POPULATION DYNAMICS AND MANAGEMENT OF INVASIVE ROCK HYRAXES, *PROCAVIA CAPENSIS* (PALLAS, 1766), IN THE CENTRAL FREE STATE, SOUTH AFRICA

by

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Spreuke 30:24-28

*24 Daar is vier goed in die wêreld wat klein is maar buitengewone wysheid het:
25 miere is nie sterk nie en tog sit hulle in die somer vir hulle kos weg; 26 dassies
het nie veel krag nie en tog maak hulle hulle tuis teen die kranse; 27 sprinkane het
nie 'n koning nie en tog trek die hele swerm in formasie; 28 'n geitjie kan jy met
die hand vang en tog kry jy hom in koninklike paleise.*

Proverbs 30:24-28

*24 "Four things on earth are small, yet they are extremely wise: 25 Ants are
creatures of little strength, yet they store up their food in the summer; 26 hyraxes
are creatures of little power, yet they make their home in the crags; 27 locusts
have no king, yet they advance together in ranks; 28 a lizard can be caught with
the hand, yet it is found in kings' palaces.*

Maele 30:24-28

*24 "Ntho di nne tse nyenyane lefatsheng, empa tse bohlale bo makatsang:
25 Bohlwa ke tjhaba se hlokang matla, empa bo bokella dijo tsa bona hlabula.
26 Dipela ke tjhaba se fokolang, empa di etsa qhobo tsa tsona mafikeng. 27 Ditsie
tsona ha di na kgosi, empa ha di falla di fofa ka mekgahlelo. 28 Mokgodutswane
o ka o tshwara ka letsoho, empa o fumanwa ka matlung a dikgosi.*

DECLARATION

I. I, Roelof Erasmus Wiid, declare that the Master's Degree research thesis that I herewith submit for the Master's Degree qualification MAGISTER SCIENTIAE ZOOLOGY at the University of the Free State is my independent work and that I have not previously submitted it for a qualification at another institution of higher education.

II. I, Roelof Erasmus Wiid, hereby declare that I am aware that the copyright is vested in the University of the Free State.

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IV. I, Roelof Erasmus Wiid, hereby declare that I am aware that the research may only be published with the dean's approval.

ROELOF E. WIID

6 February 2017

DATE

DEDICATION

I dedicate this work to the memory of my father, Roelof Wiid (28/05/1954 - 02/12/2011) and my grandmother, Sarie Germishuys (27/04/1930 – 10/03/2017) who both passed away since I started this project. From my father I have learned to be curious and to investigate the things I do not understand. From my grandmother I have learned to always show a keen interest in the activities of loved-ones, since even the smallest sign of interest can mean so much to another.

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ABSTRACT

Frequent reports of rock hyrax (*Procavia capensis*) invasions in residential areas prompted an investigation of this problem in order to identify possible solutions. From reports, problem areas in South Africa were identified, and sites within the Free State Province were selected for this study. At these sites, rock hyrax populations demonstrate an unusual annual increase. This increase has led to a food and habitat shortage, forcing individuals into residential areas in search of additional refuges and food sources. In order to manage populations, several preventive as well as control methods have been assessed and implemented. Population densities were determined using the Lincoln index and the Robson–Whitlock technique. Results obtained when both methods were used showed a positive correlation of R=0.88, calculated with Pearson's correlation coefficient. Wild populations were included in the study for comparison purposes. Additional resources within residential areas have facilitated populations to grow much larger, in some instances exceeding the natural limits (30 – 40 individuals) by 175 - 225 %. This influx contributes to human–wildlife conflict. With the use of translocation, populations were reduced within three months. The introduction of natural predators for rock hyrax population control appears to have positive results, but will have to be monitored on a regular basis. Preventive measures have shown various levels of success. Different combinations of these measures proved to have different levels of effectiveness. A combination of wire fences higher than 1.8 m, an overhang at the top and dogs from the working and/or terrier groups seemed to be most effective. The strategy to capture and translocation individuals, for the rapid reduction of the population, has been successful. Results show that the establishment of translocated populations was not successful owing to high predation rates.

Keywords: *Procavia capensis*; rock hyrax; hyrax invasions; invasion prevention, population management, questionnaire; population dynamics, Lincoln index; Robson-Whitlock technique; translocation; post-translocation monitoring

Chapter 1

Introduction

CHAPTER 1: INTRODUCTION

People are constantly altering the world and the different habitats within it. These changes result in the destruction and/or alteration of habitats and ecosystems which can lead to reduced biodiversity (Vitousek 1997). In this process of change and destruction, humans are however creating new ecosystems (Steam & Montag 1974). The increase in human structures and residential areas has several effects on animal life. Some species (avoider species) will relocate to escape these changes while other species (exploiter species) will move into the new human habitat, exploiting the additional resources available to them (Stoddart 1980). These exploiter species cause an increased opportunity for human-wildlife interactions which in turn may lead to human-wildlife conflicts (Stoddart 1980). In South Africa, an increase of residential development next to rocky outcrops is causing a decline in the natural habitat of rock hyraxes forcing them to take refuge in residential areas (Mr Lourens Goosen, 2010, pers. comm.[1]).

Due to an increase of residential development next to rocky outcrops, the natural habitat of rock hyraxes (*Procavia capensis*) is rapidly diminishing. This decrease of natural habitat led to the decline of natural predators, as natural predators either left the area (avoider species) or were removed by humans, which in turn results in less control for rock hyrax populations. The absence of natural predators seems to have aided rock hyrax populations in increasing over the last couple of years (Mr Juan Van Zyl, 2010, pers. comm.[2]).

The rock hyrax is a small, firmly built tailless mammal. Although they appear rodent-like, their evolutionary relationships lie with the Elephant and the Dugong (Estes 1991). The hyrax has short legs and small rounded ears (Stuart & Stuart 2007). The natural habitat of the hyrax includes rocky areas like mountain ranges and rocky outcrops (Stuart & Stuart 2007). Hyraxes may also be found living among the roots and leaves of several

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trees, such as prickly pears, spekboom and sisal or in holes made within erosion gulleys (Stuart & Stuart 2007). Although hyraxes are found within areas of higher rainfall they tend to favour dry areas (Stuart & Stuart 2007). Colonies in the wild may consist of 30 to 40 individuals but usually, consist of one adult territorial male with a harem of related females and their offspring, the offspring consist mainly of adolescent females and juveniles since all adolescent males are forced from the colony before they reach sexual maturity (Estes 1991). Wild populations tend to maintain a male to female ratio of about 1:2 in an average home range of approximately 4250m^2 for females and 4800m^2 for males (Estes 1991). Once adolescent males are forced from the group they will search for their own home ranges or they will stay on the edge of the colony waiting to take the place of the territorial male once he loses fitness (Estes 1991).These males do not form bachelor groups and they do not become territorial until they found a territory of their own (Estes 1991).

According to Skinner & Chimimba (2005), rock hyraxes are widely distributed throughout Africa, ranging throughout sub-Saharan and northeast Africa (Olds & Shoshani 1982, Hoeck and Bloomer 2013). The range of these animals also extends into the west of the Arabian Peninsula and into Lebanon, Jordan and Israel. (Olds & Shoshani 1982; Harrison & Bates 1991; Shoshani 2005). According to Butynski *et al.* (2015) rock hyraxes are currently listed as Least Concern in view of their wide distribution, the wide range of habitats they utilise, their large population numbers which are unlikely to decline fast enough to qualify for listing in a more threatened category. Although rock hyraxes have a gestation period of eight months and are known to give birth to one or two young (Miller 1971), rock hyrax numbers have increased to such a degree in the past that they have been listed as vermin in some areas in South Africa (Hey 1964; Kolbe 1967; Lensing 1978). Kolbe (1967) suspects that this increase, in population sizes, might be due to an increase of natural predators.

Although rock hyrax have large population numbers now, these numbers have declined in the past due to several factors such as disease, predation, territorial fighting and dispersal of males (Hoeck *et al.* 1982). The presence of parasites and diseases can play a very important role in the regulation of wild mammal populations (Young 1969; Melton

& Melton 1982) Ectoparasites, recovered from 77 rock hyraxes, included ten tick species, four species of biting lice (Ischnocera), two species of sucking lice (Anoplura) and fleas (Fourie 1983). Endoparasites included *Cestodes* and *Inermicapsifer* species (Fourie 1983). In natural environments, rock hyrax populations tend to decrease during periods of drought when food resources are limited and as a result of this, the natural and acquired resistance to parasites may deteriorate because of protein deficiency (Chandler 1953). Barry & Mundy supported this statement by reporting that entire populations have become locally extinct in, in times of drought, this extinction is mainly caused by disease (Barry & Mundy 1998).

Rock hyraxes have a variety of predators and are especially vulnerable to predation when dispersing which leads to a high male, predominantly juvenile, mortality (Hoeck 1982). According to Estes (1991), the predators of rock hyraxes comprise of snakes, cat species (ranging from servals up to lions), eagles, owls, jackals, and even mongooses may take babies. Stuart (1983) reported the occurrence of rock hyrax in the scats of large grey mongoose (*Herpestes ichneumon*). The top ranking predators of rock hyraxes are however Verreaux's eagles (*Aquila verreauxii*), martial eagles (*Polemaetus bellicosus*), cobras (*Naja* spp.), caracal (*Caracal caracal*) and leopards (*Panthera pardus*) (Estes 1991; Stuart & Stuart 2007). Juvenile hyraxes form a large portion of the prey taken by martial eagles (Boshof *et al.* (1990) and Verreaux's eagles (*Aquila verreauxii*) (Boshof *et al.* 1991). The main diet of Verreaux's eagles consists between 70 – 90% of rock hyraxes (Hoeck 1982; Jenkins 1984; Chiweshe 2007; Stuart & Stuart 2007; Symes & Kruger 2012). According to Chiweshe (2000 & 2007) the two hyrax species, yellow-spotted hyrax (Heterohyrax brucei) and rock hyrax, accounted for about 92% of the total number of prey taken by Verreaux's eagles. According to Stuart & Stuart (2007), crowned eagles, leopards, caracal and African wild cat also take considerable numbers of rock hyrax young.

It was expected that populations, situated adjacent residential areas, would only increase until the habitat could support no further growth and the lack of resources would lead to a decrease. This, however, was not the case as rock hyraxes expanded their habitat into residential areas. An abundance of food sources in gardens led to a further increase of rock hyrax numbers. On demand of the residents and Free State Nature Conservation, this study on the rock hyraxes was conducted. Several problem areas were identified all over the Free State Province, as well as other provinces. Due to the high number of reports from within the central Free State, this study only focused on the central Free State (Bloemfontein and surrounding areas) as well as a control site which is situated in the southern Free State near Bethulie.

Several methods have been implemented in the past in order to control rock hyrax populations. These methods included chemical control (Moran *et al.* 1987) and culling (Barlow *et al.* 1997). Rock hyrax numbers can be controlled by culling large portions of populations in a matter of days. This method is however not preferred as the problem areas are situated within residential areas and thus requires special permission and numerous safety measures to be followed (Lamprecht J, 2012, pers. comm.) as it is a criminal offence in South Africa (Firearm Control Act 60 of 2000) to discharge a firearm in a residential area. The reintroduction of natural predators to residential areas might be the solution to the problem and was considered as a possible control method.

Fertility control has also been used with success by several researchers (Caughley *et al.* 1992; Hinds *et al.* 2003; Hone 2004; Jacob *et al.* 2008). Fertility control, if done properly, can be expensive and will take some time to show success. The method required for this study had to rapidly decrease rock hyrax numbers in order to address the problem and therefore fertility control was not considered. Translocation of individuals had been used in previous studies with various levels of success (Stenseth 1981; Hoeck 1982; Crawford & Fairall 1984; Hoeck 1989; Banks *et al.* 2002; Wimberger *et al.* 2009). Therefore, translocation was considered as a possible control method. In the event of all other methods failing to show success, only then will culling be used in order to control rock hyrax populations.

There have been three published accounts of rock hyrax translocations, but post-release monitoring was limited. Crawford & Fairall (1984) captured and translocated 22 rock hyrax in the Eastern Cape Province, South Africa. These hyraxes were transported to a holding cage where they were held prior to release. Some of these translocated hyraxes were known to have survived for a few months after release. According to Crawford & Fairall (1984) two of the males, which were translocated, returned to the capture site area but no details were provided. Hoeck (1982) re-introduced two groups of hyrax, one group of six and another group of two, consisting of a single male and female, onto rocky outcrops in the Serengeti, Tanzania. These re-introductions seemed to have been successful since Hoeck (1982) reported that the first group grew from six to 20 individuals over a period of five years. The second group grew from 2 to 15 over 10 years (Hoeck 1989). Further details regarding these re-introductions were not provided.

The current study was initiated to provide insight on different methods of control for hyrax populations in residential areas. The aims of this study were to identify possible invasion preventive and population management methods. These methods would be implemented to prevent the hyrax invasions of properties and to rapidly decrease rock hyrax populations. Methods such as fencing properties, removing rock hyraxes and elevating predation to decrease the possibility of human-wildlife conflict were assessed. It was predicted that higher fences and/or walls would be more effective in preventing hyraxes from entering properties and that homeowners with dogs present at their properties would have fewer invasions. It was also expected that the introduction of natural predators would not be possible at all the sites and that all sites to be used would have to be inspected prior to the release of natural predators to ensure that these sites will be able to contain predators.

Key Question

What is the magnitude of the rock hyrax invasions in residential areas, within the Free State Province and what possible solutions can be implemented in order to control these invasive populations?

Aim

The main focus was to determine and assess different methods to manage and control invasive hyrax populations.

OBJECTIVE 1: To determine problem areas in Bloemfontein/Free State Province/South Africa and to select sites to represent suburban residential areas, residential wildlife estates and natural areas.

Questions:

1. How can these problem areas be determined?
2. Is there a specific problem area one should focus on for this study?

OBJECTIVE 2: To determine and compare the size and social structure of hyrax populations in natural areas, residential areas and in residential wildlife estates

Questions:

1. What method(s) can be used to determine population size?
2. Can the same method(s) be used at all the sites? If not, can data collected with different methods be compared to each other?

OBJECTIVE 3: To assess several preventive as well as control methods in order to manage hyrax populations.

Questions:

1. What different methods can be used and is there a way to compare the effectiveness of different methods with each other?
2. Is there a standardised unit to measure the level of effectiveness?

OBJECTIVE 4: Find a marking technique which will allow the identification of hyraxes after translocation

Questions:

1. What criteria needs to be met when selecting a marking technique to mark rock hyraxes prior to translocation?
2. What possible problems have been identified in the past with the selected method, if any, and can these problems be improved on?

OBJECTIVE 5: To identify suitable translocation sites in collaboration with Free State Nature Conservation.

Questions:

1. Should the distance of the release site from capture sites be taken into account when translocating individuals?

OBJECTIVE 6: To apply translocation as a method for controlling hyrax populations in residential areas and to monitor translocated hyraxes to determine if translocation was successful

Questions:

1. Is translocation bringing any relief to problem areas by decreasing population numbers?
2. When is the best time(s) to do monitoring and how long should one monitor a specific area?
3. What method should be used to determine the number of individuals that remained after translocation?
4. Was translocation successful to reintroduce rock hyraxes to the release site?

Chapter 2

Study Areas

CHAPTER 2: STUDY AREAS

Frequent reports of rock hyrax invasions in residential areas prompted an investigation of this problem in order to identify possible solutions. Numerous problem areas, in South Africa, were identified from these reports. Reports were investigated and areas with the most invasions were focused on during this study. These focus sites were located in a suburban residential area and a residential wildlife estate, both situated in Bloemfontein, Free State. A natural site, on a livestock farm near Bethulie, was included for comparison purposes. In addition to the abovementioned study sites, a site close to Bloemfontein (Kwaggafontein) was identified for the translocation of rock hyraxes. This site was specifically selected due to the presence of several outcrops which provided suitable habitat for rock hyraxes.

2.1 Geography and Geology

All of the study sites are situated within the lower Adelaide Subgroup (Visser 1984; Johnson *et al.* 2006; Partridge *et al.* 2006). This group forms part of the larger Beaufort Group which in turn is a subdivision of the Karoo Supergroup. These sites contain sedimentary rocks that consist of alternating sandstone and mudstone layers of Late Permian to Triassic age, Balfour Formations. These sedimentary rocks form the base on which deposits of Quaternary age have been deposited (Visser 1984; Johnson *et al.* 2006; Partridge *et al.* 2006).

2.2 Topography

The Heuwelsig site is located in the northwestern parts of Bloemfontein (Fig 2.1) on the edge of a rocky outcrop (29°5'20.14"S, 26°11'55.25"E). This site, situated on the frontier of Heuwelsig, encompasses the Heuwelsig Conservancy adjacent to the Heuwelsig residential area and a recreational playground for children with a combined area of 2.11 ha (Fig 2.2a).

The playground consists mainly of lawn and some trees while the conservancy consists mainly of natural vegetation (Fig. 2.3). The conservancy covers an area of 1.83 ha and is situated at an elevation of 1 454 m. Within the conservancy, an area of approximately 0.40 ha, consisting of large boulders and rocks, is colonised by rock hyraxes. Bordered by residential areas and Tempe military base, which falls under the South African National Defence Force, this site had the most reports of hyrax invasions of private properties.

Rock hyraxes were able to crawl out of the conservancy by crawling underneath the wire fence. Once out they used the storm water drains as refuges and as safe passageways to move between properties (Fig. 2.4a & b). Residents have recently used wire mesh to block the storm water drains (Fig. 2.4c) and the openings under the conservancy fences (Fig. 2.4d), in an attempt to limit possible ways for hyraxes to gain access to properties.

The Woodland Hills Wildlife Estate (29°2'48.29"S, 26°11'43.46"E) is situated 8.50 km north-northwest of Bloemfontein (Fig. 2.1) and covers approximately 77 ha. This estate is a combination of modern homes inside a conservancy where the game is free to roam among the houses. A large gorge, Diepsloot, (Fig. 2.2b), with dense tree growth and several rocky areas in the walls, is situated between the houses and presented several crevices in which rock hyraxes can take refuge. The gorge is located at an elevation of 1 379 m. The nearest rocky outcrop, Reservoir Hill (Fig. 2.2b), is situated adjacent to the gorge and had an elevation of 1 422 m with the highest point of this outcrop being approximately 650 m from the gorge. Trees and shrubs within this estate were situated on the side of the roads, in the gorge, around and on the rocky outcrop.

The livestock farm, Rusplaas (30°17'32.82"S, 25°56'3.69"E), approximately 130 km south-southwest of Bloemfontein, was selected to represent a natural area. This site covers an area of 29 250 ha and has several cliffs and rocky outcrops. Two separate rock hyrax colonies, situated on two rocky outcrops separated by a valley, were included in the study. The Kranskop Colony (30°18'38.30"S, 25°55'21.20"E) is situated on the eastern side of the smaller outcrop. This outcrop, with an elevation of 1 620 m, has a steep cliff with several clefts which is used as refuges by rock hyraxes (*vide* Fig. 2.2c & Fig. 2.5a). The Patroonkop Colony (30°18'52.21"S, 25°56'0.85"E) is situated on the south-eastern side of the larger outcrop and has bushes, small trees and large boulders as shelter for the rock hyraxes (*vide* Fig. 2.2c & Fig. 2.5b). The colony is situated at 1586 m. These colonies cover an area of 1.66 ha and 2.57 ha respectively.

Kwaggafontein (29° 6'8.25"S, 26° 6'55.98"E), a game farm utilised by the Bloemfontein Zoo and Free State Nature Conservation, is situated nearly 7 km west of Bloemfontein (*vide* Fig. 2.1) and covers an area of roughly 1 351 ha. This site has several rocky outcrops, which offered suitable habitat for rock hyraxes. Even though this site provided suitable habitat, no rock hyraxes were seen on the farm since 2012 (Mr Daryl Barnes, pers. comm.[3]). Due to the fact that rock hyraxes naturally occurred on these rocky outcrops in the past, this site is ideal for the translocation of rock hyraxes.

