%) over summer months. This could be a result of food being more readily available. Four species were collected at the sodic site: *Mastomys natalensis; Mastomys coucha*, *Saccostomys campestris* and *Tatera leucogaster Mastomys* was recorded as the dominant genus in the sodic area (n = 104). No species were recorded exclusively in the sodic area. This appeared to be as a result of insufficient cover and possibly poor food availability.

Fluctuations in species diversity occurred monthly following the trend with *Mastomys* being dominant between May and August. There appeared to be no relationship with *Mastomys* spp. at the site.

The following frequencies were recorded in the sodic site during the study period: *Mastomys* spp. (n = 104), *Saccostomys campestris* (n = 23) and *Tatera leucogaster* (n = 9). No records of *Lemniscomys rosalia, Mus minutoides, Aethomys chrysophilus, Steatomys pratensis, Graphiurus murinus, Crocidura hirta* or *Paraxerus cepapi* were recorded in the sodic site. This is a clear indication of the dependency of small mammals for sufficient cover for protection from predators. The total number of species excluding *Mastomys* amounted to 32 specimens. The total species percentages recorded in the sodic area during the study period were: *Mastomys* spp. (76.47%), *Saccostomys campestris* (16.91%) and *Tatera leucogaster* (6.62%). Species representative percentage of overall animals collected in the sodic area was 5.85% during the survey. Of all *Mastomys* spp. individuals captured during the survey, 5.54% were present on the sodic site. The percentages for the other species are 8.16% for *Saccostomys campestris* and 8.49% for *Tatera leucogaster*.

Results indicated that no species occurred in higher densities in the sodic area compared with other transects inside or outside to enclosure site. There appeared to be a generally delayed increase in *Mastomys* numbers after rainfall at the enclosure site (Fig. 44a.).

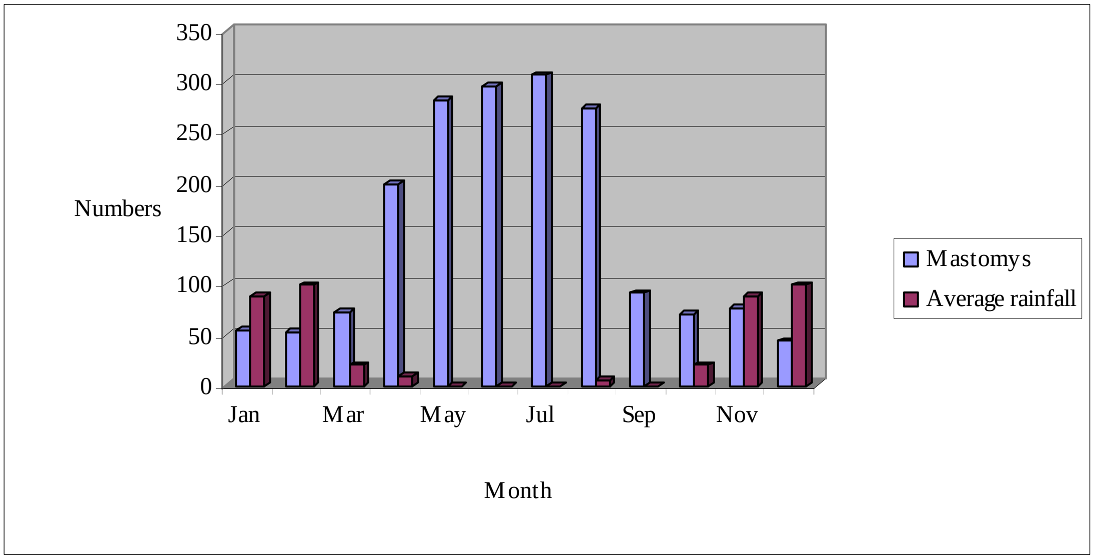


Figure 44a. Correlation between average rainfall and *Mastomys* numbers collected at the N’washitshumbe enclosure site.

Less dominant species appeared to be a synchronized with rainfall patterns at the enclosure site (Fig. 44b.).

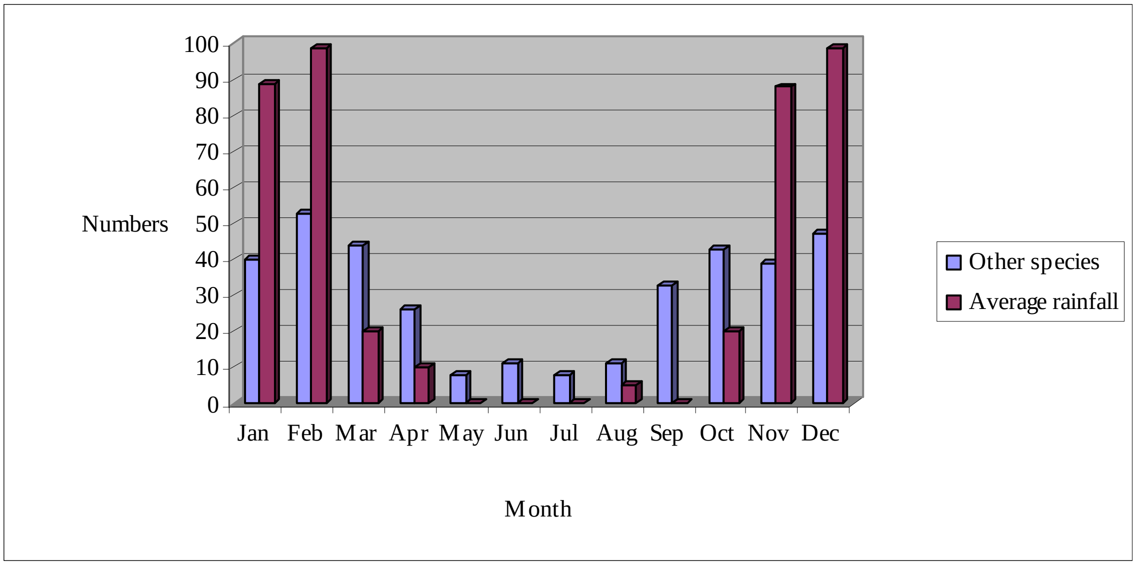


Figure 44b. Correlation between average rainfall and less abundant species collected at the N’washitshumbe enclosure site.

This conclusion was further supported by results indicating that during these surveys, small mammal assemblages inside, outside and in the fire break, were similar in species richness. There appeared to be a significant difference with regards abundance.

CHAPTER 9

STATISTICAL ANALYSIS OF BODY MEASUREMENT

9.1 Introduction

9.2 *Mastomys* spp. body measurements recorded at the N'washitshumbe enclosure site (Table 10)

Table 10. Means ($\bar{x}$) of total *Mastomys* spp. body measurements recorded at the N'washitshumbe enclosure site.

Variable	N	Mean	Std Dev	Minimum	Maximum
Tail (mm)	1071	8.3386461	1.3448096	1.4	110.2
Ear (mm)	1071	14.277078	4.1403534	4.09	19.55
Foot (mm)	1072	20.8807	5.889577	5	150
Total Length (mm)	1071	18.500598	3.5074088	8.5	111
Mass (g)	1072	29.746409	10.869434	4	68

9.2.1 *Mastomys* tail analysis:

Differences in environmental conditions may result in significant differences in the lengths of the tails of *Mastomys*. The influence of grid, place and climate within the study area on the length of *Mastomys* tails was investigated using analysis of variance

(ANOVA). Data on specimens collected under different climatic conditions were recorded and divided according to rainfall and temperature. Four categories were identified: cold and dry conditions, cold and wet conditions, hot and dry conditions and hot and wet conditions. (Table 11).

Table 11. Analysis of variance of the influence of different environmental conditions on the length of *Mastomys* tails.

Source	DF	F Value	Pr > F
Grid	2	51.35	<.0001
Place	3	2.56	0.5286
Grid* Place	3	0.74	0.5286
Climate	3	7.19	<.0001

The result of the analysis indicated that grid and climate are statistically significant at 5 % level.

Pair wise comparisons of grid levels using Scheffe’s test indicate that grid C differed significantly ($p<0.05$) form the other two grids with regard to the length of *Mastomys* tail (Table 12).

Table 12. Mean ($\bar{x}$) tail length in relation to grid position at the N'washitshumbe enclosure site.

Grid	N	Mean	Std Dev
A	346	8.13439306^a	1.25548157
B	317	7.95555205^a	1.14761976
C	278	8.92582734^b	1.3747527

* Means ($\bar{x}$) with different superscript differ significantly at 5% level

Post hoc pairwise comparisons using Scheffe's test indicated that the tail lengths of animals caught during hot and dry conditions differed significantly($p<0.05$) to those caught during other climatic conditions (Table 13). This could be as a result of a larger number of adult animals being recorded during hot and dry periods.

Table 13. Mean ($\bar{x}$) tail length in relation to climatic condition at the N'washitshumbe enclosure site.

Climate	N	Mean	Std Dev
Cold and Dry	123	8.14813008^a	1.10642487
Cold and Wet	273	8.43567766^a	1.37472123
Hot and Dry	246	8.08780488^b	1.26391587
Hot and Wet	299	8.43822742^a	1.3709008

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to climatic conditions

The expectation was that place would have a significant influence as different management practices result in variation in vegetation structure inside the enclosure opposed to the outside. Vegetation surveys indicated significant differences in vegetation structure at grid C due to the area being predominantly a vlei. Differences in *Mastomys* tail length at this site appeared to be the result of a large percentage of adult animals recorded at this site. There appeared to be movement of adults animals to vlei areas in winter as a result of decreased cover in other grids.

This result is influenced by a greater number of juvenile and sub-adult animals collected over the winter months of the year. A large number of young are born during hot and wet months becoming active later in the year resulting in higher capture success rate.

9.2.2 *Mastomys* ear analysis:

Differences in environmental conditions may result in significant differences in the length of the ears of *Mastomys*. The influence of grid, place and climate within the study area on *Mastomys* ears was investigated using analysis of variance (ANOVA) (Table 14).

Table 14. Analysis of variance of the influence of different environmental conditions on the length of *Mastomys* ears.

Source	DF	F Value	Pr > F
Grid	2	0.77	0.4614
Place	3	1.15	0.3262
Grid* Place	3	0.93	0.424
Climate	3	2.34	0.0719

Pair wise comparisons of grid, place, grid* place and climate using Scheffe's test was used to analyse these variables. Results indicated that there was no significance ($p>0.05$) between these variables with regard to the length of *Mastomys* ears.

9.2.3 *Mastomys* foot analysis:

Differences in environmental conditions may result in significant differences in the length of the hind feet of *Mastomys*. The influence of grid, place and climate within the study area on *Mastomys* feet was investigated using analysis of variance (ANOVA) (Table 15).

Table 15. Analysis of variance of the influence of different environmental conditions on the length of *Mastomys* feet.

Source	DF	F Value	Pr > F
Grid	2	1.65	0.1931
Place	3	0.93	0.4248
Grid* Place	3	1.05	0.3711
Climate	3	2.66	0.0468

Pair wise comparisons of grid, place, grid* place and climate using Scheffe’s test was used to analyse these variables. Results indicated that there was no significance (p>0.05) between these variables with regard to the length of *Mastomys* feet.

9.2.4 *Mastomys* total body length analysis:

Differences in environmental conditions may result in significant differences in the total body length of *Mastomys*. The influence of grid, place and climate within the study area on *Mastomys* total length was investigated using analysis of variance (ANOVA) (Table 16).

Table 16. Analysis of variance of the influence of different environmental conditions on the length of *Mastomys* total body length.

Source	DF	F Value	Pr > F
Grid	2	8.85	0.0002
Place	3	1.13	0.3340
Grid* Place	3	0.38	0.7650
Climate	3	6.62	0.0002

The results of the analysis indicate that grid and climate are statistically significant at 5 % level. The expectation was that place would have been significantly different as different management practices result in variation in vegetation structure inside opposed to outside the enclosure (Table 17).

Table 17. Means ($\bar{x}$) total body length in relation to grid position at the N'washitshumbe enclosure site.

Grid	N	Mean	Std Dev
A	347	18.3089625^a	4.39791682
B	317	18.0619243^a	3.73128619
C	277	19.0642599^b	2.25399498

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to grid position

Data on specimens collected under different climatic conditions were recorded and divided according to rainfall and temperature. Four categories were identified: cold and dry conditions, cold and wet conditions, hot and dry conditions and hot and wet conditions. Post hoc pairwise comparisons using Scheffe's test indicated that the total body length of animals caught during hot and dry conditions differed significantly ($p<0.05$) from animals caught during hot and wet conditions as well as those caught during other climatic conditions (Table 18).

Table 18. Means ($\bar{x}$) total body length in relation to climatic condition at the N'washitshumbe enclosure site.

Climate	N	Mean	Std Dev
Cold and Dry	123	18.3512195^{a}	1.83210735
Cold and Wet	273	18.3039927^{a}	1.37472123
Hot and Dry	246	17.8847154^{b}	2.09175966
Hot and Wet	299	19.0829766^{b}	4.74654005

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to climatic conditions

This result is influenced by a greater number of juveniles and sub-adult animals collected over the winter months of the year. A large number of young were born during the hot and wet months becoming active later in the year which resulted in a higher capture success rate of younger animals during hot and dry periods.

No significant (p>0.05) relationship was recorded between place and grid* place for *Mastomys* total body length.

9.2.5 *Mastomys* mass analysis:

Differences in environmental conditions may result in significant differences in the mass of *Mastomys*. The influence of grid, place and climate within the study area on *Mastomys* mass was investigated using analysis of variance (ANOVA) (Table 19).

Table 19. Analysis of variance of the influence of different environmental conditions on the length of *Mastomys* mass.

Source	DF	F Value	Pr > F
Grid	2	6.53	0.0015
Place	3	3.25	0.0212
Grid* Place	3	0.29	0.8360
Climate	3	30.27	< 0.0001

Pair wise comparisons of grid levels using Scheffe's test was used to analyse these variables. Results indicated that grid C and A differed significantly (p<0.05) from the other two grids with regard to *Mastomys* mass (Table 20).

Table 20. Means ($\bar{x}$) mass in relation to grid position at the N'washitshumbe enclosure site

Grid	N	Mean	Std Dev
A	348	45.8364943^{b}	10.6459916
B	316	43.0797152^{a}	11.1930631
C	278	42.7476978^{b}	9.6942670

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to grid position

Vegetation surveys indicate significant differences in vegetation structure at grid C due to the area being predominantly a vlei. Differences in *Mastomys* mass at this site appeared to be the result of a large percentage of adult animals recorded there.

Differences in place may result in significant differences in the mass of *Mastomys*. The influence of grid, place and climate within the study area on *Mastomys* mass was investigated using analysis of variance (ANOVA) (Table 21).

Table 21. Means ($\bar{x}$) mass in relation to transect position at the N'washitshumbe enclosure site

Level of place	N	Mean	Std Dev
Around	254	44.9133858^{a}	11.1049778
Inside	264	43.6507576^{a}	9.9230499
Outside	366	44.3271858^{a}	10.9428044
Sodic	58	39.5275862^{b}	8.8405524

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to grid position

Differences in environmental conditions may result in significant differences in the mass of *Mastomys*. The influence of grid, place and climate within the study area on *Mastomys* mass was investigated using analysis of variance (ANOVA) (Table 22).

