Investigating Small Mammal community structure as a possible indicator of improved habitat integrity in an area cleared of alien vegetation.

by

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ABSTRACT

Small mammal communities have been identified as possible indicators of the ecological integrity of different areas. Small mammal species are adapted to micro habitats and therefore can be affected by small-scale changes, which can be monitored to assist in biodiversity studies.

Alien vegetation eradication programs have been ongoing across many areas of South Africa. These eradicated areas are believed to be able to restore to the original condition and therefore improving the biodiversity of the area. However, many ways of assessing ecological integrity are time consuming and expensive. By assessing the small mammal diversity and community structure in eradicated areas, judgments could be made about the success of implemented eradication programs. As small mammal surveys can be done readily, the ability to use them as indicators allows them to be implemented in all eradicated areas to indicate conditions of area over various time periods and can be utilized on a continual basis.

This study investigates to which extent small mammal community structure (including the specific species present and the species richness) could indicate improved habitat integrity in areas cleared of alien vegetation. Small mammal communities in three areas, (i) area infested with Black Wattle (*Acacia mearnsii*), (ii) area cleared of Black Wattle and (iii) a control area which have no records of alien vegetation, were assessed. Data was captured using PVC live traps similar to Sherman and Willan traps. Traps were placed along transects in each area, once a month, from October to December 2013 for four consecutive days at a time.

A total of 690 individual were caught during the 5400 trap nights of the study, with an overall trap success of 12.78%. In total five small mammal species were caught; one musk shrew (*Crocidura flavescens*) and four rodents. There was a significant difference between the number of small mammals caught between the three areas, with the control area and the cleared area being the most similar. Both the Shannon-Wiener and the Simpson's diversity indexes were used, with the Shannon-Wiener indicating some significant differences between the areas and the Simpson's indicating that there was not a significant difference between the areas.

The Friedman Anova indicated a significant difference in the amount of species caught between the areas, with the Wilcoxon test indicating that there was significantly less species in the infested than in both the control and cleared areas; no difference was found between the cleared and the control areas. A similar difference in the total amount of individuals caught was also found. This was also found for the three most numerous species *Rhabdomys pumilio, Micaelamys namaquensis*, *Otomys irroratus*. Two species *Saccostomus campestris* and *Crocidura flavescens* were found in low numbers at both the control and cleared plots, but could not be found at the infested site.

This study indicates that small mammal communities are different between the areas sampled with the infested area having the lowest species richness and abundance. The cleared area is not significantly different from the control area, but has a significantly higher species richness and abundance than the infested area, indicating that the area has improved and that small mammals could be used as an indicator of ecological integrity after alien eradication.

No clear indicator species were identified, due to only five species being recorded. *Rhabdomys pumilio* dominated all areas sampled and has been identified to occur from very disturbed to pristine areas.

Where more time and assistance is available, future studies will benefit from the inclusion of ecological integrity indices on other taxa, such as vegetation, alongside the small mammal communities. This would allow for correlations to be drawn and report on integrity at different levels of the ecosystem. As such the ecological integrity of the area can be determined using already proven indices to compare with the small mammal results. A further recommendation is that future small mammal studies should also include extended seasonal sampling including autumn and winter which have proved to yield higher trap success.

Declaration of own work

I **Jean Jacques de Klerk, 2011144413**, declare that this assignment is my own work, that it has not been submitted for any other degree, at UFS or any other University or any higher education institution, and that all resources that I have used or quoted are indicated in the text and acknowledged in the list of references.

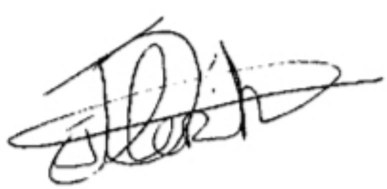

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Table of Contents

List of Tables

List of Figures

CHAPTER 1

INTRODUCTION AND OUTLINE

Alien invasive plant species pose a great threat to biodiversity, world-wide. In South Africa 200 introduced plant species have been classified as invasive (Chamier *et al*. 2012; Poona 2001). Alien invasive species are considered to be the second most significant threat to biodiversity, after direct habitat destruction (Holmes *et al*. 2000). These species are associated with various negative implications, including native species loss and lead to increased fire intensity which in turn can have secondary effects on the habitat as well as lead to decreased river flows (Chamier *et al*. 2012). South Africa is a water scarce country, with almost all its accessible water being allocated for use (DWA 2010). Alien vegetation is listed as one of the factors limiting the water supply of South Africa through impacting the quality and quantity of rivers and dams (DWA 2010).

Alien vegetation eradication programs are, and have been, ongoing across many areas of South Africa for a long time and their schemes have been classified as the most ambitious in the world (Galatowitsch & Richardson 2005; Rouget *et al*. 2004). This is done in order to attempt to restore biodiversity in areas where alien vegetation have become established and altered the habitat, as well as to try and improve water quality and quantity. The eradicated areas are believed to be able to restore to the original condition and therefore improving the biodiversity of the area. Indicators that have been identified however take time to be evaluated such as insects (Pearson 1992), reptiles (Letnic *et al*. 2004).

By lowering the biodiversity of an area, various trophic levels are impacted and hence there is a need for various trophic levels to be monitored or assessed to identify threats. Small mammal communities have been studied in areas with invasive *Lantana* sp., where species diversity was lower than in less disturbed areas (Avenant & Kuyler

2002), as well as in areas in different stages of succession and of ecological integrity (see Avenant 2011). This poses a threat to other trophic levels as increased small mammal diversity has been proven to increase overall species richness, functional diversity and, therefore, ecological integrity of an area (Carey & Johnson 1995). They are adapted to micro habitats and therefore can be affected by small scale changes, which can be monitored to assist in biodiversity studies.

Small mammal communities have been identified as possible indicators of the ecological integrity of an area in the grassland biome as well as sustainable habitat management in conserved areas (Avenant 2000, 2011; Kaminski *et al*. 2004). Small mammals, therefore, can be utilized as an inexpensive, relatively quick estimate of habitat health or improvement (Avenant & Cavallini 2007). They could especially be useful short-term identification systems of biodiversity increase or vegetation improvement as other indices may recover more slowly after disturbance (and small mammals recover fairly quickly (Avenant 2011).

By assessing the small mammal diversity and community structure in eradicated areas, judgments can be made about the success of implemented eradication programs. As small mammal surveys can be done readily, the ability to use them as indicators allows them to be implemented in all eradicated areas to indicate conditions of area over various time periods and can be utilized on a continual basis. Avenant (2005, 2011) suggested a hypothesis where small mammal diversity will increase along with the succession of an area, which could indicate habitat improvement. As they are adapted to smaller habitat scales they can indicate ecological integrity change on a scale assisting Environmental Impact Assessments, which are normally done on a local scale.

No small mammal studies have been conducted on Kariega Game Reserve and therefore no data is available on species richness or community structures. The survey will allow small mammal community composition and structure to be investigated, as well as identifying the species that occur in the habitats. Small mammals for this study will include, mice/rats, shrews and elephant shrews, which can all be caught in the PVC live traps.

1.1 Research question

To what extend does small mammal diversity, species richness and community structure indicate improved integrity in alien-eradicated areas?

1.2 Summary of methodology

The methodology is addressed in more detail in chapter 4. This summary is to aid in explaining how the data was collected to achieve the objectives and aims of the study. Through sampling three different areas on Kariega Game Reserve, this study aimed to identify the difference in small mammal species diversity, species richness and community structure between the areas. This data allowed identification of whether there are differences between the areas and to assess these. Live traps were placed along transects in each habitat to cover as great a surface area of each habitat as possible.

1.3 Objectives and aims:

In order to answer the main research question, this study aims to:

- To determine which species of mice, shrews and elephant shrews are present in specific habitats on Kariega Game Reserve.
- Determine the community structure, species richness and diversity of small mammal species in an area infested with alien vegetation.
- Determine the community structure, species richness and diversity of small mammal species in an area cleared of alien vegetation.
- Determine the community structure, species richness and diversity of small mammal species in a control area that has never had alien vegetation.

- Assess if indicator species, groups or indices can be identified to use as habitat improvement indicators.

1.4 Thesis outline

This thesis is divided into seven chapters and a reference list (using the Harvest referencing method). Chapter 1 (current) gives a background on the situation with alien vegetation in South Africa and the area of study and how small mammals could assist in evaluating the success of eradication projects for overall biodiversity. It stipulates the aims and objectives of the project, which will assist in answering the research question.

Chapter 2 consists of a concise literature review on the role of small mammals in habitats, the impact of alien vegetation on biodiversity, the current eradication projects, and different sampling methods of small mammals, as well as studies involving small mammal diversities and communities, and statistical analysis used during small mammal studies.

Chapter 3 and 4 describes the study area including the vegetation and climate; it also describes the methodology that was used during the study including the sampling method or trapping protocol and the data analysis that was used.

Chapter 5 and 6 explains the results that were obtained during the study, discuss them and, what they mean for the study, and explains the differences recorded between the three areas.

Chapter 7 is a brief conclusion of the study, including limitations and recommendations for further or future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Role of small mammals

The relationships between any animal and their environment are complex. Small mammal communities are no different and have been related to biotic and abiotic factors (Avenant 2000; Els & Kerley 1996). Avenant (2000, 2011) indicated that changes in small mammal habitats are associated with change in small mammal diversity and that disturbances in habitat can be associated with a decrease in small mammal species richness. Rodents and shrews are also adaptable and can specialize particularly in small habitats, and therefore they could be indicators for smaller areas (Avenant 2000). They also play an important role in terrestrial ecosystems as a prey base, as predator and functions in nutrient cycling; therefore, they might be able to be used as biological indicators of change (Taylor *et al*. 2007; Dale & Beyeler 2001). Direct monitoring of small mammal communities might be used as a relatively inexpensive, timely method for indicating ecosystem integrity and functioning (Avenant 2000). However more information on diversity indices and species in different habitats is required for this to be possible especially outside the Free State grasslands. Limited information on many habitats is available on small mammal diversity, and their abundance in South Africa. These indices also need to be correlated with current habitat integrity indices, such as of insects (Pearson 1992) and reptiles (Letnic *et al*. 2004), to ensure accurate and concise evaluations (Kaiser *et al*. 2008).

As small mammals occupy micro habitats and have a distinct relation with example the substrate and vegetation type and cover, they can be affected by micro and macro changes caused by management practices (Krystufek *et al*. 2007; Kearney *et al*. 2007). This expresses the need to assess what impact management decisions about alien vegetation control may have on small mammal species and communities.

It is very important to accurately sample small mammal communities, as failure to do so may result in incorrect information, which will affect decisions or conclusions (Magurran 2004). The greater the sampling effort, the greater the chances of recording all species within the community (Magurran 2004). Some species however are more difficult to sample, and no single sample regime is sufficient in collecting all species equally effective. Some species are trap shy and will be under-represented (Magurran 2004; Rowe-Rowe & Meester 1982), and some methodologies might be limiting to exclude some species. Trap size may cause capture bias data (Kok 2011; Anthony *et al*. 2005; Rowe-Rowe & Meester 1982).

2.2 Invasive vegetation

Exotic vegetation can have adverse effects on the biodiversity of an area. By changing the vegetation structure and diversity, other levels of the trophic level could be affected. By changing the landscape and vegetation, small mammal habitats are altered which lead to a reduction in species diversity of small mammals in the area (Horncastle *et al*. 2005). It is expected that extended ecological disturbance will lead to a loss of ecosystem integrity associated with invasion by exotic organisms, which can be reflected in a decline in small mammal species richness (Avenant 2000, 2005, 2011).

Black Wattle (*Acacia mearnsii*) is an alien plant which has major implications on water sources (Dye & Jarmain 2004) as well as biodiversity; it outcompeting the indigenous vegetation and lowers the overall biodiversity (Boudiaf *et al*. 2013; Lowe *et al*. 2008). Black Wattle is native to Australia and was introduced in the 19th century in plantations for the production of tannins (de Neergaard *et al*. 2005). It is listed among the top 10 invading species in South Africa, growing extensively on large areas of the country (Nel *et al*. 2004; Le Maitre *et al*. 2000). All habitat types are susceptible to invasion whether grasses, forbs, shrubs or trees, and it therefore pose a big threat to overall biodiversity (van Rooyen 2002). This leads to invasive species having an influence on ecosystem goods and services to people, with water supply and reduced biodiversity as an example (Richardson & van Wilgen 2004).