Three rocky outcrops are situated on this site (vide Fig. 2.2d): Brandkop, Renosterkop and Bomakop. The largest of the three, Bomakop, is situated in the south-west corner of the game farm and extends over a total area of 67.57 ha with an elevation of 1 444 m above sea level. Almost a third of this rocky outcrop, 22.55 ha, was situated outside the boundary fence of the game farm and was therefore not included in any surveys. Brandkop is relatively centrally located and covers an area of 54.97 ha with an elevation of 1 457 m above sea level. This outcrop could be divided into two distinct parts, the peak and the plateau. The smallest of the three, Renosterkop, covered an area of 18.03 ha and is situated 1 444 m above sea level.

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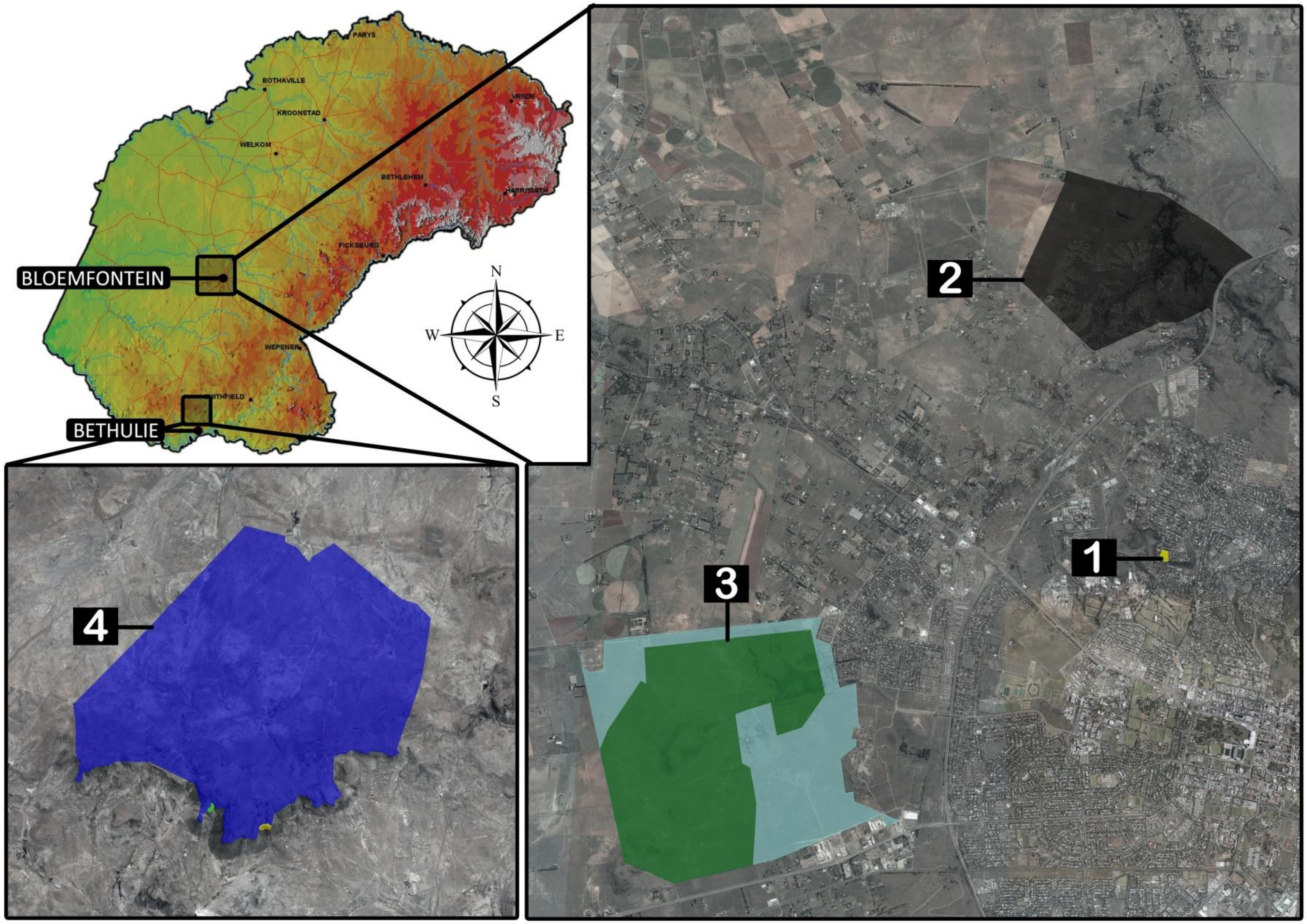

Figure 2.1 Location of the study sites within the Free State Province. Heuwelsig (1), Woodland Hills Wildlife Estate (2) and Kwaggafontein Game Farm (3) are situated in the central Free State. Rusplaas (4), a livestock farm, is situated near Bethulie in the southern Free State.

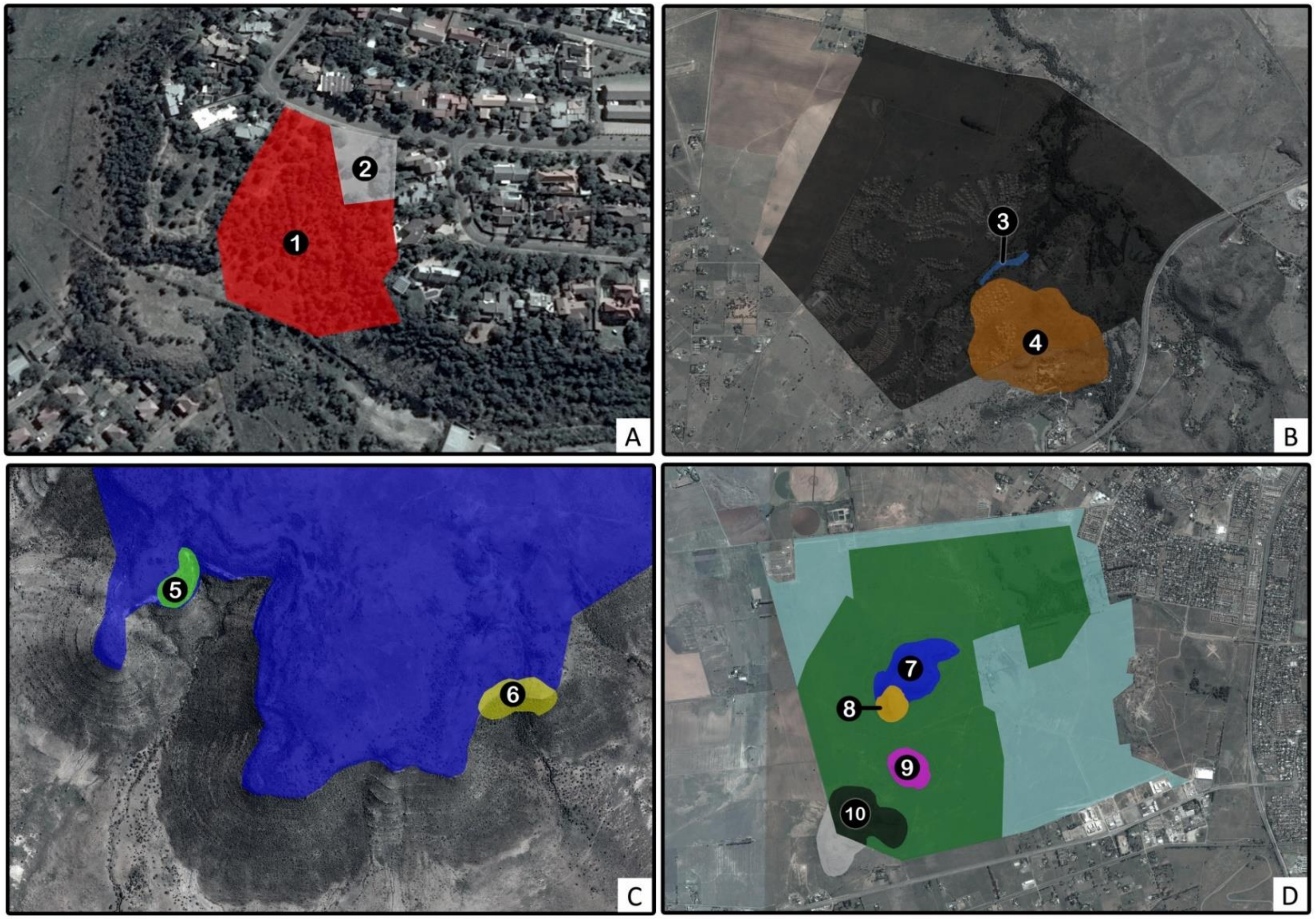

Figure 2.2 Location of different areas/outcrops at study sites. The Heuwelsig site (A) encompasses the Heuwelsig Conservancy (1) and a recreational playground (2). The Woodland Hills Wildlife Estate (B) contains Diepsloot (3), a large gorge, /and Reservoir Hill (4). The farm Rusplaas (C) has two colonies, Kranskop Colony (5) and Patroonkop Colony (6) situated on the southern rocky outcrops. The rocky outcrops at Kwaggafontein (D): Brandkop plateau (7), Brandkop peak (8), Renosterkop (9) and Bomakop (10).

Figure 2.3 Difference in vegetation, at the Heuwelsig site. The playground to the left of the fence and the Heuwelsig Conservancy on the right-hand side of the fence.

Figure 2.4 Storm water drains, at the Heuwelsig site, were used as refuges and as safe passage (A & B). Wire mesh used to close storm water drains (C) and openings under the fence (D).

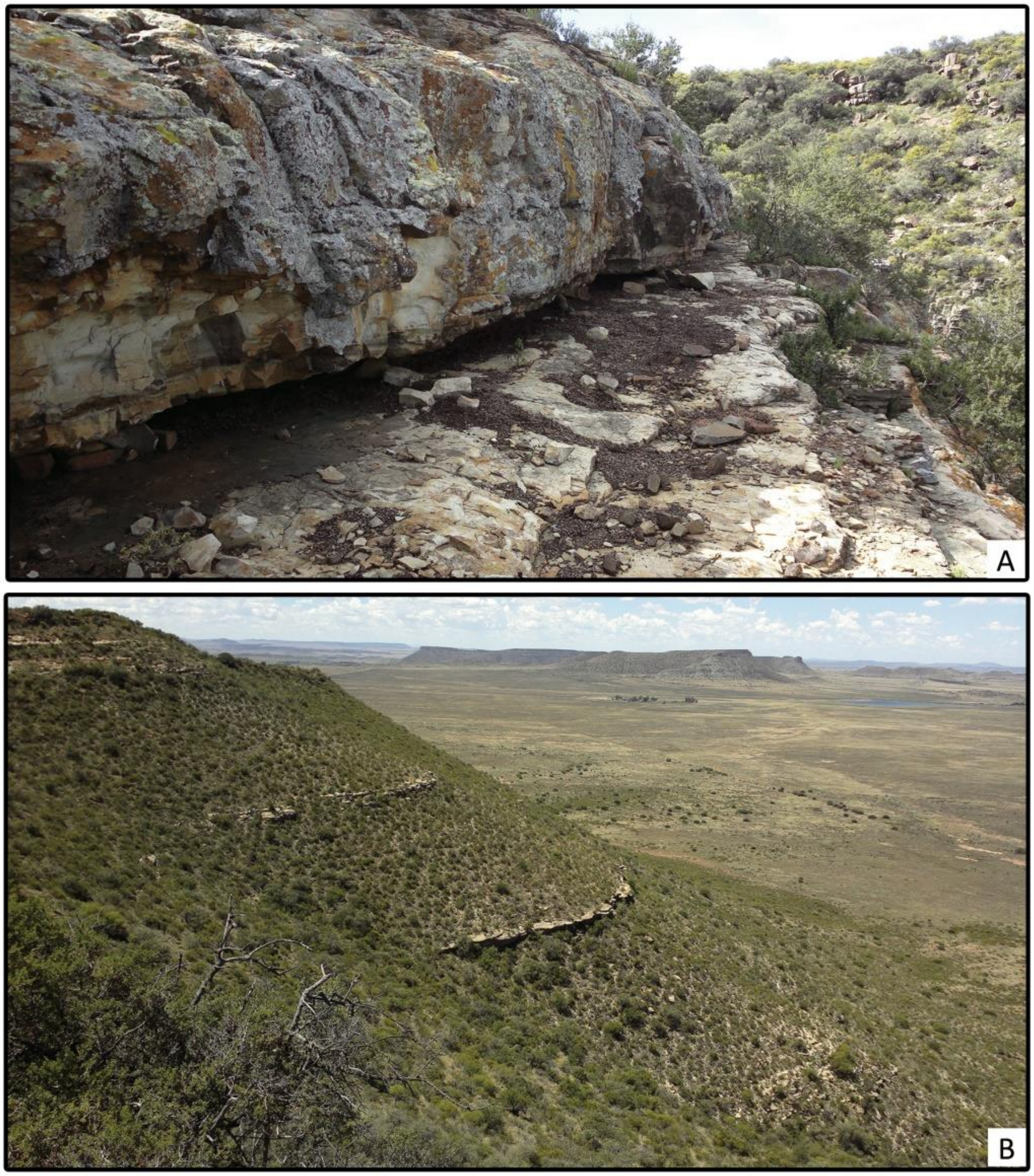

Figure 2.5 Topographical differences between the two rocky outcrops, Kranskop (A) and Patroonkop (B), at the farm Rusplaas.

2.3 Climate

All meteorological information was provided by the South African Weather Service. The weather station, situated at the Bloemfontein Airport, provided the data used to represent the climate for all Bloemfontein sites (Heuwelsig Site, Woodland Hills Wildlife Estate and Kwaggafontein). The weather station, situated at the Gariep Dam, provided data used to represent the climate for the natural site at Rusplaas, Bethulie. All unavailable data were supplemented with information acquired from the web page Wunderground.com.

Bloemfontein is situated in a summer rainfall region, receiving most of its rainfall from mid-October to late April (Fig. 2.6) with an average annual rainfall of 534 mm. During this study (2010 – 2015), Bloemfontein had an average annual rainfall of only 465 mm (Fig 2.6), which would be even lower if the abnormally high rainfall during 2010 – 2011 (839 mm) is not included in the calculation. Maximum temperatures can reach up to 42 °C during the summer months and temperatures as low as -9 °C with regular frost are common during the winter months. The average annual maximum temperature is 25 °C and the average annual minimum temperature is 7 °C.

The Gariep Dam Station, also situated in a summer rainfall region, received most of its rainfall from early December until mid-April (Fig. 2.7) with an average annual rainfall of 386 mm. The rainfall was not much different during the study period (2010 – 2015) since an average annual rainfall of 372 mm was recorded during this time (Fig. 2.7). Maximum temperatures can reach up to 43 °C during the summer months and temperatures as low as -10 °C with regular frost are common during the winter months. The average annual maximum temperature is 25 °C and the average annual minimum temperature is 9 °C.

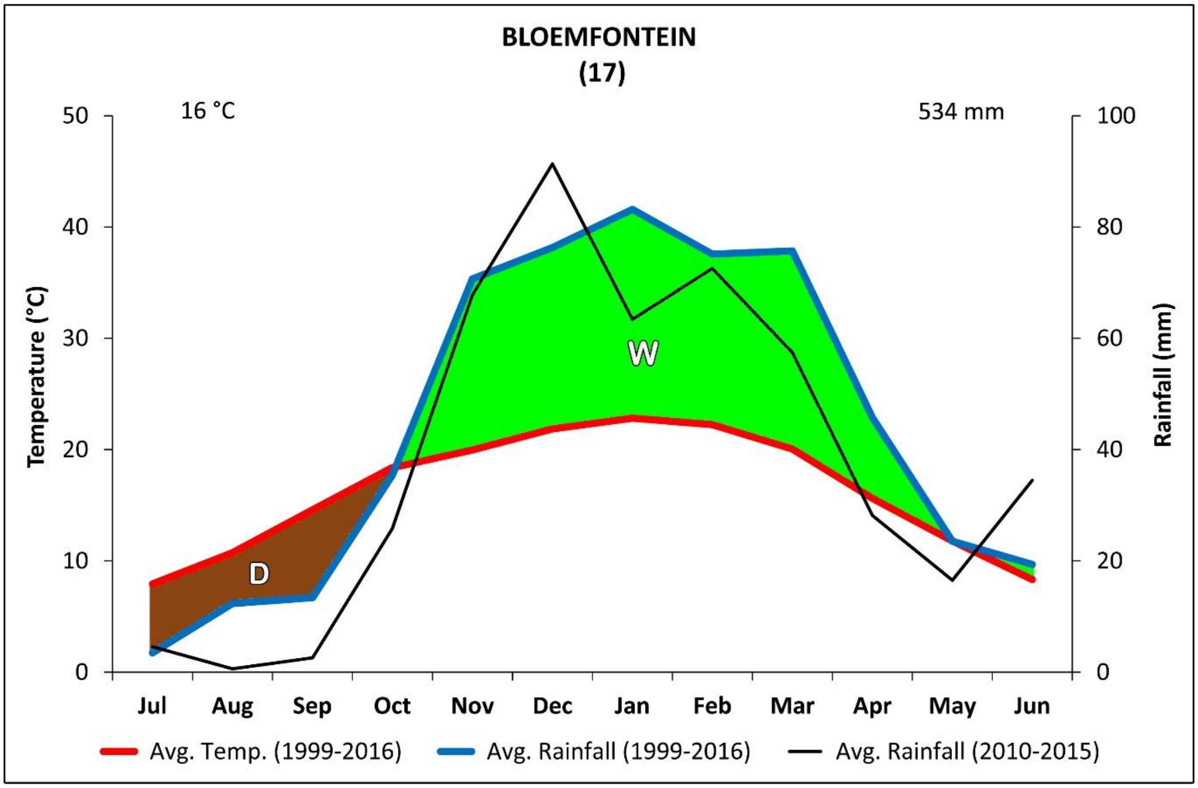

Figure 2.6 Climate diagram of Bloemfontein, central Free State, according to the method of Walter (1964 & 1979). Number between brackets indicates years of observation. Average annual temperature and rainfall is indicated on the top-left and top-right, respectively. Wet season (W) and dry season (D) is indicated on the graph.