Table 22. Means ($\bar{x}$) mass in relation to climatic condition at the N'washitshumbe enclosure site

Climate	N	Mean	Std Dev
Cold and Dry	122	47.5245902^{a}	9.9330096
Cold and Wet	274	42.2007299^{b}	10.4418782
Hot and Dry	247	40.2265182^{b}	8.1587551
Hot and Wet	299	47.3284281^{a}	11.4970828

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to climatic conditions

Post hoc pairwise comparisons using Scheffe's test indicate that mass of animals caught during hot and dry conditions differed significantly($p<0.05$) to those caught during other climatic conditions (Table 22)

9.3 Statistical analysis of *Saccostomys campestris* body measurements recorded at the N'washitshumbe enclosure site (Table 23)

Table 23. Means ($\bar{x}$) of total *Saccostomys campestris* variables recorded at N'washitshumbe enclosure site.

Variable	N	Mean	Std Dev	Minimum	Maximum
Tail (mm)	120	3.829833	3.362554	2.3	4.6
Ear (mm)	120	13.992	1.374938	11.3	17.44
Foot (mm)	121	19.42281	1.171745	16.08	22.39
Total Length (mm)	120	16.08892	1.7629	12	19.7
Mass (g)	121	50.82893	16.26549	20	85

9.3.1 *S. campestris* tail analysis:

Differences in environmental conditions may result in significant differences in the tail lengths *Saccostomys*. The influence of grid, place and climate within the study area on *Saccostomys* tails was investigated using analysis of variance (ANOVA) (Table 24)

Table 24. Analysis of variance of the influence of different environmental conditions on the length of *Saccostomys* tails.

Source	DF	F Value	Pr > F
Grid	2	0.88	0.4166
Place	3	1.77	0.1569
Grid* Place	3	1.06	0.3692
Climate	2	3.27	0.0421

Pair wise comparisons of grid, place, grid* place and climate using Scheffe's test was used to analyse these variables. Results indicate that there is no significance (p>0.05) between these variables with regard to the tail length of *S. campestris*.

9.3.2 *S. campestris* ear analysis:

Differences in environmental conditions may result in significant differences in the length of *S. campestris* ears. The influence of grid, place and climate within the study area on *S. campestris* ear was investigated using analysis of variance (ANOVA) (Table 25).

Table 25. Result Analysis of variance of the influence of different environmental conditions on the length of *S. campestris* ears.

Source	DF	F Value	Pr > F
Grid	2	1.01	0.3677
Place	3	0.96	0.4161
Grid* Place	3	0.58	0.6312
Climate	2	7.39	0.0010

Pair wise comparisons of grid, place and grid* place using Scheffe's test was used to analyse these variables. Results indicate that there is no significance (p>0.05) between these variables with regard to ear length of *S. campestris.*

Data on specimens collected under different climatic conditions were recorded and divided according to rainfall and temperature. Four categories were identified, cold and dry conditions, cold and wet conditions, hot and dry conditions and hot and wet conditions. Post hoc pairwise comparisons using Scheffe's test indicate that ear lengths of animals caught during hot and dry conditions differed significantly(p<0.05) to those caught during other climatic conditions (Table 26).

Table 26. Means ($\bar{x}$) ear length in relation to climatic condition at the N'washitshumbe enclosure site

Climate	N	Mean	Std Dev
Cold and Wet	21	13.1890476^a	1.25165452
Hot and Dry	27	13.8044444^a	1.52030193
Hot and Wet	63	14.4149206^b	1.21575129

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to climatic conditions

This result is influenced by a greater number of adult animals collected over the summer months of the year. A large number of young are born in late summer months resulting in young being collected in winter.

9.3.3 *S. campestris* foot analysis:

Differences in environmental conditions may result in significant differences in the length of *Saccostomys* feet. The influence of grid, place and climate within the study area on *Saccostomys* hind feet was investigated using analysis of variance (ANOVA) (Table 27).

Table 27. Analysis of variance of the influence of different environmental conditions on the length of *Saccostomys* feet.

Source	DF	F Value	Pr > F
Grid	2	0.86	0.4271
Place	3	0.91	0.4413
Grid* Place	3	0.12	0.9494
Climate	2	5.71	0.0045

Pair wise comparisons of grid, place and grid* place using Scheffe's test was used to analyse these variables. Results indicate that there is no significance ($p>0.05$) between these variables with regard to the feet lengths of *S. campestris*.

Post hoc pairwise comparisons using Scheffe's test indicate that feet lengths of animals caught during hot and dry conditions differed significantly($p<0.05$) to those caught during other climatic conditions (Table 28)

Table 28. Means ($\bar{x}$) feet length in relation to climatic condition at the N'washitshumbe enclosure site

Climate	N	Mean	Std Dev
Cold and Wet	21	13.1890476^{a}	1.25165452
Hot and Dry	27	13.8044444^{a}	1.52030193
Hot and Wet	63	14.4149206^{b}	1.21575129

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to climatic conditions.

9.3.4 *S. campestris* total body length analysis:

Differences in environmental conditions may result in significant differences in the total body length of *Saccostomys*. The influence of grid, place and climate within the study area on *S. campestris* total length was investigated using analysis of variance (ANOVA) (Table 29).

Table 29. Analysis of variance of the influence of different environmental conditions on the length of total body length

Source	DF	F Value	Pr > F
Grid	2	0.05	0.9527
Place	3	0.82	0.4848
Grid* Place	3	0.35	0.7870
Climate	2	16.74	< .0001

Post hoc pairwise comparisons using Scheffe's test indicate that total body lengths of animals caught during cold and wet conditions differed significantly ($p<0.05$) to those caught during other climatic conditions (Table 30).

Table 30. Means ($\bar{x}$) total body length in relation to climatic condition at the N'washitshumbe enclosure site

Climate	N	Mean	Std Dev
Cold and Wet	21	14.4000000^a	1.59185426
Hot and Dry	27	15.9111111^b	1.84752086
Hot and Wet	63	16.7153968^b	1.47350780

***** Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to climatic conditions.

This result is influenced by a greater number of juvenile and sub-adult animals collected at the end of summer.

9.3.5 *S. campestris* mass analysis:

Differences in environmental conditions may result in significant differences in the mass of *Saccostomys*. The influence of grid, place and climate within the study area on *Saccostomys* mass was investigated using analysis of variance (ANOVA) (Table 31).

Table 31. Analysis of variance of the influence of different environmental conditions on the length of *Saccostomys* mass.

Source	DF	F Value	Pr > F
Grid	2	0.78	0.4606
Place	3	1.14	0.3364
Grid* Place	3	1.16	0.3295
Climate	2	14.33	< .0001

Post hoc pairwise comparisons using Scheffe's test indicate that the mass of animals caught during the hot and wet conditions differed significantly ($p<0.05$) from those caught during other climatic conditions (Table 32).

Table 32. Means ($\bar{x}$) mass in relation to climatic condition at the N'washitshumbe enclosure site

Climate	N	Mean	Std Dev
Cold and Wet	21	50.7619048_a	12.9611140
Hot and Dry	27	65.7407407_b	17.6909203
Hot and Wet	63	70.7031250_b	14.2435501

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to climatic conditions

This result is influenced by greater food availability in the wet summer months which resulted in a higher average body weight

9.4 Statistical analysis of *Tatera leucogaster* body measurements recorded at the N’washitshumbe enclosure site (Table 33)

Table 33. Means ($\bar{x}$) of total *Tatera* body measurements recorded at N'washitshumbe enclosure site

Variable	N	Mean	Std Dev	Minimum	Maximum
Tail (mm)	60	13.9475	3.056438	2.4	28.9
Ear (mm)	60	18.265	2.078907	10.13	21.63
Foot (mm)	60	32.9405	1.576047	29.16	36.49
Total Length (mm)	60	26.73	3.162347	13.9	32
Mass (g)	59	63.22034	15.06431	22	90

9.4.1 *T. leucogaster* tail analysis:

Differences in environmental conditions may result in significant differences in the length of the tails of *Tatera*. The influence of grid, place and climate within the study area on *Tatera* tail was investigated using analysis of variance (ANOVA) (Table 34).

Table 34. Analysis of variance of the influence of different environmental conditions on the length of *Tatera* tails.

Source	DF	F Value	Pr > F
Grid	2	1.51	0.2322
Place	3	0.24	0.8662
Grid* Place	2	0.60	0.5509
Climate	3	0.81	0.4945

Pair wise comparisons of grid, place, grid* place and climate using Scheffe's test was used to analyse these variables. Results indicate that there is no significance (p>0.05) difference between these variables with regard to the length of *T. leucogaster* tails.

9.4.2 *T. leucogaster* ear analysis

Differences in environmental conditions may result in significant differences in the length of *Tatera* ears. The influence of grid, place and climate within the study area on *Tatera* ear was investigated using analysis of variance (ANOVA) (Table 35).

Table 35. Analysis of variance of the influence of different environmental conditions on the length of *Tatera* ears.

Source	DF	F Value	Pr > F
Grid	2	0.14	0.8695
Place	3	0.64	0.5956
Grid* Place	2	0.12	0.8903
Climate	3	0.85	0.4758

Pair wise comparisons of grid, place, grid* place and climate using Scheffe's test was used to analyse these variables. Results indicate that there is no significance (p>0.05) between these variables with regard to the length of *T. leucogaster* ear.

9.4.3 *T. leucogaster* foot analysis

Differences in environmental conditions may result in significant differences in the lengths of the feet of *Tatera*. The influence of grid, place and climate within the study area on *T. leucogaster* feet was investigated using analysis of variance (ANOVA) (Table 36).

Table 36. Analysis of variance of the influence of different environmental conditions on the length of *Tatera* feet.

Source	DF	F Value	Pr > F
Grid	2	1.37	0.2638
Place	3	2.69	0.0568
Grid* Place	2	1.74	0.1856
Climate	3	0.38	0.7699

Pair wise comparisons of grid, place, grid* place and climate using Scheffe's test was used to analyse these variables. Results indicate that there is no significance (p>0.05) between these variables with regard to the length of *Tatera* feet.

9.4.4 *T. leucogaster* total body length analysis

Differences in environmental conditions may result in significant differences in the total body lengths of *Tatera*. The influence of grid, place and climate within the study area on the total body length was investigated using analysis of variance (ANOVA) (Table 37).

Table 37. Analysis of variance of the influence of different environmental conditions on the length of *Tatera* total body length.

Source	DF	F Value	Pr > F
Grid	2	0.60	0.5547
Place	3	0.19	0.9017
Grid* Place	2	2.82	0.0694
Climate	3	0.61	0.6141

Pair wise comparisons of grid, place, grid* place and climate using Scheffe's test was used to analyse these variables. Results indicate that there is no significance (p>0.05) between these variables with regard to the length of *T. leucogaster* total body length.

9.4.5 *T. leucogaster* mass analysis

Differences in environmental conditions may result in significant differences in the mass of *Tatera*. The influence of grid, place and climate within the study area on *Tatera* mass was investigated using analysis of variance (ANOVA) (Table 38).

Table 38. Analysis of variance of the influence of different environmental conditions on the length of *Tatera* mass.

Source	DF	F Value	Pr > F
Grid	2	2.30	0.1112
Place	3	0.37	0.7735
Grid* Place	2	0.67	0.5149
Climate	3	4.38	0.0084

Pair wise comparisons of grid, place and grid* place using Scheffe's test was used to analyse these variables. Results indicate that there is no significance ($p>0.05$) between these variables with regard to the mass of *T. leucogaster*.

Post hoc pairwise comparisons using Scheffe's test indicate that the mass of animals caught during hot and dry conditions differed significantly($p<0.05$) to those caught during hot and wet conditions (Table 39).

Table 39. Means ($\bar{x}$) mass in relation to climatic condition at the N'washitshumbe enclosure site

Climate	N	Mean	Std Dev
Cold and Dry	3	81.6666667^{a}	5.8594653
Cold and Wet	9	72.1111111^{b}	15.8149016
Hot and Dry	9	65.2222222^{b}	10.6978710
Hot and Wet	37	82.9729730^{a}	14.1881924

* Means ($\bar{x}$) with different superscript differ significantly at 5% level in relation to climatic conditions.

This result is influenced by a greater number of adult animals collected during the wet conditions. A large number of young were born during hot and wet months becoming active later in the year which resulted in a higher capture success rate of young after the wet season.

Insufficient numbers of *Lemniscomys rosalia*, *Mus minutoides*, *Aethomys chrysophilus*, *Graphiurus murinus*, *Steatomys pratensis*, *Crocidura hirta* and *Paraxerus cepapi* were collected to conduct analysis of variance (ANOVA).

CHAPTER 10

ASSOCIATION OF PREDICTED PROBABLITITES AND OBSERVED RESPONSES OF RODENTS TO VEGETATION COMMUNITUES AT THE N'WASHITSHUMBE ENCLOSURE SITE

10.1 Introduction

Differences in environmental conditions and vegetation communities may result in significant differences in the species richness and abundance of small mammals in an area. The influence of climate, grid, transect, vegetation community and the interactions between these variables on small mammal assemblages was investigated using logistic regression. These influences increasing the odds of capturing *Mastomys* at the enclosure site were considered.

10.2. Vegetation communities favoured by *Mastomys* spp. (species 1) present at the enclosure site.

Vegetation community vs. climate ($p < 0001$) as well as transect ($p < 000.1$) was statistically significant for *Mastomys* (Table 40).

Table 40. Logistic regression for *Mastomys* presence probability.

Effect	DF	Chi-Square	Pr > ChiSq
Vegetation Community x Climate	51	576.3829	<.0001
Transect	2	61.4831	<.0001

Thirteen plant communities where identified at the study site (Chapter 5). Each community was indexed with *Mastomys* numbers and the analysis indicates certain vegetation communities are significant using a logistic regression (Table 41). The amount (%) in which it increases the odds in given by index values, calculated by the procedure. The index values are presented in Table 41. An index value of 1 has no affect on the odds, a value smaller than 1 decrease the odds, while a value lager than 1 increase the odds.

Table 41. Analysis of maximum likelihood estimates for *Mastomys* spp.