In South Africa, NEMBA (National Environmental Management Biodiversity Act, Act 10 of 2004) regulations have been established where the government now requires that protocols need to be made for all invasive alien plant species to be monitored, controlled, and eradicated (Poona 2001; Kidd 2011). Since 1984, regulations were promulgated in the Conservation of Agricultural Resources Act, Act 43 of 1983 (CARA) (Poona 2001). It provides protection of natural vegetation and the combating of invasive plant species. It also places invasive species in three categories of severity of which Black Wattle is in Category 2 (Poona 2001).

Fire has a great impact on small mammal communities (Avenant 2011), with different fire regimes and intensities having different impacts (Kern 1981; MacFadyen *et al.* 2012). Therefore alien vegetation can have further secondary effects on small mammal communities by changing fuel loads of the fire.

2.3 Experimental designs in small mammal surveys

Many different methods for trapping small mammals have been used in various studies. The choice of method usually varies due to different goals and time available. Avenant & Cavallini (2007) utilized fixed transects during 10 day snap trapping periods. Following this and previous studies by the same author (Avenant 2000a+b), it was advised that standardization was accomplished by trapping for four consecutive days and nights. Whittington-Jones *et al.* (2008) studied the differences in diversity between bush clumps and open areas in the Eastern Cape and used transects within each area to indicate if there are any diversity differences. As well as transects, plots or grids can be used to determine diversity and abundance of small mammal species. This method however requires a relatively large amount of traps if large areas are studied (Muck & Zeller 2006).

Choosing which method to utilize is strongly influenced by the equipment, goals and time for the study. Studies have indicated that transects had higher success than grid and plot sampling (Pearson & Ruggiero 2003). When both methods were compared in same vegetation and situations, transects yielded greater trap success (total captures and individual totals), and a greater species number than on grids (Pearson & Ruggiero 2003). Transects can be modified according to requirements and do not have a fixed structure or theory of use and a wide variety of transect set ups have been used in various studies (Avenant & Kuyler 2002; Avenant 2000a+b; Whittington-Jones *et al*. 2008; Muck & Zeller 2006; Kasangaki *et al.* 2003).

As diversity changes between habitats and areas, the methods used to determine the diversities between vegetation types need to be standardized to allow for the data to be comparable (Avenant & Kuyler 2002; Avenant 2011).

The overall goal and purpose of the study influences the trap choice used in a study on small mammals. A variety of trap types are available each with their own advantages and disadvantages. There are mainly two groups of traps, live and lethal traps. Live traps such as Sherman traps, Elliott aluminum traps and Willan PVC construction traps, were used in various studies to determine species diversity and allowing for recapture studies of species when needed (Gibson *et al*. 2004; Muck & Zeller 2006; Whittington-Jones *et al*. 2008; Taylor 1998). Lethal traps such as wooden snap-traps and Museum special traps were used when species captured were kept for museum records or when external studies were done on the species (Avenant 2000; Avenant & Kuyler 2002). Some studies done have indicated live trapping have yielded significant more captures than snap traps and that Sherman traps (similar Willan PVC construction traps) yielded greater species richness than other live traps (Lee 1997; Torre *et al*. 2010); other studies (see Avenant 2011) have shown that the snap traps are at least as effective as PVC live traps in sampling number of specimens, but that some species and specific individuals (e.g. young males of some species) of other species does not enter the box traps. Some studies have also indicated that the use of a combination of traps will yield greater success, as some small mammal species might avoid certain traps and will influence the data.

Alongside the type of trap that is used in a study, the bait that is used is important. Small mammals feed on a variety of food sources from insects to seeds and thus will be attracted differently with various bait types. When diversity is the goal of a study it is suggested to use a bait type with combination that will attract both rodents and insectivores, and a combination of peanut butter, rolled oats, sunflower oil and marmite have been used on many occasions (Earl 1970; Avenant 2011). The sunflower oil is to keep the bait from drying out and marmite is known to lure also the insectivores.

During small mammal trap surveys using live capture, some mortality has been recorded (Kok 2011). Therefore it is suggested to check the traps regularly to prevent species dehydrating or overheating in the traps. Checking the traps each morning and early evening is recommended during surveys (Muck & Zeller 2006; Whittington-Jones *et al*. 2008).

Survey duration is a study specific aspect and needs to be designed for the purpose of a study. Avenant & Cavallini (2007) however indicated that four consecutive days and nights is the optimum duration for a removal-trapping survey. This time frame gives enough days to allow for optimum species trap success. Having traps out for more than 4 days did not show any increase in species and therefore is not necessary if the goal of the study is species diversity (Avenant & Cavallini 2007).

2.4 Previous small mammal studies

Only a few studies have been completed on small mammals in the Eastern Cape and therefore a significant amount of information on small mammals is interpreted from various studies of other areas. The studies in the Eastern Cape mainly focused on altitude (Kok 2011) or habitat preference between bush clump and open area (Whittington-Jones *et al*. 2008) and small mammals in mountain grasslands (Armstrong

& Van Hensbergen 1996). Some older studies were completed in the national parks of the Eastern Cape such as Addo Elephant National Park and Mountain Zebra National park to identify small mammal species of the area (Swanepoel 1975; De Graaff & Nel 1970). From these studies it is estimated that approximately 14 rodent species and 2 shrew species are to be expected in the study area.

Studies in other habitats were conducted for different goals. Monadjem & Perrin (2003) studied small mammals of Swaziland. It was found that there were significant seasonal differences in species richness and community structure and that fire had a severe impact on small mammal communities. It was also recorded that generalist species increased greatly after the fire with other species number reducing (Monadjem & Perrin 2003). Small mammal studies in KwaZulu-Natal were completed to assess habitats of species in Umvoti Vlei Conservancy (Fuller & Perrin 2001), iSimangaliso Wetland Park (Taylor *et al*. 2007) and general abundance and community composition of small mammals in protected areas (Taylor 1998). It was also found that seasonal fluctuation in species richness with higher species richness in late autumn and early winter in the Free state.

2.5 Statistical analysis

Many statistical formulas have been used in different studies on small mammal species, all depending on sample size and trap method, as well as objective of the study. Three measures of abundance that most were used were species richness, diversity and evenness. Species richness is the number of species collected during the survey. Shannon-Wiener and Simpson's diversity indices indicates both the number of species and how individuals are represented between all species (Avenant & Cavallini 2007; Kasangaki *et al*. 2003). The evenness is the distribution of the abundance of species and will be assessed by using a formula called Evar which ensures that the variance is taken over log abundances to ensure the index is not dependent on the units used (Smith & Wilson 1996; Tuomisto 2012).

2.6 Small mammal communities as indicators

The aim of this study is to determine if and what small mammal indicators can be used in future studies to quickly and cheaply evaluate if the integrity of an area cleared from alien vegetation is improving. Studies have suggested that small mammal species richness and diversity decline along with habitat degradation (see Avenant 2011). Generalists tend to dominate community numbers in areas with a low ecological integrity and specialist species establish in vegetation that is in good condition as they outcompete generalists; therefore these species could be possible indicators of recovery (Avenant 2011). If this correlation can be identified, these indicator species can be used to determine if the eradication program is successful or if more attention needs to be given to the area.

Avenant (2011) evaluated the theoretical basis for this prediction that is found in Tilman's hump-shaped curve model (Tilman 1982) (Figure 1).

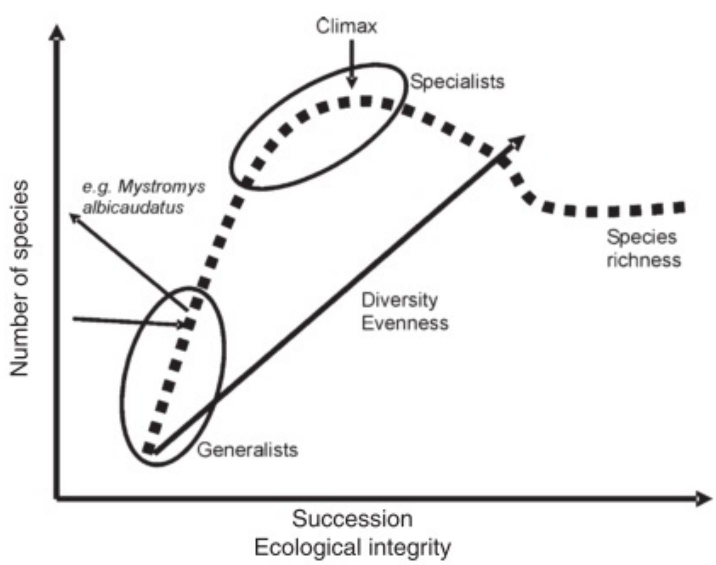

Figure 1. Hypothesis for using small mammals as indicators of habitat integrity. [Following Avenant 2011**].**

This model predicts an increase in species richness and diversity along with the advancing successional stages after a disturbance until ecological climax is reached (Avenant 2011). Furthermore Avenant (2011) identified that generalists occupy the habitat after the disturbance and generally more specialists establish toward succession climax.

CHAPTER 3

STUDY AREA

3.1 Location

Kariega Game Reserve is located, approximately 45 km south of Grahamstown (33°35'S, 26°37'E), along the R343 (Figure 2). It lies between the Kariega River and Bushmans River Valleys and is approximately 9000ha in size and varies from an altitude of 380 m a.s.l. at the base of the Kariega River Valley to and altitude of 710 m a.s.l. in the northwest corner of the reserve. The primary geological formations of the reserve include Beaufort Group shale, mudstone, solonetic soils and sandstone, and Cape Supergroup sandy clays and lithosols (Low & Rebelo 1996). The main source of water for the reserve is dams as well as the perennial Kariega River in the east and Bushmans river in the west (Figure 3).

The area on which the study will focus is the eastern section of the reserve between the R343 and the Kariega river (Figure 2, Figure 3). This area was selected as the reserve has up to date vegetation and management data for this section.