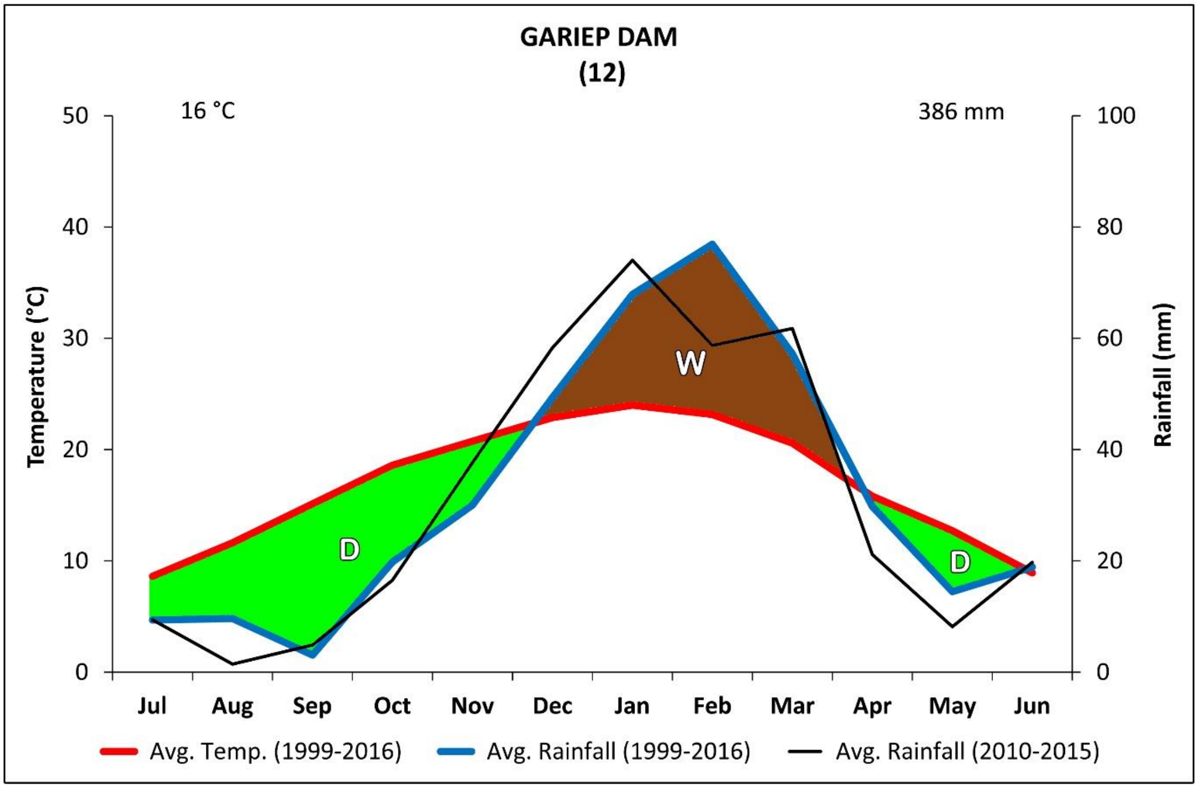

Figure 2.7 Climate diagram of Gariep Dam, southern Free State, according to the method of Walter (1964 & 1979). Number between brackets indicates years of observation. Average annual temperature and rainfall is indicated on the top-left and top-right, respectively. Wet season (W) and dry season (D) is indicated on the graph.

2.4 Vegetation

All of the study sites are situated within the Grassland Biome (Mucina *et al.* 2006). According to Acocks (1988) the natural site, Rusplaas near Bethulie, can be classified as Karoo Veld Type. The other three sites could either be classified as Karoo Veld Type or Sweet Grassland Veld Type or both, due to the location of these sites which is almost on the border of these two veld types (Acocks 1988). Rutherford & Westfall (1994) however suggests that the natural site, Rusplaas near Bethulie, falls within the Nama Karoo Biome while the other sites fall within the Grassland Biome.

All of the study sites fall within the Dry Highveld Grassland Bioregion which is divided into different units of grassland and shrubland, according to their distinctive structural vegetation types (Van Oudtshoorn & Van Wyk 2006; Mucina *et al.* 2006; Van Oudtshoorn 2012). Highveld Grasslands are found on the wide-ranging plateau in the central parts of South Africa. This rising and falling plateau is infrequently broken by rocky outcrops or river valleys that cut into the plateau and is so often found throughout the Free State Province. Annual precipitation controls the vegetation patterns and this causes the difference in vegetation types. Some study sites have only one type of vegetation unit (Mucina *et al.* 2006) whiles others had up to three different types of vegetation units (Fig. 2.8).

The Heuwelsig Conservancy, situated on the edge of a rocky outcrop, consists of vegetation described as Winburg Grassy Shrubland (Mucina *et al.* 2006) (Fig. 2.8a). True to the description provided by Mucina *et al.* (2006), the Heuwelsig Conservancy was dominated by wild olive (*Olea europaea africana*), blue guarri (*Euclea crispa crispa*), karoo kuni-bush (*Searsia burchelli*), karee (*Searsia lancea*) and buffalo thorn (*Ziziphus mucronata*).

The Woodland Hills Wildlife Estate contains three different types of vegetation units: Bloemfontein Dry Grassland, Winburg Grassy Shrubland and Bloemfontein Karroid Shrubland (Fig. 2.8a). These units occur in patches throughout the Estate. Winburg Grassy Shrubland and Bloemfontein Karroid Shrubland occur on and directly adjacent to the rocky outcrop, while Bloemfontein Dry Grassland can be found in the open areas around the rocky outcrop. Small trees and tall shrubs can be found on the edge and within the gorge that runs through this site. Trees such as karee, sweet thorn (*Vachellia karroo*), buffalo thorn and the bergkiepersol (*Cussonia paniculata*) can be found in this area (Mucina *et al.* 2006). Tall Shrubs such as blue guarris, hedge spike-thorn (*Gymnosporia polyacantha*), cross-berry (*Grewia occidentalis*) and camphor bush (*Tarchonanthus camphorates*) are also found within the gorge, along the stone-wall and alongside the road.

Two different vegetation units were present on the farm Rusplaas: Xhariep Karroid Grassland and Besemkaree Koppies Shrubland however both rock hyrax colonies were situated within the Besemkaree Koppies Shrubland region (Fig. 2.8b). Trees such as sweet thorn, karee, buffalo thorn and kiepersol were found in this area (Mucina *et al.* 2006). Large part of the veld consist of several grass species with low shrubs, tall shrubs and trees situated closer to the rocky outcrops and cliffs.

Kwaggafontein, situated just outside Bloemfontein, consists of two vegetation units: Bloemfontein Dry Grassland and Winburg Grassy Shrubland (Mucina *et al.* 2006) (Fig. 2.8a). This game farm was dominated by (*Themeda trianda*) and several tree species such as wild olive, blue guarri, karoo kuni-bush, karee and buffalo thorn could be found near the rocky outcrops. Situated on the one side of the game farm was a grove of eucalyptus trees (*Eucalyptus saligna*) and (*Eucalyptus grandis*) which provided cover and shade for the larger wildlife.

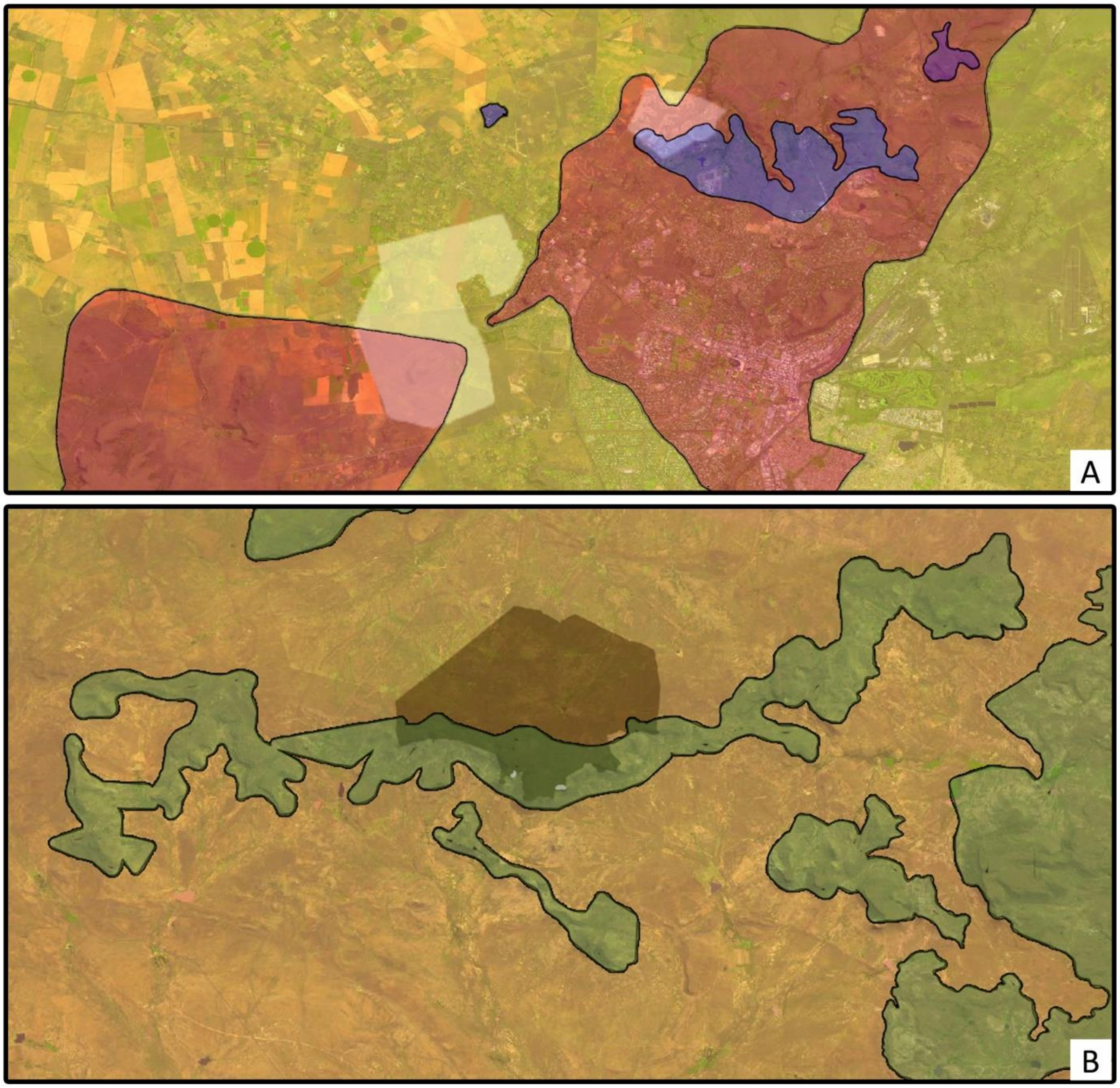

Figure 2.8 The different vegetation zones (black lines) found at the study sites. Vegetation in and around Bloemfontein (A); Bloemfontein Dry Grassland (yellow), Winburg Grassy Shrubland (red) and Bloemfontein Karroid Shrubland (blue). Vegetation types in and around Rusplaas (B); Xhariep Karroid Grassland (orange) and Besemkaree Koppies Shrubland (green). Maps modified from Google Earth Pro Map Data ©2015 AfriGIS (Pty.) Ltd.

2.5 Wildlife

At the Heuwelsig site, which represented suburban residential areas, wildlife was limited to rock hyraxes and smaller mammals, and the commonly found urban bird species. The Heuwelsig Conservancy contained several antelope species in the past but these had been removed periodically and replaced with different species. Species that occurred previously at this Reserve included springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus pygargus phillipsi*), impala (*Aepyceros melampus*), steenbok (*Raphicerus campestris*), red hartebeest (*Alcelaphus buselaphus*) and eland (*Tragelaphus oryx*). During the last ten years all large mammals have been systematically removed from this conservancy (Mr Juan van Zyl, pers. comm.[4]).

The Woodland Hills Wildlife Estate, which represented residential wildlife estates, had several antelope species, smaller mammal species, a variety of bird species but terrestrial mammal predator species were absent. Terrestrial reptile species such as Cape cobra (*Naja nivea*) and the puff-adder (*Bitis arietans*) can occur on the estate although no sightings have been recorded recently (Mr Jaco van Zyl, pers. comm.[5]). The Estate was established in 2004 and although possessing suitable habitat, not many larger species were present on this estate at that stage. Most of the larger species had to be introduced into the Estate. Species found on this estate during the study included springbok, steenbok, waterbuck (*Kobus ellipsiprymnus*), lechwe (*Kobus leche*), sable antelope (*Hippotragus niger*), roan antelope (*Hippotragus equinus*), gemsbok (*Oryx gazelle*), nyala (*Tragelaphus angasii*), kudu (*Tragelaphus strepsiceros*), bontebok (*Damaliscus pygargus pygargus*), tsessebe (*Damaliscus lunatus*), giraffe (*Giraffa camelopardalis*) and plains zebra (*Equus quagga*).

[4] Present address: 21 Neville Holmes Crescent, Heuwelsig, Bloemfontein, 9301, South Africa.
[5] Present address: 249 Woodland Hills Boulevard, Woodland Hills Wildlife Estate, Bloemfontein, 9301, South Africa. *landgoed@woodlandhills.co.za*

The farm Rusplaas, which represented natural areas, was mainly utilised as a livestock farm. The farm however had several species of wildlife including several antelope species, smaller mammal species and a variety of bird species. One clear difference between this site and the two residential sites was the presence of terrestrial predator species.

According to Estes (1991), the predators of rock hyraxes comprise of snakes, cat species (ranging from servals up to lions), eagles, owls, jackals, and even mongooses may take babies. Stuart (1983) reported the occurrence of rock hyrax in the scats of large grey mongoose (*Herpestes ichneumon*). Juvenile hyraxes form a large portion of the prey taken by martial eagles (Polemaetus bellicosus) (Boshof *et al.* (1990) and Verreaux's eagles (*Aquila verreauxii*) (Boshof *et al.* (1991). The ranking predators on rock hyraxes are Verreaux's eagles and martial eagles, cobras and leopards (Estes 1991). The main diet of Verreaux's eagles consists between 70 – 90% of rock hyraxes (Stuart & Stuart 2007; Symes & Kruger 2012). According to Chiweshe (2000 & 2007) the two hyrax species, yellow-spotted hyrax (*Heterohyrax brucei*) and rock hyrax, accounted for about 92% of the total number of prey taken by Verreaux's eagles. According to Stuart & Stuart (2007), crowned eagles, leopards, caracal and African wild cat also take considerable numbers of rock hyrax young. Numerous species, known to hunt rock hyraxes according to Estes (1991), such as the caracal (*Caracal caracal*), black-backed jackal (*Canis mesomalas*), African wild cat (*Felis silvestris lybica*), serval (*Leptailurus serval*), and mongooses was present on the farm. Other predators, known to hunt rock hyraxes, include raptor species such as the Verreaux's eagles (*Aquila verreauxii*) and martial eagles (*Polemaetus bellicosus*) and reptile species such as the cape cobra and the puff-adder was seen on the farm in the past (Mr Harm Grobbelaar, pers. comm.[6]).

[6] Present address: Rusplaas, Bethulie, Xhariep, South Africa.

The Kwaggafontein Game Farm was selected as a suitable translocation site due to the presence of several predatory and non-predatory species. Game species found on this game farm included springbok, blesbok, steenbok, sable antelope, eland, hartebeest, black wildebeest (*Connochaetes gnou*), zebra, white rhinoceros (*Ceratotherium simum*) and ostrich (*Struthio camelus*). Predatory species present on the game farm included the caracal, black-backed jackal, African wild cat, serval, yellow mongoose, Cape grey mongoose, Cape fox, Verreaux's eagle and the booted eagle (*Hieraaetus pennatus*) was also seen on the farm.

Chapter 3

Materials and Methods

CHAPTER 3: MATERIALS AND METHODS

All methods used during this study have been approved by the Animal Ethics Committee of the University of the Free State; Animal Experiment Number 09/2013. General permits with permit numbers 01/9158, 01/12568, 01/16993 and 01/20911 were issued annually by the Free State Department of Economic Development, Tourism and Environmental Affairs (DETEA) since 2011. These permits were issued in terms of the Biodiversity Act 10 of 2004 (Threatened or Protected Species Regulations) and in Terms of Nature Conservation Ordinance no 8 of 1969 which granted permission to capture, collect and transport rock hyraxes (*Procavia capensis*) within Bloemfontein and surrounding areas.

3.1 Determining problem areas

In order to determine problem areas, an awareness campaign was launched to inform the public of this particular rock hyrax invasion problem. Local newspapers and radio stations facilitated this awareness campaign and also requested the public to report any rock hyrax related problems. From these reports, problem areas all over South Africa were identified. Reports were investigated and areas with the most invasions were focused on during this study (see Chapter 2).

3.2 Capture and handling

Due to large capture success of rock hyraxes in previous studies (Fourie 1983; Fourie & Perrin 1986) similar traps, with modifications, as used in aforementioned studies were built according to the requirements of Free State Nature Conservation and used to capture rock hyraxes. Ten traps, 750 mm × 300 mm × 300 mm, with wire mesh sides and a single trap door (operated by a treadle) were constructed to capture rock hyraxes (Fig. 3.1). Due to nasal injuries reported by Fourie (1983), traps were slightly modified by using welded mesh with a smaller aperture, 25 mm x 13 mm x 1.6 mm, and by adding 5 mm thick Perspex panels, 290 mm x 290 mm, at the back and front of the trap.

As suggested by Fourie (1983) trapping at each site was started with a pre-baiting period in which traps were left open. Traps were baited with oranges in the morning just after sunrise and monitored every second hour.

As ambient temperatures affect body temperature (Bartholomew & Rainy 1971; Brown & Downs 2006), rock hyraxes will sun bask to increase body temperature early in the morning and on cold days but will seek cooler refuges during hot days to avoid unnecessary water loss. The capturing of rock hyraxes will prevent these rock hyraxes from regulating their body temperatures by using the ambient temperatures; therefore the placement of traps had to be carefully considered in order to provide traps with sufficient shade cover on warm days and sufficient sun during cold days.

Trapping of rock hyraxes was primarily done during the dry seasons (May - September) as it was easier to lure and trap these animals with baited traps due to the scarcity of natural food sources during these harsh times. Individuals were removed from the traps with a restraining-noose. In an attempt to limit the stress on the animals whilst being handled, all individuals were covered with a blanket once removed from the trap and all data collection (marking, measuring, weighing and determining the sex of individuals) was done as fast as possible.

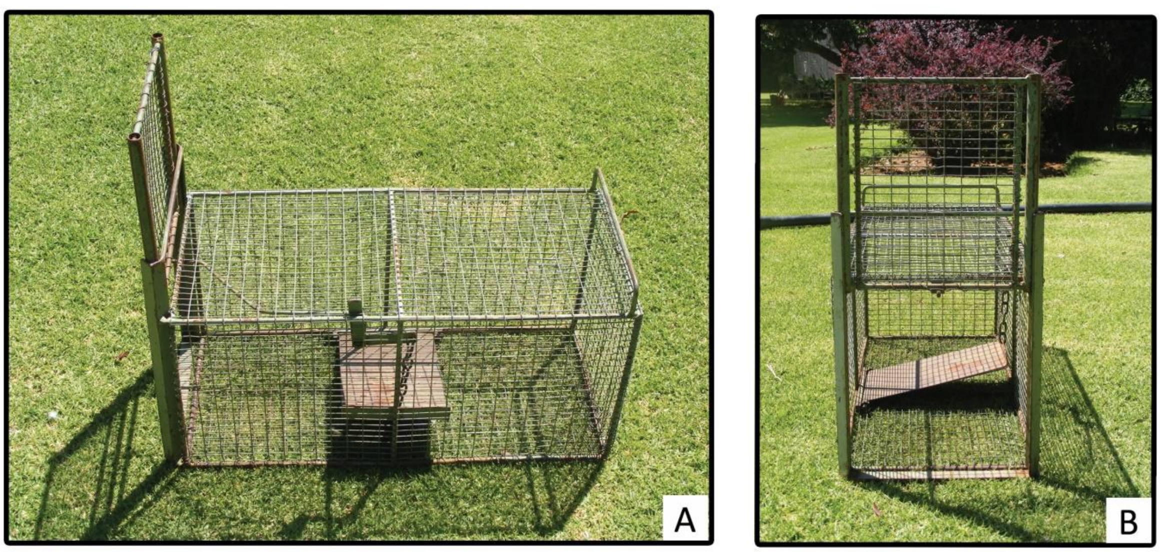

Figure 3.1 Lateral view (A) and frontal view (B) of the traps used to capture rock hyraxes.

3.3 Transport and Housing

Freeze branding trials required animals to be held captive, in temporary holding pens, for varying periods of times. Temporary housing was also required during translocation, as a minimum of 30 individuals had to be captured before being translocated. A general permit to catch, collect and transport the rock hyrax have been obtained from the DETEA. The holding pens were situated at the Bloemfontein Zoo. In order to safely transport animals from the capture sites to the holding pens and from the holding pens to the translocation sites wooden crates with separate compartments, of equal size, were constructed (Fig 3.2). The dimensions of these transport crates were 750 mm x 400 mm x 250mm. These crates also had a welded mesh panel 750 mm x 400 mm x 125 mm (aperture, 25 mm x 25 mm x 1.6 mm) on the one side of the crate.