Effect	Level	Index
Inter	.	0.3985
Vegetation community no. x Climate	1 x hot & wet	0.1787
Vegetation community no. x Climate	1 x cold & wet	0.9066
Vegetation community no. x Climate	1 x hot & dry	0.4843
Vegetation community no. x Climate	1 x cold & dry	0.9799
Vegetation community no. x Climate	2 x hot & wet	0.1661
Vegetation community no. x Climate	3 x hot & dry	1.0432
Vegetation community no. x Climate	**3 x cold & dry**	**8.753**
Vegetation community no. x Climate	4 x hot & wet	0.4761
Vegetation community no. x Climate	4 x cold & dry	4.2888
Vegetation community no. x Climate	5 x hot & wet	0.3582

Vegetation community no. x Climate	5 x cold & wet	1.41
Vegetation community no. x Climate	5 x hot & dry	0.8839
Vegetation community no. x Climate	**5 x cold & dry**	**12.3357**
Vegetation community no. x Climate	6 x hot & dry	0.8682
Vegetation community no. x Climate	6 x cold & dry	2.6958
Vegetation community no. x Climate	7 x hot & wet	0.2646
Vegetation community no. x Climate	7 x cold & wet	0.8527
Vegetation community no. x Climate	7 x hot & dry	0.3900
Vegetation community no. x Climate	7 x cold & dry	1.3066
Vegetation community no. x Climate	8 x hot & dry	0.9111
Vegetation community no. x Climate	**8 x cold & dry**	**29.4708**
Vegetation community no. x Climate	9 x hot & wet	0.6234
Vegetation community no. x Climate	**9 x cold & dry**	**13.3952**
Vegetation community no. x Climate	10 x hot & wet	0.4856
Vegetation community no. x Climate	10 x hot & dry	0.8664
Vegetation community no. x Climate	**10 x cold & dry**	**11.4181**
Vegetation community no. x Climate	11 x hot & wet	0.3426
Vegetation community no. x Climate	11 x cold & wet	1.2236
Vegetation community no. x Climate	11 x cold & dry	0.7593
Vegetation community no. x Climate	12 x hot & wet	0.1535
Vegetation community no. x Climate	12 x cold & wet	0.8343
Vegetation community no. x Climate	12 x cold & dry	2.4325
Vegetation community no. x Climate	13 x hot & wet	0.3115
Vegetation community no. x Climate	13 x cold & dry	2.2273
Transect no.	1	1.9205
Transect no.	2	1.024
Transect no.	3	0.5086

The following variable indexes indicate a maximum probability of capturing *Mastomys* at the enclosure site.

The assumptions were that a greater number of rodents would occur in areas with a higher basal cover. Surveys indicated significant differences in the number of *Mastomys* present in association with specific vegetation communities. This is largely due to the amount of cover available as well as the quality of the grass seed produced

Mastomys appear to be more readily captured during cold and dry climatic conditions. Five vegetation communities are favoured by *Mastomys* at the N'washitshumbe enclosure site. These include the *Panicum coloratum* - *Setaria incrassata* community, Panicum *maximum* - *Panicum coloratum* community, *Cenchrus ciliaris* - *Colophospermum mopane* community, *Setaria incrassata* – *Dalbergia melanoxylon* community and the *Panicum maximum* - *Urochloa mosambicensis* community.

Mastomys appear to be less readily captured during hot and wet and to a lesser extent hot and dry climatic conditions. Seven vegetation communities are not favoured by *Mastomys* during these hot and wet conditions at the enclosure site. These include the *Schmidtia pappophoroides* - *Heteropogon contortus* community, *Schmidtia pappophoroides* - *Setaria incrassate* community, *Panicum maximum* - *Panicum coloratum* community, *Panicum coloratum* - *Colophospermum mopane* community, Sporobolus *ioclados* - *Sporobolus nitens* community, *Cyperus textilis* - *Andropogon* vlei community and the *Sporobolus pyramidalis* - *Andropogon* vlei community.

Climatic conditions clearly have a strong influence on the probability index with regards to *Mastomys* abundance. There is a strong correlation with these results and the population explosion which occurred at the site over the winter period.

Interestingly, *Mastomys* appear to select vegetation communities with grass plants whom produce nutritious seeds. *P. coloratum*, *P. maximum* and *C. ciliaris* are recognized in megaherbivore terms as highly palatable species. Megaherbivores are known to select areas as a result of palatable grasses, which also appears true for small mammals

10.3 Vegetation communities favoured by other all other species of rodent present at the enclosure site

Climate (p < 0.0155), transect (p < 000.5) and vegetation community (p < 0001) were statistically significant for small mammal species other than *Mastomys* (Table 42). Interactions between the variables could not be analyzed due to the low abundance of these species.

Table 42. Logistic regression for small mammal species probability other than *Mastomys*

Effect	DF	Chi-Square	Pr > ChiSq
Climate	3	10.3910	0.0155
Transect	2	15.1522	0.0005
Vegetation Community	12	53.7446	<.0001

The index values are presented in Table 43. An index value of 1 has no affect on the odds, a value smaller than 1 decrease the odds, while a value lager than 1 increase the odds.

Table 43. Analysis of maximum likelihood estimates for small mammal species other than *Mastomys*.

Effect	Level	Index
Inter	.	0.03699
Climate	Cold & dry	0.65968
Climate	Cold & wet	1.03603
Climate	Hot & dry	1.05622
Climate	**Hot & wet**	**1.38528**
Transect	**1**	**1.99053**
Transect	2	0.86011
Transect	2	0.58409
Vegetation community no.	1	0.78380
Vegetation community no.	**2**	**1.34380**
Vegetation community no.	**3**	**1.68236**
Vegetation community no.	4	0.46529
Vegetation community no.	**5**	**1.73916**
Vegetation community no.	**6**	**1.36957**
Vegetation community no.	7	0.66952
Vegetation community no.	8	0.77090
Vegetation community no.	**9**	**1.56440**
Vegetation community no.	**10**	**1.63853**
Vegetation community no.	11	1.16311
Vegetation community no.	12	0.55622
Vegetation community no.	13	0.59494

The following variable indexes indicate a maximum probability of capturing other species at the enclosure site.

Other species appear to be more readily captured during hot and wet climatic conditions. Transects situated outside the enclosure site were favoured by these species. Six vegetation communities are favoured by species other than *Mastomys* at the N'washitshumbe enclosure site. These include the *Schmidtia pappophoroides* - *Setaria incrassate* community, *Panicum coloratum* - *Setaria incrassata* community, *Panicum maximum* - *Panicum coloratum* community, *Aristida bipartita* - *Colophospermum mopane* community, *Setaria incrassata* – *Dalbergia melanoxylon* community and *Panicum maximum* - *Urochloa mosambicensis* community. Interestingly, these species also generally favour communities with highly palatable grasses.

Other species appear to be less readily captured during cold and dry conditions, inversely related to *Mastomys.* Four vegetation communities are not favoured by these species at the enclosure site. These include the *Schmidtia pappophoroides* - *Urochloa mosambicensis* community, *Panicum coloratum* - *Colophospermum mopane* community, *Cyperus textilis* - *Andropogon* vlei community and *Sporobolus pyramidalis* - *Andropogon* vlei community.

Interestingly, the probability of collecting a species other than *Mastomys* in the *Panicum coloratum* - *Colophospermum mopane* community is unlikely, this could be as a result of high numbers of *Mastomys* in the community type. Generally, these species select similar plant communities to *Mastomys*.

Small mammals, both *Mastomys* and other species present at the enclosure site, appear to select habitat according to grass seed production and nutritive quality under correct climatic conditions.

CHAPTER 11

INFLUENCE OF FIRE ON SMALL MAMMAL POPULATIONS AT THE N'WASHITSHUMBE ENCLOSURE SITE

11.1 Introduction

The affect of fire on small mammal populations has been investigated as a limiting factor influencing population growth and migration. Fire is expected to have a devastating and immediate affect on dynamics and structure of small mammal populations. Current results however indicate that small mammals appear to be adapted to post-fire conditions, with some species even favouring such conditions. Several policies applicable to the conservation of rare antelope species in the Kruger National Park are outlined, one of which was the construction of enclosures that would not allow animals in or out (Joubert 1974). These enclosures were established to allow intensive scientific research of rare ungulate species, as well as acting as a breeding nucleus for the augmentation of free ranging herds. These areas are actively managed by limiting fire to the landscape by means of surrounding fire breaks. The occasional burning of vegetation is a natural ecological phenomenon, occurring often as a result of lightening (Komarek 1964). In the past, the area that is now known as the Kruger National Park were subjected to much indiscriminate burning, probably since the advent of early man. With the advent of man the incidence of burning probably increased with its use by man for his own ends, for example, to drive game towards hunters, to force game to immigrate into certain areas and to use it as a management tool. The result has been the more widespread appearance of “fire climaxes” in the vegetation (Tansley 1935). However, fire in the major vegetation biomes of forest and grassland are generally different (Daubenmire 1968a) both in terms of actual fire processes and ecological effects. These are summarized by Ahlgren & Ahlgren (1960) for forest fires and by Daubenmire (1968a) for grassland fires. The emphasis of this literature is on the effects of burning on vegetation (e.g. Hopkins 1965; Kucera & Koelling 1964), while comparing the effects of these fires on mammals are less well documented (Kern 1977). However, Kern (1977) provides a detailed analysis of the influence of fire on populations of small mammals in the KNP. Researchers in the KNP have for many years instigated the long term study of burning vegetation with the establishment of burning plots in the major vegetation units of the Park for research purposes (Brynard 1964).

Fire serves as a selection mechanism in savanna ecosystems by creating diversity in both time and space (Hugo 2004) with numerous potential ecological impacts related to frequency, intensity and seasonality. Fire brings about vegetation change by changing intensity, frequency (Jacobs 2001), duration and fire height (Trollope 1982). Fire intensity, a measure of energy released in fires, varies with fuel moisture content, wind and slope conditions (Jacobs 2001).

11.2 Affects of fire on small mammal populations at the N'washitshumbe enclosure site

Fire breaks surrounding the N'washitshumbe enclosure site are burnt annually and were burnt as part of the management plan for the area in July 2004. This burn was at the peak of a *Mastomys* spp. population explosion experienced in the area. Large numbers of *Mastomys* spp. were recorded before, during and after burning, one month later no immediate population decrease was found. According to Kern (1977) small mammal populations decrease two weeks after burning. This appears not to be the situation experienced at the N'washitshumbe enclosure site.

Trapping success differed insignificantly pre- and post burning. The months May, July and August harbored a capture success rate of over 80% of *Mastomys* spp. Trapping success decreased significantly (> 75%) in December, four months after the area was burnt. in July. The reason appeared to be the result of local movements to surrounding areas inside and outside the enclosure that were not burnt. According to Kern (1977) small scale immigration, mainly of adult animals, takes place with the migrant species being *Aethomys chrysophilus*, *Mastomys natalensis*, *Steatomys pratensis* and *Saccostomys campestris*. There is evidence from this study that when *Mastomys* spp. numbers decreased, *Tatera leucogaster* and *S. campestris* numbers increased and vice versa (Chapter 6). The *Mastomys* population increased over the winter period, while populations of *T. leucogaster* and *S. campestris* decreased dramatically. Kern (1977) recorded that populations recovered four months after burning when grass seeds had returned.

This eventual decrease could be a result of food being less readily available for large numbers of animals. Interestingly, other species of small mammal increased after *Mastomys* numbers decreased. This appears to be as a result of less interspecies competition. Seven species were recorded over this period at the enclosure site: *Mastomys natalensis*, *Mastomys coucha*, *Saccostomys campestris, Tatera leucogaster*, *Lemniscomys rosalia and Aethomys chrysophilus.*

The following four monthly frequencies recorded for *Mastomys* were: April 2004 (n = 199), May 2004 (n = 282), July 2004 (n = 306) and August (n = 274). These frequencies differed significantly from the total value of other species i.e. *S. campestris* and *T. leucogaster* recorded from the same area: April 2004 (n = 26), May 2004 (n = 8), July 2004 (n = 13) and August (n = 11) (Fig. 45.).

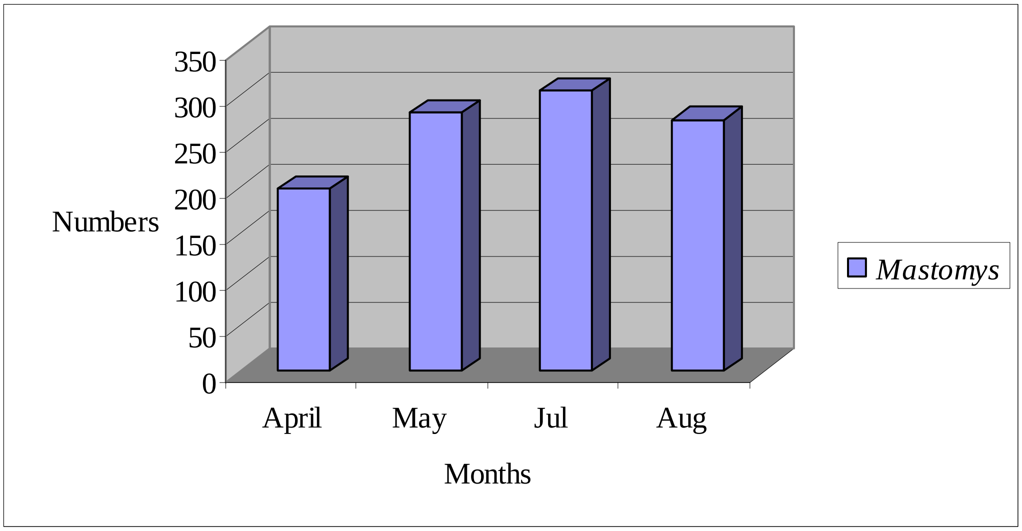


Figure 45. Graph illustrating the comparison of small mammal abundance before, during and a month after the early July burn at the N'washitshumbe enclosure site

Mastomys dominated the area during the pre-, burning and post fire impact. Direct fire inflicted mortality appeared not to occur in these small mammals assemblages. Eventual decreases in the population probably as a result of the lack of cover, increased predation, less available food and increased inter and intra species competition. With the eventual decrease of *Mastomys* numbers in December 2004 (n = 44) and April 2005 (n = 26), numbers of the other species increased significantly as a result of a change in habitat structure, due to limited rainfall during the post burning period and the absence of a dominant species. This resulted in an open, less densely vegetated habitat, favoured by *T. leucogaster*. *T. leucogaster* numbers increased significantly in April 2005 (n = 25).

S. campestris, *T. leucogaster* and *L. rosalia* contributed 16.58% of the total small mammal population recorded at the site. Similarly to Kern (1977), *Mastomys* spp. numbers decreased in summer months, particularly in April 2005 (39.6%). The small mammal response to burning is considered by Beck & Vogl (1972) not to be so much a response to fire as it was a reaction to a fire-altered habitat. Hence, the burning regime with the least detrimental (or most beneficial) effects on small mammals appears to be that of not burning at all. Since small mammals are important as prey species for the smaller carnivores and some birds of prey, both a variety and a high biomass are desirable. African Long-tailed shrike's (*Corvinella melanoleuca*) were witnessed attempting to catch and kill *Mastomys* released on a burnt area in the absence of suitable cover. Assuming, therefore that an annual burning treatment is continued in the fire breaks surrounding the N'washitshumbe enclosure site, it would appear to be satisfactory for maintaining small mammal species diversity, albeit to a certain extent at the cost of the highest population density. A burning program therefore promotes diversity opposed to high densities of a single species. There, however, should be enough areas of sufficient size which remain unburned and which can, therefore, act as refugia.