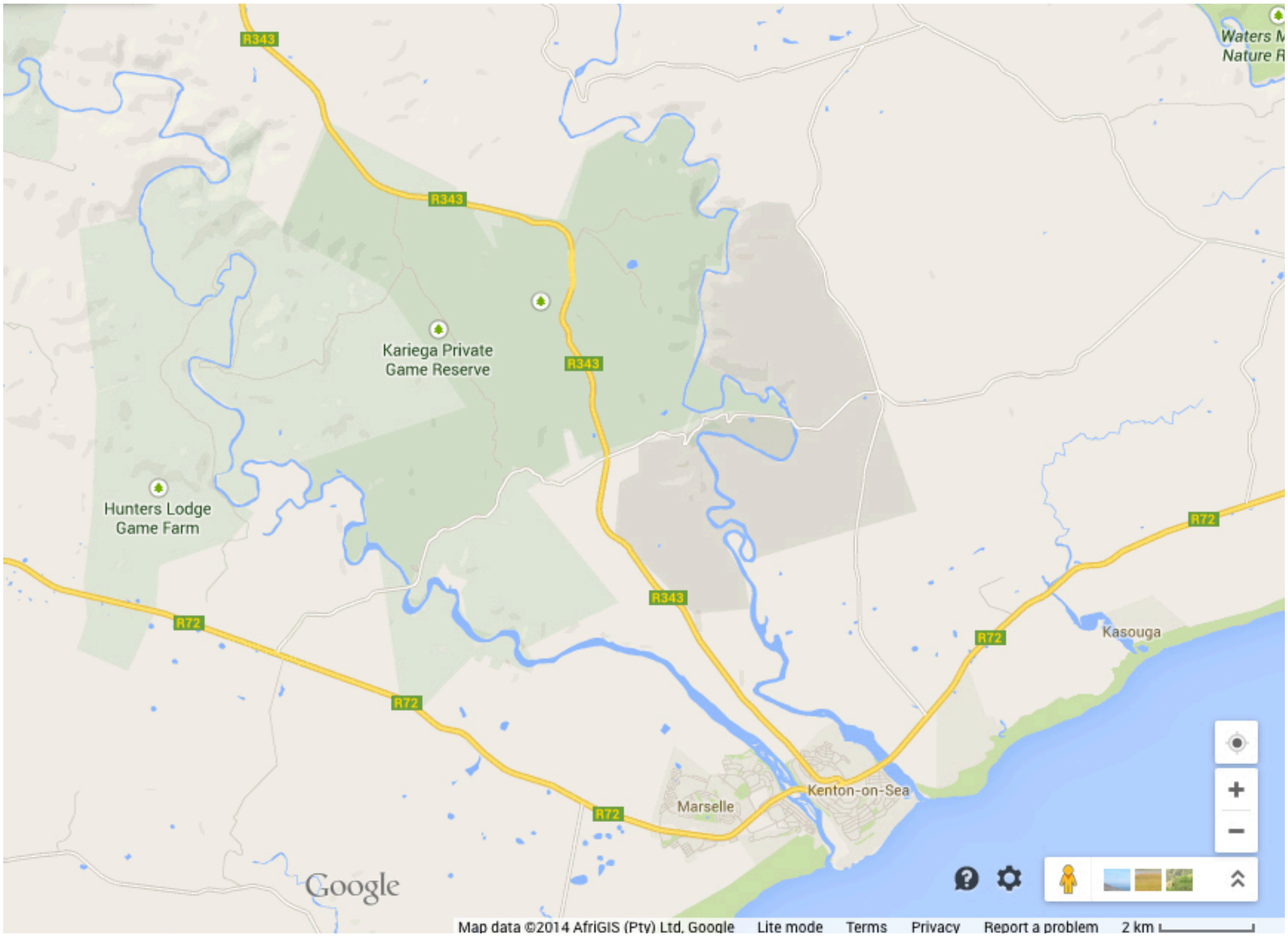

Figure 2. Map indicating the location of Kariega Game Reserve along the R343.

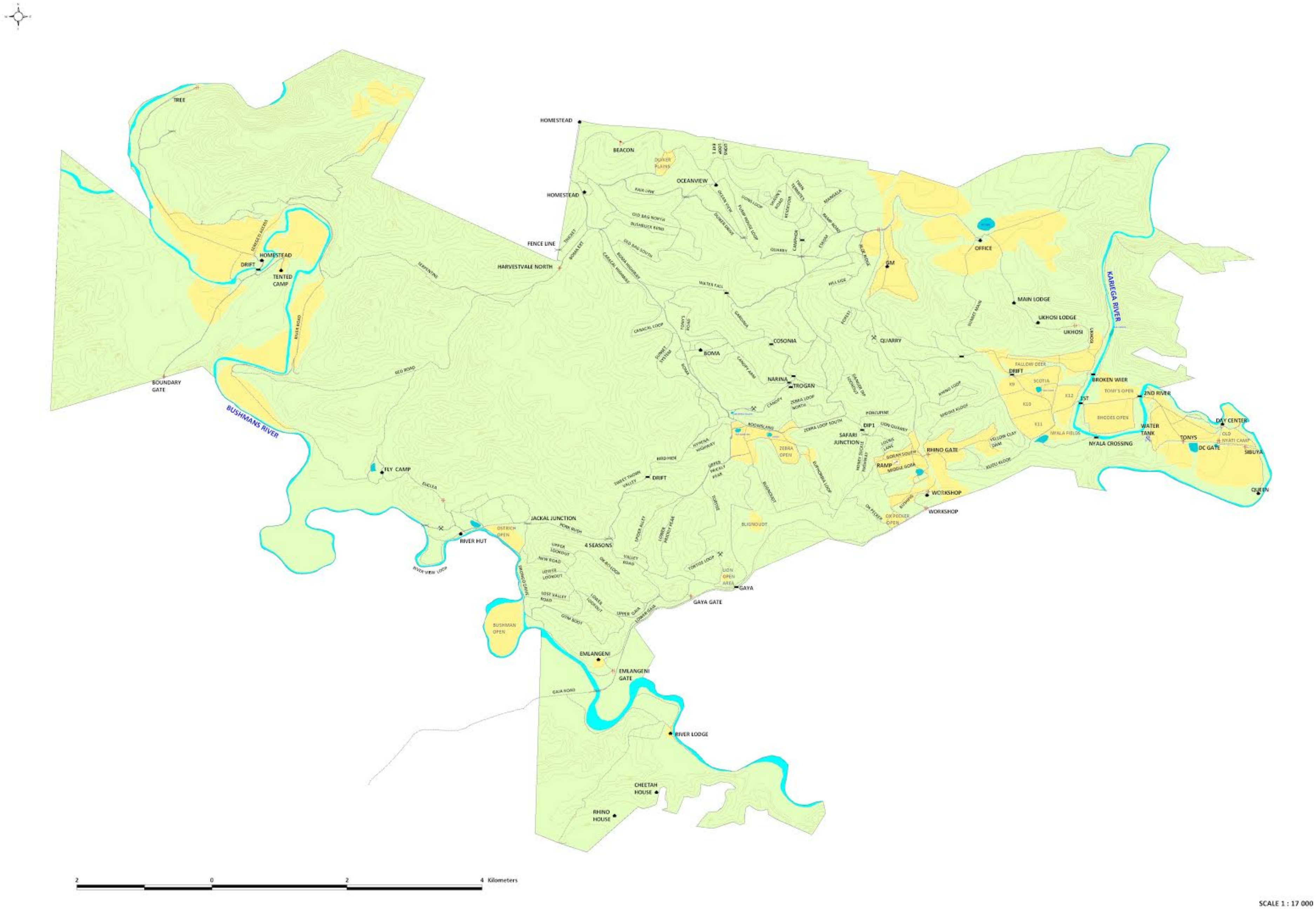

Figure 3. Map of Kariega Game Reserve indicating the roads, rivers and homesteads.

3.2 Climate

3.2.1 Temperature

Temperature averages were taken from onsite data collected. The warmest month average measured for the year 2011 on the reserve was for January and February (26˚C) and the coldest month (night temperature) was for June and July (9˚C) (Figure 4). This is accurate with the mean long term temperatures for the area (Weather Bureau 1986).

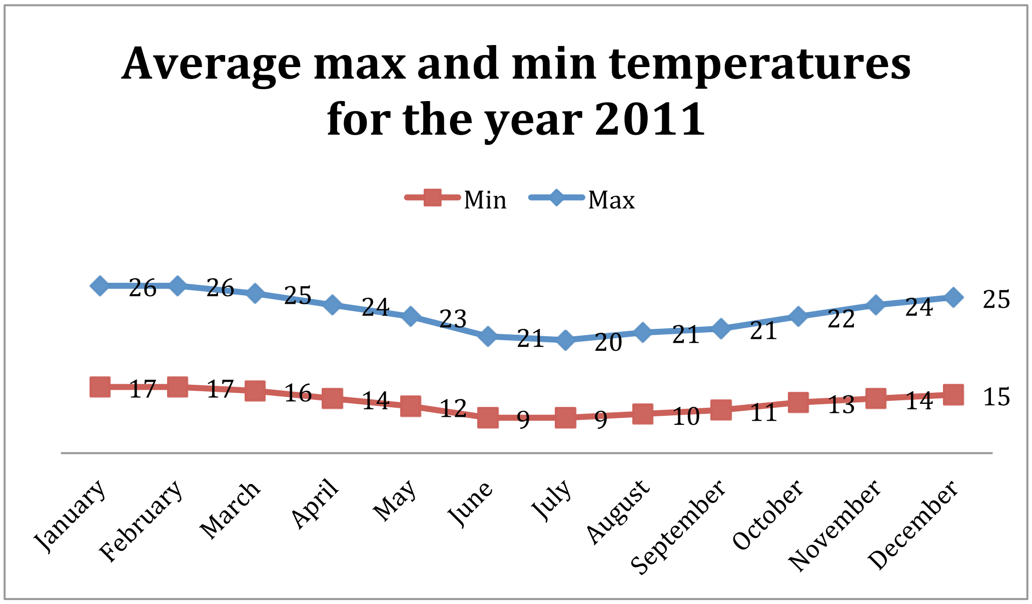

Figure 4. Illustration of the average maximum and minimum temperatures of Kariega Game Reserve for 2011.

3.2.2 Rainfall

The Eastern Cape has a high varied and inconsistent rainfall pattern that differs from west to east. The reserve is located in the spring-dominated rainfall area of the Eastern Cape, but has a clear bi-modal rainfall pattern i.e. March-April and October-November (Stone *et al.* 1998) (Figure 5). The average rainfall for the reserve was compiled from data collected by Kariega Game Reserve's volunteer programme, between 2007 and

2011 (Figure 5). The average annual precipitation for the closest town for which data were available, Port Alfred, for the period 1936 to 2003 was 640 mm (Department of Economic Development and Environmental Affairs, 2009, Hoare, 2006).

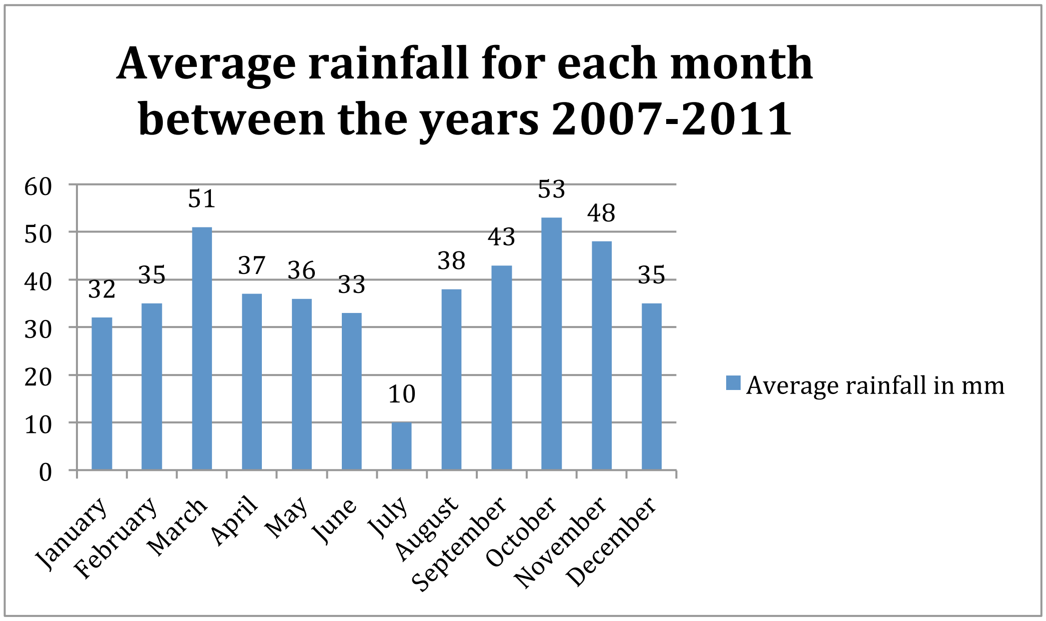

Figure 5. Illustration of the average rainfall for Kariega Game Reserve for the period 2007-2011.

3.3 Vegetation

Seven biomes are present in the Eastern Cape (Department of Economic Development and Environmental Affairs, 2009, Figure 6). Three major vegetation types are present on the reserve, namely Kowie Thicket, Albany Coastal Belt and Cape Estuarine Salt Marshes (Mucina & Rutherford 2006), with Kowie thicket being the dominant vegetation type (Parker, 2004). Characteristic species include *Cassine aethiopica, Euphorbia triangularis, E. tetragona* and *Plumbego auriculata* (Low & Rebelo 1996). *Acacia cyclops, Acacia mearnsii* and *Lantana camara* has also invaded some of this vegetation type on the reserve.