Figure 3.2 Lateral view of wooden crate used to transport rock hyraxes.

Eight holding pens were available to use at the Bloemfontein Zoo. These holding pens were positioned directly next to each other and are divided into two sections, the enclosure and the den (sleeping quarters). The enclosure and the den are connected with a rubber flap door which enables animals to move freely between the two sections. The dens were all of equal size 3 m x 3 m x 2 m, constructed out of brick with a corrugated-iron roof, and had cement floors and is connected by a small corridor 1.5 m wide.

The enclosure sections of these holding pens were not equally sized. The two enclosures on the outside (Fig. 3.3, far left and far right) were similar in size; with the other cages decreasing by 1 m in length per cage as you move to the centre (Fig. 3.3). These cages had the following dimensions 7 – 10 m x 3 m x 2 m.

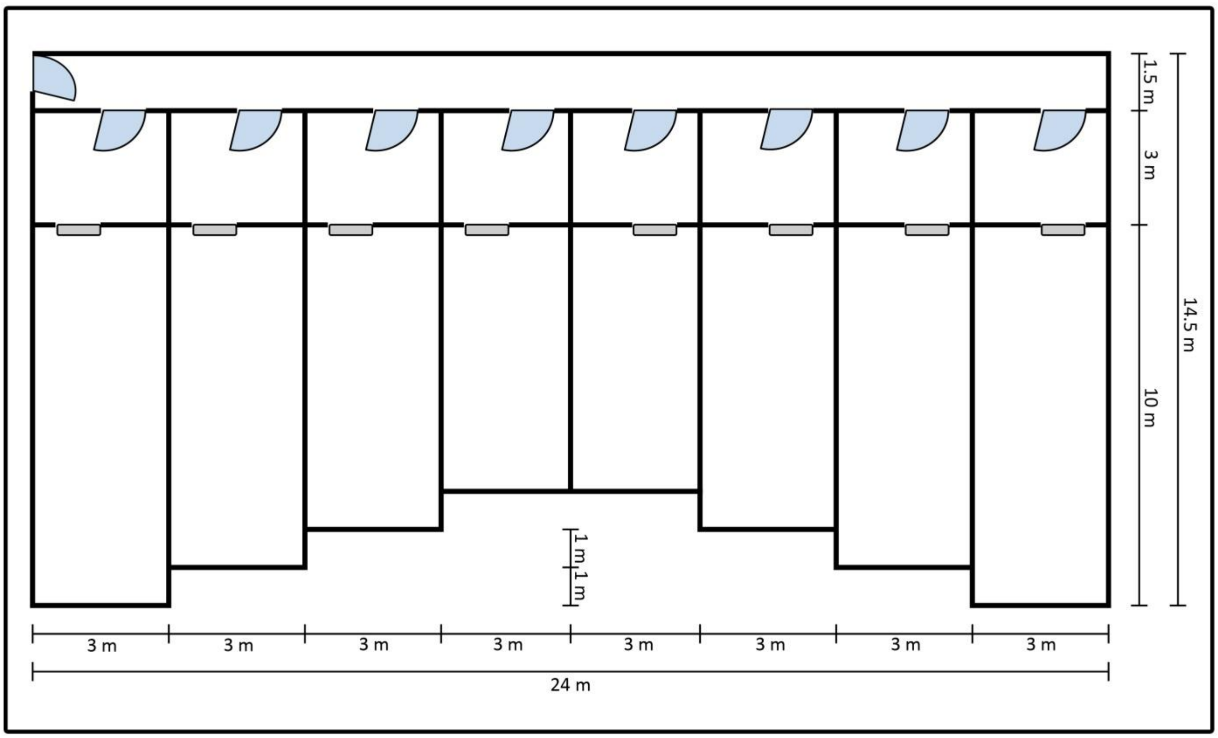

Figure 3.3 Layout of the holding pens at Bloemfontein Zoo. Doors (light blue) and flap doors (grey) is used to access the den and enclosure areas.

3.4 Age determination

In order to determine the composition of populations, the correct age of individuals had to be determined. Therefore, once captured, individuals were weighed, measured and the sex of each individual determined. Measurements of body mass were used to categorize individuals into one of three age groups (juvenile, subadult and adult) using the means and standard deviations of body mass and comparing it to those documented by Fairall (1980). In order to estimate the age, in months, of each individual a multiple regression and predictive equation as described by Fairall (1980) was used. This method was viable to determine the age of both sexes.

3.5 Population size and composition

Population estimates were done at the different sites, during 2011 - 2015, in order to determine the size of populations. The Lincoln Index (Lincoln 1930; Chapman 1951; Seber 1973) and the Robson-Whitlock technique (Robson & Whitlock 1964; Fairall & Crawford 1983) were used to calculate population estimates. The Lincoln Index is a straightforward mark - recapture method based on an initial phase where animals are captured, marked and released. This phase is then followed by a second phase of re-capturing individuals. For this method to be valid, marked and unmarked individuals must have the same chance of being captured during the second phase.

The Robson-Whitlock technique is based on recurrent counts of individuals at a specific site or area. It is also based on the likelihood that all the animals at this specific site or area can be seen at any counting occurrence. The largest count and the second largest count is then used to calculate the population estimate by using the formula provided by Fairall & Crawford (1983) and Robson & Whitlock (1964). An approximate upper confidence limit (Nμ) (Adams 1951; Fairall & Crawford 1983) was also calculated at the 95% [$100(1-\alpha)$] level.

Estimates at the Heuwelsig Site were calculated during June - July for 2011 and 2012 and during November and December for 2013. Estimates at the two colonies on Rusplaas were calculated during March and April 2012. At Woodland Hills Wildlife Estate, estimates were calculated during March and April 2013 and 2015. Estimates at the Kwaggafontein Game Farm were calculated during November 2013, September and November 2014 and repeated in September 2015.

The Lincoln Index was used at the Heuwelsig Site, Woodland Hills Wildlife Estate and Kranskop during this study. Due to the steep slope and inadequate areas to place the traps, trapping of rock hyraxes at Patroonkop was not possible and therefore the Robson-Whitlock Technique was used instead.

One of the assumptions for the Lincoln Index is that the population should be closed, i.e. N (number of individuals in the population) should be constant, and thus no births or deaths should occur. As this method could not be used during the breeding season or when natural predators were present, both methods, the Lincoln Index as well as the Robson-Whitlock Technique were used concurrently when possible, to determine population sizes at the different sites. This was done in order to evaluate the use of the Robson-Whitlock Technique for future population estimates where the use of the Lincoln Index could not be applied.

In order to determine the composition of each colony, information regarding the total number of males, females, adults, sub-adults and juveniles were collected. The number of individuals was used to determine the sex ratio of each colony. Where ever sex ratios are used, the male are mentioned first followed by the ratio of females. The sex ratio of adult individuals was also collected. The Pearson's Correlation Coefficient (Kenney & Keeping 1962; Acton 1966; Edwards 1976) was used to test correlation between population sizes and sex ratios.

3.6 Body Condition Index, Density and Biomass

The body condition index (CI), as defined by Barry & Mundy (1998), was calculated for the different populations. This body condition index was calculated as follows; $CI = [total\ body\ mass\ (kg)\ /\ total\ body\ length\ (cm)]$ (Barry & Mundy 1998).

Population density was calculated determining the number of individuals present in a specific area and is usually measured in number of individuals per hectare and/or number of individuals per kilometre squared (Davies 1994, Barry & Mundy 1998, Narasimmarajan *et al.* 2014). Since Davies (1994) used a calculated average weight of the whole population and Barry & Mundy (1998) used a set weight for juveniles, to calculate biomass, their calculations would either over or under estimated the biomass. A new calculation (which seems to be more accurate), derived from the methods of Davies (1994) and Barry & Mundy (1998), was used to determine the total population biomass. The following calculation was used to calculate biomass;

Key: Average = $\bar{x}$, Adult = A, Sub-adult = S, Juvenile = J, Males = ♂♂, Females = ♀♀;

$$\begin{aligned} Biomass\ for\ study\ area &= (\bar{x}\ mass\ A\ ♂♂ \times\ number\ A\ ♂♂) + (\bar{x}\ mass\ A\ ♀♀ \times\ number\ A\ ♀♀) \\ &+ (\bar{x}\ mass\ S\ ♂♂ \times\ number\ S\ ♂♂) + (\bar{x}\ mass\ S\ ♀♀ \times\ number\ S\ ♀♀) \\ &+ (\bar{x}\ mass\ J\ ♂♂ \times\ number\ J\ ♂♂) + (\bar{x}\ mass\ J\ ♀♀ \times\ number\ J\ ♀♀) \end{aligned}$$

3.7 Marking Techniques

3.7.1 Temporary Markings

During the first phase of the Lincoln Index, rock hyraxes were captured and marked. These markings had to last until the second phase have been completed, thus three to four weeks. Two different types of temporary markings were tested, which entails the application of a number directly to the skin of each rock hyrax. In order to apply this number to the skin, a circular patch, 50 mm in diameter, had to be shaved on the rump of the rock hyrax (Fig 3.4a). A bright luminescent water based paint that is clearly visible on the hyrax fur (Fig. 3.4b), and an alcohol based black permanent marker (Fig. 3.4c) were used to apply the number on the rump of the animals.

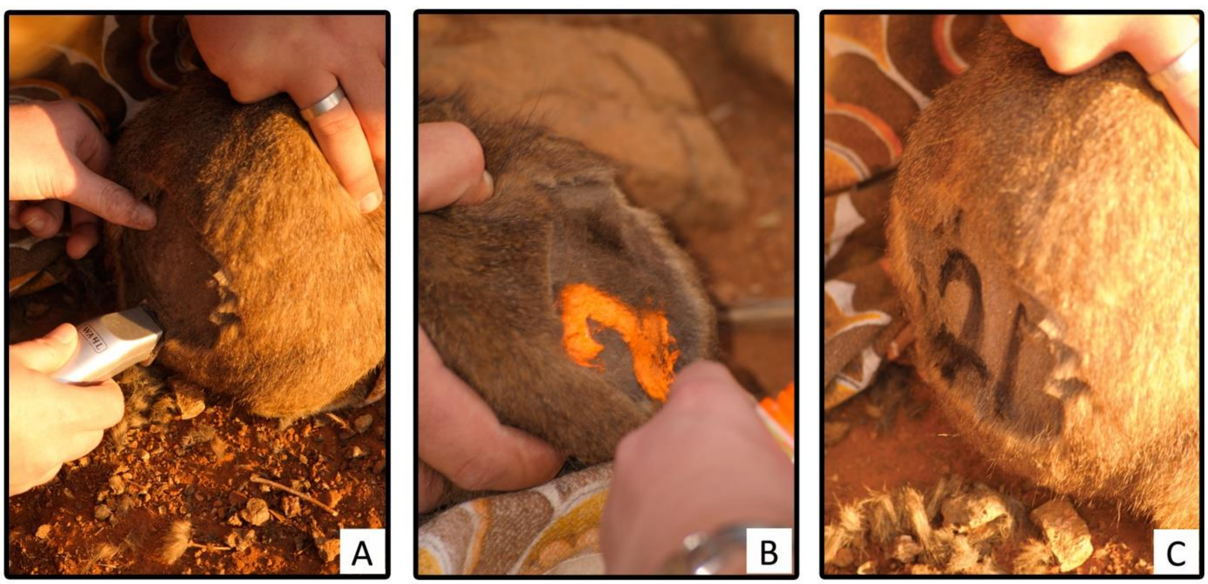

Figure 3.4 The round area shaved on the rump of each individual (A), in order to apply the temporary markings using a bright luminescent water based paint (B) and a permanent marker (C).

3.7.2 Permanent Markings

Permanent markings had to comply with specific ethical as well as legal approval. Apart from legislation requirements, such markings must also be easily visible from a distance. It must furthermore last at least for the total duration of the study before it should be considered as a viable method.

Freeze branding, an acceptable method as a marking technique which will be discussed in detail in Chapter 4 (Marking Techniques), was used to permanently mark rock hyraxes as this method met all the requirements set beforehand. The exact branding times for freeze branding rock hyraxes could not be found in the literature and therefore experimental trials had to be done in order to determine the optimal branding time for rock hyraxes. The decision was made to do the initial branding trials using liquid nitrogen as a coolant which was easily obtainable from the PAREXEL® Early Phase Clinical Unit at the University of the Free State.

Five adult rock hyrax males were captured and held captive at the Bloemfontein Zoo holding pens; this made it possible to easily recapture these individuals for inspection every month. Branding was done on the flank of the rock hyrax as this area provided a smooth and flat surface required for branding. Hyraxes were branded on both flanks, using different branding times for each flank. Branding irons, with copper alloy branding heads and steel handles, with a length of 125 mm, were used to brand the hyraxes. The dimensions of the copper alloy branding heads which were numbered 0 - 9 were 85 mm x 50 mm x 10 mm deep and had a branding surface of 10 mm. The surface area of each branding iron had a 5 mm wide concave groove, which was approximately 2 mm deep, in the middle of the surface.

Ten trial brands, two brands per rock hyrax, with branding times varying from 1 - 7 seconds were done. Normal branding procedures as described by Hall *et al.* (2004) and Bertram *et al.* (2006), included the branding area to be clipped (the process of cutting hair short using an electric clipper), cleaned and sprayed with a layer of alcohol, which aided in transferring the cold temperature from the branding iron to the skin, before branding could commence. In addition to the normal branding procedure, hyraxes were also sprayed with a disinfectant wound spray/aerosol right after branding. Individuals were recaptured monthly and branded areas inspected and photographed in order to monitor the results for each branding time. This was done for a period of eight months after individuals were branded.

3.8 Populations Management Methods

Several preventive and control methods were observed and tested during this study. This was done at the Heuwelsig Site as this was one of the areas with the most frequent reports of rock hyrax invasions. Preventive methods had to adequately decrease the number of rock hyrax sightings in residential areas whilst controlling methods had to rapidly decrease rock hyrax numbers and then keep populations within its natural limits in order to be regarded effective or successful.

3.8.1 Preventive Methods

3.8.1.1 Questionnaires

Information was gathered from 23 homeowners by means of a questionnaire in July 2011. Their homes were situated directly adjacent or across the street from the Heuwelsig site. This questionnaire (Appendix 1) was created to obtain information regarding several aspects of properties including (1) barriers which surrounds the properties, (2)number and breed of dogs if any, (3) time of day and number of hyrax sightings and (4) type of damages caused at properties and (5) the total cost of repairs.

3.8.1.2 Supplementary Feeding

Rock hyraxes were fed within the Heuwelsig Site in order to establish if this, additional feeding, will prevent rock hyraxes from entering residential areas in search of food. Feeding took place twice a week at two feeding locations, roughly 30m apart, centrally located in relation to the residences. Feed consisted of chopped vegetables, chopped fruits and rabbit pellets (Epol: Johannesburg). Three plastic containers (30 cm × 15 cm × 60 cm), with a volume of 27 litres each, were filled with the chopped vegetables and fruit and divided between the two locations. A 50 kg bag of rabbit pellets were also divided between the feeding locations.

A total volume of 40.5 litres chopped fruit and vegetable mix and 25 kg of rabbit pellets were thus placed at every feeding location on a feeding day. Daily counts of rock hyraxes at the 23 houses in Heuwelsig were done for a period of one week prior to the provision of supplementary food as well as two consecutive weeks during the time supplementary food was provided. From this data, an average daily number of rock hyraxes per property were calculated per period.

3.8.2 Control Methods

3.8.2.1 Introduction of natural predators

One of the methods for controlling hyrax populations included the introduction of natural predators. After a comprehensive literature study, the decision was made to introduce a caracal as they are effective natural predators of rock hyraxes. A suitable individual would be obtained in collaboration with Free State Nature Conservation. In March 2013, Free State Nature Conservation captured a female caracal on a livestock farm and the animal was released at the Heuwelsig Conservancy shortly after capture. Since the Heuwelsig Conservancy, a proclaimed conservancy, was enclosed by game fences it was possible to release the animal at this site. According to Mr. Lourens Goosen (pers. comm. 2013[7]) female caracals usually have smaller home ranges than males. A study done by Avenant and Nel (1997; 1998 & 2002) also confirm that the average home range size of male caracals (mean 26.9 ± 0.75 km^2) were significantly larger than those of female caracals (mean 7.39 ± 1.68 km^2).

3.8.2.2 Translocation

In order to capture rock hyraxes for translocation, methods, as described in 3.2.1, were used. Once a rock hyrax was removed from a trap the individual was immediately placed in a wooden transport crate suitable to transport two rock hyraxes, each individual in its own compartment. Rock hyraxes were then transported to the holding site and held in captivity.

[7] Present address: Department of Economic Development, Tourism and Environmental Affairs (DETEA), Bojanala Building, 34 Markgraaf Street, Bloemfontein, 9301, South Africa. *goosenl@detea.fs.gov.za*

According to Estes (1991), rock hyrax colonies may consist of 30 to 40 individuals in the wild and will usually consist of one territorial adult male with a harem of females and their offspring. Wild populations tend to maintain a male to female ratio of about 1:2.

Rock hyraxes were kept in holding pens until a group of at least 30 rock hyraxes, with a group composition similar to that in the wild, could be formed. Groups were not held for any specific time, but the time in the holding pens ranged from two to eight weeks. Only the last group were held for more than six months in order to allow pups that were born in captivity to reach an age of at least three months. Once a minimum of 30 rock hyraxes was captured these rock hyraxes were translocated to a site further than 7 km from the capture site as rock hyraxes have been reported to return to their former home ranges which were more than 4 km from the release site (Crawford & Fairall, 1984).

The presence of a highly territorial white rhinoceros bull, protective of a new-born calf (Mr Rudi Vertue pers. comm. 2013[8]), at the site of translocation prevented post-translocation monitoring for the first four translocation groups. The bull has displayed aggressive behaviour towards vehicles entering his territory and therefor it was not recommended to remain in the same area for extended periods (Mr Rudi Vertue pers. comm. 2013[8]). The territorial bull is known to approach stationary vehicles in its territory and has damaged vehicles before (Mr Daryl Barnes pers. comm.[9]). Therefore it was possible to enter the game farm to release rock hyraxes but it was not possible to remain in the area for extended periods of time to observe the translocated individuals. At the time of relocating the 5th and 6th groups, proper post-translocation monitoring could be done.

[8] Present address: Bloemfontein Zoo, Henry Street, Bloemfontein, 9301, South Africa. *nature@civic.mangaung.co,za*

[9] Present address: Bloemfontein Zoo, Henry Street, Bloemfontein, 9301, South Africa. *daryl.barnes@mangaung.co.za*

Rock hyraxes were monitored post-translocation in order to determine the success of translocation. Post-translocation monitoring was conducted according to the method used by Wimberger *et al.* (2009) where the population is monitored intensively direct after release and with decreasing intervals of monitoring up to the 12th month after translocation (Table 3.1).

All observations, during post-translocation monitoring, were done from a fixed observation point using binoculars. As a safety precaution, all observations were preceded by scouting for rhinoceroses, at least 30 minutes prior to sunrise using a spotlight with a red filter when necessary, to determine their location and distance from the release site.

Table 3.1 Protocol for post-translocation monitoring from the first day up to 12 months after translocation. (*Protocol* a*dapted from Wimberger et al. (2009))*

Week	**Observations per week**
Week 1	Daily
Week 2	Twice a week
Week 3 – 4	Once a week
Week 5 – 8	Twice a month
Week 9 - 24	Once a month
Week 52	Single observation (One year after translocation)

Observations protocol comprised of counts at 15-minute intervals, initiated 10 - 15 minutes prior to sunrise and concluded around 10:00 in the morning. This was followed by walking a transect of 1.71 km at Brandkop Peak and driving three transects of 2.74 km, 2.29 km & 2.54 km respectively at the other release sites. All count methodology followed that of Rudran *et al.* (1996) and Bothma (2002). Observations were done from the vehicle, stopping every 250 m.