There were differences between the numbers of rodents occurring in bottomlands compared to the middle and uplands sections of the N'washitshumbe enclosure in winter. Rodent numbers decreased in these areas in summer where as numbers increased in the middle and upland sections as a result of dense cover returning to these areas as well as a greater diversity of grass species. Immigration could perhaps have been stimulated by burning that occurred in the upland areas earlier in the year or by the longer survival of green vegetation material in the damp conditions as a result of the vlei. Bellier (1967) found in a study in the Ivory Coast that at the end of the dry season many rodents moved temporarily into patches of unburned savanna located on damper grounds to the edge of the forest, and that such areas played important roles as seasonal refugia. These local movements reversed in the second year at the N'washitshumbe enclosure site during the post-burning period of the bottom lands in July 2004 (Fig. 46.).

Figure 46. A photograph illustrating a burn on transect C1 outside on the bottom-slope of the catena at the N'washitshumbe enclosure site

According to Kern (1977), winter populations are often markedly high as to suggest that immigrations occurred, possibly from surrounding burned areas. It is important to note that throughout the study the species composition is relatively stable. To summarize, total mammal density is not immediately affected by burning of the veld. Species richness may increase after burning due to a decrease in numbers of the dominant species found in the area. With regards to individual species, less dominant species appear to decrease in winter. This could be as a result of being out competed by the dominant species or as a result of the vast number of such dominant animals approaching the traps prior to the less common species still occurring at the enclosure. De Wit (1972) recorded a decline in *Mastomys* spp. in spring, when food supply was at it lowest. Both Smithers (1975) and Swanepoel (1972) noted that in times of food shortage *M. natalensis* gave way to other species.

There are obviously many factors which influence the habitat preference of small mammals, such as vegetation and food supply, soil type, cover and litter, but unfortunately little is known in detail of the ecology of certain small mammal species. There is no doubt however, that all habitat parameters should profitably be considered in order to explain the observed capture success described. Certain areas were not burnt totally, which could provide a certain degree of cover and food (Fig. 47.).

Figure 47. A photograph illustrating a partial burn on transect B2 outside the top-slope of the catena at the N'washitshumbe enclosure site

Kern (1977), states that the tree and shrub components of the vegetation are probably not important as the majority of cover and food is gained from the herbaceous layer. This appears to be true with the majority of species collected at the enclosure site, however more detailed studies are required with regards to arboreal species. *Paraxerus cepapi* and *Graphiurus murinus* appear dependent on woodland for their distribution and local movement. According to Kern (1977), *T. leucogaster* is largely restricted to areas of relatively low percentage of cover and little litter, however, this study indicates that although the species favors open areas, the species is not restricted to these areas. Kern (1977) reported *Crocidura hirta* to give preference to areas with a high percentage of cover and a thick litter layer. Unfortunately only one specimen of *C. hirta* was collected over the duration of this study. The specimen was collected in the vlei, representing a high percentage cover and a thick litter layer. The majority of rodents occurring in the area probably prefer areas with a good (70 – 90%) but not excessive (< 90%) cover but without a very thick, impeding litter layer. This is expected to influence and limit the numbers of small mammals occurring inside the enclosure in the absence of fire. Moribund grass builds up and appears to hamper rodent activity (Fig. 48.).

Figure 48. A photograph illustrating the dense moribund grass inside the N'washitshumbe enclosure site.

It appears that *T. leucogaster* flourishes in areas where the percentage of cover is less than 70% and that once the cover becomes too dense (i.e. > 70%) and there is sufficient litter to form a definite surface layer, this species declines. Records collected in the severe drought of April 2005 supported this assumption. *Mastomys* spp. represented the highest number of small mammals in all grids during winter. In general there are insufficient records of individual species from different burning treatments to allow any reasonable assessment of whether a particular burning treatment had any effect on reproduction activity. However, there was nothing in the records obtained to suggest that burning did affect reproductive activity.

Cook (1959) recorded an “immediate post-burn crash” in rodent populations in both bush and grass following a fire in California, and Lawrence (1966) noted an immediate post-burn reduction in numbers following a chaparral fire in the Sierra Nevada foothills of California. Neither Cook (1959) nor Lawrence (1966) found any evidence of emigration from burnt areas. Cook (1959) suggested that since seed food remained intact after the burn (though not necessarily the case at the N’washitshumbe enclosure study) cover or lack of it was probably important in the initial post-burn decline, and Lawrence (1966) suggested that removal of cover would expose the small mammal population to increased attack by predators. However, Neal (1970) discounted predation as being important since the fall in numbers was so rapid that a marked increase in numbers of predators would be called for to account for it, and no such increase in small carnivores or raptors was noticed.

Lawrence (1966) presents evidence that is unlikely to be any significant mortality during the actual fire since any animals that can escape down a burrow to a depth of a few inches would be safe. This is particularly so in an area such as the Kruger National Park where in general the fire burns along a narrow front which passes over any particular point such as a burrow in a very short space of time (one or two minutes at the most). A “cool burn” is therefore less intense than a “hot burn” and therefore has less impact on small mammal populations. The evidence of partially burnt grass at the N’washitshumbe enclosure site gave evidence of a cool burn. It seems therefore that reported drastic post-burn reductions in small mammal numbers probably relate to removal of cover, and in the case of certain species to emigration, rather than to the increased influence of predators or direct mortality during the fire (Kern 1977).

The distribution and post-burn movements of small mammals can be satisfactorily explained in terms of cover and litter preferences. Kern’s (1981) study tended to emphasize the effect of fire on small mammals during the first post-burn year and he showed that prior to burning, diversity was low but population numbers were high. After burning, the resident populations soon crashed, however, as soon as the vegetation began to recover, diversity increased with the arrival of pioneer species. Higher densities, however, did not return until the cover was once again reasonable, by the middle to end of the rainy season.

Results of this study indicated that rodents appeared not to favour moribund grass, and immigration from surrounding areas could have resulted in higher numbers recorded outside the enclosure site when compared with the inside. Results indicate that the occasional fire my not hamper small mammal assemblages but may actually benefit certain species through opening areas for harvesting seeds, germination, of nutritious new growth and encourage plants to grow inflorescences, which is important in the diet of the majority of rodents.

CHAPTER 12

ECTO-PARASITES ON RODENT SPECIES AT THE N'WASHITSHUMBE ENCLOSURE SITE

12.1 Introduction

The Kruger National Park (KNP), which comprises an area of approximately 2 million ha, is situated in the north-eastern Lowveld of Mpumalanga and Limpopo provinces of South Africa. Two major vegetation types are recognised in the Park and 35 landscape zones have been identified (Gertenbach 1983). It lies within the distribution range of more than 20 ixodid tick species (Horak 1998).

12.2 Material and methods

Ticks were collected randomly from different species of rodents over May and June 2004. Care was taken to ensure ecto-parasites found on small mammals were labeled with the correct host. Ticks and other parasites were collected on cotton wool used to anesthetize the rodent captured. Different species of rodent were anesthetized in pre-marked bags specifically marked for the species in question. Tick samples were then sent to the Veterinary Research Institute at Onderstepoort for identification.

12.3 Results

Ixodid ticks were collected from several rodent species and from the vegetation at the N'washitshumbe enclosure site in the northern Kruger National Park during 2004. A total of five tick species were recovered from the common rodent species found in the enclosure area.

12.3.1 *Boophilus decoloratus*

Larvae of *B. decoloratus* were collected on three species of rodent found at the enclosure site. These included *S. campestris, M. natalensis, and T. leucogaster* (Table 44). According to Horak (1998), wild ruminants and zebras are all efficient hosts of this tick. The total numbers of *B. decoloratus* recovered exceeded those of any other tick species collected. However *B. decoloratus* did not prove to be the most abundant tick on the vegetation at the enclosure site. It is however, a one-host tick present throughout the year (Horak *et al.* 1992b) and consequently these ticks occur on hosts for longer periods of time and with less attrition between the stages of development, resulting in the large numbers of ticks collected from host animals. *B. decoloratus* are found on zebras *(Equus burchellii*), giraffes (*Giraffa camelopardalis*), impalas (*Aepyceros melampus*) and kudus (*Tragelaphus strepsiceros*), while *R. zambeziensis* are found on lions (*Panthera leo*), impalas (*Aepyceros melampus*), kudus (*Tragelaphus strepsiceros*) and scrub hares (*Lepus saxatilis*) (Horak & Fourie 1991). *B. decoloratus* were collected inside the enclosure and in the fire break on the top and bottom slope of the catena. *B. decoloratus* larvae are not known to feed on rodents and those recovered may have accidentally been on the rodents when captured.

12.3.2 *Rhipicephalus appendiculatus*

R. appendiculatus were not collected on any of the small mammals collected but in low numbers on vegetation**.** According to Horak (1998) zebras (*E. burchellii*) and various ruminant species are good hosts of the immature stages of *R. appendiculatus,* while lions (*P. leo*) and scrub hares (*L. saxatilis)* also harboured small numbers. Scrub hares (*L. saxatilis*) examined in a Valley Bushveld region of the Eastern Cape Province also harboured *R. appendiculatus* (Horak & Fourie 1991). Lions (*P. leo*) are recorded to be excellent hosts of adult *R. appendiculatus*, which may have been occasioned by the poor health of some individuals (Horak 1998).

12.3.3 *Rhipicephalus simus*

Nymphs and larvae of *R. simus* were recorded on Multimammate mice *Mastomys* species at the N'washitshumbe enclosure site (Table 44). According to Horak (1998), red veld rats (*Aethomys chrysophilus*) are the preferred hosts of immature *R. simus.* Horak (1998) also found that Gerbils (*Tatera leucogaster*) captured in the same trap-lines as the veld rats were free from infestation. Adult ticks preferred the large monogastric animals with lions (*P. leo*), being the hosts of choice. Horak (1998) found that of all adult ticks collected from the vegetation by drag-sampling, *R. simus* were the most numerous.

According to Horak *et al*. (1983a), the adults of *R. simus* are generally more abundant on the vegetation of gullies than on open grasslands and woodlands. *R. simus* was collected outside the enclosure site at the top and bottom-slopes of the catena.

12.3.4 ***Rhipicephalus zambeziensis***

Larvae of *R. zambeziensis* were collected on *Mastomys* species at the N'washitshumbe enclosure site (Table 44). Within the KNP, ruminants and scrub hares (*L. saxatilis*) appeared to be good hosts of the immature stages of this species (Horak 1998). Impala (*A. melampus*), kudu (*T. strepsiceros)* and particularly lion (*P. leo*) are good hosts of the adults. Tick burdens of the lions may have been influenced by their state of health (Horak 1998). *R. zambeziensis* larvae were collected inside the enclosure site on the top slope of the catena. *R. zambeziensis* larvae are not known to feed on rodents and those recovered may have accidentally been on the rodents when captured.

12.3.5 ***Rhipicephalus lunulatus***

Nymphs of *R. lunulatus* were collected on *Mastomys* species at the N'washitshumbe enclosure site (Table 44). These nymphs were found exclusively in the vlei area at the bottom slope of the catena.

12.3.6 *Amblyomma hebraeum*

The major species collected on vegetation at the enclosure site being the larvae of *Amblyomma hebraeum*. *A. hebraeum* is a species known to occur on lion (*P. leo*), Burchell's zebras (*E. burchellii*), giraffe (*G. camelopardalis*), impala (*A. melampus*), kudu (*T. strepsiceros*) and helmeted guinea fowl (*Numida meleagris*). No records of *A. hebraeum* were recorded on rodents at the enclosure site.

Drought adversely affected the abundance of free-living ticks questing on the vegetation and those living on rodents. Noticeable fewer ticks were collected on rodents over drier periods.

Large mites (*Laelaps giganteus*), similar in size to many of the nymphs of many tick species, infested all the rodents collected. Some speciments had five to ten mites and others up to 20 or 50. Eleven of the rodents had fleas varying in number from one to six individuals. Five rodents species (*M. natalensis*, *A. chrysophilus*, *S. campestris*, *T. leucogaster* and *L. rosali)* had between nine and three tick larvae, three rodent species had two tick nymphs and one rodent species had 3 larvae and a nymph.

Table 44. List of ecto-parasites found on rodent species collected at the N'washitshumbe enclosure site during May and June 2004.

Rodent species	Grid No	Date	*B. decoloratus*	*R. lunulatus*	*R. simus*		*R. zambeziensis*	Mites	Fleas
			Larvae	Nymphs	Larvae	Nymphs	Larvae		
M. natalensis	A2	01.06.04				5		Pos	
S. campestris	C2	01.06.04	8					Pos	2
M. natalensis	A1 + A2	31.05.04						Pos	2
M. natalensis	B2	31.05.04						Pos	
A. chrysophilus	A3	31.05.04						Pos	1
M. natalensis	A1 + A2	01.06.04						Pos	3
M. natalensis	B3	31.05.04					4	Pos	2
M. natalensis	A3	01.06.04						Pos	
M. natalensis	C1	31.05.04		6				Pos	3
M. natalensis	C2 + C3	31.05.04	3	7				Pos	1
T. leucogaster	B2	31.05.04	7					Pos	6
M. natalensis	A3	31.05.04						Pos	3
M. natalensis	C2 + C3	01.06.04		6				Pos	2
M. natalensis	C1	01.06.04						Pos	1
M. natalensis	B1 + B2	31.05.04			9			Pos	
L. rosalia	B2	01.06.04						Pos	

CHAPTER 13

ECOLOGICAL IMPORTANCE AND MANAGEMENT OF RODENT POPULATIONS AT THE N'WASHITSHUMBE ENCLOSURE SITE

13.1 Introduction

Rodents form an important component of a natural system, vital in maintaining ecological health. Small mammals are an important component of the system of energy flow through any ecosystem as they are both consumers and prey (Golley *et al.* 1975). Rodents, although one of the most successful group of animals are sensitive to environmental changes, especially changes in habitat due to human influences. The relatively undisturbed ecosystem of the Kruger National Park represents an ideal situation in which to study natural populations of small mammal assemblages because the assemblages and predator communities as well as the habitats have been largely unaffected by man, except for the triennial burning regime, since the 1920's (Braack 1983). The N'washisthumbe enclosure site however, provides the unique opportunity to assess changes due to management influence.

However, in the Kruger National Park only Kern (1981) and Watson (1987) have investigated small mammal assemblages to any degree. They showed that the triennial rotation burning regime, employed for the control of bush encroachment and fire risk (Brynard 1964), maintained diversity in the small mammal communities by substantially altering the habitat structure. Results from this study concur with their findings, in that changes in habitat structure create more suitable habitat for other species, ensuring a dynamic, complex evolution of dominance and sub-ordinance of species.

13.2 Implications for management

The N’washitshumbe enclosure site is an artificial environment, in that certain section are managed differently. The environment inside, in the fire break surrounding and outside the enclosure differ significantly in that the habitat structure is influenced by varying degrees of elephant, buffalo and fire impact. Kruger National Park management aims to (Braack 1997) “maintain biodiversity in all its natural facets and fluxes and to provide human benefits, in keeping with the mission of the National Parks Board, in a manner which detracts as little as possible from the wilderness qualities of the Kruger National Park”.