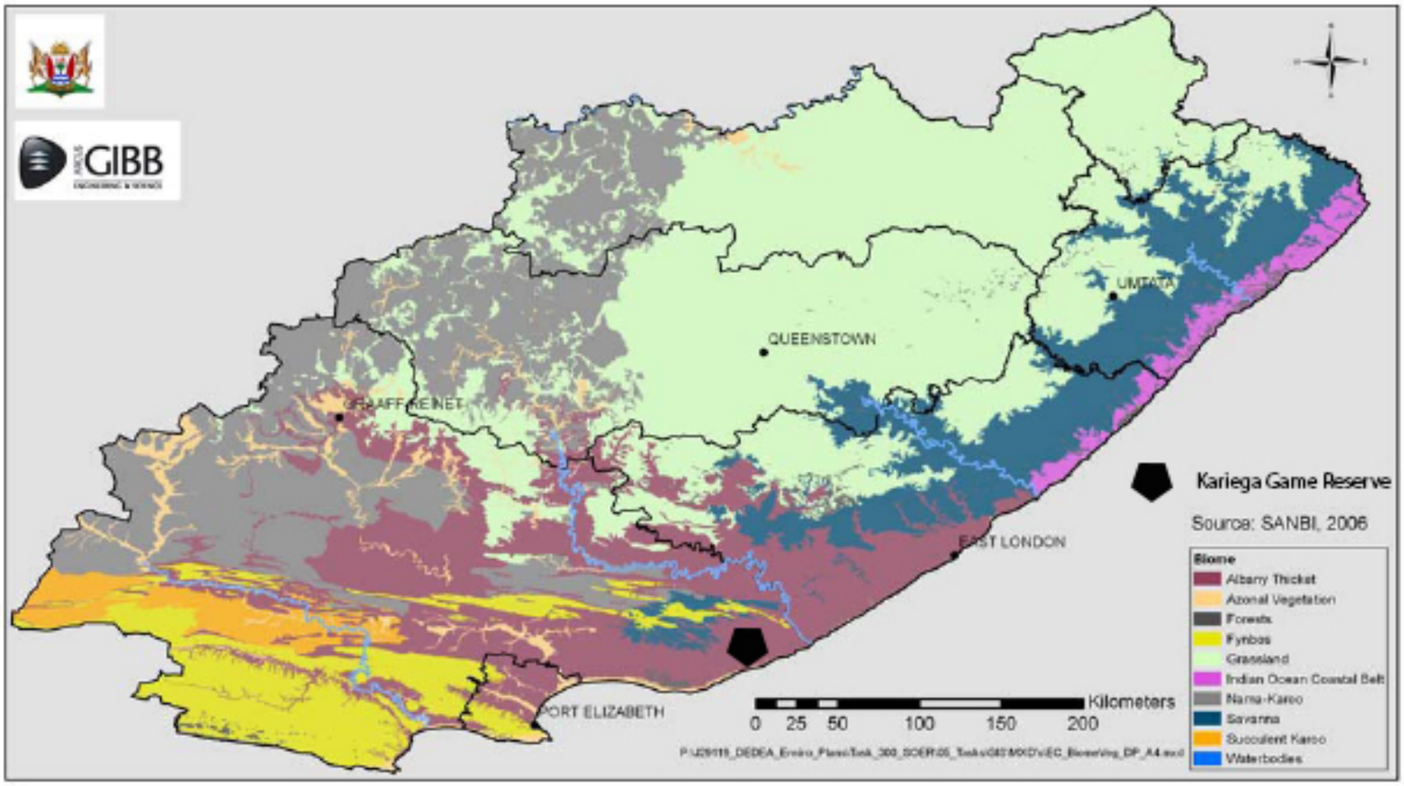

Figure 6. The seven Biomes present in the Eastern Cape indicating the area of the Albany Thicket (Department of Economic Development and Environmental Affairs, 2009: 15).

The three areas that were selected were:

1) Area heavily infested with Black Wattle (*Acacia mearnsii*).
2) Area that has been cleared of Black Wattle, 10-14months prior to the study.
3) Area in good condition to be used as a control, similar to the other areas in aspect, soil type and altitude (Figure 7).

These areas were selected from the reserve's alien vegetation prioritization maps, which were compiled by the management and volunteer programme to assist in alien eradication. Heavy infested areas were classified as areas that had established population of alien plants consisting of adults and seedlings. The cleared areas were classified as areas where eradication projects have been implemented, and more than 85% of the alien vegetation has already been removed.

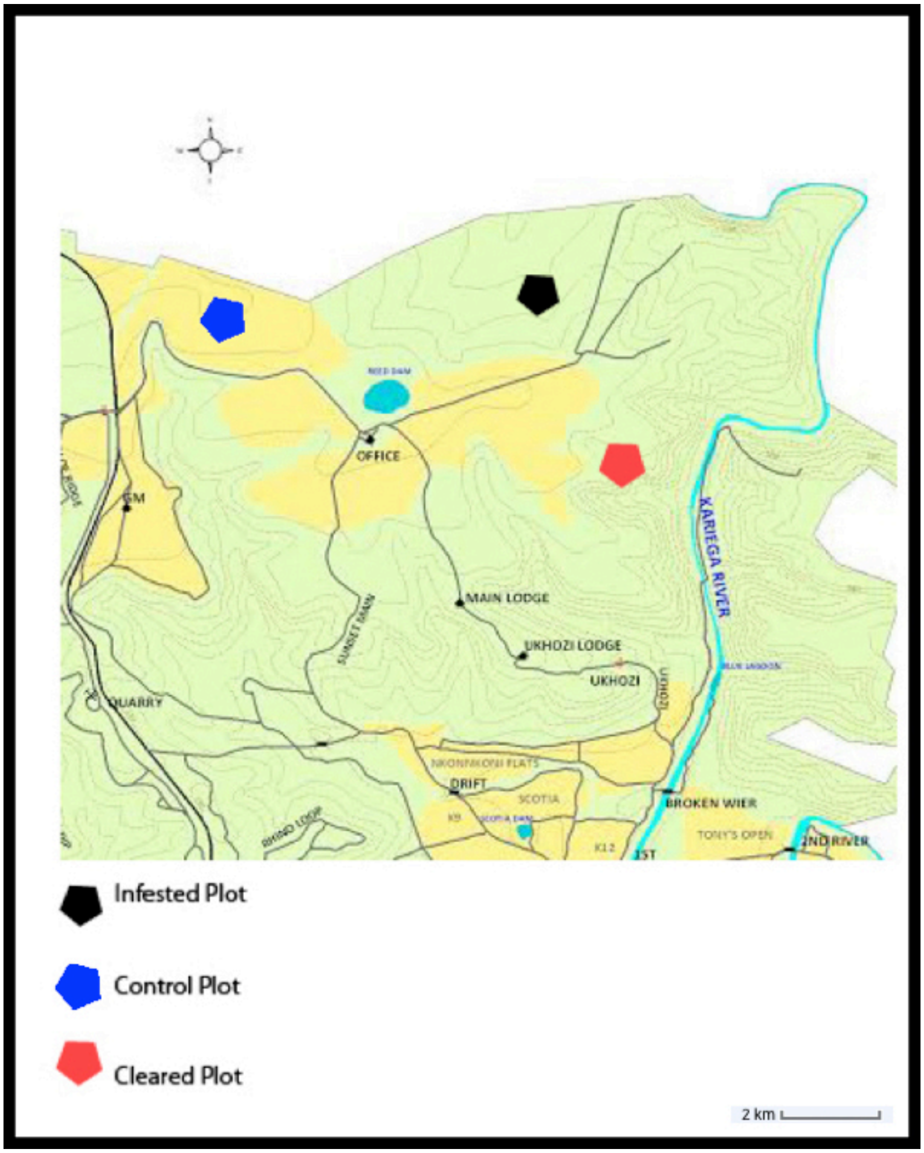

Figure 7. Map indicating the three habitats that were surveyed.

No small mammal studies have been done on the reserve and therefore no data is available on species richness or community structures.

CHAPTER 4

METHODOLOGY

4.1 Experimental design

Data were recorded from three different areas on Kariega Game Reserve by using live traps similar to Sherman and Willan PVC construction traps. These traps were made by me, replicating an example PVC construction trap received from Dr. Avenant from the National Museum in Bloemfontein. Live traps enable re trapping over months, as no specimens were removed from the study area.

It was established that there are 15 potential species present in the area (Table 1) (Kok 2011; Els & Kerley 1996; Whittington-Jones *et al*. 2008; De Graaf & Nel 1970; Krystufek *et al*. 2007; Swanepoel 1975). All possible species that could be caught have been researched (according to Skinner & Chimimba (2005)), and it has been determined that all species, except *Mastomys coucha* and *Mastomys natalensis*, could be identified without needing to study the skull morphology; therefore correct identification is possible from live specimens. If a species cannot be identified, a reference specimen will be taken and donated to a museum for identification.

Table 1. List of Small mammal (rats, shrews and elephant shrews) species that could possibly occur on Kariega Game Reserve (see text for references).

Species	
Scientific name	**English name**
Crocidura flavescens	Greater Red Musk Shrew
Dendromus melanotis	Grey climbing mouse
Dendromus mesomelas	Grants climbing mouse
Elephantulus rupestris	Western rock elephant shrew
Graphiurus murinus	Woodland dormouse
Graphiurus ocularis	Spectacled dormouse
Macroscelides proboscideus	Round eared elephant shrew
Mastomys coucha	Southern multimammate mouse
Mastomys natalensis	Natal multimammate mouse
Micaelamys namaquensis	Namaqua rock rat
Mus minutoides	Pygmy mouse
Myotomys unisulcatus	Karroo/Bush vlei rat
Otomys irroratus	Vlei rat
Rhabdomys pumilio	4 Striped grass mouse
Saccostomus campestris	Pouched mouse

As the goal was to determine species diversity, different transects were selected in each of the three researched areas. These transects allow for bigger areas to be covered within each researched area, allowing for optimum diversity to be recorded.

Traps were placed in three selected transects within each randomly selected area (Figure 8). Each transect had 50 traps, spaced at 5m from each other (Ferreira & Avenant 2003; Tew & Todd 1994). Transects were at least 200m from each other at all times to ensure larger area coverage and statistical analyses. The edge transects were more than 50m from any vegetation edge, to reduce the possibility of catching species from neighboring habitats. This gives a total of 150 traps in each area and a total of 450 traps per survey period for all three areas (Ferreira & Avenant 2003; Tew & Todd 1994). All individuals caught were hair-clipped at the base of the tail to enable recording of recaptures.

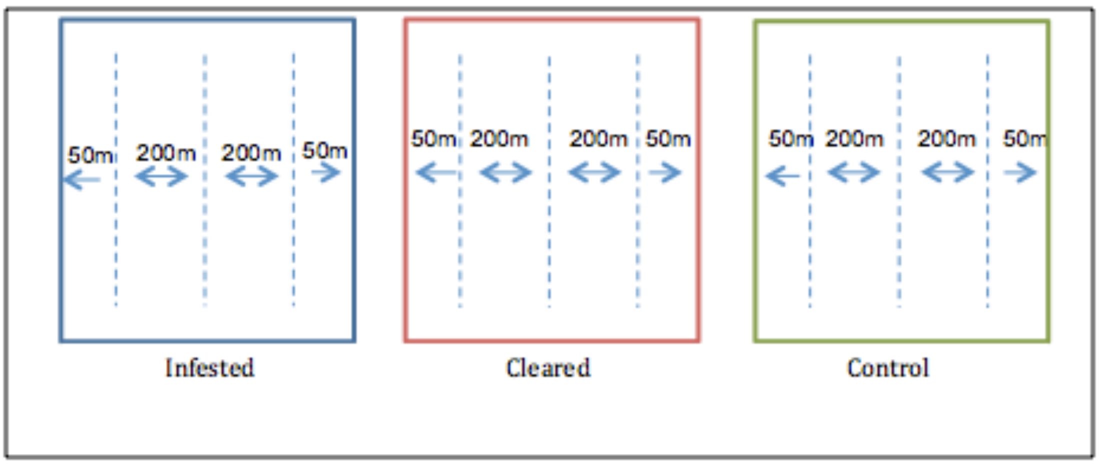

Figure 8. Illustration of the sample design for the study in the three different habitat types.