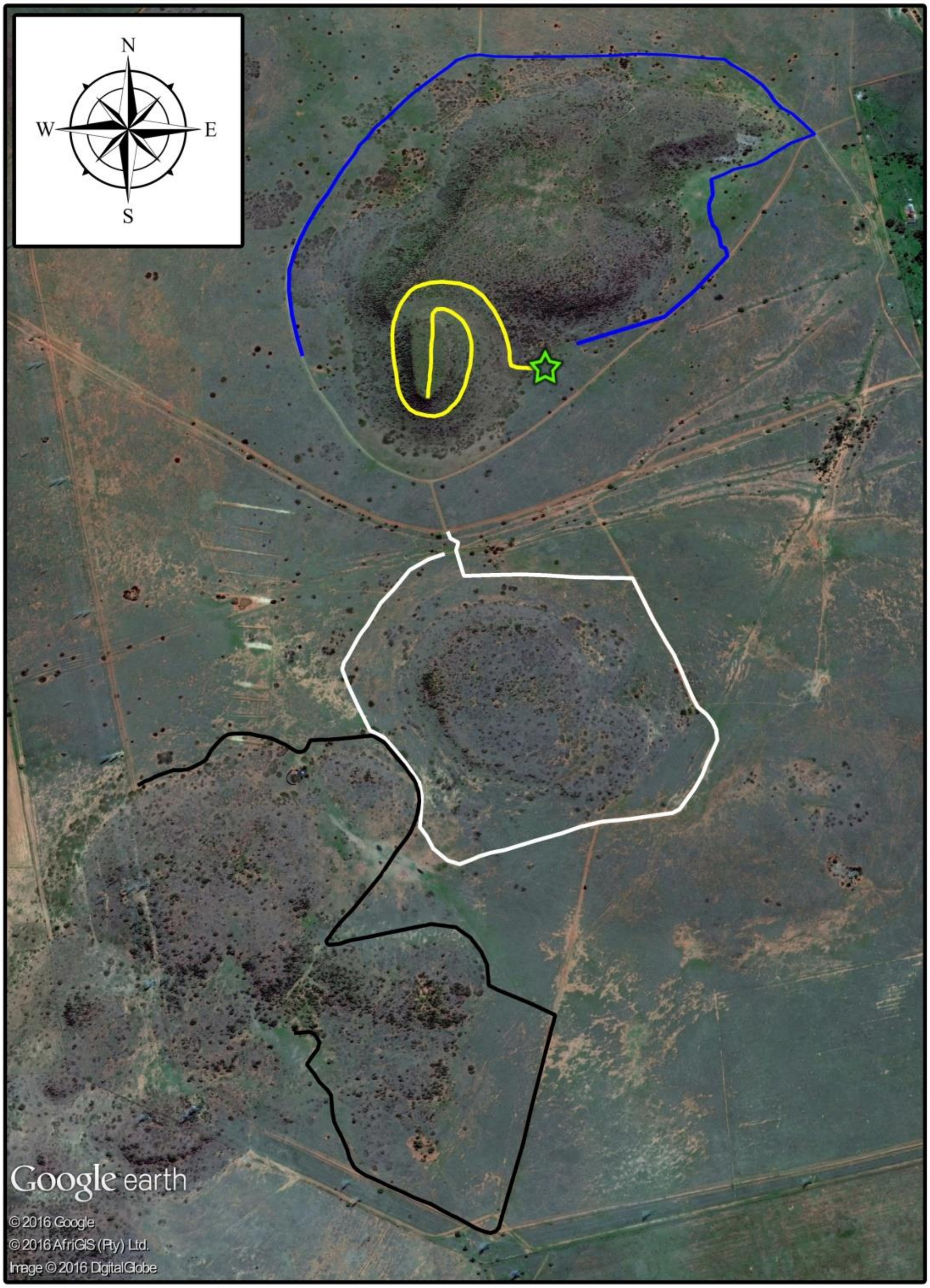

Figure 3.5 The location of the fixed observation point (green star), the 1.71 km walk transect (yellow) and three drive transects, 2.74 km (blue), 2.29 km (white) & 2.54 km (black) used during post-translocation monitoring at Kwaggafontein.

3.9 Study Timeline

Due to the numerous overlapping aspects of this study, a simplified timeline, for ease of reference, is included (Fig 3.6). This timeline indicates all the aspects that was done at each study site, with the start and end date of each aspects.

3.10 Data Analysis

All statistical analysis of data has been done using Microsoft Excel (Microsoft Office 2010). ANOVA tests were used to test the hypotheses that the average body measurements and average body mass of rock hyraxes from all populations were the same. F-tests were used to test the hypotheses that the average body measurements and average body mass of rock hyraxes between two populations were the same. ANOVA and Kriskal-Wallis tests were used to determine any significant differences between the effectiveness of the different preventive measures tested. Body condition index and the biomass were calculated according to the methods of Davies (1994) and Barry and Mundy (1998). The age of individuals is done with regression and predictive equations as used by Fairall (1980). Population sizes were determined using the Robson-Whitlock technique and the Lincoln Index. All correlations between data were made using the Pearson Correlation Coefficient. Probability levels of 95% ($p < 0.05$) and 99% ($p < 0.01$), was constantly used to distinguish between significant and highly significant statistical differences.

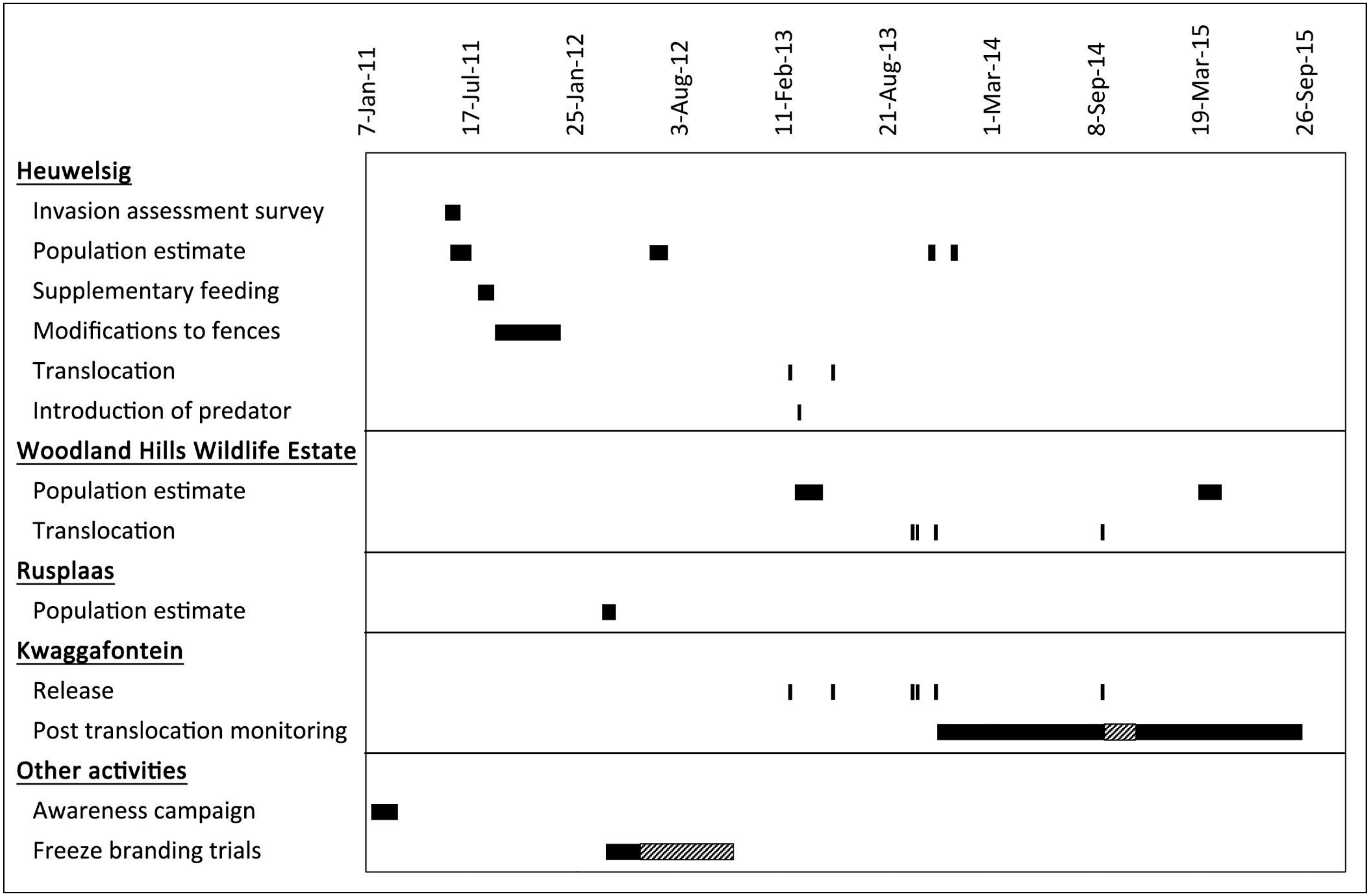

Figure 3.6 Timeline of the different aspects of the study to occur at the different study sites. Black Bars indicate the duration of each aspect of the study while overlapping aspects of the study is emphasised with diagonal black and white lines.

Chapter 4

Invasion Assessment Survey

CHAPTER 4: INVASION ASSESSMENT SURVEY

From the reports following the awareness campaign, specifically launched to inform and request the public to report any rock hyrax related problems, numerous problem areas all over South Africa were identified (Fig. 4.1). From these problem areas study sites with the most frequent reports were identified as study sites (see Chapter 2). At the commencement of this study, a survey was conducted at the properties which surround the Heuwelsig Site, since this was one of the areas with the most frequent reports of rock hyrax invasions. The objective of this survey was to gather information, regarding each property, in order to gain further insight on the type of preventive methods currently in place and how effective these methods are in keeping hyraxes out. Information gathered from this questionnaire would then be used to compare the effectiveness of current preventive methods, such as barriers and dogs, and from that determine which method or combination thereof will be the most effective in preventing hyraxes from entering properties.

In order to gather the required information from homeowners a questionnaire was created. Specific questions were included to gather information regarding (1) barriers which surrounds the properties, (2) number and breed of dogs, if any, (3) time and number of hyrax sightings, (4) hyrax age and activity, (5) type of damages caused at properties and (6) the total cost of repairs. A total of 19 questions with a further nine sub-questions were included in the questionnaire (Appendix 1).

The results of this questionnaire will be presented as percentages of the number of responses to each question. Results will not only be represented in numerical order, as they appeared in the questionnaire, but will also be broken down into different sections according to the different type of preventive methods. Discussion regarding the effectiveness of each preventive method will be done in the chapter on Population management (Chapter 7).

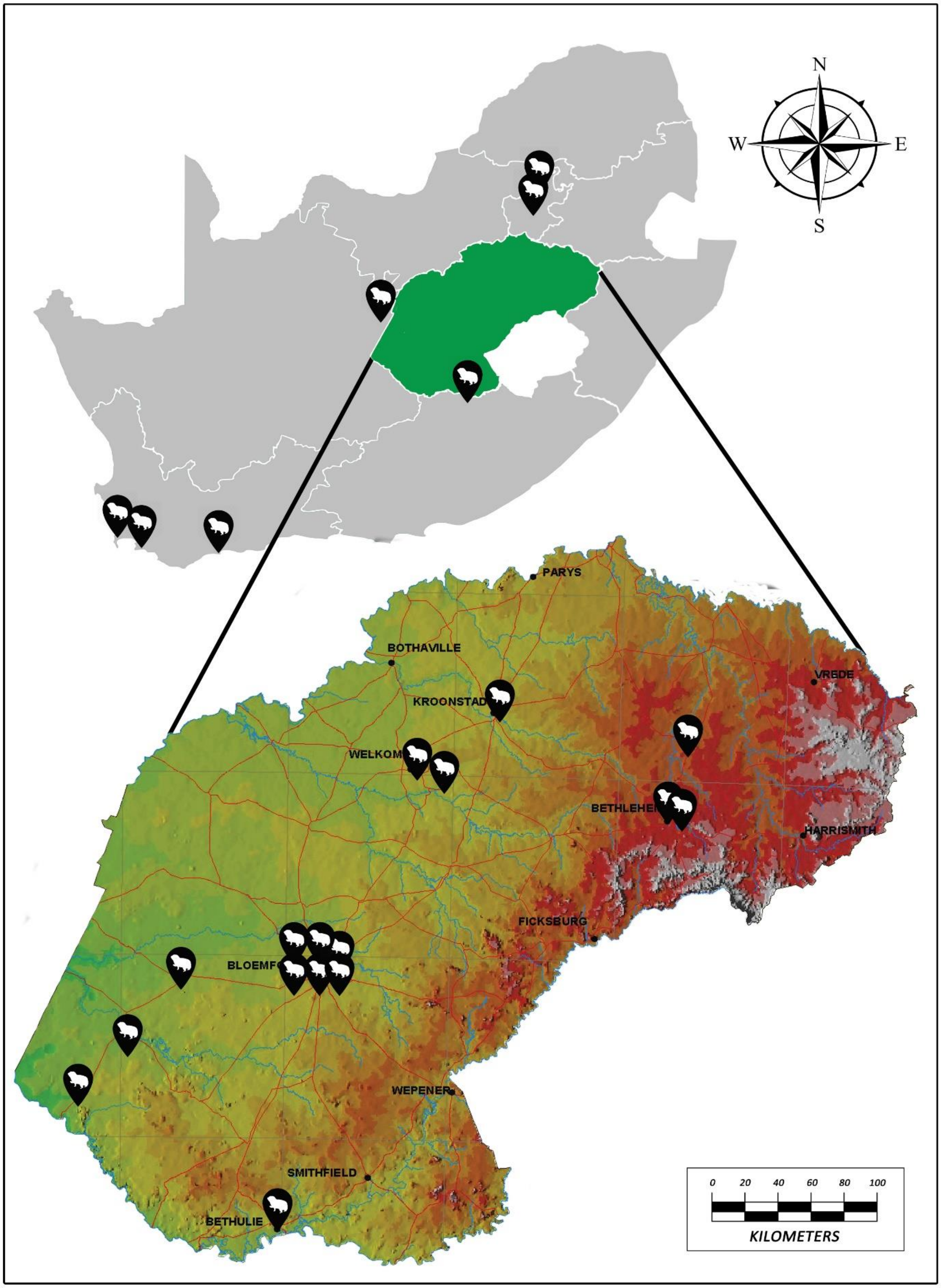

Figure 4.1 Locations of all reported problem areas situated within the Free State and the rest of South Africa.

4.1 Results and Discussion

4.1.1 Barriers

In order to gather information regarding barriers which surround properties, six barrier related questions were included in the questionnaire (Table 4.1). All property owners indicated that they had a barrier surrounding their property. Barriers were divided into two distinct categories namely open (those with openings or gaps) and solid barriers. These two categories were further divided into four main types of barriers, wire fences and devils fork fences which fall within the first category of open barriers, as wells as brick walls and precast concrete walls which fall in the solid barrier group.

Table 4.1 Barrier related questions included in the questionnaire. The number in the last column indicates the corresponding question number in the questionnaire.

1	Is there a fence around your property?	Q1
2	If yes, what type of fence?	Q1.1
3	If you selected the brick wall option in 9.1 is this brick wall plastered or not	Q2
4	What is the height of your fence?	Q3
5	If it is a wire fence, what type of wire fence is it?	Q4
6	Does the fence have an overhang?	Q5
7	Electric wires on or next to the fence?	Q6

From these four types of barriers the wire fences were preferred over the other three types since 56% of the properties were enclosed by a wire fence (Fig. 4.2: Q1). The occurrence of wire fences was more than double that of barrier type occurring second most, brick walls, which only enclosed 22% of the properties. Only 9% of these brick walls were plastered and painted (Fig. 4.2: Q2). Majority of the properties, 65%, opted for a fence higher than 1.5 m (Fig. 4.2: Q3). The best part (83%) of the wire enclosed properties opted for a diamond mesh fence of which 39% had a preference towards mesh with an aperture larger than 50 mm (Fig. 4.2: Q4). In addition to their current barrier only 43% of homeowners, 13% and 30% respectively, opted for additional safety methods such as an overhang at the top of the barrier (Fig. 4.2: Q5) or an electric fence (Fig. 4.2: Q6).

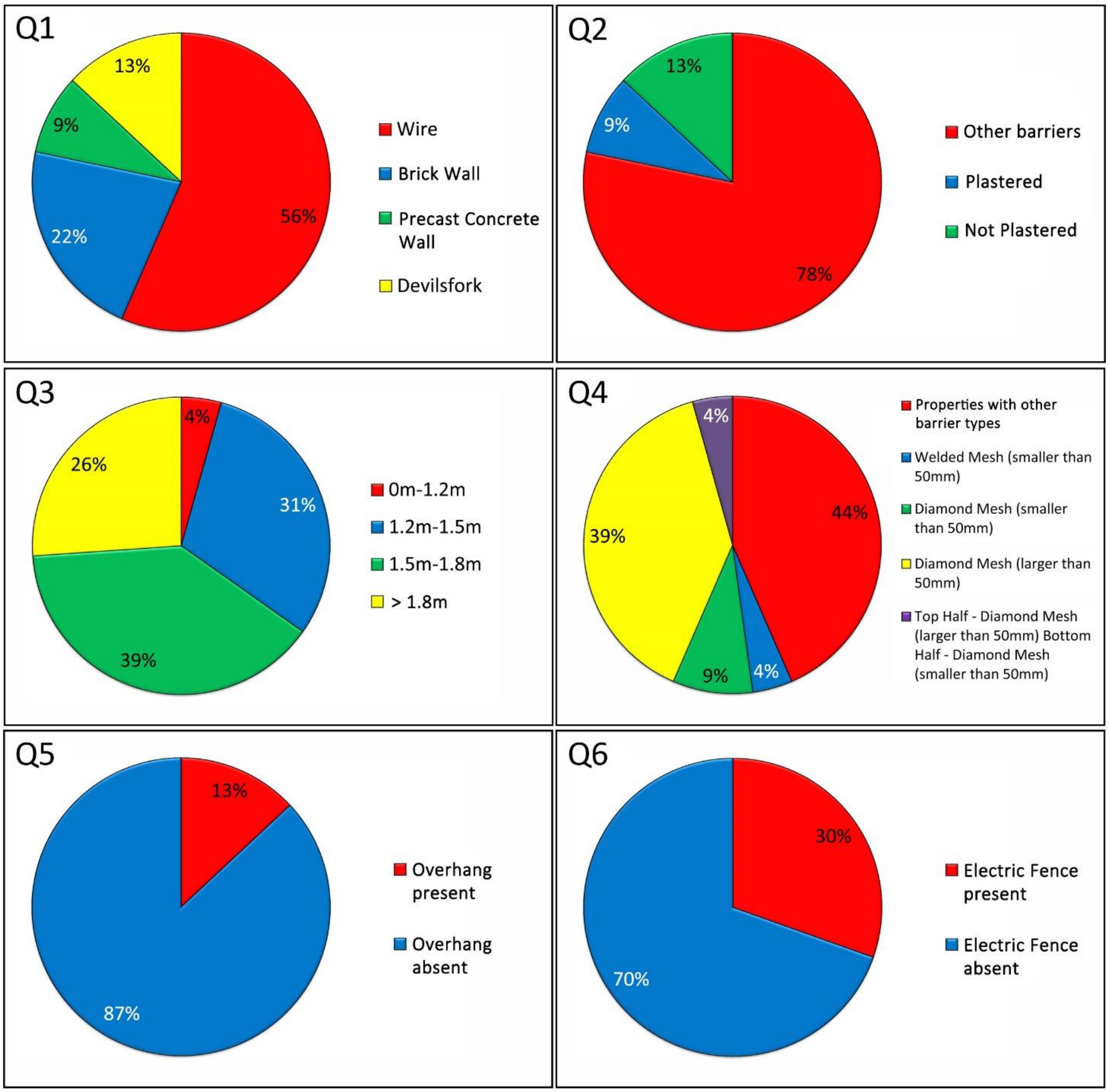

Figure 4.2 Responses to Questions 1 to 6 (Q1-Q6) by the 23 homeowners. The total number of responses per question, marked by the 23 homeowners, is indicated as a percentage.