This mission statement refers to both the management of terrestrial and aquatic ecosystems and the use of “biodiversity” in context as described by Noss (1990). Biodiversity has three main attributes – structure, composition and function. Noss (1990) expanded these attributes into a nested hierarchy that incorporates elements of each attribute at five levels of organization – regional landscape, community, population, species and genetic. Results indicate that biodiversity may be altered significantly with changes in landscape as a result of increased impact. A landscape which was primarily park land and through a process of excessive herbivore impact developed into grassland may result in the loss of certain species that strongly dependent on woody plants. This change in habitat may also result in the widening distribution range of other species favouring open, less wooded areas. When this situation occurs on a small scale, the effects are not detrimental to the biodiversity of the park; however when the impact is experienced across the entire park, losses in suitable habitat and associated species can be expected. This browsing by large mammals has seriously altered the structure and composition of the wooded vegetation. This has resulted in vast areas altered from essentially thickets to open, scrub studded vistas. Cadanasso & Pickett (2000 & 2001) have shown that such changes have functional consequences for systems. Large mammal disturbances therefore affect all three attributes of biodiversity across different levels of organization, including small mammal assemblages. Monitoring and predicting the effects of herbivore impacts on small mammal populations through altering vegetation structure is therefore of the utmost importance to managers aiming to maintain all aspects of biodiversity.

Woodland dormouse *G. murinus* and tree squirrel *P. cepapi* are species strongly associated with wooded habitat. The N'washitshumbe enclosure site is heavily wooded with Marula *Sclerocarya birrea* and a variety of other tree species. The division between various management sections can be clearly observed, even without surveying vegetation. This resulted in these two rodent species being collected inside the enclosure while being absent outside. On a large scale this change in vegetation structure could result ultimately in the loss of these two species. There are rodent species i.e. the tree rat *Thallomys* *pendulcus* which are dependent on wooded areas to a far greater extent. These species were absent from the site, although the site was well within their distribution range.

Every species has certain requirements on habitats and patches within. The degree and quality of structures connecting those patches are supposed to be a crucial factor for movement and dispersal, and therefore for the gene flow within and between populations ("connectivity"). Thus, for arboreal small mammals like the tree rat *T. pendulcus*, density, distribution and quality of suitable trees should have an influence on their distribution. Also, structures like shrubs may or may not be considered as connecting landscape elements. Impacts on vegetation structure is usually assessed through examination of aerial photographs, such analysis rarely detect imbalances or signs of local extinction in species assemblages. Long term monitoring of small mammal population structure is important to identify possible losses on a small scale.

These changes in species and habitat structures may result in the increase in certain species. Fat mouse *S. pratensis* was collected outside the enclosure site, but not within. This species favours open areas opposed to wooded environments. Long term changes in the habitat from woody to grassland may result in an increase in this species which could in turn result in an imbalance in the ecosystem and a decrease overall biodiversity.

The Kruger Park has incorporated flux of natural concepts into their management policy and monitor changes according to a system of Thresholds of Probable Concern

(TPCs). Flux and variability are inherent and integral parts of savanna ecosystems (Levick 2001). TPCs represent the upper and lower levels of change in selected biotic and abiotic variables that act as indicators of ecosystem condition. They form hypotheses of the limits of acceptable change in structure, composition and function of an ecosystem. When these limits are reached, management action is required to moderate the causes or the TPC needs to be shifted to a more realistic level (Rogers & Biggs 1997). The selection of appropriate indicators is therefore an essential component of management process. At present, changes in small mammal assemblages are limited. Little attention has been given to changes in diversity and abundance with regards to changes in vegetation structure and loss of suitable habitat. Broad scale analyses linked to aerial photography is unlikely to detect small, yet significant changes to species or populations. Losses and increases in small mammal diversity and changes in population assemblages with a decrease in large tree species are probable.

This study indicates that certain rodent species are resilient to changes in habitat structure i.e. *Mastomys*, however populations of certain species may be reduced or lost with a decrease in wooded vegetation due to habitat loss. Further investigation is needed to determine whether these concepts could be more widely applied to different disturbances, landscape and ecosystem types.

Officials in the KNP are concerned about the effect of fire and elephant densities on microhabitat and the rippling effect it has on other animals in the food chain. This project falls within the TPC program of the KNP and provides valuable data for rodent monitoring. The preliminary results suggest that certain species are being affected with changes in vegetation structure with the uncontrolled growth in elephant population.

13. 3 Ecological processes affecting small mammal assemblages

Changes in ecological processes are expected to affect small mammal populations over time. Effects of browsing exclusion at the community and population level are already evident and subtle changes on a small scale are evident with a decreased percentage in woody cover.

According to Levick (2001) little difference in woody percentage cover (Fig. 49.) was found inside and outside the enclosure site in 1987. In 2001, however, woody cover inside the enclosure was 116% greater than outside the enclosure. Differences between years resulted from a 23% decrease in aerial cover outside the enclosure, and a 190% increase on the inside of the enclosure.

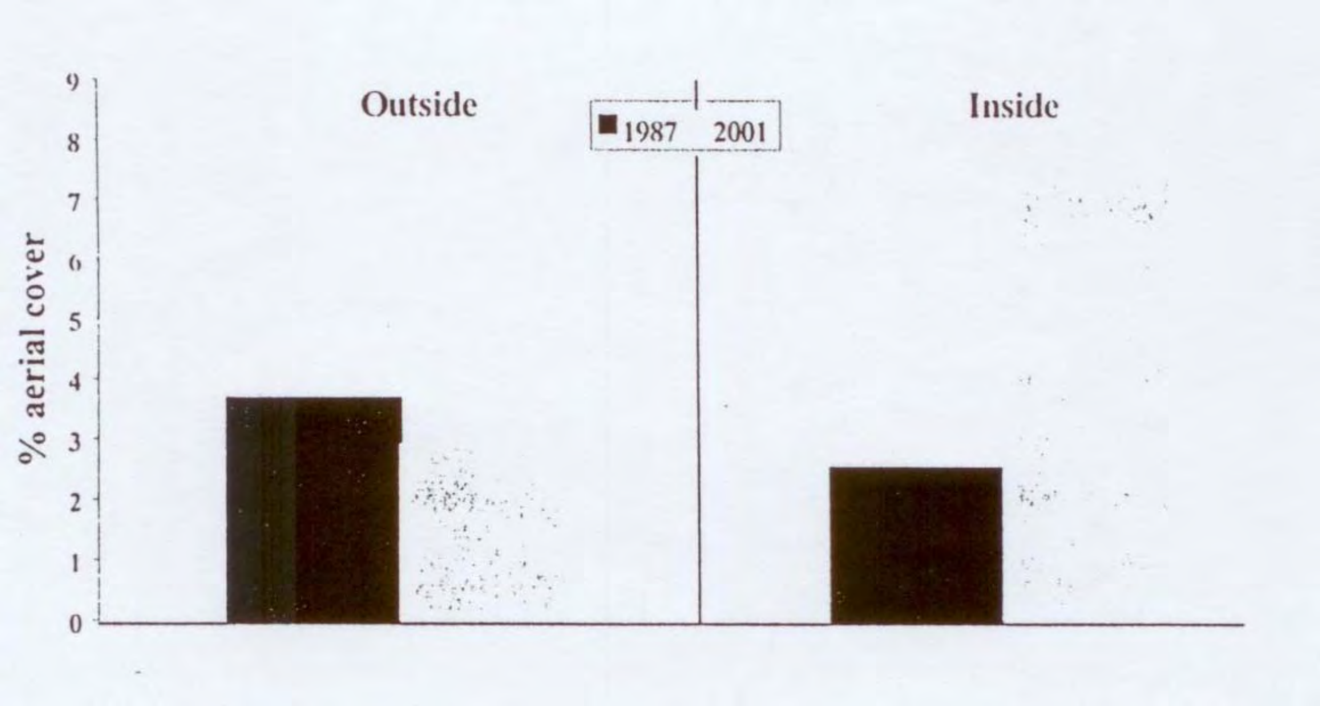


Figure 49. Cover percentage of wood plants, inside and outside the enclosure (Levick 2001)

According to Levick (2001) the general decrease in woody plant cover occurring on the basalts of KNP has been attributed to fire and elephant disturbances. The difference in percentage aerial cover of woody plants inside and outside the enclosure illustrates the effect that large mammalian herbivores and fire can have on a landscape. Fire frequencies have been very similar (4.3/yrs inside and 4/yrs outside), however, which indicates that browsing is responsible for the large reduction in percentage aerial cover of woody vegetation outside the enclosure (Levick 2001). Certain small mammal species appear to be affected by these changes in woody plant cover.

Impacts of browsing can be seen in the height class distributions of woody plants inside and outside the enclosure (Levick 2001). As indicated by Levick (2001), numbers of medium to large trees have been decreased rapidly in a relatively short period of time. These changes are reducing suitable habitat for certain woodland loving species. Further research into the habitats of these species needs to be conducted in order to determine what requirements are needed at which critical point. Height class distribution inside the enclosure (Fig. 50a.) is bimodal with a large number of trees occurring in the medium and tall height classes.

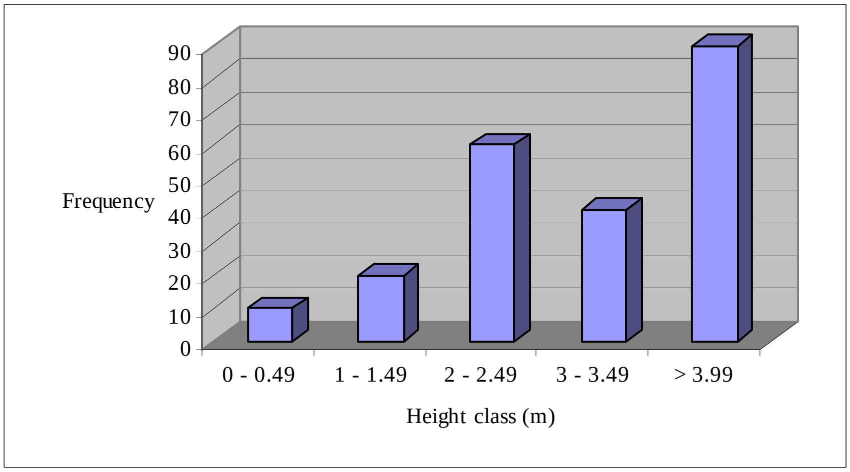


Figure 50a. Height class distribution of woody plants inside the N'washitshumbe enclosure.

Outside the enclosure, height class distribution is unimodal with most trees occurring in the short to medium height class (Fig. 50b.).

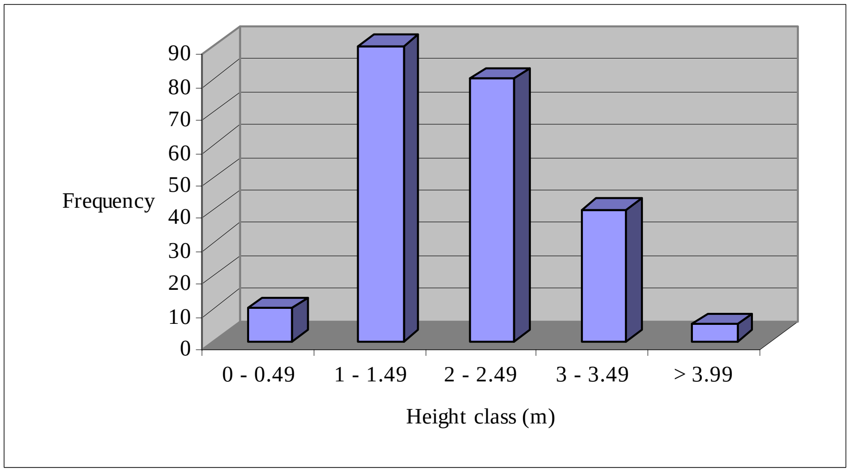


Figure 50b. Height class distribution of woody plants outside the N'washitshumbe enclosure.

These differences are directly related to the intensity and frequency of fire and large herbivore impact. Certain species of rodents are directly affiliated with medium to large trees for food, shelter and breeding purposes.

13.4 Micro-habitat preference of small mammals inside, around and outside the N'washitshumbe enclosure site

13.4.1 Vegetation and rodent dynamics

Small mammals have long been associated with vegetation structure, often resulting in the absence or presence of certain species of rodents. Based on aerial and fixed-point photographs, the cover and density of woody scrubs and trees in the Kruger Park, between 1940 and 1998, have shown a 12% increase on granite substrates and a 64% decrease on basalt substrates such as the Northern Plains (Eckhardt *et al.* 2000). The significant decrease in the basalt soils has been attributed to the fire return period of 4.2 to 17 years and effect of elephant herbivory. In 1960 the elephant population was estimated, using very coarse techniques, to be around 1000 animals. It is now thought that this number must have been closer to 4000 as a rigorous count in 1966 produced 6500 animals. In subsequent years the population has been maintained around 7500 animals through culling.

The presence of grazers, such as zebra and buffalo, is usually higher on the basalts due to the relative abundance of nutrients and rapid recovery of grasses after grazing. Trees in the basalts therefore receive more competition from grasses than those in less fertile granites (Levick 2001). The N'washitshumbe enclosure site on the basalt is an indication how the vegetation structure should appear in an environment with less elephant impact. If Eckhardt *et al.* (2000) findings are correct, the same percentage of suitable habitat for certain woodland loving rodent species is reduced.

The fence line at the enclosure site is clear evidence of the drastic change in vegetation structure. This fence line contrasts the outside condition with that on the inside indicating a significantly greater phytomass of bush and a higher proportion of trees in the >3m height classes inside the N'washitshumbe enclosure (Trollope *et al.* 1998). Small mammal species confined to woodland were, not surprisingly, found inside the enclosure only. These differences in vegetation and small mammal diversity were attributed to the interaction of elephant and fire impacts on the vegetation outside the enclosure.

Results indicated a certain degree of seasonal habitat selection within *Mastomys* populations. This movement between slopes of the catena was evident between winter and summer months. *Mastomys* appeared to move from the bottom slope i.e. vleis to mid- and top slopes in summer. The inverse relationship appeared to occur in winter, with an increase in rodent numbers in low lying areas. Duncan (1975) found that topi (*Damaliscus lunatus*) exhibited a clear seasonal pattern in habitat selection. The dry season was characterized by selection for lower catena levels, whereas the wet season was characterized by grazing in the upper levels of the catena. This behaviour pattern therefore mirrors findings recorded during this study with *Mastomys*, which resulted in high numbers being collected in the vlei area during winter, while recording higher numbers in the upper sections of the catena during summer. Rodents are cover dependant; this could be directly related to the vlei area being denser over the winter period. According to Duncan (1975), topi selected areas within the catena as a result of the growth stage of the grass, and not the species composition. Ultimately, the effect of seasonal change in habitat selection was to maintain animals in grasslands of roughly the same grass quantity throughout the year, i.e. optimal topi habitat in the wet season was found to have grass in an intermediate growth phase, while in the wet season the optimal habitat had the most mature and abundant grass available (Duncan 1975).