The traps were placed out for 4 consecutive days and nights during each survey period with the traps being placed the evening of day one in order to be able to collect data on the morning check of day two and will be removed after data collection of the evening of day five (at conclusion of the 4th 24h period). Avenant & Cavallini (2007) found that 4 consecutive days and nights of removal survey is sufficient to sample the diversity of an area, as more than 4 days did not indicate a significant increase in diversity.

Surveys were done once a month, from October till December 2013 (=3 surveys) to ensure that a large data sample can be collected. Surveys excluded full moon periods including 3 days prior and post, as studies have indicated that some species are less active during bright moonlit evenings and this might influence the data (Upham & Hafner 2013; Price *et al*. 2013).

Trap nights can be defined as 1 trap set for a 24 hour period (Avenant 2000; Rowe-Rowe & Lowry 1982). Each area therefore will have a total of 600 trap nights (150 traps per area for 4 days) and a total of 1800 trap nights per area after the completion of the study (and a total of 5400 trap nights on the three sites). Data were collected twice a day: every morning 6-8am and evening 6-7pm to ensure consistency, reduce mortalities of caught individuals, and re-bait traps if needed.

The bait consisted of a mixture of peanut butter, rolled oats, sunflower oil and marmite to attract as wide a variety of small mammal species, as possible (as explained in Chapter 2).

To standardize the data collection each individual specimen captured were placed into a clear plastic bag and a picture taken to confirm identification where necessary, and to keep as record. Voucher specimens of difficult to identify species would have been kept and donated to a museum to assist in identification, but this was not necessary.

Data recorded at each transect was:

- the species,
- total amount of trap hits per transect,
- recapture.

The measures of abundance used were trap success, species richness and species diversity (calculated with Shannon-Weiner information index and the Simpson's index).

All data recorded from all transects were logged into an excel spreadsheet to have organized data and easy data analysis for results to be evaluated.

4.2 Data Analysis

All data analysis were completed according to a standard approach. Most of the data were analyzed using Excel and the statistical programme *Practistat*. Trapping results to be presented include the number of captures, species caught, number of individuals/species caught, trap success, species richness, Simpson's diversity, Shannon diversity (heterogeneity), evenness, as well as the correlation of these data between the three different areas.

Trap success (indication of density) of each area were determined, as the number of small mammals captured per 100 trap nights (Avenant, 2000, 2011). Species richness is the numbers of species collected, and were recorded over the entire study.

Data were combined for areas sampled and totals of each survey. This allowed the analysis of differences between areas, as well as between each survey (month).

The Bray-Curtis similarity index were used to test the similarity between the three areas (Magurran 2004), as

$$BC_{ij} = \frac{2C_{ij}}{S_i + S_j} ,$$

where C_{ij} is the sum of the lesser value for only those species in common between both sites, and S_i and S_j are the total number of specimens counted at both sites. The value of this index ranges between 0 and 1, with 1 being identical and 0 being not similar at all.

The Shannon-Wiener diversity index and Simpson's index were used, to indicate the number of species per transect as well as how the abundance of the species are distributed. This data will allow for the difference in diversity between the three areas to be calculated in order to evaluate if there are any evidence of change in diversity between cleared and infested areas.

The Shannon-Wiener diversity index folrmula is

$$H = - \sum_{i=1}^{s} (P_i * \ln P_i)$$

where:

H = the Shannon diversity index

P_i = fraction of the entire population made up of species i

S = numbers of species encountered

∑ = sum from species 1 to species S (Rowe-Rowe & Meetser 1982; Magurran 2004).

The Simpson's diversity index formula (according to Magurran 2004) is

$$1 - D = \sum\left(\frac{n_i[n_i - 1]}{N[N - 1]}\right),$$

where *ni* is the number of individuals in the *ith* species, and N is the total number of individuals. The value of both these indices ranges between 0 and 1 and the greater the value, the greater the sample diversity.

To determine the evenness or relative abundance / a species evenness index calculation were used, namely Evar (Avenant 2011; Smith & Wilson 1996; Tuomisto 2012).This indicates how evenly the species per transect and habitat type are distributed, and therefore also how evenly the species recorded per transect compares to that in the total data.

The Evar formula (according to Smith & Wilson 1996) is

$$1 - 2/\pi \cdot \arctan\left\{ \sum_{S=1}^{S} \left(\ln(x_s) - \sum_{t=1}^{S} \ln(x_t)/S \right)^2 / S \right\}$$

Statistical analysis were done on all the raw data collected during sampling, and not on mean values.

The data was tested for normality using a Shapiro-Wilk test (Ashcroft & Pereira 2003), to determine if a parametric or non-parametric Anova should be used to determine if there is a significant difference between the three areas. This test was used to determine if the null hypothesis, that there are no significant differences between the three areas, can be accepted or rejected (P-value at 0.05) (Ashcroft & Pereira, 2003; Kaiser *et al*. 2008).

Further analysis was done by using a Friedman Anova, to test if there were any significant differences between the areas in terms of amount of species and amount of individual trapped between the areas per day. When the test indicated that there were some differences in the data set, a Wilcoxon Matched Pairs Test was done between each two variables to identify which data set was different from which between the areas and months.

All analytical data and figures were illustrated using tables and graphs.

CHAPTER 5

RESULTS

A total of 690 individuals were caught during the 5400 trap nights of the study, giving an overall trap success of 12.78% (Table 2,Figure 9). A relatively low number of recaptures were recorded, with only 13 recaptures in total; these were excluded from the diversity calculations as they were not new individuals, but were included in calculating the overall trap success and the Friedman Anova calculations using daily trap results. In total five small mammal species were caught: one musk shrew (*Crocidura flavescens*) and four rodents (Table 4). In all three areas *Rhabdomys pumilio* was the most abundant (Table 4). There was a clear difference in abundance between the three months sampled with the highest abundance in October and the lowest in December (Figure 10,Table 3).

Infested area: In total three of the five species were caught in the Black Wattle infested area, with the lowest species diversity, lowest total abundance and the lowest trapping success rate of all three areas sampled (Table 2, Figure 9). A total of 131 individuals were caught making up 18.99% of the total individuals for all areas (Table 2).

Cleared area: In total all five species were caught in the area cleared of Black Wattle, with a trapping success of 14.5% (Table 2, Figure 9). A total of 261 individuals were caught making up 37.83% of the total individuals for all areas (Table 2).

Control area: All five species were collected in the area that has not had any alien vegetation recorded in it. The control area had the highest trap success and highest total abundance between all the areas (Table 2, Figure 9). A total of 298 individuals were caught making up 43.19% of the total individuals for all areas (Table 2).

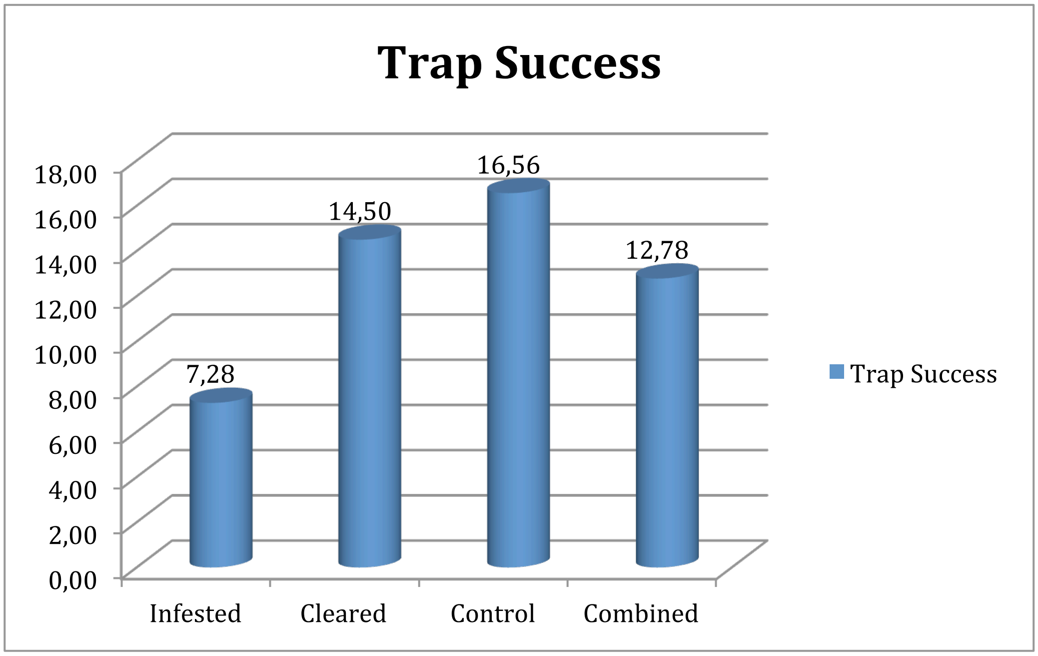

Figure 9. Illustration of the trap success between the areas sampled.

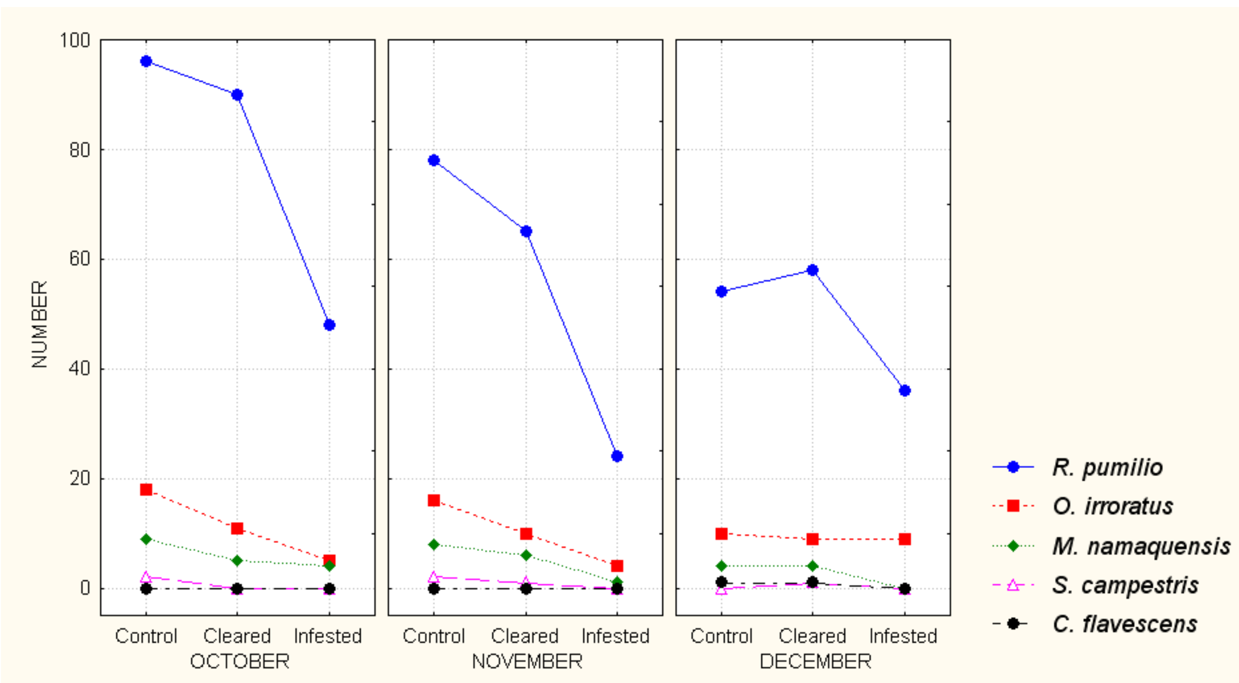

Figure 10. The number of small mammals caught in each area, each month on Kariega Game Reserve, 2013.