4.1.2 Dogs

Five questions were included in the questionnaire to collect information regarding dogs at the different properties (Table 4.2). All responses regarding dogs are summarized in Fig. 4.3. Only 22% of the homeowners indicated that there is no dogs present at their property (Fig. 4.3: Q7). Although the total number of dogs at properties ranged from one to four, the majority of homeowners indicated that they have two dogs (Fig. 4.3: Q8).

To determine if the dogs could move around, during the day or night, in order to patrol the property it was necessary to include a question regarding the movement and sleeping arrangements of dogs at each property. Results from the questionnaire indicated no real preference towards where the dogs were kept during the night since 26% indicated that their dogs slept indoors, 26% of the dogs slept outside and 26% allowed the dogs to move around freely during the night between inside and outside (Fig. 4.3: Q9).

Table 4.2 Dog related questions included in the questionnaire. The number in the last column indicates the corresponding question number in the questionnaire.

1	Do you have any dogs?	Q7
2	If Yes, provide details of the dogs	Q8
3	Number of dogs?	Q8.1
4	Breed of dog/s?	Q8.2
5	Are the dogs free to move around at night or do they sleep indoors?	Q9

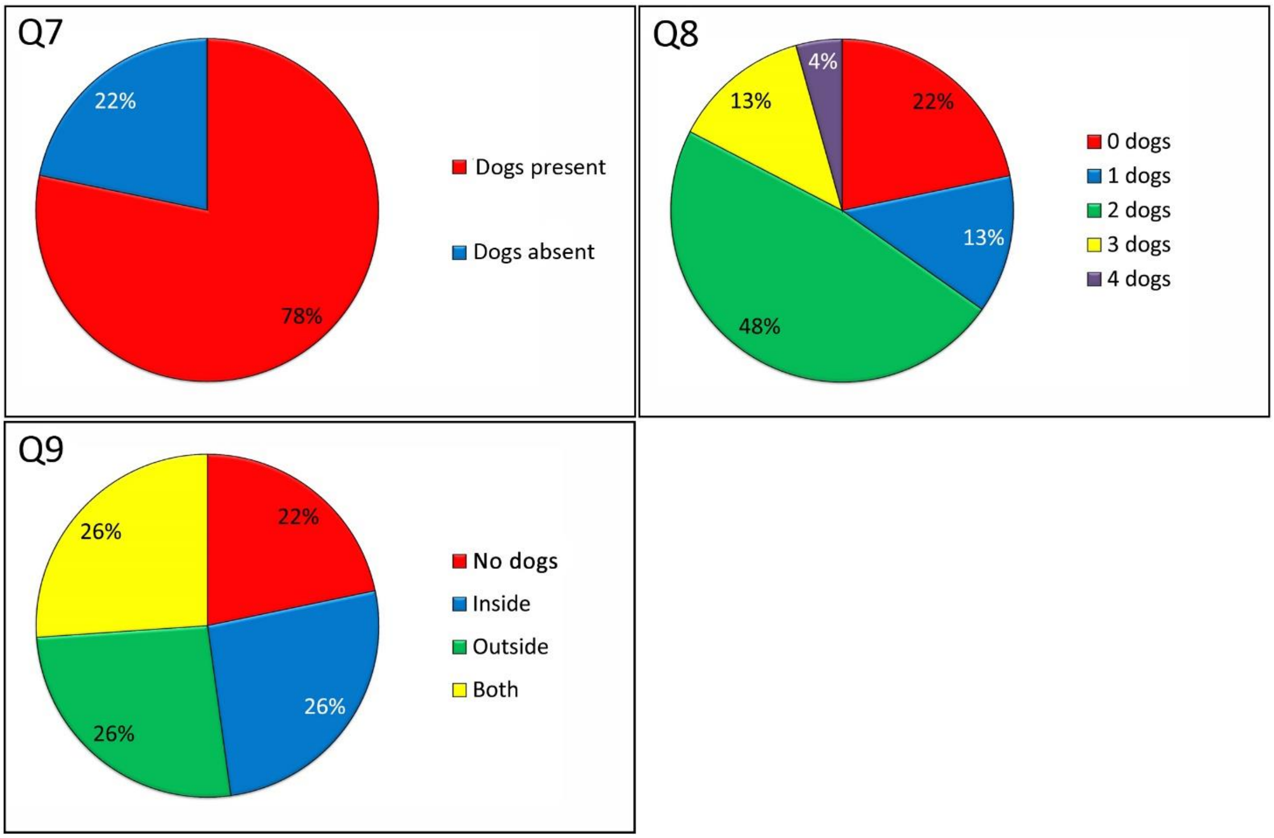

Figure 4.3 Responses to Questions 7 to 9 (Q7-Q9) by the 23 homeowners. The total number of responses per question, marked by the 23 homeowners, is indicated as a percentage.

4.1.3 Sightings and Activity

Seven questions were included in the questionnaire in order to gather information regarding the sightings of hyraxes and their activity. The responses regarding the sightings are summarized in Fig. 4.4. The number of hyrax sightings was of great importance to establish which properties were visited regularly by hyraxes. As could be seen from the results there is none of the categories that stood out from the rest (Fig. 4.4: Q10, Q11 & Q12). Nearly half of the responses, 43%, indicated that they see one to three hyraxes in their properties per day (Fig. 4.4: Q13). Homeowners indicated that more sightings occur during 06:00 - 12:00 each day, and second most during 18:00 - 00:00 (Fig. 4.4: Q14). 48% indicated that hyraxes were feeding at properties while 34% said they were lying in the sun (Fig. 4.4: Q15). The majority of the animals seen were adult individuals (Fig. 4.4: Q16).

Table 4.3 Rock hyrax sighting related questions included in the questionnaire. The number in the last column indicates the corresponding question number in the questionnaire.

1	How many DAYS OF THE WEEK do you see hyraxes in your yard?	Q10
2	How many TIMES PER WEEK do you see hyraxes?	Q11
3	How many TIMES PER DAY do you see hyraxes?	Q12
4	What is the AVERAGE NUMBER of hyraxes that you see in your property per day?	Q13
5	During what part of the day do you see hyraxes in your yard?	Q14
6	What are the hyraxes doing when you see them?	Q15
7	What is the size of the hyraxes you see?	Q16

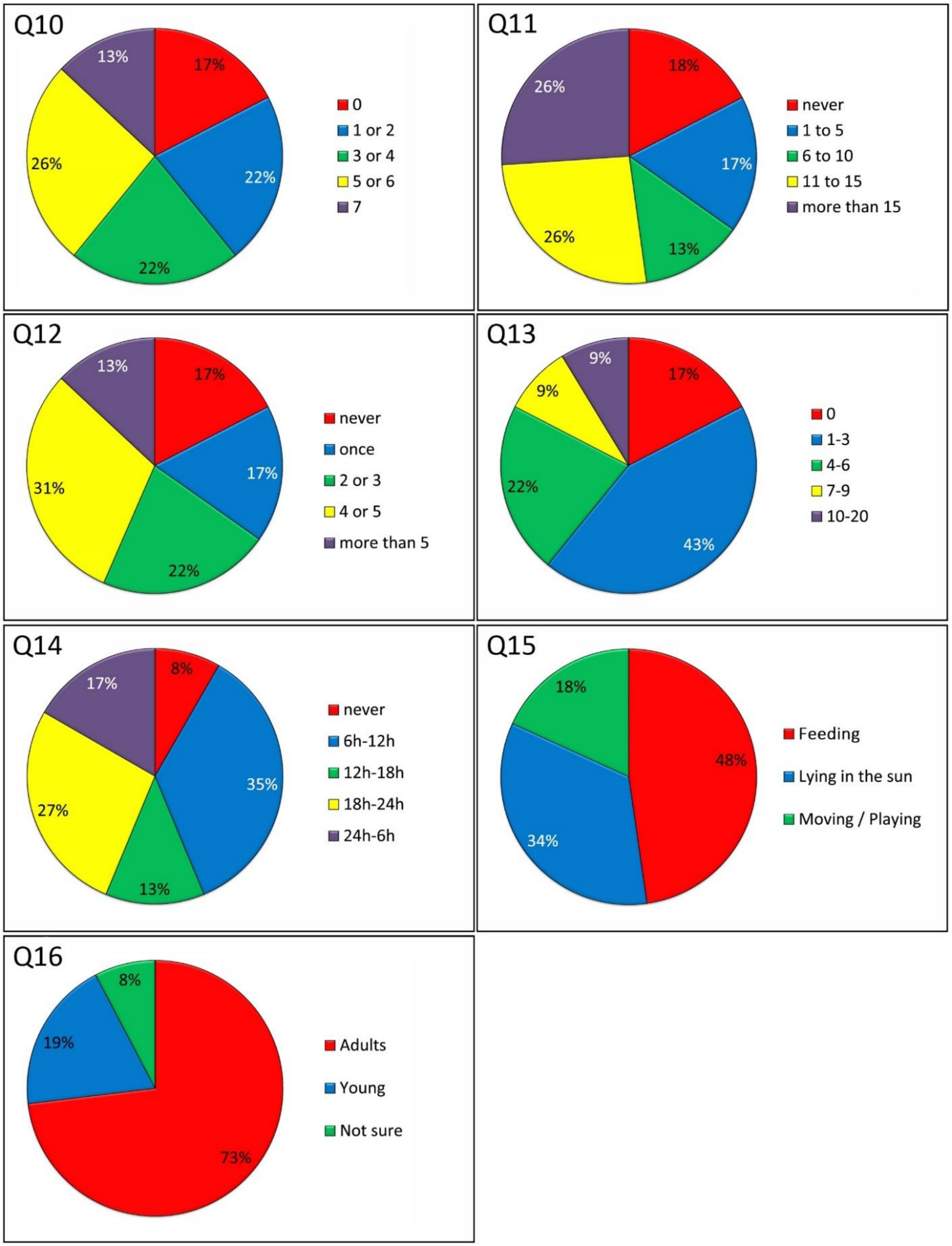

Figure 4.4 Responses to Questions 10 to 16 (Q10 – Q16) by the 23 homeowners. The total number of responses per question, marked by the 23 homeowners, is indicated as a percentage.

4.1.4 Damages & Costs

Two questions, with relevant sub questions, were included to establish the type of damage caused by rock hyraxes and to determine the cost towards repairs of those damages. Three predetermined categories of damages were included in the questionnaire (Table 4.3). Results from different sections in the questionnaire were compared in order to determine how damages and costs are influenced by barrier type, barrier height, breed of dogs and a combination of some of these variables.

One of the biggest damage causing factors of these hyrax invasions is the fact that rock hyraxes make use of midden, sites sometimes referred to as latrines (Fig. 4.5). In the residential areas these midden sites were located on roofs (Fig. 4.6), on or next to walls (Fig. 4.7a & d), in gardens and in some cases, where rock hyraxes managed to enter roofs; these middens were found on the ceiling boards within the roof (Fig. 4.7b & c). Damage to structures is thus mainly caused by these hyrax droppings and urine. These excrements caused stains on walls and paving stones (Fig. 4.7a & d), caused damp in ceiling boards (Fig. 4.7b) and in severe cases caused the ceiling board to collapse under the weight of the droppings (Fig. 4.7c).

In most instances where damage to gardens were reported these damages were limited to plants being eaten, partially or completely, by hyraxes (Fig. 4.8) or trees being damaged when hyraxes stripped them of bark or leaves (Fig. 4.9). Several homeowners found hyrax middens in their gardens. One homeowner reported damage to the solar panel of the pump of the fountain in the garden. Hyraxes were regularly seen whilst climbing or lying on the rocks, which this fountain was built from (Mrs Hannie von Berg, pers. comm. 2011[10]). This damage was still categorised as damage to gardens since the fountain was a garden feature.

[10] Present address: Neville Holmes Crescent 16, Heuwelsig, Bloemfontein, 9301, *svonberg@mf.co.za*

All damages mentioned for the third category, People and Pets, included medical costs towards the treatment of injuries. One homeowner also reported medical expenses towards the treatment of parasitic worms. Dogs had to be dewormed once every two to three weeks since they get infected with parasitic worms when they ingest hyrax droppings within the property (Mrs Philline van der Walt, pers. comm. 2011[11]). Whether dogs are indeed infected by parasites from hyrax dropping could not be confirmed.

Table 4.4 Damages and cost related questions included in the questionnaire. The number in the last column indicates the corresponding question number in the questionnaire.

1	In what category do the damages caused by hyraxes fall?	Q17
2	Structures (paint, leaking roofs, damaged ceilings, etc.)	Q17.1
3	Garden (eaten plants, trampled, and those that had to be replaced, etc.)	Q17.2
4	People & Pets (any medical costs due to injuries caused by hyraxes)	Q17.3
5	What is the cost towards repair of these damages per year?	Q18
6	Structure (paint, leaking roofs, damaged ceilings, etc.)	Q18.1
7	Garden (eaten plants, trampled, and those that had to be replaced, etc.)	Q18.2
8	People and Pets (any medical costs due to injuries caused by hyraxes, etc.)	Q18.3

[11] Present address: Neville Holmes Crescent 24, Heuwelsig, Bloemfontein, 9301, *0827892321*

Figure 4.5 Typical rock hyrax midden site located at the Heuwelsig conservancy.

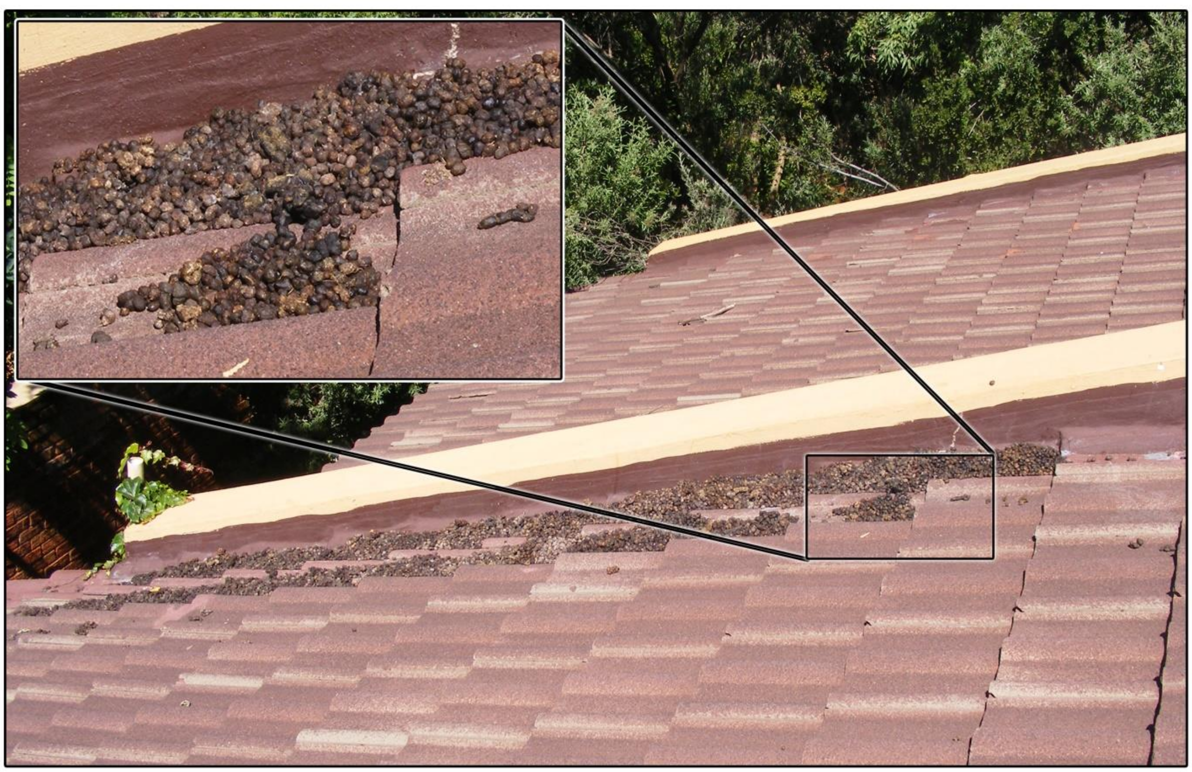

Figure 4.6 Hyrax midden located on the roof of one of the properties of a house close to the Heuwelsig conservancy.

Figure 4.7 Damage caused to structures by hyrax middens included stains to walls (A), damp ceilings (B), collapsed ceilings (C) and stained paving stones (D).

Figure 4.8 Damage caused to flowering plants included plants where only the flower was eaten (A) and plants were the entire plant, flower and leaves were eaten (B).

Figure 4.9 Bark and leaf stripped branches (blue arrows) caused by hyraxes in the Heuwelsig conservancy.

As part of the questionnaire, homeowners were requested to provide the monetary value of cost (in South African Rands) towards repairs of damages during the last 12 months. These costs were divided into three categories: costs towards repairing damages to structures, costs towards repairing damages to gardens and costs towards the treatment of injuries and/or any other medical expenses caused by rock hyraxes. The total costs towards damages and injuries caused by hyraxes were R 76 861.00. The responses of all 23 homeowners have been summarized in Figure 4.10.

From the values provided by the homeowners, it was clear that total costs towards repairing damage to structures was almost twice as high as costs towards repairing or replacing damage to gardens. Cost towards repairing structures was about two and a half times higher than costs associated with the treatment of injuries or medical expenses (Table 4.5). In order to see if the cost towards repairs are different in the presence of the different variables, the cost associated with each of the following preventive methods were determined: (1) type of barrier, (2) height of barrier, (3) dog groups and (4) a combination thereof.

The total costs towards repairing damages for each of the following preventive methods: barrier type (Table 4.6), barrier height (Table 4.7), supplementary attachments to barriers (Table 4.8) and dog group (Table 4.9) were noticeably different. Keeping in mind that the accumulated costs of one preventive method might be higher than those of other methods, comparison of total costs to determine how effective a preventive method might be might create a false perception. Calculating the average costs might provide a more accurate reflection of the effectiveness of each preventive method.

Wire fences with an aperture smaller than 50 mm had the lowest average cost towards repairs, when compared to other barriers, while precast concrete walls had the highest average cost (Table 4.5). Barriers with a height of 0 m - 1.2 m had the highest average cost, whereas barriers with a height of more than 1.8 m had the lowest average cost towards repairs associated with them (Tables 6.6). Some fences had supplementary attachments added in order to improve the effectiveness of these fence. The average costs at properties with an overhang were considerably lower than those without an overhang (Table 4.7). Properties with additional electric fences had similar results (Table 4.7).