Buffalo and roan have also been observed to utilize the catena in such a manner, by moving to the bottomlands in the dry season, and then moving upwards with the progression of the wet season (Joubert 1976; Sinclair 1977; Heitkonig 1993). Rodents appear to follow a similar trend but possibly selecting these areas for cover from predation, avoiding areas with short, leafy swards. According to Grunnow *et al.* (1980) and Scoones (1995), the end of the dry season, particularly during the months July through to October, is a crucial period for herbivores.

Scoones (1995) coined the phrase “key resource habitat type”, referring to areas utilized by cattle during the dry season as a buffer against the increasingly poor quality forage available in the dry season. Key resources may include vegetation growing in areas where soil moisture is retained, such as drainage lines, sumps and evergreen trees, or more dispersed resources such as browse and its fallen leaves (Illius & O’Connor 1999).

Small mammals, here defined as free-living small rodents or shrews (<120g) following the stricter usage of Delany (1976), have many characteristics which make them invaluable for mammalian ecological studies, both at the community and the population levels. These include their small size, short life cycle and high reproductive capacity (Delany 1976). Whereas their high metabolic requirements make small mammals particularly vulnerable to environmental deterioration, fecundity in certain species enables them to repopulate areas quickly when conditions improve. Certain small mammal species are known to cope efficiently with and recover quickly from ecological disasters which would cause local extinction of larger terrestrial mammals (Bouliere 1975). Certain species will survive drastic changes in vegetation structure, although more sensitive species may be lost from the system as a result of such changes.

Results indicated a population explosion of *Mastomys* between April and August 2004 at the enclosure site, where the population grew exponentially. The population appeared to regulate itself as a result of increased demands on limited food resources. Population regulation in small mammals is probably best exemplified by the tremendous fluctuations in numbers of the voles and lemmings of the northern hemisphere (Krebs & Myers 1974). Although hypotheses concerning how and why population regulation occurs are many, most can be divided into four distinct but related concepts. First are density-dependent factors on individuals in a population or community, which vary as the number of individuals per unit area changes (Ricklefs 1973). Food, shelter, breeding sites as well as numbers of predators may work as density-dependent factors. However, when and how these factors start to influence the small mammals depends on the limits of each species' ecological flexibility.

Second is density-independent regulation which can occur when external factors such as weather, fire, and water, influence individuals in a population or community regardless of the number of individuals per unity area (Ricklefs 1973). Fire at the enclosure site appeared to have a delayed effect on the population growth. Vegetation biomass was decreased, seeds and other vegetative matter were removed and ultimately the effect reduced the carrying capacity of the immediate environment.

Related to the first two concepts but expressed from a slightly different angle is the third idea of intrinsic or self-regulation, where population regulation occurs as a result of things animals do rather than by direct interaction with resources or predation (Caughley & Krebs 1983). Examples of this type of regulation would be limited breeding seasons, spacing behaviour and/or dispersal (Grant 1970; Grant & Morris 1971; Krebs 1979; Spencer & Cameron 1983).

The fourth concept is population regulation by extrinsic means that is regulation which results from factors outside of the animals' inherent behaviour. This would pertain to such factors as resource availability, predators, disease, or weather (Caughley & Krebs 1983). Extrinsic factors, then, could encompass both density-dependent and density-independent factors while behaviours denoting intrinsic regulation may be triggered by various extrinsic circumstances. Population regulation and especially community regulation is rarely one alternative or the other, but rather the result of the interactions between the different mechanisms (Caughley & Krebs 1983). Results appear to indicate a combination of mechanisms occurring simultaneously at the enclosure site. Populations decreased within the enclosure, hence not directly related to fire but rather a self regulatory influence, possibly as a result of limited rainfall in the general area. Evidence does however suggest that fire and other affects contribute towards a decrease and ultimately a reduction in the population of *Mastomys* at the enclosure site. Interestingly, with the ultimate decrease in *Mastomys* numbers, other species, especially *T. leucogaster* increased significantly (Chapter 6).

13.4.2 Reproduction in small mammal populations at the N'washithsumbe enclosure site

Signs of reproduction and reproductive activity were recorded during this study. A large percentage (n = 73%) of male *Mastomys* captured during March and April had their testicles descended; inversely none had testes descended during the winter months. A pregnant female was trapped in early May and juveniles were recorded in early May and late June. According to Smithers (1975) *M. natalensis* breeds all year round in Zimbabwe with a falling off in May/June. From studies on the highveld both Coetzee (1965) and De Wit (1972) both indicate the breeding season as the end of the rain season and start of the dry season, with a winter quiescence. Results from this study indicated that the majority of matings took place during the rainy season, which in turn resulted in a large influx of young animals at the beginning and duration of winter months.

Data from the present study suggest a summer and autumn breeding season. Low percentages of reproductively active *S. campestris* males were found till late April, but from then, none were found until late November when 100% of males had testes descended. Female's reproductive activity was similar except that 25% were perforated by mid-October, rising to 50% by early November. Juveniles of less than 20 g were recorded in mid-October. The breeding season therefore seems to be from spring to autumn. Limited data on reproduction were recorded for less abundant species. Breeding appeared to be related to rainfall resulting in a delayed increase (Figs. 51a, b.).

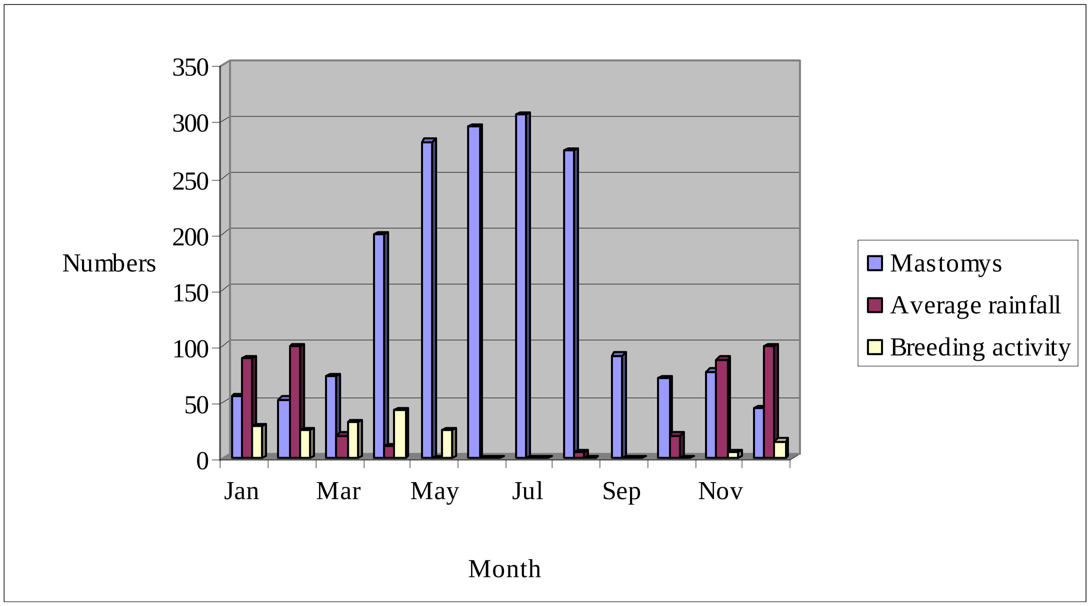


Figure 51a. A histogram illustrating breeding activity of *Mastomys* species in relation to average rainfall.

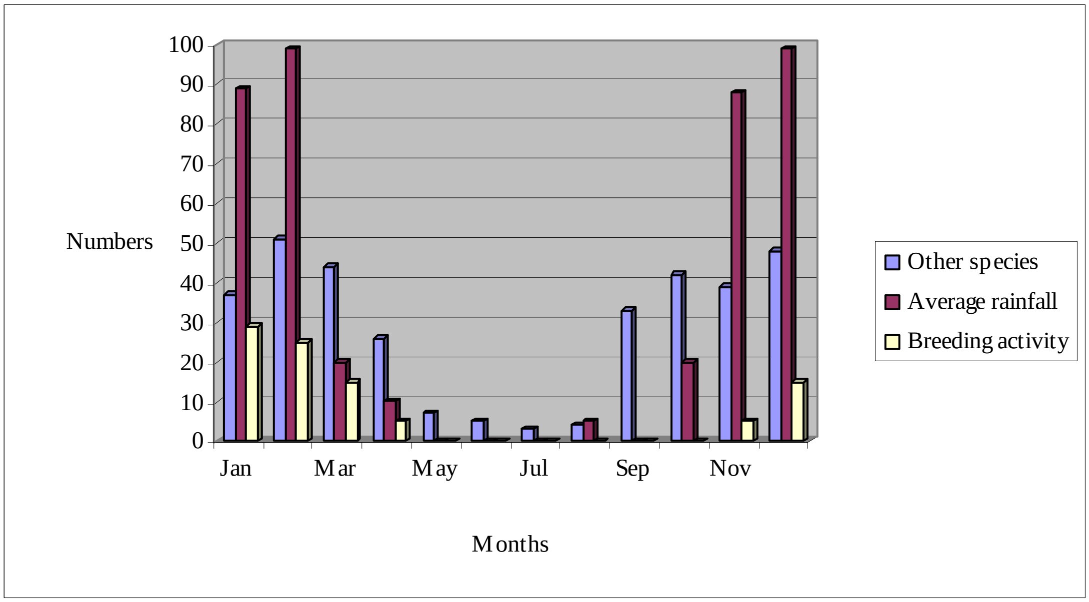


Figure 51b. A histogram illustrating breeding activity of less abundant species in relation to average rainfall.

CHAPTER 14

DISCUSSION

Interpretation of trapping results of small mammals outside and in the fire break surrounding the N'washitshumbe enclosure site is complicated by the fact that many rodents could potentially be trapped even if only part of their home range fell into a survey area, which could give rise to biases in population estimates based on trapping rates (Bowers *et al.* 1996). This possibility does not exist inside the enclosure where movement appears restricted. Although this effect may become evident in future work at the enclosure, it was not important during the present study, as this study was initiated to identify trends in understanding small mammal assemblages.

Indigenous rodent populations are limited by fluctuating resources availability which includes food and shelter (Monadjem & Perrin 1998). Combined with the influence of predation, rodent communities need a specialized set of conditions if they are to persist in viable numbers. Human induced disturbances include management of grazing, alterations of the natural fire regime and woody vegetation removal.

Results indicated that small mammal populations were similar in all management units at the enclosure site, except for a limited number of key species. The following frequencies were recorded during the study period: *Mastomys* spp. (n = 1878), *Saccostomys campestris* (n = 282), *Tatera leucogaster* (n = 106), *Lemniscomys rosalia* (n

= 32), *Aethomys chrysophilus* (n = 12), *Mus minutoides* (n = 12), *Graphiurus murinus* (n = 1), *Steatomys pratensis* (n = 1) and *Paraxerus cepapi* (n = 1). The only insectivore recorded was *Crocidura hirta* (n =1).

The important species to discuss are the abundant and less frequently recorded species. This spectrum of highly populated to scarcely populated species may provide an indication of environmental health at the enclosure site. According to Bronner *et al.* (1988), Brooks (1982), Davis & Meester (1981) rodent population densities in perennial grasslands of the South African highveld are highly seasonal, with reproduction taking place between November and March, reaching peaks in population numbers during March and April. During winter (May-September) vegetation dies down because of frost, and rodent populations decrease substantially (Davis 1973; Smithers 1983).

This study provides evidence that rodent population assemblages on the northern plains of the Kruger National Park exhibit similar trends, however numbers are recorded to peak in June, July and August. This could have resulted due to late rains and dense vegetation cover in the absence of frost. According to Withers (1979), *M. natalensis* is known to undergo population eruptions in warmer habitats. These surveys were performed monthly capturing reproduction, seasonal changes and changes in vegetation densities.

Results indicated an extreme fluctuation in *Mastomys* populations during this study. Initially only *M. natalensis* was expected to be recorded at the enclosure site, however, preliminary genetic analysis indicated that *M. natalensis* and *M. coucha* occur in the area. The medically and agriculturally important Natal multimammate mouse *M. natalensis* (A Smith 1834) and the multimammate mouse *M. coucha* (A. Smith 1836) are sibling species and cannot easily be distinguished morphologically. Although both *M. natalensis* and *M. coucha* are widely distributed in their combined geographic range in South Africa (Meester *et al.* 1986; Skinner & Chimimba 2005; Musser & Carleton 1993), their respective distributional ranges still remain uncertain. Known verified locality data showed the two cryptic species to be either sympatric or to occur in close proximity at four localities. These localities include Pretoria (Gauteng province) and Satara (Kruger National Park) in the north-eastern part of South Africa, as well as Grahamstown and the Addo Elephant Park in the Eastern Cape Province. The record in the Kruger National Park can be extended to incorporate the northern plains north of Shindwedzi.

M. natalensis is expected to occur in the low altitude, high rainfall eastern coastal region, extending to north-eastern South Africa, while *M. coucha* is recorded to occur in high altitude, moderate rainfall of central and north-eastern South Africa. Members of the genus *Mastomys* are small to medium-sized murid rodents and are widely distributed in Africa (Musser & Carleton 1993). The taxonomic problem is exacerbated by the presence of high levels of cytogenetic diversity within the genus (Green *et al.* 1997). Some of the systematic problems within the genus *Mastomys* are well reviewed in a more recent systematic synthesis of the genus (Granjon *et al*. 1997) in which, for example, the authors argue about the inappropriate use of the name *hilderbrandtii* for the more commonly used *hubertii* in West Africa. In southern Africa alone, three species, namely, *M. shortridgei*, *M. natalensis* and *M. croucha* are recognized (Meester *et al.* 1986; Skinner & Chimimba 2005; Musser & Carleton 1993; Granjon *et al.* 1997). The two cytotypes have also been reported to differ in gross sperm and bacular morphology, reproductive behaviour, pheromones, and ultrasonic vocalizations (Skinner & Chimimba 2005; Musser & Carleton 1993). All these differences together with the absence of hybrids in areas of sympatry strongly suggested reproductive isolation between the two chromosomal races (Gordon & Watson 1986). This led to the recognition of two cryptic species referred to as the nominate species *M. natalensis* for the 2n = 32 cytotype and *M. coucha* for the 2n = 36 cytotype (Meester *et al.* 1986; Skinner & Chimimba 2005; Musser & Carleton 1993). Despite the cytogenetic, electrophoretic, and a variety of other reported differences, the two cryptic species cannot easily be distinguished on qualitative external and/or cranial morphology (Gordon & Watson 1986). However, a subsequent study by Dippenaar *et al.* (1993) revealed subtle cranial morphometric differences between the two sibling species, but cautioned that such data need to be carefully evaluated before being applied due to the potential influence of geographic variation over the species' distributional ranges.