The Bray-Curtis index values for comparing the similarities between the three areas indicated that the cleared area and the control area were the most similar (0.93) (Figure 11).

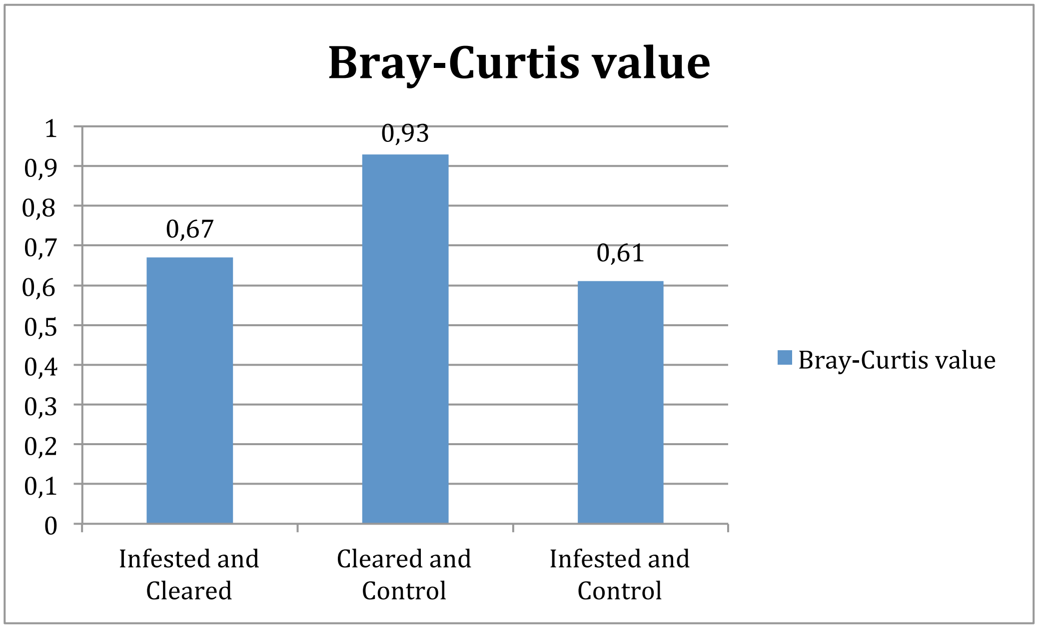

Figure 11. Illustration of the Bray-Curtis values indicating similarity between the Cleared and Control area.

Table 2. Summary of sampled data on the three plots on Kariega Game Reserve.

Study site	Number of Captures		Number of trap nights	Trap success	Species richness	Shannon Diversity Index	Simpsons index of diversity	Evenness
	N	**%**		**%**				
Infested	131	18.99	1800	7.28	3	0.5565	0.3023	0.3578
Cleared	261	37.83	1800	14.5	5	0.5945	0.3053	0.1631
Control	298	43.19	1800	16.56	5	0.7463	0.389	0.1748
Total	**690**		**5400**	**12.78**	**5**	**0.6578**	**0.3368**	

Table 3. Summary of data collected of small mammal abundance at each area during each mont

Species	**October**			**November**			**December**		
	Infested	**Cleared**	**Control**	**Infested**	**Cleared**	**Control**	**Infested**	**Cleared**	**Control**
Otomys irroratus	5	11	18	4	10	16	9	9	10
Rhabdomys pumilio	48	90	96	24	65	78	36	58	54
Micaelamys namaquensis	4	5	9	1	6	8	0	4	4
Saccostomus campestris	0	0	2	0	1	2	0	1	0
Crocidura flavescens	0	0	0	0	0	0	0	1	1
Total	57	106	125	29	82	104	45	73	69
Total per area	**288**			**215**			**187**		

The Friedman Anova indicated a significant difference in the amount of species caught between the areas (F=11.02857, N=12, df=2, p<0.00403), with the Wilcoxon test indicating that there was a significant difference between the cleared and infested area (Z=2.395, p<0.02), but not between the cleared and the control area (Figure 12).

The Friedman Anova further indicated a significant difference in the amount of individuals caught per day between the areas (F=19.5, N=12, df=2, p<0.0001) (Figure 13), with some species indicating significant differences caught per day per area such as *Rhabdomys pumilio* (F=18.17778, N=12, df=2, p<0.00011 (Figure 14), *Micaelamys namaquensis* (F=7.589744, N=12, df=2, p<0.0225) (Figure 15), *Otomys irroratus* (F=9.5, N=13, df=2, p<0.00866) (Figure 16). There were no significant differences in individuals caught between the areas for *Saccostomus campestris* and *Crocidura flavescens*, due to the low number of captures of these species; none of these species could be found in the infested area, but both were found in the control and cleared plots.

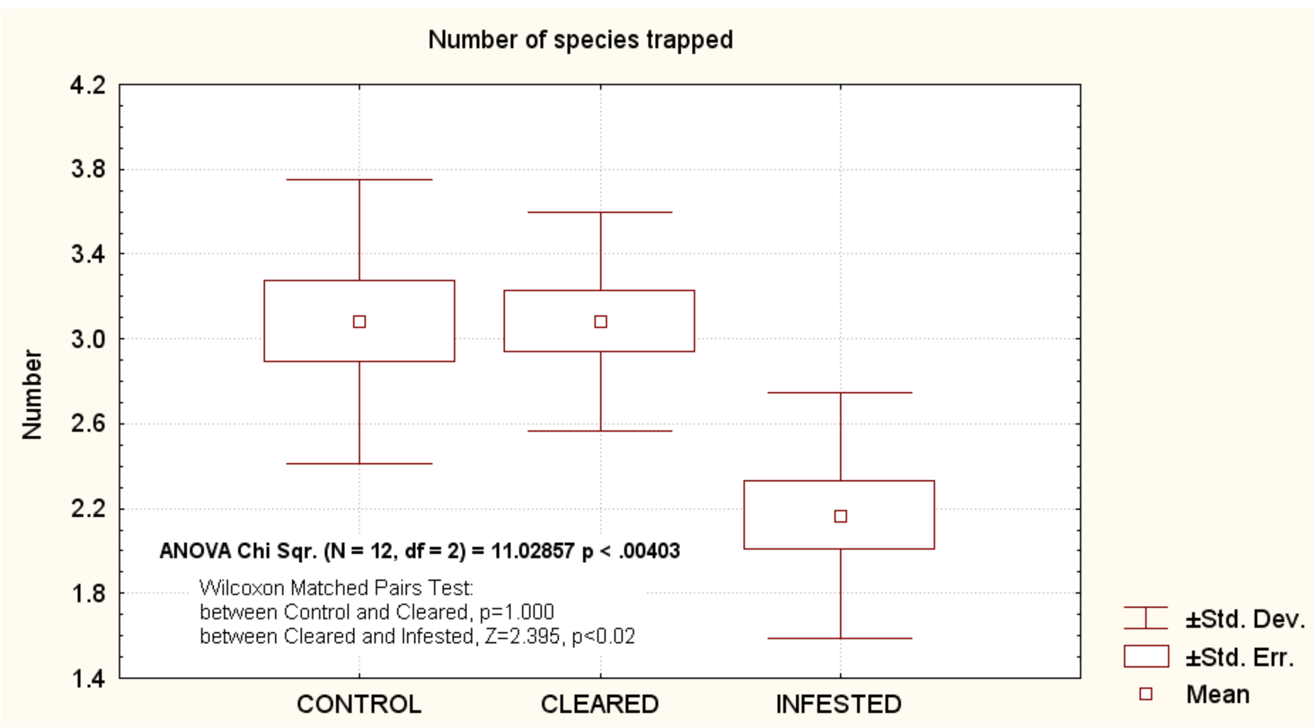

Figure 12. Graph indication the number of species trapped per area sampled.

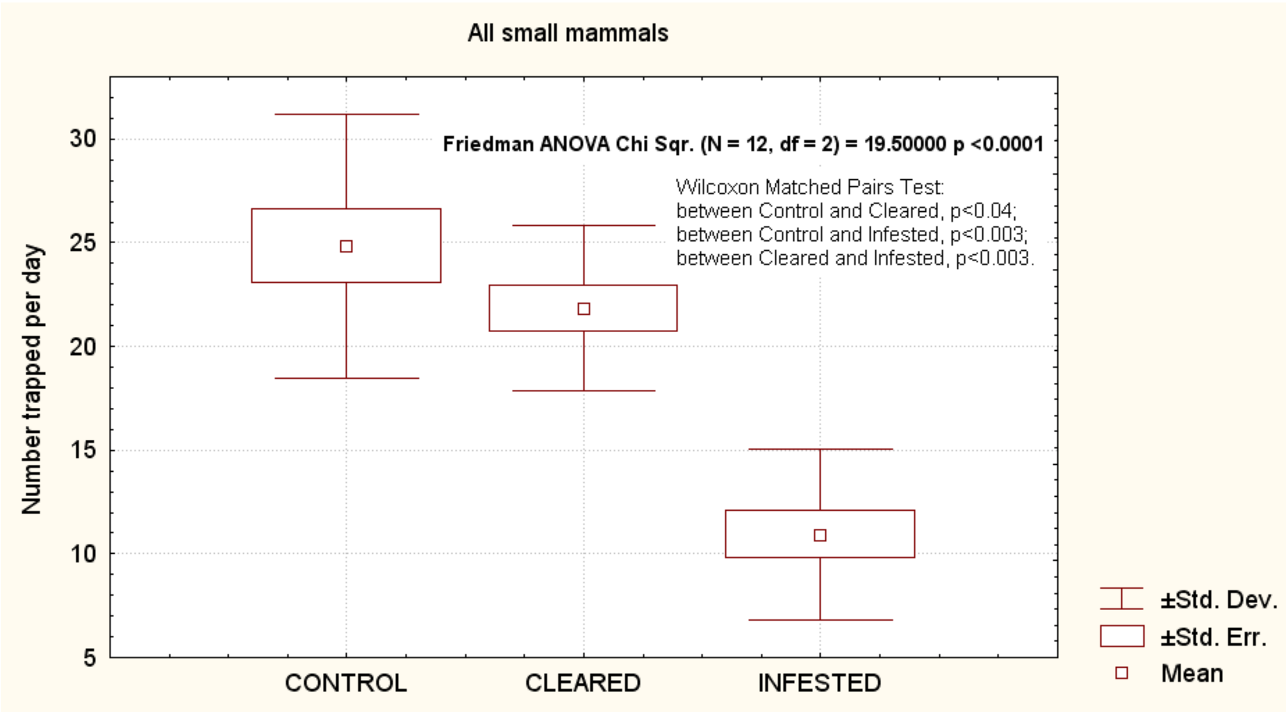

Figure 13. Graph indicating the average amount of small mammals trapped per day per area.