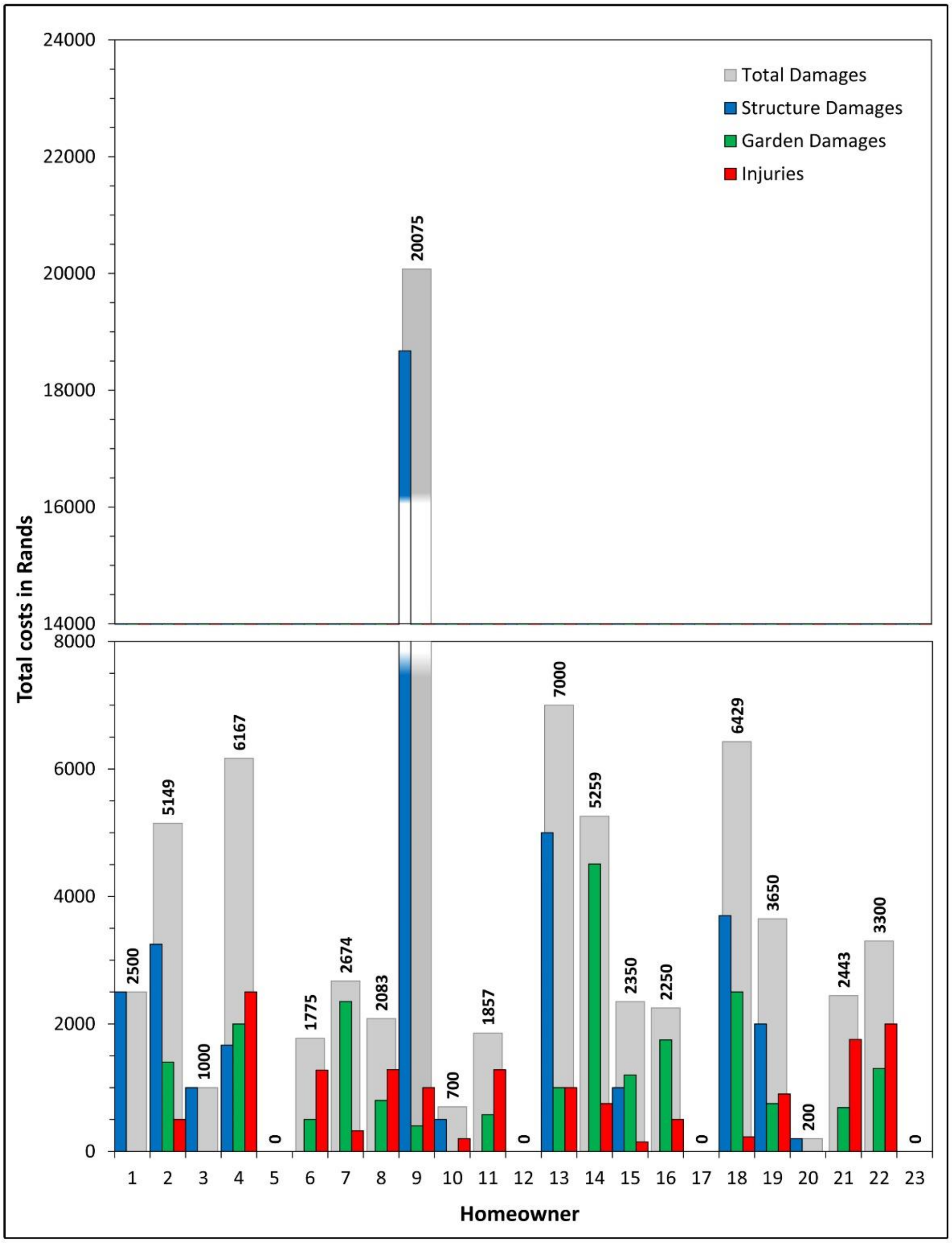

Figure 4.10 Responses to Questions 17 by the 23 homeowners. The blue, green and red bars respectively indicate the damages to structures, damages to gardens & cost towards injuries for each homeowner. The total damages for each homeowner is indicated by the grey bar.

Table 4.5 Costs to damages and injuries caused by hyraxes in Heuwelsig neighbourhood.

Category	**Total costs (n = 23)**	**Maximum value recorded**	$\bar{x}$ **cost**	**± SE**
Damages to structures	R39 491.00	R18 675.00	R1 717.00	± R826.34
Damages to gardens	R21 720.00	R4 509.00	R944.35	± R231.67
Treatment of injuries	R15 650.00	R2 500.00	R680.43	± R152.01
Total	**R76 861.00**	**R25 684.00**	**R3341.78**	

Table 4.6 Summary of costs to damages, in the presence of different barriers types.

Category	**n**	**Total costs**	$\bar{x}$ **cost**	**± SE**
Devil's Fork Fences	**3**	**R7 600.00**	**R2 533.33**	**± R419.00**
Precast Concrete Walls	**2**	**R26 242.00**	**R13 121.00**	**± R6 954.00**
Brick Walls (All)	**5**	**R11783.00**	**R2 356.60**	**± R1 262.16**
plastered	2	R2 700.00	R1 350.00	± R614.70
not plastered	3	R9 083.00	R3 027.60	± R898.59
Wire Fences (All)	**13**	**R31 236.00**	**R2 402.77**	**± R599.93**
diamond mesh with aperture larger than 50mm	9	R22 413.00	R2 490.33	± R2 256.14
diamond mesh with aperture smaller than 50mm	2	R1 000.00	R500.00	± R267.26
diamond mesh with top aperture larger than 50mm and bottom aperture smaller than 50mm	1	R2 674.00	R2 674.00	± R0.00
welded mesh with aperture larger than 50mm	1	R5 149.00	R5 149.00	± R0.00

Table 4.7 Summary of damages, in the presence of barriers of different heights.

Height of Barrier	n	Total costs	$\overline{x}$ cost	± SE
0m – 1.2m	1	R20 075.00	R20 075.00	± R0.00
1.2m – 1.5m	7	R27 770.00	R3 967.14	± R736.25
1.5m – 1.8m	9	R20 083.00	R2 231.44	± R703.28
> 1.8m	6	R8 933.00	R1 488.83	± R866.17

Table 4.8 Supplementary attachment to existing fence and the costs in the presence or absence of these structures.

Supplementary attachment	n	Total costs	$\overline{x}$ cost	± SE
Overhang				
Present	3	R200.00	R66.67	± R66.67
Absent	20	R76 661.00	R3 833.05	± R971.01
Electric Fence				
Present	7	R14 000.00	R2 000.00	R796.92
Absent	16	R62 861.00	R3 928.81	R1 208.53

Due to the mere number of dog breeds that exist today, dogs were grouped according to the seven groups system (Anonymous 2011, Anonymous 2014). Upon comparison of the different types of dogs, the highest cost towards repairs were associated with dogs from the hound group while dogs from the working group had the lowest cost towards repairs (Table 4.8). Upon investigation of where these dogs were allowed to sleep at night, it seemed that properties were dogs were allowed to sleep inside had a higher cost towards damage repairs while properties where dogs were allowed to sleep outside had the lowest cost towards repairs. A breakdown of the cost towards repairs, into the three categories, clearly indicate that cost towards the repair of structures was the greatest contributor to most of the costs associated with dog groups (Fig. 4.11).

Table 4.9 Summary of damages, in the presence of the different dog groups followed by a summary of damages according to where the dogs slept at night.

Presence of dogs	**n**	**Total costs**	**$\bar{x}$ cost**	**± SE**
No Dogs	4	R12 149.00	R3 037.25	± R1 341.53
Toy Group	5	R29 649.00	R5 929.80	± R3 612.67
Terrier Group	4	R22 888.00	R5 722.00	± R2 427.95
Herding Group	3	R9 842.00	R3 280.67	± R996.46
Sporting Group	3	R7 232.00	R2 410.67	± R1 371.13
Hound Group	1	R6 429.00	R6 429.00	± R0.00
Working Group	3	R5 143.00	R1 714.33	± R757.35
Non-Sporting Group	2	R4 693.00	R2 346.50	± R2 346.50
Damage according to movement				
Restricted to indoors	6	R35 991.00	R5 998.50	± R2 855.66
Restricted to outside	6	R7 000.00	R1 166.67	± R577.73
Both inside and outside	6	R21 721.00	R3 620.16667	± R1 220.23

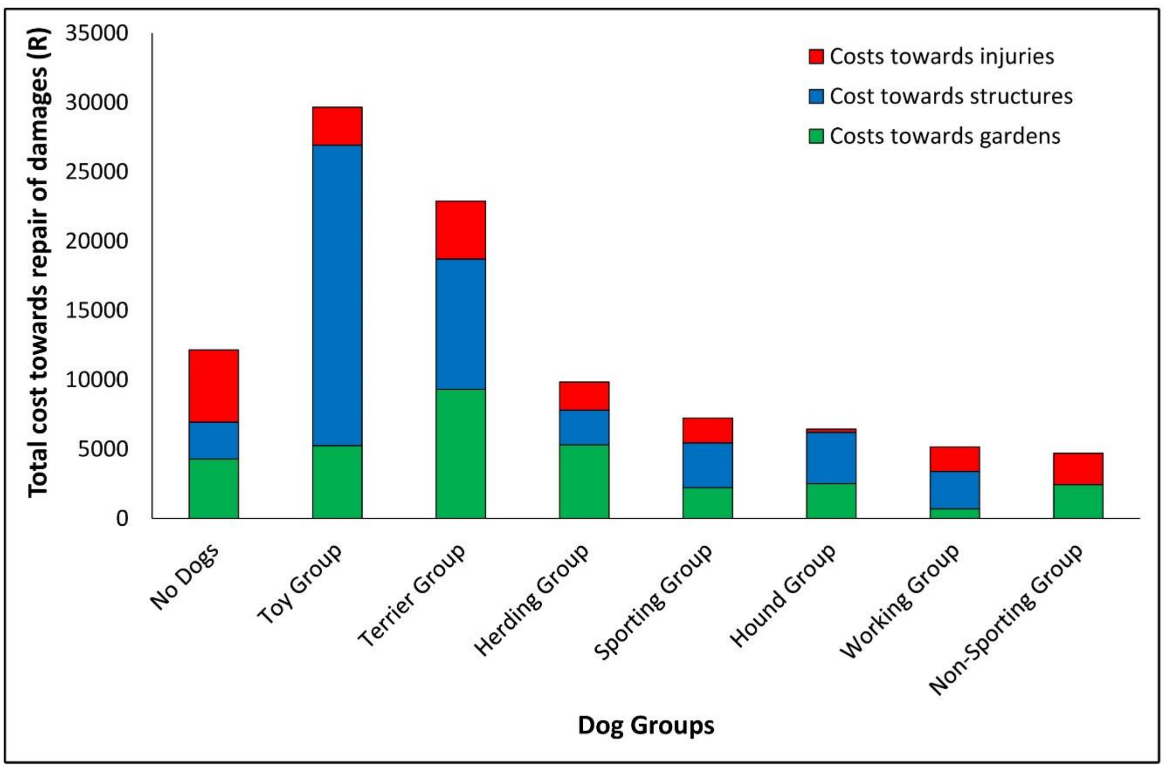

Figure 4.11 The total damages caused by hyraxes for each of the three categories in the presence of specific dog groups.

Although some barrier types, barrier heights and dog groups seem more effective when comparing these single variable results one however cannot ignore the fact that these different variables might have an entirely different costs toward repairs value associated with them, when they are combined with another variable. Therefore, prior to reaching a final conclusion, the combination of different variables had to be investigated.

4.1.5 Combination of variables

The combination of total cost of repairs in the presence of dogs and each of the following variables; type of barrier (Fig. 4.12), height of barrier (Fig. 4.13) and number of sightings (Fig. 4.14) makes it possible to determine of the total contribution by each variable to the total cost.

For example, the total cost of repairs reported at properties enclosed by precast concrete walls were R26 242.00 (*vide* Table 4.5) and the total cost of repairs reported at properties with dogs from the Toy group or properties without dogs were R29 649.00 and R12 149.00 respectively (*vide* Table 4.7). The combination of these two variables, type of barrier and dog groups, now enables one to determine that the total cost toward repairs for properties enclosed by precast concrete walls with dogs from the toy group or no dogs were R20 075 and R6 167 respectively (Fig. 4.12).

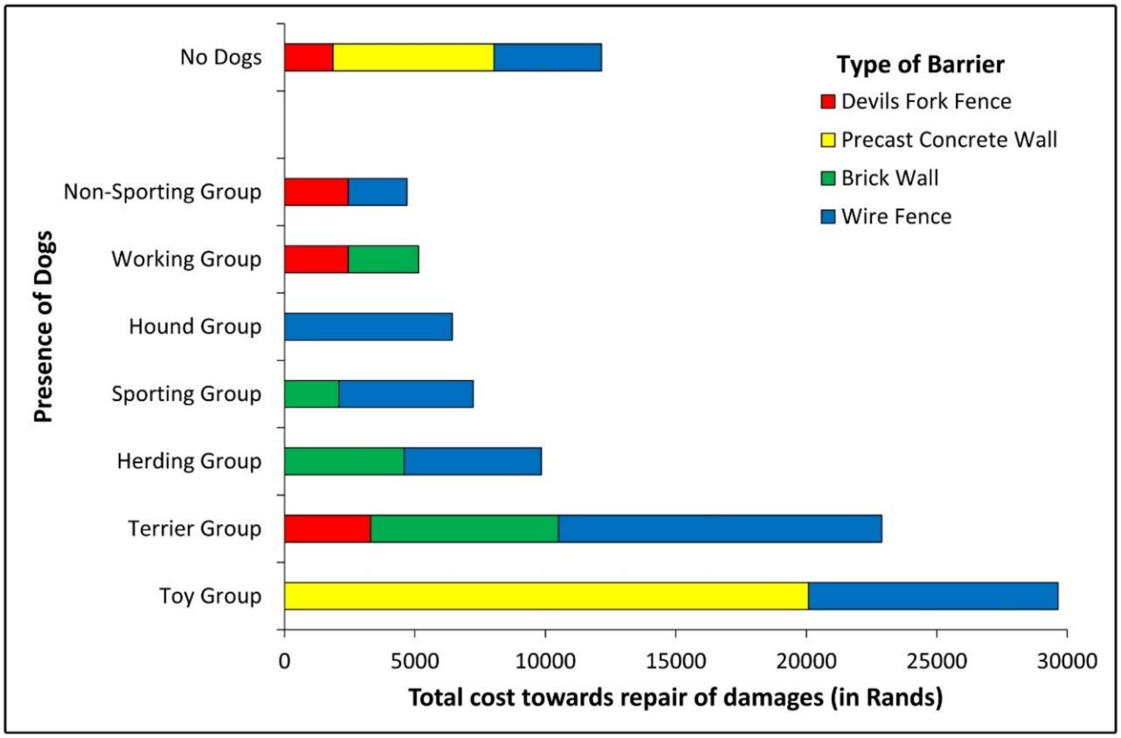

Figure 4.12 The total damages caused by hyraxes at properties considering different types of barriers and the presence or absence of dog groups.

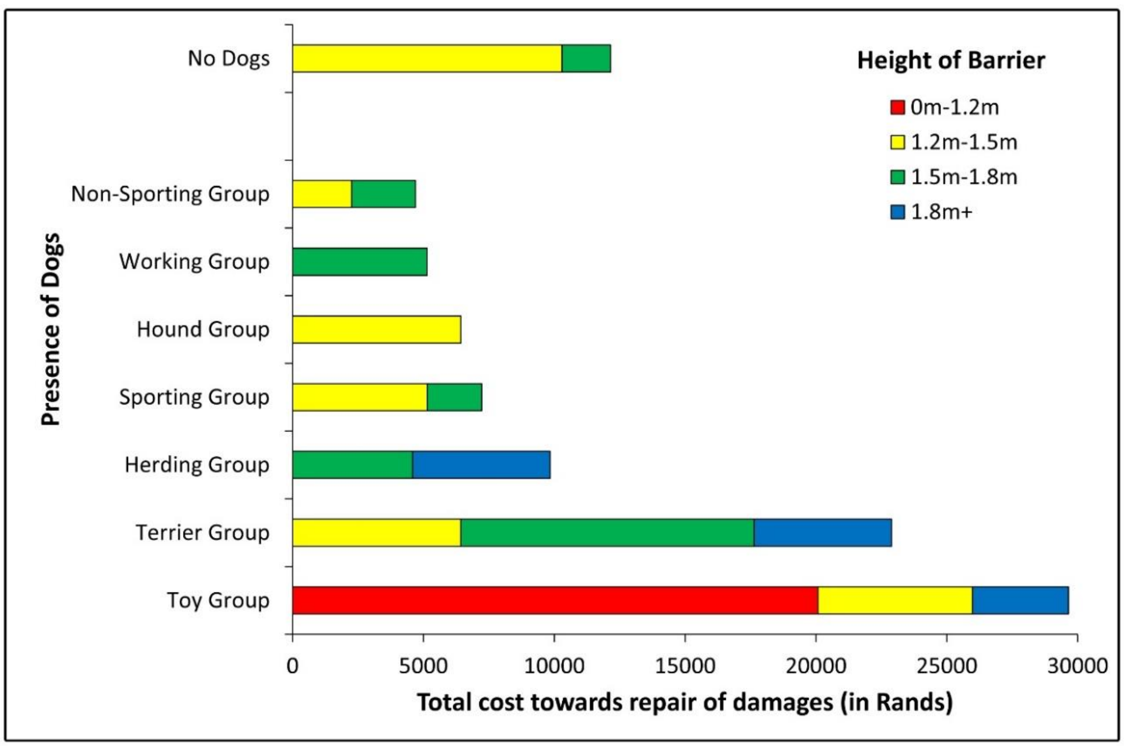

Figure 4.13 The total damages caused by hyraxes at properties considering different heights of barriers and the presence or absence of dog groups.

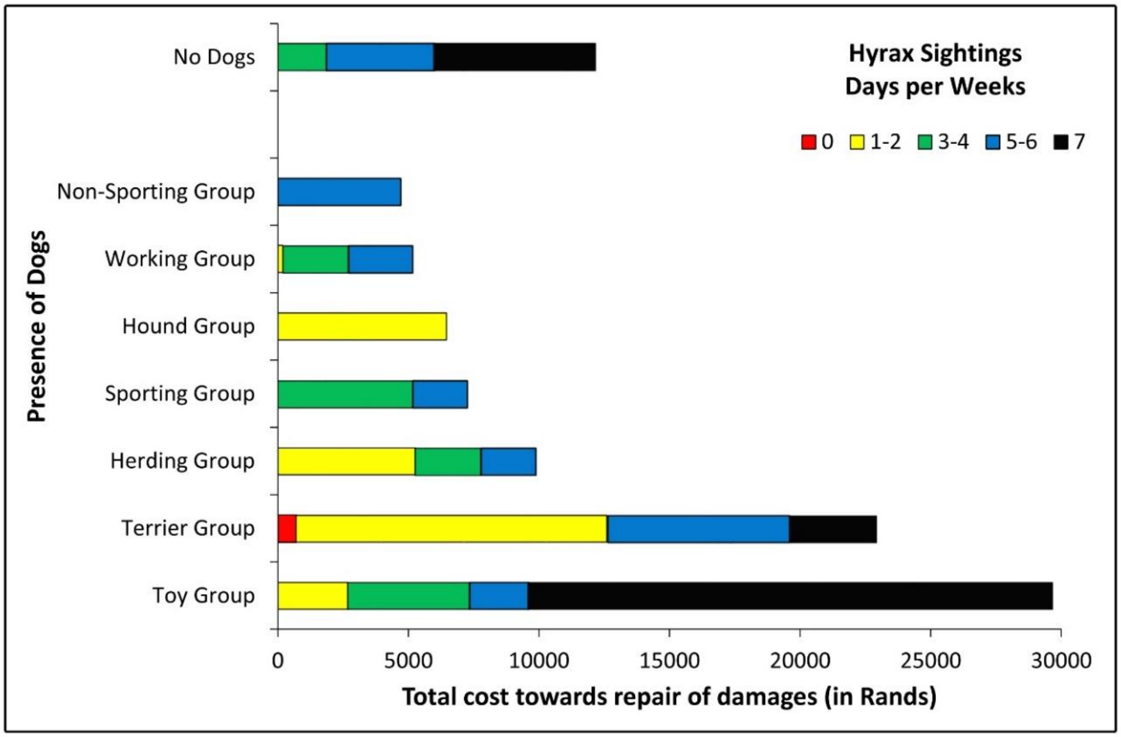

Figure 4.14 The total damages caused by hyraxes at properties considering the number of hyrax sightings (days per week) and the presence or absence of dog groups.