Petersen (2006) suggests that small mammal dietary habits have a significant predatory impact on increaser seeds and seedlings within landscapes that contain suitable habitat. This high energy requirement of small mammals, alongside their continuous, if fluctuating abundance in the landscape is one of the many limiting effects on highly nutritive seeds and seedlings. Grazing mammals may affect their habitat by selective feeding on a particular plant species and plant parts, and by disturbing the substrate in which these plants are rooted (Petersen 2006). Like their larger counterparts, small mammals are important contributors to the biodiversity of woodland savanna ecosystems in sub-Saharan Africa (Linzey & Kesner 1997). Such animals are important ecosystem, components as consumers, dispersers of seed, burrowers and prey for carnivores and raptors (Avenant 2000).

Small mammal community structure and species richness has been related to biotic and abiotic variables such as habitat structure and complexity, area, productivity, predation, trampling and grazing, surrounding landscape and distances between areas of similar habitats (Avenant 2000). Presumably due to the practical difficulties of study, lack of knowledge and the megaherbivore focus of researchers, small mammals are generally under studied in most reserves.

Petersen (2006) found small mammal abundance and diversity to be linked and correlated with grass biomass. Biomass appears to be linked to the foraging activity and concentration of megaherbivores and anthropogenic management of the area (in the N'washitshumbe enclosure's case, the absence of fire and large herbivores). Small mammal populations, whilst fluctuating through time are a constant influence within landscapes that contain suitable habitats. Healthy ecosystems support a wide range of wildlife fauna species in all niches. Control of large megaherbivores is important in preventing further impacts of these animals, decreasing the potential of habitat to support certain small mammal species.

Data recorded at the N'washishumbe enclosure site indicated a high degree of species domination and inter- and intra species competition. *Mastomys* are rodents indicative of disturbance, regularly reaching plague proportions in agricultural lands. Populations of the species regularly experience explosions after a period of relative stress i.e. limited resources due to drought, followed by a period of relative plenty. This results in a rapid increase in reproduction and a corresponding increase in the overall population. *Mastomys* numbers were greatest during winter months, decreasing sometime after the site was burnt. Results appeared to be indicative of the site experiencing a partial burn and it is speculated that sufficient grass seeds on the ground and other plant material could be found by rodents after the burn to temporarily sustain the population. This research indicated that certain management practices have a positive influence on rodent species diversity and abundance, while others have a negative influence. These management activities may result in changes in vegetation structure, density and species composition, which may result in altered habitat being selected or rejected by certain species of small mammal, depending on their habitat requirements. As with the megaherbivores, small mammals are important components of a landscape. The general abundance and species richness of small mammal species is impacted by grazing and land use, which contribute to overall habitat change.

The fire break surrounding the enclosure site was burnt in July 2004, resulting in a 100% burn in certain areas. Although an immediate and detrimental effect on *Mastomys* population was expected, capture success was greater post burn compared with pre- burn. Signs of a decrease in the population only occurred in September 2004. They could have temporarily fled to adjacent areas during the burn and returned afterwards. It is assumed that the population decreased gradually due to a decrease in food and cover, an increase in competition and an increase in predation as a result of a lack of cover. The population probably sustained itself by feeding on the verges of the burnt area. This assumption is based on the result of a lower mean annual temperature associated with collecting localities for *M. coucha*, and it is suggested that the species is more likely to be affected by drought than *M. natalensis*. Further research is needed at the enclosure site to confirm this assumption.

It is accepted that frequent fires result in the vegetation becoming less wooded over time, thus favouring rodent species preferring open areas i.e. *T. leucogaster* and *S. pratensis*, while having a negative influence on species favouring wooded habitat i.e. *G. murinus*.

Results indicated possible local extinction of certain species outside the enclosure i.e. *G. murinus* as a result of a decrease in suitable habitat. An increase in certain species outside the enclosure i.e. *S. pratensis* can be expected. However, we have found that species diversity inside, outside and in the fire breaks is relatively similar (Chapter 11). It appears that the majority of small mammal assemblages do not recognize the differences in habitat because the micro-habitats in all three management sections still contain sufficient resources for survival. The mammal species do not only move through certain areas but inhabit all three management units.

Diffendorfer *et al.* (1995) found that fragmentation increases the distance moved by three species of small mammals increased, whereas the proportion of animals moving decreases. It is possible that increased movement is a result of decreased resource availability. In the case of *G. murinus*, a decrease in numbers with a decline in large trees, or alternatively local extinction as a result of unsuitable habitat is expected. According to Noss & Csuti (1997), local extinctions are expected to decrease species diversity within habitat remnants. It is believed that the main reason for small mammal reaction is not overwhelmingly different in and outside the N'washitshumbe enclosure as the processes of habitat change has been gradual, as opposed to other fragmentation experiments involving abrupt removal of vegetation. Gradual fragmentation allows small mammals to adapt and interact with those in the surrounding habitat (Johnson *et al.* 2002). Ultimately, we expect habitat changes to have strong effects on certain small mammal species, however these do not appear evident at this stage except for specific key species clearly absent from inside the enclosure. It is, therefore, highly desirable to perform a longer-term study on the changes in small mammal community structure over time.

The N'washishumbe vlei in the Kruger National Park is separated from a mopane matrix by the vlei boundary (Levick 2001). The boundary has been delineated in terms of grass species and soil characteristics, but not woody vegetation, which is an integral component of savanna ecosystems. This large enclosure provides the opportunity to study the changes of vegetation on small mammal assemblages. The vlei differs considerably from the surrounding vegetation types in species composition and habitat. Woody species are patchier than that of the grasses (Levick 2001). Browsing disturbance and fire has altered the structure, composition and function of the area. It is recommended that certain small mammal species be used as indicators of change in landscape. Gradual changes in vegetation structure, density and composition may result in gradual changes in certain species of small mammal, which when monitored could act as an early warning signal that imbalances occur within the system.

Petersen (2006) found both abundance and diversity of small mammals appeared related to site habitat structure and grass biomass. Grass biomass and trapping studies showed that small mammal abundance and diversity showed a direct positive correlation to grass biomass under storey and habitat quality. Petersen (2006) demonstrated a link between grass biomass, small mammal abundance and diversity and their potential increaser seed/seedling predatory activities in semi-arid Lowveld Savannas in South Africa.

Animals have traditionally been viewed as passive components of ecosystems, merely responding to the conditions to which they are subjected (Naiman *et al.* 2000). Large animals are, however, responsible for biogeochemical, successional and landscape alterations that may persist for centuries (Levick 2001). Large animals alter vegetation structure and assist in developing microtopography through herbivory and soils and nutrient movement (Naiman & Rogers 1997). This in turn effects the distribution of certain small mammal species relying on a specific vegetation structure. Organisms that cause physical state changes in abiotic or biotic materials are referred to as ecosystem engineers if they directly or indirectly modulate the availability of resources to other species (Jones *et al.* 1994). Elephant (*Loxodonta africana*) and other large herbivores are thus referred to as ecosystem engineers, altering vegetation structure to the detriment or favour of certain species of small mammals. Their grazing and trampling has pronounced effects on the distribution of vegetation.

The problem in the KNP is that high elephant densities may influence the abundance of arboreal rodents and insectivores on the northern plains. The abundance and species richness of rodents in these areas with elephant activity provides a clear indication whether elephant action has a direct effect on the vegetation, rodent populations and thus all creatures feeding on rodents.

CHAPTER 15

GENETIC SAMPLE ANALYSIS

Tissue extracts were obtained from nine individuals of the Genus *Mastomys* at the N'washitshumbe enclosure site. The two *Mastomys* species are almost identical regarding visible morphology, making field identification impossible. Currently *M. coucha* and *M. natalensis* share a common distribution in Mpumalanga and Limpopo provinces where their preferred habitats of savanna and grassland meet (Skinner & Chimimba 2005; Smit 2001). *Mastomys coucha* is commonly found in grassland areas with low scrub whereas the savanna biome is inhabited by *M. natalensis*. Both species are tolerant of a wide variety of habitats and the described distribution by Skinner & Chimimba (2005) is only provisional. Often these rodents are found in areas recovering from habitat destruction, being considered a pioneer species, or in close association with human populations (De Graaff 1981). Along with being a suspected carrier of EMCV, *M. coucha* acts as a reservoir for the plague causing organism Rickettsian Yersinia and *M. natalensis* is the carrier of Lessa fever and Mopeia, a lessa like virus (Smith *et al.* 2001).

Their chromosome number, sperm morphology and haemoglobin variations are however different, and as described by Smit (2001), genetic markers may be used in species determination with a laboratory. This method uses the comparative analysis of allozyme variations (Kneidinger 2005). Muscle, kidney and bladder samples were collected of each individual specimen were collected and placed in Eppendorf tubes. Muscle samples were used for allozyme analysis whereas kidney and bladder samples were used for viral identification (Kneidinger 2005). In the field, samples were frozen in liquid nitrogen and stored at -80˚C and transported to the laboratory. Samples were analyzed electrophoretcially using standard horizontal starch gels to determine their species classification (Kneidinger 2005). Previous work by Smit *et al.* (2001) was used as a reference.

Kneidinger (2005) analyzed *Mastomys* samples in KNP for *Encephalomyocarditis* virus (EMCV), typically affecting and maintained in nature by rodent populations and identified to cause fatal heart disease in African elephant *Loxodonta Africana* populations of the KNP in 1993. The Genus *Mastomys* was linked to the outbreak of this virus. Grobler *et al.* (1995) reported the virus present in the park from 1987 and its prevalence was found in three regions from samples obtained within the KNP between 1993 and 1994. Furthermore, a temporal correlation between the occurrence of a population explosion and prevalence to EMCV in rodents and the occurrence of the disease in elephants was established (Grobler *et al.* 1995). EMCV belongs to the Genus *Cardiovirus* of the family Picornaviridae (Knowles *el al.* 1998). The virus typically affects rodents and Zimmerman (1994) considered them as the natural host of EMCV, attributing its maintenance in nature to this host.

Kneidinger (2005) analyzed nine samples collected during this study at the enclosure of which 88.0% were *M. coucha*, with 11.1% being *M. natalensis*. Identification was facilitated by previous literature from Smit (2001) which stated that fixed allele differences occurred between *M. coucha* and *M. natalensis* at AAT-1 enzyme coding locus. As represented in Figure 52a, staining for AAT-1 revealed one locus for either species with that of *M. natalensis* appearing closers to the positive terminal than that of *M. coucha*. With reference to Ayala (1982), it was seen that individuals of *M. coucha* were heterozygous at the AAT-1 gene coding, with a three banded heterozygote present within the sampled specimens (Figure 52b) (Kneidinger 2005). All sampled individuals of *M. natalensis* were homozygous exhibiting only one band.

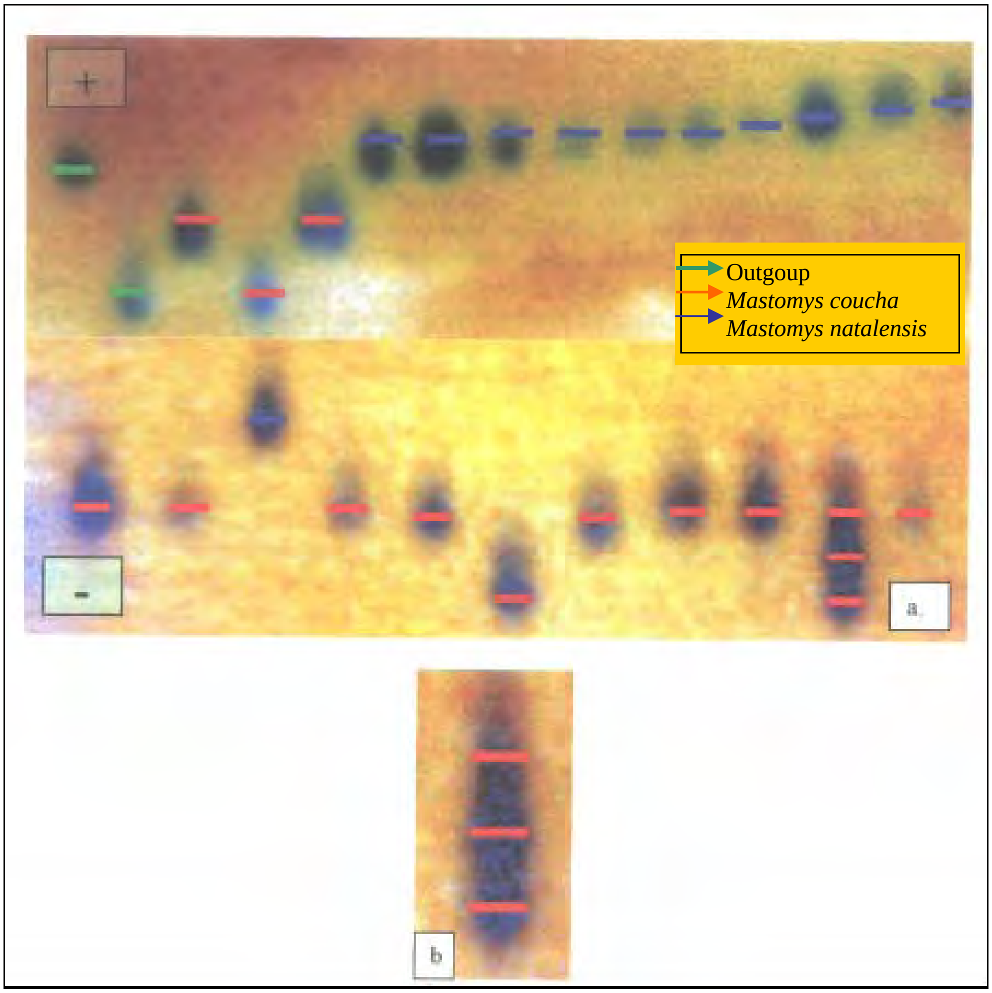


Figure 52. (a) Fixed allele differences between M. coucha and M. natalensis at AAT-1. (b) The dimeric structure of the AAT-1 enzyme coiding locus (Kneidinger 2005).

This demonstrated that *M. coucha* appeared to have more genetic variation than *M. natalensis* within the KNP region, at the AAT-1 locus (Kneidinger 2005).

The greater variety of the *M. coucha* population at the KNP could be considered as a result of the disturbed habitat associated with the locality at which all the individuals of this species were obtained from. The maintenance of genetic variation within *M. coucha* may be a survival strategy to adapt to harsher habitat conditions. In this case however rapid evolutionary radiation of rodent species must be considered as both *Mastomys* species are found within the enclosure. Smit (2001) concluded that, with a chromosomal mutation, *M. natalensis* gave rise to a younger *M. coucha* which became reproductively isolated. The N'washitshumbe enclosure is used not only as a species specific enclosure but as a testing site within the KNP and therefore sections are often burned resulting in habitat that must be recolonized by plants and animals alike. This suggested that as a pioneer species *M coucha* is more prevalent while *M. natalensis* is more adept to residing alongside humans, being located in large numbers near human habitation (Kneidinger 2005).