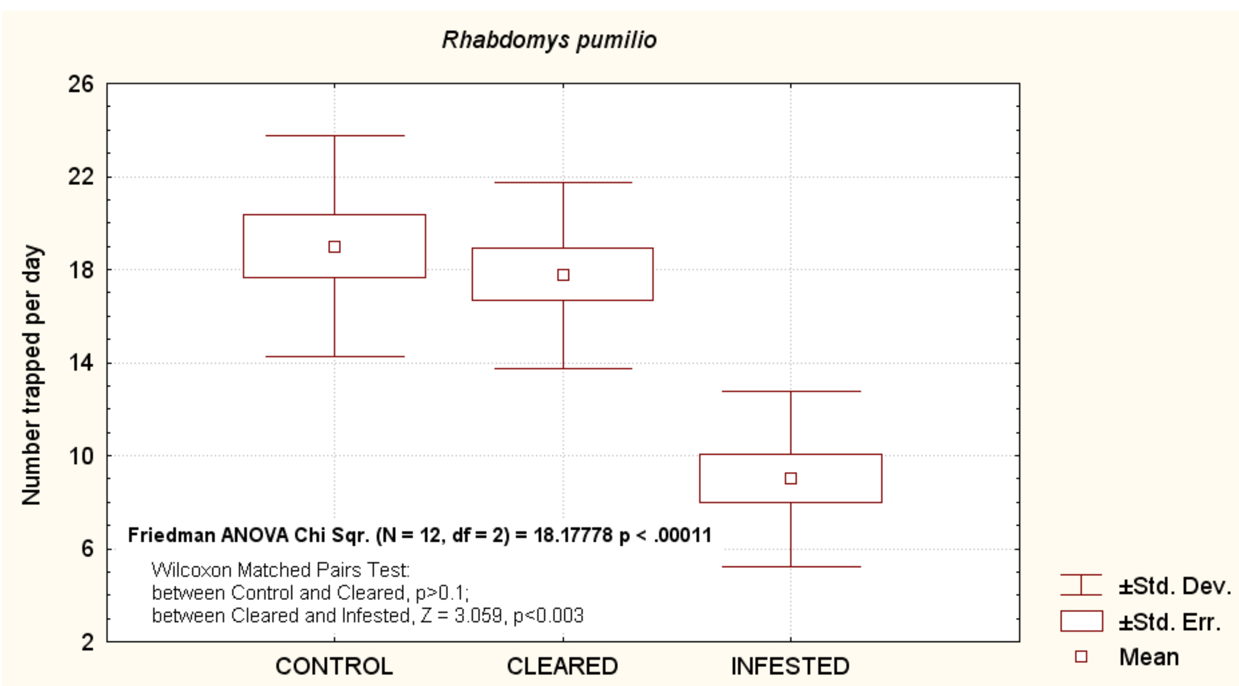

Figure 14. Graph indicating the difference in amount of trapping of *Rhabdomys pumillio*.

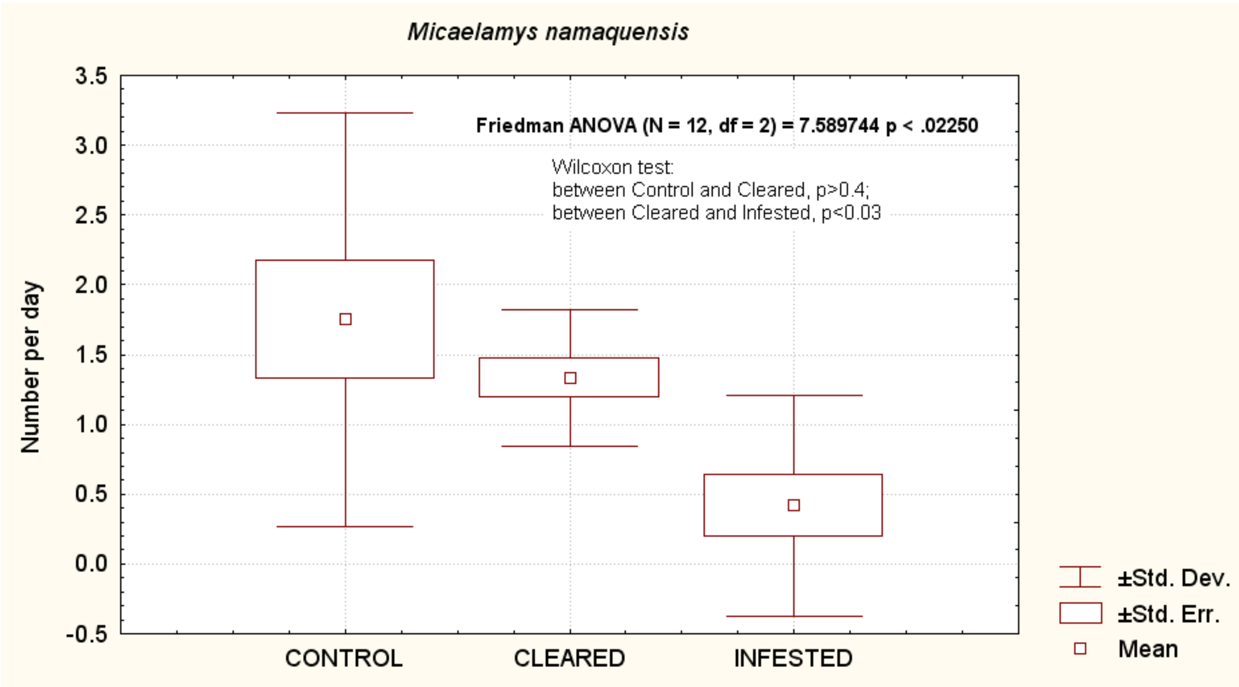

Figure 15. Graph indicating the difference in amount of trapping of *Micaelamys namaquensis*.

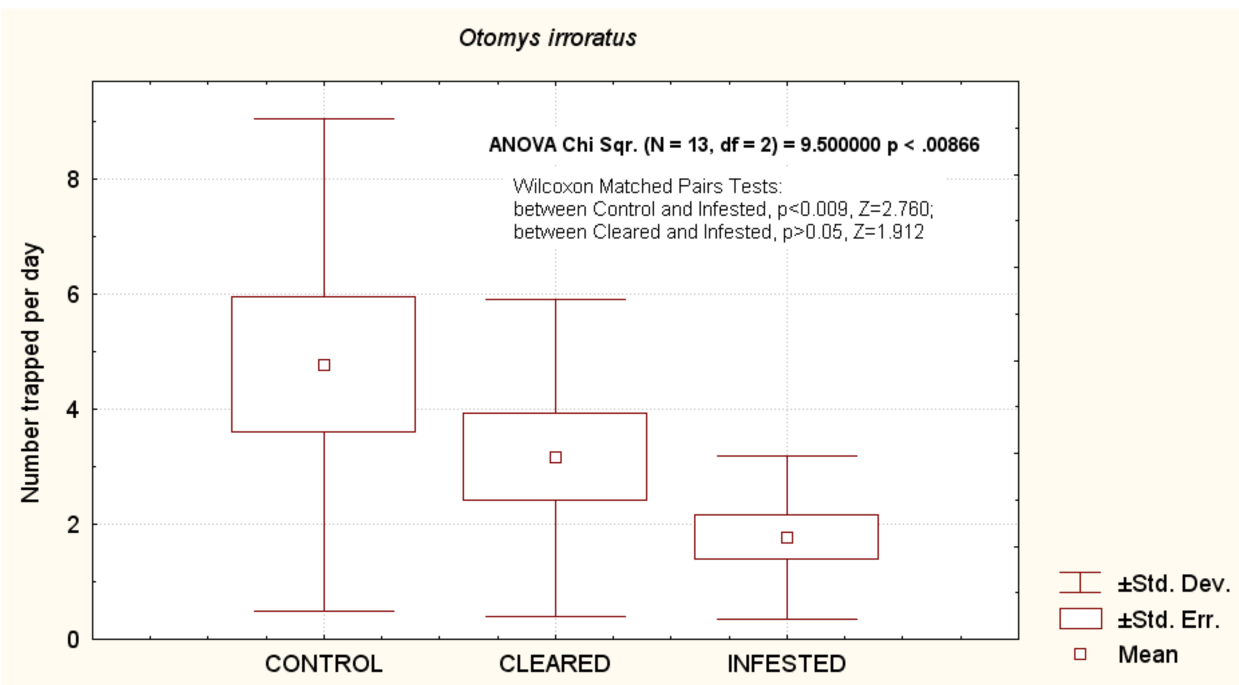

Figure 16. Graph indicating the difference in amount of trapping of *Otomys irroratus*.

5.1 Species Diversity

The diversity of each area was calculated with the Shannon-Wiener diversity index and the Simpson's diversity index.

The Shannon-Wiener index value for the areas were; (i) the infested area 0.5565, (ii) the cleared area 0.5945 and (iii) the control 0.7463 respectively (Table 2, Figure 17). The results indicated that the control area had the highest diversity due to the highest score, and the infested area had the lowest diversity due to the lowest score. Statistically there was no significant difference between the diversity of the cleared area and the infested area ($t=0.65$, $df=6$, $p>0.05$). The control area was significantly more diverse than the cleared area ($t=3.31$, $df=8$, $p<0.05$) as well as the infested area ($t=3.41$, $df=6$, $p<0.05$).

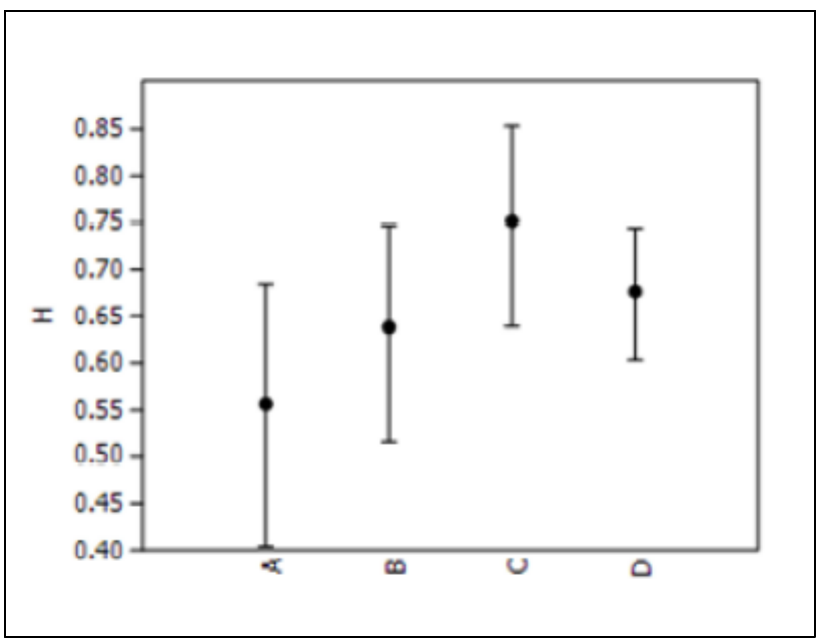

Figure 17. Illustration of the difference in Shannon Diversity index value between the areas. (A= Infested, B= Cleared, C= Control, D= Combined).

The Simpson’s index value for the areas were; (i) the infested area 0.3023, (ii) the cleared area 0.3053 and (iii) the control area 0.389 respectively (Table 2,Figure 18). The control area had the highest Simpson’s score, meaning that it was the most diverse and that the infested area with the lowest score was the least diverse. The difference however was not significant between any of the areas, (i) between the infested and cleared area (t=0.05,df=6, p>0.05), (ii) between the control and the cleared area (t=1.77, df=8, p>0.05) and (iii) between the control and the infested area (t=1.52, df=6, p>0,05).

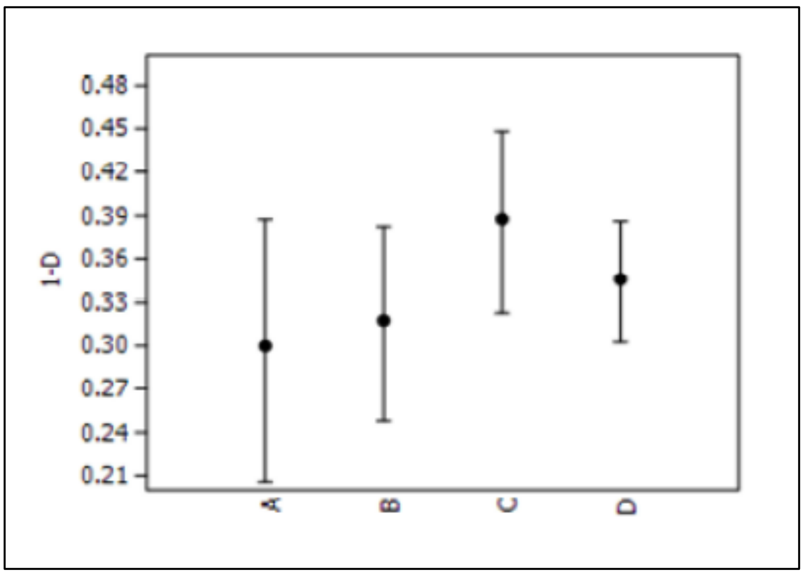

Figure 18. Illustration of the difference in Simpsons Diversity index value between the areas. (A= Infested, B= Cleared, C= Control, D= Combined).