The smaller number of *M. natalensis* individuals found in the enclosure may be attributed to the limited, yet evident, presence of humans or the overlap of habitat biomes inhabited by the two individual *Mastomys* species. Provisionally it may be assumed that both species are found within the region of the N'washitshumbe enclosure of the park. Kneidinger *et al.* (2005) determined that none of the individuals sampled of the two individual *Mastomys* spp. were carriers of EMCV. Novel results however were obtained concerning the genetic variation of *M. coucha* in comparison to that of *M. natalensis* at the enclosure**.**

Extensive genetic work on samples collected during this study is presently being done. These results will provide valuable information regarding frequency and percentage of *M. natalensis* in relation to *M. coucha*. Further information regarding seasonality, management activity and slope selection will provide valuable information for further study of these two morphologically similar species at the enclosure site.

CHAPTER 16

CONCLUSION

This study was primarily concerned with defining and assessing ecosystem health and providing ecological indicators for ecosystem management through evaluating and understanding small mammal assemblages at the N'washitshumbe enclosure site on the northern plains of the Kruger National Park. Different management influences and seasonal changes in the ecosystem were assumed to have a profound impact on the diversity and abundance of small mammal assemblages. Certain species appeared to have a broader ecological niche than other more habitat specific species.

Of the 73 species of rodents that occur in southern Africa, 34% (25 taxa) are found in the KNP. It is known that rodents form the staple diet for many birds, reptiles and mammals, thereby occupying a key position in the intricate balance of nature. Apart from forming a food source for many animals they also have the ability to modify the environment during plague conditions. Rodents play a major role in the consumption of seeds of many plant species, thereby influencing plant recruitment. Different rodent species also favour different habitat conditions. For these reasons rodents as well as insectivores are important indicators of ecosystem health and worth of attention at the enclosure site.

A total of 36 trap-nights were employed over fifteen months to assess diversity and abundance of rodents in, outside and around the Nwashitshumbe enclosure site. The distributions and movements of small mammals can be explained in terms of cover and litter preference (Kern 1981). “16” live trapping surveys of small mammals were preformed in, outside and around the N’washitshumbe enclosure in the Northern Plains of the Kruger National Park. Despite extensive differences in management action, assemblage structure within the enclosure site appeared similar to that outside. We conclude that, 38 years after enclosure construction, certain small mammal populations do not appear fragmented.

Records for the various species included *Mastomys* spp. (n = 1106), *Saccostomys campestris* (n = 129), *Tatera leucogaster* (n = 61), *Lemniscomys rosalia* (n = 11), *Aethomys chrysophilus* (n = 6), *Mus minutoides* (n = 8), *Graphiurus murinus* (n = 1), *Steatomys pratensis* (n = 1), *Crocidura hirta* (n = 1) and *Paraxerus cepapi* (n = 1). Important species to monitor in future being species collected in low numbers. These species are specific to a certain habitat structure and appear to be strongly influenced by changes in vegetation density and structure.

The assessment of small mammal diversity on the catena results in significant differences as a result of species niche separation. The catena was divided into three broad categories, top, middle and bottom slope. The N’washitshumbe enclosure site occurred on a gradient including vlei, the vlei boundary and an upland region. The eastern section of the enclosure site is the floodplain vlei area and the vlei boundary, henceforth collectively referred to as the bottomlands as this area occurs at the lowest point of the catenal gradient within the enclosure. The western area of the enclosure lay higher up than the bottomlands on the landscape gradient and is referred to as the middlelands. The top section of the enclosure, been the highest point on the catenal gradient, is referred to as uplands. All of the data collected in these areas were marked accordingly. Catenal structure appeared insignificant in determining species richness and abundance, however played a role in seasonal movement of small mammals.

Data were also recorded in transects at different areas according to management action at the enclosure site. The management of the site resulted in significant differences in vegetation diversity, density and height. The assessment of small mammal diversity at these management units resulted in significant differences as a result of altered habitat. These management units were divided into three broad categories, outside, around and inside the enclosure site. Key species were recorded inside opposed to outside as expected. Woodland dormouse *G. murinus* and tree squirrel *P. cepapi* were collected inside the enclosure but were absent outside. These species are strictly associated with woodland and dense vegetation. *S. pratensis* was recorded outside the enclosure site but were absent from inside the enclosure. This species is associated with an open, less wooded environment.

These inventories are valuable for aiding in conservation related decisions, since decisions are often made at local scales and small mammals can provide a rich source of data on environmental change (Kremen *et al.* 1993).

Changes in habitat resulted in changes in plant communities. Plant community consist of a combination of abiotic factors such as soil, rockiness and climate and biotic factors such as plant and animal composition with each element influencing the other. Therefore a plant community can be seen as an ecosystem and these should be managed effectively to ensure the future well-being of the organisms. The plant communities at the N'washitshumbe enclosure were identified, described and ecologically interpreted.

The Braun-Blaunquet approach proved to be an accurate and effective way to identify and classify plant communities based on their floristics. An ordination was successfully used to confirm and refine the classification and to determine any environmental gradients. All plant communities could be related to specific environmental conditions and the communities are therefore floristically and ecologically distinguishable and interpretable.

With the exclusion of large herbivores, an impact on the structure of the vegetation within the enclosure resulted. Inside the enclosure, trees have increased in height and in percentage basal cover, while those outside have remained short and have decreased in percentage aerial cover. Structural changes in veld with *Sclerocarya birrea* and *Hyphaene petersiana* have been particularly severe. The composition of the woody boundary has also been affected by the exclusion of browsing disturbances and differed dramatically inside and outside of the enclosure. Inside the enclosure, *Combretum imberbe*, *Combretum hereroense*, *Lannea schweinfurthii*, *Sclerocarya birrea* and *H.*

petersiana have established. Outside, however, species composition is much lower with only *H. petersiana* persisting.

The project has acted as a small mammal indicator, assessing vegetation structure and taking in to consideration small mammal groups that reflect the diversity across a set of environments, thus acting as surrogates for the "wholesale" biodiversity (Gaston 1996a; McGeoch 1998). The conservation value of an area is typically judged using a measure of species richness, or some variant of it (Gaston 1996b; Angermeier & Winston 1997).

Savanna ecosystems are characterized by co-dominance between two different life forms, grasses and trees (Higgens *et al.* 2000). Petersen (2006) describes the removal of small mammal species through habitat alteration may well, alongside fire, overgrazing, climate change and other factors be complicit in the increasing of densification of woody shrubs and trees in southern African savannas. This is difficult to quantify, however, should not be ruled out when discussing plant cover and density inside and outside the N'washitshumbe enclosure site.

Management encompassing best practice for savanna flora and fauna remains an extremely complex matter, requiring broad in-depth understanding of landscape, it ecological components and the dynamics thereof. This data suggests that managing areas to maximize species richness, especially key small mammal assemblages, should be achived by maintaining diverse and structurally varied habitats in the correct proportions.

CHAPTER 18

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Appendix A: Total number of species correlated with capture months at the N'washitshumbe enclosure site

Month	Species										
	Mas spec	*Sac cam*	*Tat leu*	*Lem ros*	*Aet chr*	*Mus min*	*Gra mur*	*Ste pra*	*Cro hir*	*Par cep*	Total
Jun-03	105	29	7	1	4	0	0	0	0	0	146
Jul-03	116	16	11	9	1	1	0	0	0	0	154
Aug-03	87	18	7	6	0	5	0	0	0	0	123
Sep-03	70	19	4	7	2	2	0	0	0	0	104
Oct-03	91	24	7	5	2	4	0	1	0	0	134
Nov-03	75	17	0	0	1	0	0	0	0	0	93
Jan-04	47	22	0	0	0	0	0	0	0	0	69
Feb-04	55	47	2	0	0	0	1	0	1	0	106
Mar-04	79	36	8	0	0	0	0	0	0	0	123
Apr-04	221	21	8	0	0	0	0	0	0	0	250
May-04	154	2	3	0	2	0	0	0	0	0	161
Jun-04	130	0	1	1	0	0	0	0	0	0	132
Jul-04	309	6	5	2	0	0	0	0	0	0	322
Aug-04	274	7	4	0	0	0	0	0	0	0	285
Dec-04	44	13	13	0	0	0	0	0	0	1	71
Apr-05	21	5	26	1	0	0	0	0	0	0	53
Total	1878	282	106	32	12	12	1	1	1	1	2326

Appendix B: Total percentage of species correlated with capture months at the N'washitshumbe enclosure site

Month	Species										
	Mas spec	*Sac cam*	*Tat leu*	*Lem ros*	*Aet chr*	*Mus min*	*Gra mur*	*Ste pra*	*Cro hir*	*Par cep*	Total
Jun-03	4.53	1.22	0.30	0.04	0.22	0.00	0.00	0.00	0.00	0.00	6.31
Jul-03	5.05	0.70	0.39	0.48	0.13	0.04	0.00	0.00	0.00	0.00	6.79
Aug-03	3.74	0.78	0.22	0.30	0.04	0.26	0.00	0.00	0.00	0.00	5.35
Sep-03	3.09	0.78	0.09	0.35	0.09	0.13	0.00	0.00	0.00	0.00	4.53
Oct-03	3.96	1.04	0.30	0.22	0.09	0.17	0.00	0.04	0.00	0.00	5.83
Nov-03	3.35	0.78	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	4.18
Jan-04	2.39	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.26
Feb-04	2.26	2.13	0.09	0.00	0.00	0.00	0.04	0.00	0.04	0.00	4.57
Mar-04	3.18	1.57	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.09
Apr-04	8.66	0.78	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.79
May-04	12.27	0.04	0.17	0.04	0.09	0.00	0.00	0.00	0.00	0.00	12.62
Jul-04	13.32	0.28	0.22	0.09	0.00	0.00	0.00	0.00	0.00	0.00	13.88
Aug-04	11.92	0.3	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.4
Dec-04	1.91	0.57	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.04	3.09
Apr-05	0.91	0.26	1.09	0.04	0.00	0.00	0.00	0.00	0.00	0.00	2.31
Total	80.54	12.11	4.32	1.56	0.70	0.61	0.04	0.04	0.04	0.04	100.00

Appendix C: Total frequency of species correlated with sex ratio data at the N'washitshumbe enclosure site

Species	Sex			
	Male	Female	Unknown	Total
Mastomys species	970	905	3	1878
Saccostomys campestris	137	145	0	282
Tatera leucogaster	49	57	0	106
Lemniscomys rosalia	18	14	0	32
Aethomys chrysophilus	6	6	0	12
Mus minutoides	5	7	0	12
Graphiurus murinus	1	0	0	1
Steatomys pratensis	1	0	0	1
Crocidura hirta	0	1	0	1
Paraxerus cepapi	1	0	0	1
Total	1188	1135	3	2326

Appendix D: Total percentage species correlated with sex ratio recorded at the N'washitshumbe enclosure site

Species	Sex			
	Male	Female	Unknown	Total
Mastomys species	41.70	38.91	0.13	80.74
Saccostomys campestris	5.89	6.23	0.00	12.12
Tatera leucogaster	2.11	2.45	0.00	4.56
Lemniscomys rosalia	0.77	0.60	0.00	1.38
Aethomys chrysophilus	0.26	0.26	0.00	0.52
Mus minutoides	0.21	0.30	0.00	0.52
Graphiurus murinus	0.04	0.00	0.00	0.04
Steatomys pratensis	0.04	0.00	0.00	0.04
Crocidura hirta	0.00	0.04	0.00	0.04
Paraxerus cepapi	0.04	0.00	0.00	0.04
Total	51.07	48.80	0.13	100.00

Appendix E: Total frequency of species correlated with capture-recapture data at the N’washitshumbe enclosure site

Species	Capture-Recapture		
	Recapture	New Animal	Total
Mastomys species	755	1106	1861
Saccostomys campestris	151	129	280
Tatera leucogaster	45	61	106
Lemniscomys rosalia	21	11	32
Aethomys chrysophilus	5	6	11
Mus minutoides	4	8	12
Graphiurus murinus	0	1	1
Steatomys pratensis	0	1	1
Crocidura hirta	0	1	1
Paraxerus cepapi	0	1	1
Total	981	1325	2306

Appendix F: Total percentage of species correlated with capture-recapture data at the N'washitshumbe enclosure site

Species	Capture-Recapture		
	Recapture	New Animal	Total
Mastomys species	32.74	47.96	80.7
Saccostomys campestris	6.55	5.59	12.14
Tatera leucogaster	1.95	2.65	4.6
Lemniscomys rosalia	0.91	0.48	1.39
Aethomys chrysophilus	0.22	0.26	0.48
Mus minutoides	0.17	0.36	0.52
Graphiurus murinus	0	0.04	0.04
Steatomys pratensis	0	0.04	0.04
Crocidura hirta	0	0.04	0.04
Paraxerus cepapi	0	0.04	0.04
Total	42.54	57.46	100

Appendix G: Total frequency of species correlated with slope at the N'washitshumbe enclosure site

Species	Grids			
	A (Middle)	B (Top)	C (Bottom)	Total
Mastomys species	692	659	527	1878
Saccostomys campestris	138	85	59	282
Tatera leucogaster	40	45	21	106
Lemniscomys rosalia	0	12	20	32
Aethomys chrysophilus	2	4	6	12
Mus minutoides	4	8	0	12
Graphiurus murinus	0	1	0	1
Steatomys pratensis	1	0	0	1
Crocidura hirta	0	0	1	1
Paraxerus cepapi	1	0	0	1
Total	878	814	634	2326

Appendix H: Total frequency of species correlated with transects at the N’washitshumbe enclosure site

Species	Transects									Total
	1A	1B	1C	2A	2B	2C	3A	3B	3C	
Mastomys species	249	250	264	289	235	159	154	174	104	1878
Saccostomys campestris	62	34	23	43	36	13	33	15	23	282
Tatera leucogaster	28	21	12	1	12	0	11	12	9	106
Lemniscomys rosalia	0	1	15	0	11	5	0	0	0	32
Aethomys chrysophilus	1	4	3	0	0	3	1	0	0	12
Mus minutoides	1	0	0	0	4	0	3	4	0	12
Graphiurus murinus	0	0	0	0	0	0	0	1	0	1
Steatomys pratensis	1	0	0	0	0	0	0	0	0	1
Crocidura hirta	0	0	1	0	0	0	0	0	0	1
Paraxerus cepapi	0	0	0	0	0	0	1	0	0	1
Total	342	310	318	333	298	180	203	206	136	2326

Appendix I: Total frequency of species correlated with management influence at the N’washitshumbe enclosure site

Species	Area				
	Around	Inside	Outside	Sodic	Total
Mastomys species	524	487	763	104	1878
Saccostomys campestris	79	61	119	23	282
Tatera leucogaster	13	23	61	9	106
Lemniscomys rosalia	11	5	16	0	32
Aethomys chrysophilus	0	4	8	0	12
Mus minutoides	4	7	1	0	12
Graphiurus murinus	0	1	0	0	1
Steatomys pratensis	0	0	1	0	1
Crocidura hirta	0	0	1	0	1
Paraxerus cepapi	0	1	0	0	1
Total	631	589	970	136	2326