5.2 Evenness

Evar results for the various areas were; (i) the infested area 0.3578, (ii) the cleared area 0.1631 and (iii) the control area 0.1748 (Table 2). The infested area was a significantly more even than the infested area (t=3.21, df=6, $p<0.05$) as well as cleared area and the infested area (t=3.32, df=6, $p<0.05$). There was no significant difference between the cleared area and the control area (t=0.25, df=8, $p>0.05$).

Table 4. Summary of the amount of species caught at each of the three sample areas on Kariega Game Reserve.

Species	Infested	Cleared	Control	Total
Order: RODENTIA				
Otomys irroratus	18	30	44	92
Rhabdomys pumilio	108	213	228	549
Micaelamys namaquensis	5	15	21	41
Saccostomus campestris	0	2	4	6
Order: EULIPOTYPHLA				
Crocidura flavescens	0	1	1	2
Total	**131**	**261**	**298**	**690**

CHAPTER 6

DISCUSSION

The purpose of this study was to determine to what extent small mammal communities and diversities could indicate improved habitat integrity in areas where invasive plant species were eradicated. There was higher diversity, species richness and total abundance in the eradicated area compared to the infested area, although not all analyses indicated significant differences. The cleared area was also the most similar to the control area according to the Bray-Curtis index.

Small mammal community structures differed between the three areas sampled. This however was not always significant as species richness, species abundance, trap success and the species diversity (Shannon-Wiener values) between the areas indicated differences, but the Simpson’s diversity value did not indicate a significant difference.

Due to the fact that the Shannon-Wiener diversity indicated significant differences between the three areas, further studies were done to identify where and how significant the differences between the areas sampled were.

The Friedman tests indicated a significant difference in the amount of species caught as well as the amount of individuals caught per day between the infested and the control area. This indicates that alien vegetation has an effect on the small mammal communities by reducing the species richness and densities. This is also indicated by the fact that two species were not caught in the infested area at all (*Saccostomus campestris* and *Crocidura flavescens*).

From the Friedman test it was also clear that there were significant differences between the cleared and infested area, with the cleared and control area being very similar with only some differences. This indicates that the small mammal communities improved in the cleared area, which could indicate that alien vegetation removal possibly has a positive effect on small mammal communities.

The fact that fewer species were recorded in the infested area, is consistent with other studies that indicate a relationship between the level of disturbance and species diversity (see Avenant 2011; Monadjem & Perrin 2003). Even though the species diversity were higher in the cleared and control area than the infested area, it is expected that these indices will increase with time, after the initial clearance of alien vegetation (O'Farrell *et al*. 2008). The time frames of the cleared areas were different and no correlating index was sampled in this study to identify any trends. Longer time might be needed for the small mammal community to establish which could indicate habitat improvement. Studies have indicated that small mammal diversities are higher in areas with vegetation cover than areas without, and therefore more time allocated for vegetation recovery after eradication could have different species diversity results (Whittington-Jones *et al*. 2008).

Rhabdomys pumilio dominated all the areas and has in other studies been identified at almost all levels of succession. It can also be an indication of primary productivity of the area and in this study *R. pumilio* numbers increased significantly from infested to cleared to never-infested control area. They are omnivorous and can occur in various habitats (Avenant 2000; Avenant 2011). The presence of *Crocidura flavescens* in both the cleared area and the control area, could be interpreted as another indication of ecological integrity as identified by studies suggesting that insectivores are good indicators of habitat health (Pocock & Jennings 2007; Avenant 2011) The fact that it was only recorded once in each of these two areas, however, creates questions that can only be answered by continued trapping of the areas.

The dominance of *Rhabdomys pumilio* (diurnal) and *Otomys irroratus* (nocturnal) in all three areas may support studies that indicated they are closely related to vertical foliage diversity (Els & Kerley 1996; Krystufek *et al*. 2007), as all three areas did have high percentage of bush clumps or trees. It might, however, also simply be related to difference in primary productivity (see above).

To conclude, *Michaelamys namaquensis, Saccostomus campestris* and *Otomys irroratus* can only be regarded as habitat specific species, and not necessarily as indicator species of ecological integrity (see Avenant 2011). As this study did not focus on studying small mammal habitat preferences, no microhabitat data was recorded to correlate with where these species were caught.

6.1 Data compared to other areas in the Eastern Cape

Only a few other studies on small mammals have been done in the Eastern Cape and none have been done along the Kariega River. Only five species were recorded out of the estimated 16 possible species in the area (see section 2.4). These species were identified from literature (Skinner & Chimimba 2005, Krystufek 2007; Whittington-Jones 2008) and not actual recordings on the property. Over all species richness in this study was similar to other studies done in the Eastern Cape, ranging from five to seven species per habitat (Krystufek *et al*. 2007; Whittington-Jones *et al*. 2008; Els & Kerley 1996). Trap success in this study (overall = 12.78%) was, however, higher than that of other studies in the Eastern Cape (Krystufek *et al*. 2007; Whittington-Jones *et al*. 2008; Els & Kerley 1996). Although all three areas were dominated by one species, the high trap success does indicate the validity of the experimental design for the area, and further studies can continue following similar experimental designs.

Species diversity values were lower than most other areas (Krystufek *et al*. 2007; Whittington-Jones *et al*. 2008) but was similar to diversity values in the Groendal Wilderness areas (Els & Kerley 1996). The season of sampling might have influenced this data, as Avenant (2011) indicated that late-autumn and earlt-winter samples yielded greater results. Further studies are needed to prove similar seasonal differences for the area studied. The two diversity indices used gave different results in terms of significance. Here the Simpson's diversity index, although not as widely used, accepted and therefore analyses was based on its results. The Shannon-Wiener index was utilized to allow for comparability with previous studies done on small mammals, as most earlier studies used it for diversity calculations (Avenant & Cavallini 2007; Avenant 2011; Whittington-Jones 2008).

The higher diversity and species abundance in the cleared area does indicate improved small mammal communities from the infested area, which can indicate improvement in habitat health, which could be used to indicate the success of the eradication programs of the reserve.

6.2 Data comparison between areas

The highest number of individuals were caught in the control area and the lowest number in the infested area, which indicates that there were less favourable conditions, which is expected possibly due to lower primary productivity and overall food availability).

Species diversity values can be influenced by low species richness or by species domination (Magurran 2004). All three areas had relatively low species richness, with the infested area only having three species and the control and cleared area having the same species plus two addition, *Saccostomus campestris* and *Crocidura flavescens*.
In all three areas *Rhabdomys pumilio* dominated, and this resulted in fairly low species diversities in all three areas sampled.

The higher diversity and species abundance in the cleared area can indicate improvement in habitat health, which could be used to indicate the success of the eradication programs of the reserve. This is further supported by the significant difference in species richness as well as the amount of individuals caught per day between the infested area and the cleared area, with the cleared area and control area being similar. This indicates that alien vegetation removal as a positive effect on the small mammal communities.

The Simpson's diversity values indicated that there were different diversities in each of the areas sampled but they were not significant. As mentioned before, this data gets influenced by the evenness and the species richness of the sample. Longer sampling periods with more trap nights might result in different results.

A possible reason for the cleared area not indicating a significant difference in species diversity compared to the infested area is the time period after clearing. More time might be needed after the invasive species were removed and a time period stretching over more that one year will be interesting. A combination with studying vegetation indexes for ecological integrity in all the cleared areas at different time periods should add to the knowledge.

6.3 Small mammals as indicator species

Just as studies in the grassland biome indicated that small mammal trap success poses challenges for using small mammals as indicators of ecological integrity (Avenant 2011), so does this hold true for the results in this study. Studies did indicate that small mammal diversity and species richness could potentially be used as indicators of ecological integrity, although when trap successes are low, a combination of species richness, diversity and abundance should be used as well as presence of specialists and not just focused on the diversity (Avenant 2011). To achieve this, sampling at the optimum time (when densities are high and food starts to decline (Avenant 2011) is important.

Most of the species caught during the study seemed to be linked to substrate, with *Michaelamys namaquensis* occurring in areas with rocks and *Saccostomus campestris* and *Otomys irroratus* occurring in habitats as described by Skinner & Chimimba (2005).

The high trap success of *Rhabdomys pumilio* in all areas indicate high overall food resources as they are omnivorous (Skinner & Chimimba 2005), with significantly more individuals caught in the control area compared to the infested area.

The low numbers of the two extra species collected in the control and cleared areas also warn us to be cautious with our conclusions about indicator species. Further studies would need to be done, preferable during autumn and winter, to possibly have higher success rates and species richness. It is also suggested that the cleared area needs to be sampled at a longer time period after eradication to allow for vegetation succession and small mammal species that may re-enter.

Even though no alien vegetation has been recorded in the control area, no other indices were recorded to estimate the health of the area, and could have been affected by overgrazing or other disturbance prior to sampling, which could account for lower diversities. A further recommendation is, therefore, to study these small mammal communities alongside other ecological indicators such as vegetation indices. This should allow for more concise indication of habitat health and small mammal correlation, as has been done in other studies (see Avenant & Cavallini 2007; Avenant *et* al. 2008; Avenant 2011).

CHAPTER 7

CONCLUSION

The main purpose of the study was to investigate to which extent small mammal diversity, species richness and community structures could indicate improved habitat integrity in areas cleared of alien vegetation. Although there was not clear significant differences in diversities between the areas, species richness and community structures were different and the cleared area was significantly more similar to the natural control area, an indication of higher ecosystem integrity.

More information on small mammal indices and communities will assist in ecological integrity evaluations for various habitats in the larger study area. Small mammal communities adapt readily to changes in their habitat or environment. The current study partly confirmed that small mammal communities could be used as a fast, easy and relatively cheap method of identifying habitat health. While the relatively low species richness and diversities recorded during the study makes decision-making and assumption difficult, certain aspects could be used to identify trends and serve as a base for future studies.

Only five species were recorded during this study, and no clear indicator species could be identified. Most of the objectives set out by this study were obtained. Even though only a few species were recorded, the data could be used to update Kariega Game Reserve's small mammal database. The community structure, species richness and diversity in each of the three habitats were determined, which can be used as a baseline study for future studies on small mammals in the area. The study also indicates that there is a significant difference in the small mammal species richness and abundance between the cleared area and the infested area, indicating that the alien eradication program has a positive effect on the area evident in the small mammal communities.

With further studies, especially at a more appropriate time of the year, more data could assist in identifying further characteristics of the small mammal community structures and diversities between the areas. Due to time limitation, the study was done during spring and summer (October to December) which, according to various studies, yields lower success rates, therefore it is suggested that further or following studies need to include extended seasonal sampling including autumn and winter which have proved to yield higher trap success. It is recommended that future studies need to also study the vegetation communities of these various areas to determine the ecological integrity of each, which then can be correlated with small mammal indices. It is anticipated that longer time after eradication might bring the small mammal community closer to that of the natural, control, area.

With the significant difference observed in species richness and abundance between the infested and control area, it is clear that the alien vegetation has a negative impact on the ecological integrity of the area. This small mammal community study therefore, already, indicate the need for management to continue eradication of invasive species. The study also indicates some level of improvement in the cleared area (through the similarity to the control area and higher species richness). Greater further studies could, therefore, benefit the reserve in being able to identify indicator species as well as the use of small mammals to monitor eradication program success.

This study therefore indicates that small mammal communities are different between the areas sampled with the infested area having the lowest species richness and abundance. The cleared area is not significantly different from the control area, but has a significantly higher species richness and abundance than the infested area, indicating that the area has improved and that small mammals could be used as an indicator of ecological integrity after alien eradication.

Alien vegetation eradication and control programs are long and costly and in the case of Black Wattle, the control and removal is enforced by the law. Small mammal densities and diversity are strongly affected by management decisions, whether on large or small scale. Being able to monitor these management efforts readily and cheaply will benefit future decision-making. More information on the small mammal communities of various areas and certain indicators species can assist in monitoring these practices.

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