4.2 Conclusion

Using a questionnaire to gain insight from property owners proved to be very successful. These responses have been summarised and grouped according to properties with barrier which contains openings or gaps (Appendix 2) and solid barriers (Appendix 3); a combined summary of the responses is also available (Wiid & Butler 2015; Appendix 4). Using the cost toward repairing damages as a guideline, it is possible to identify several variables that stood out due to their level of effectiveness. Having wire fences with an aperture smaller than 50 mm, barriers with a height of higher than 1.8 m, barriers with an overhang, dogs from the working group and having dogs sleep outside seemed like the best way to limit damages caused by hyraxes. The information gathered regarding barriers, dogs, damages and costs toward repairs made it possible to formulate several ideas regarding population management strategies which might help to limit and/or control these invasions. Several possible methods, to prevent hyraxes from entering properties, have been identified and will now require testing to determine if they could be successful.

Chapter 5

Marking Techniques

CHAPTER 5: MARKING TECHNIQUES

Identification of individuals is of utmost importance in many behavioural studies of wildlife. When individuals in a population cannot be identified by unique coat patterns, markings or colour, it is necessary to apply markings in order to achieve this goal. As it is difficult to identify individuals of hyrax populations, two types of markings were used during this study. Temporary markings were required in order to distinguish between individuals during the implementation of the Lincoln Index. These markings needed to last for approximately one month until the second phase of the Lincoln Index was completed. Permanent markings, visible from a distance, were required to last for at least one year to enable the monitoring of rock hyraxes after translocation. It was not important to identify individual marked animals after translocation but to distinguish such animals from those that were not released as part of the translocation project.

During previous studies several methods to mark small mammals permanently, have been used with different levels of success. These methods included hot-iron branding (Schwartzkopf-Genswein *et al.* 1998, McMahon *et al.* 2006), freeze branding (Kambitch *et al.* 1969, Hadow 1972, Lazarus and Rowe 1975, Rood and Nellis 1980, Sherwin *et al.* 2002), tattooing (Lindner & Fuelling 2002, Silvy *et al.* 2005, Petit *et al.* 2012), toe-clipping (Fairley 1982, Pavone and Boonstra 1985, Wood and Slade 1990, Fisher & Blomberg 2009), ear notching (Beausoleil *et al.* 2004, Petit *et al.* 2012), ear tagging (metal and plastic) (Fourie 1983, Fourie & Perrin 1986, Wood & Slade 1990, Salamon & Klettenheimer 1994) and electronic identification (GPS collars, radio collars or microchips) (Wimberger *et al.* 2009, Barocas *et al.* 2011). Factors that influenced the selection of marking techniques included: level of success in other studies, practicality of method as well as the effect that the procedure has on the animals.

According to Fourie (1983) and Fourie & Perrin (1986), the morphology of a rock hyrax's ears, which is short, round and very soft, makes ear-tagging difficult. In order to successfully employ ear-tagging for rock hyraxes, the hair has to be shaved and the tag inserted as deep as possible into the ear cartilage (Fourie 1983, Fourie & Perrin 1986). This procedure will require anaesthetics in order to sedate hyraxes which in turn would require the transportation of such animals to a veterinarian or to have a veterinarian present at the capture site. During the administration of anaesthetic chemicals, the risk of death of hyraxes increase when the anaesthetics is not administered correctly or if individuals were not handled correctly while recovering from anaesthetics (Wimberger *et al.* 2009). Although Lazarus & Rowe (1975) ear-tagged hyraxes using the surgical procedure, they reported a low success rate. According to them a large percentage of ear-tags were lost either because it was tore out of the ear or that the ear got infected resulting in losing the ear-tag. Because of the above-mentioned risks and difficulties, ear tagging was rejected as a possible marking method.

Toe-clipping, ear notching and ear-tattooing have been used in the past to mark animals. These methods, however, require additional handling as animals have to be recaptured in order to check for marks. Lindner & Fuelling (2002) recommends using ear-tattooing as an alternative to toe-clipping as this technique is less invasive and provides a large range of markings to be used but acknowledges that the efficacy of ear-tattooing in high densities populations, where large numbers of unique codes are required, are limited compared to toe-clipping. All three methods were rejected due to the fact that it is not possible to identify animals over a large distance by the use of these markings.

Researchers have used implanted microchips in order to identify individuals after translocation (Barocas *et al.* 2011). This method was not considered as it was not visible from a distance and required individuals to be recaptured and scanned in order to be identified. GPS and VHF Collars have been used by researchers in the past to track and identify individuals. These have been used on hyraxes with different levels of success. According to Wimberger *et al.* (2009), it is essential to use radio-telemetry for post-translocation monitoring. This method would be ideal to identify and track individuals over a distance after translocation and met all the predetermined requirements. Due to a large number of individuals to be translocated it was not practical to collar all these individuals and therefore this method was not considered.

Following an extensive literature study, in which all the advantages and disadvantages were considered, freeze branding was selected as the preferred method to be used to permanently mark rock hyraxes. This method met all the predetermined requirements: it is permanent, it is visible from a distance, easy to apply and relatively cheap when compared to other methods (GPS and VHF collars) that also met the requirements.

According to Kambitsch *et al.* (1969) freeze branding is a relative painless technique to use. When applying the very cold branding iron the pigment-producing melanocytes in the hair follicles of the animal are destroyed. This results in white hair growth instead of coloured hair growth. Bertram *et al.* (2006) reported that white hair growth was visible from 6 - 10 weeks after freeze branding cattle. According to Rood & Nellis (1980), white hair was visible on mongooses within 3 weeks and fully regrown within 5 - 6 weeks.

In the past liquid nitrogen or dry ice and alcohol, mixtures were used as coolants. Liquid nitrogen cools to a temperature between -175°C and -196°C while the dry-ice (a mixture of dry-ice and 95% ethanol) cools to a temperature between -65°C and -78°C. Branding times will vary depending on the coolant used, the ambient temperature, the species of animal, the age of the animal and the hide thickness of the animal being branded. Although freeze branding was used in previous studies in order to mark rock hyraxes, no reference to exact branding times, when liquid nitrogen was used as a coolant, could be found in the literature.

According to Hall *et al.* (2004); Bertram *et al.* (2006) and Parish (2006) the branding times, when using liquid nitrogen, will be shorter due to the lower temperature reached when using this coolant. Fourie (1983) reported branding times of 7 seconds for adult rock hyraxes and 4 seconds for juveniles, using a mixture of dry ice and alcohol. Sherwin *et al.* (2002) used branding times between 1.5 - 7 seconds to brand bats, also using a mixture of dry ice and alcohol. A branding time of 5 seconds was used by Rood & Nellis (1980) to brand mongooses using Quick-Freeze, which cooled to a temperature of approximately -45 ºC. Hadow (1972) reported a branding time of 25 - 40 seconds, 20 - 35 seconds and 20 - 35 seconds respectively on squirrels, rats and mice using dry ice and alcohol as a coolant. Bertram *et al.* (2006) used liquid nitrogen and used branding times between 6 - 12 seconds to brand horse yearlings.

5.1 Results and Discussion

5.1.1 Temporary Markings

Two different types of temporary markings were tested, which entails the application of a number directly to the skin of each rock hyrax. In order to apply this number to the skin, a circular patch, 50 mm in diameter, had to be shaved on the rump of the rock hyrax. A bright luminescent water based paint that is clearly visible on the hyrax fur (Fig. 5.1a), and an alcohol based black permanent marker (Fig. 5.1b) were used to apply the number on the rump of the animals.

These temporary markings were applied during the first phase of the mark and recapture technique where the Lincoln index was used. The two different marking mediums resulted in different levels of effectiveness. The number painted with non-toxic luminescent paint on the rump of the hyrax, lasted for less than a week. Losing this mark so quickly might be as a result of the behaviour of these animals which crawl into burrows several time per day and/or dust bathing which occurred often. In addition to this behaviour, the natural oily secretion of the dorsal gland might also be the reason for the ineffectiveness of the paint. In contrast, the number written on the rump with the permanent marker lasted nearly three weeks. Dust bathing made the number fainter but it was still readable and could be rewritten once rock hyraxes were recaptured (Fig. 5.2). Shaved patches took more than eight weeks to regrow to normal length which made the visibility of the number more effective. Based on results of the marking trials, the decision was made to use clippers and a permanent marker to mark individuals for all subsequent capture phases.

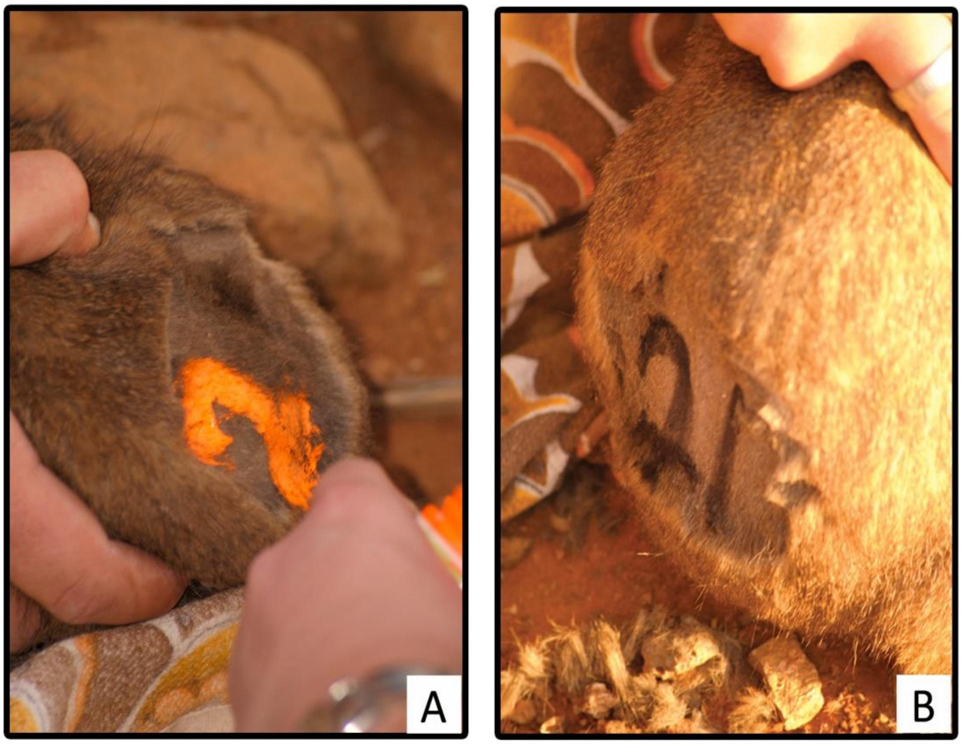

Figure 5.1 Temporary marked numbers applied to the rump of individuals using non-toxic luminescent paint (A) and a permanent marker (B).

Figure 5.2 Remark of faded number with a permanent marker after three weeks since initial marking.

The clippers provided a temporary mark which would last more than one month while marking individuals with a number using a permanent marker made it possible to distinguish between individuals when recaptured within three weeks.

5.1.2 Permanent Markings

In order to permanently mark hyraxes, branding irons, submerged in liquid nitrogen, were used to freeze brand rock hyraxes. Irons were initially cooled for 10 - 15 minutes prior to branding. After the initial brand, irons were allowed to cool for 1 - 2 minutes in liquid nitrogen before applying the next brand. Branding was done on the flank of the rock hyrax as this area provided a smooth and flat surface required for branding.

Freeze branding trials were divided into two phases. This was done with the intention of using estimated branding times, obtained from literature, during the first phase and then extending or decreasing the branding times during the second phase in order to determine an optimum branding time for rock hyraxes. The first phase of freeze branding was done using two male adult rock hyraxes followed by the second phase, where three male adult rock hyraxes were used. Branding procedures as described by Hall *et al.* (2004) & Bertram *et al.* (2006) was followed. Individuals were branded on both flanks using branding times of approximately 2.5, 3.5, 4.5 and 5.5 seconds respectively during the first phase and branding times of 1, 2, 3.5, 4, 6 and 7 seconds respectively during the second phase. Skin, immediately after branding, appeared indented and frozen in the shape of the applied branding iron (Fig. 5.3a & b). The skin defrosted within seconds, followed by a distinct swelling of the area (Fig. 5.4a & b) within 15 – 30 seconds after branding. The swelling subsided within 2 - 3 hours. Individuals showed slight discomfort by wriggling when the branding irons were applied, but the moment the skin was numbed by the cold irons, usually within a second or two, the wriggling stopped. As precautionary measure to prevent infection, disinfectant wound spray was applied to the brand sites directly after branding as well as during follow-up inspections. Hyraxes branded during the first phase were inspected four and eight weeks after branding since the first white hair growth was expected between three to six weeks after branding.

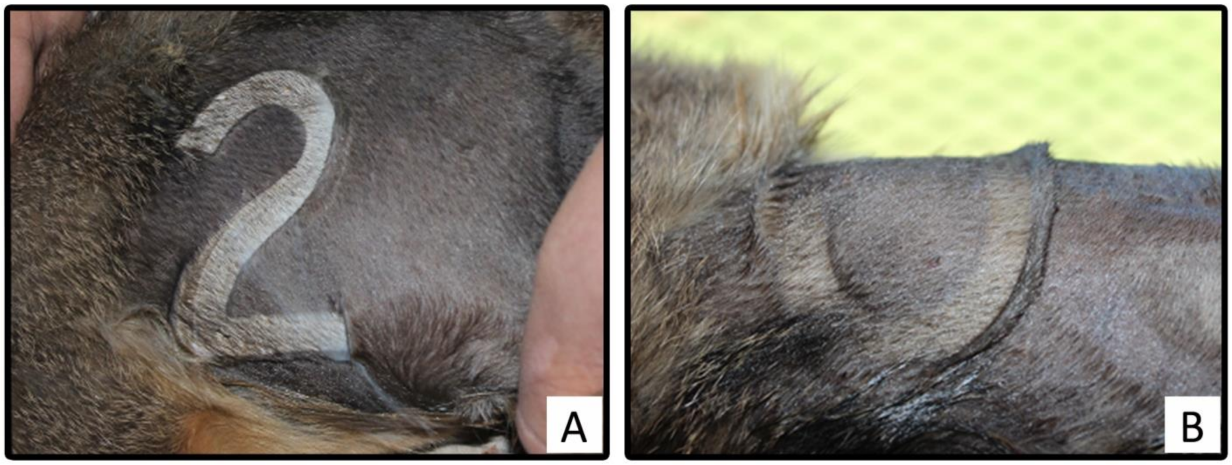

Figure 5.3 Skin appeared frozen (A) and indented (B) upon inspection immediately after branding.

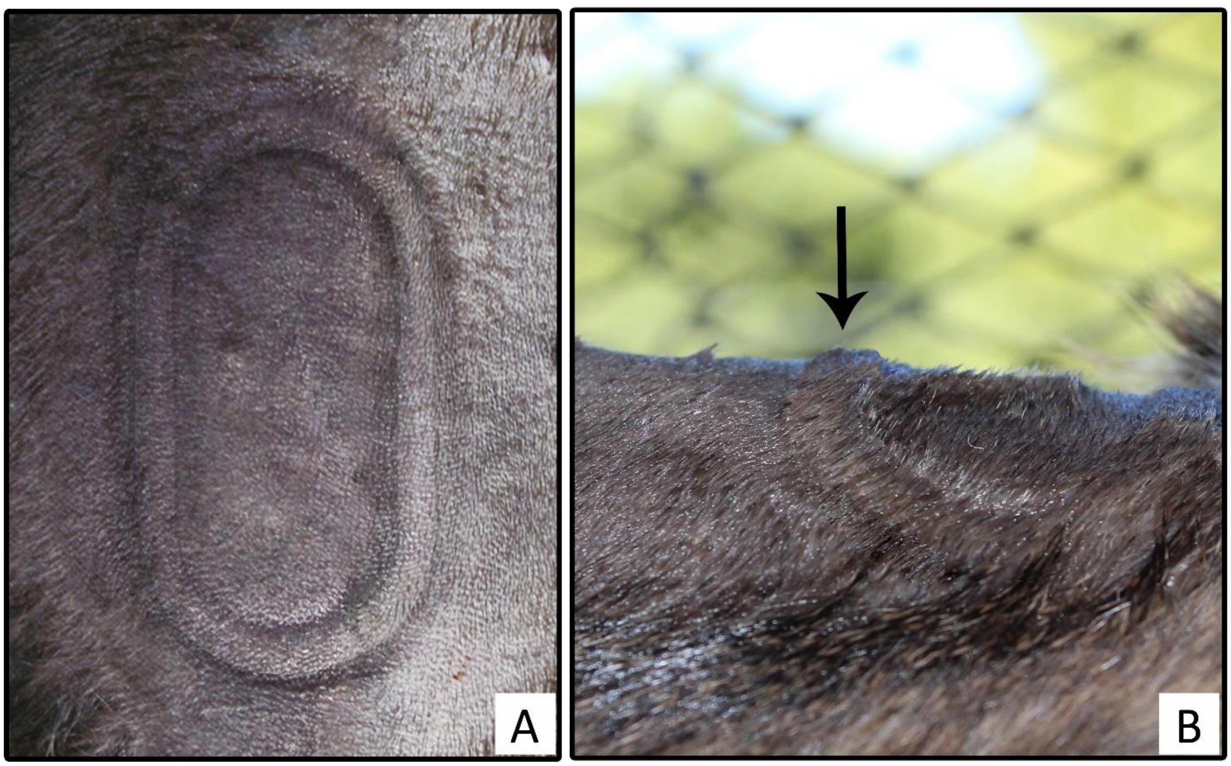

Figure 5.4 A raised version of the brand appeared 15 - 30 seconds after branding iron was applied (A & B) and the skin appeared swollen (arrow) for 2 - 3 hours before subsiding (B).

During the initial inspection, four weeks after branding, it was noticeable that clipped hair has regrown to roughly one-third of the normal length. No white regrowth was visible at this stage. A clear distinction could be made between brands which were applied either for the correct duration or too short and brands which were applied for too long. Brands applied for either the correct duration or too short showed little or no peeling of skin and very little scab formation (Fig. 5.5a). The presence of large scabs, hairless areas and a prominent peeling of skin were visible at those brands where branding irons were applied for too long (Fig. 5.5b).

At the second inspection, eight weeks after branding, it was evident that clipped hair has regrown to roughly two-thirds of the normal length (Fig. 5.5c & d). White hair growth however was not visible. Only after re-clipping the hair at the brand area the white regrowth, in the shape of the number, could be seen on the flanks (Fig. 5.5e & f). Hairless areas (Fig. 5.2f), a result of branding irons applied for too long, were still visible at this stage. According to Hall *et al.* (2004), in cattle, it is normal for skin to form a scab two to three weeks after freeze branding and to peel thereafter. Hall *et al.* (2004) and Wagner *et al.* (2000) mention that hair follicles can be damaged when freeze branding irons are applied for too long. As a result of this, hair will not grow back, simulating a brand similar to those produced by means of hot branding. Fourie (1983) also reported scab formation when irons were applied too long during freeze branding.

The quality of each brand was inspected and photographed and the results for each brand thoroughly documented (Appendices 5 – 19). The final inspection occurred during November 2013, 31 weeks and 23 weeks respectively after the first and second branding phase took place. At this time all brands were photographed prior to and directly after clipping (Fig. 5.6 & Table 5.1). Only one brand was visible prior to clipping (Fig 5.6i). Although all brands produced white hair growth, branding times ranging from 1 – 3 seconds produced very little or even no colouration while branding times ranging from 4.5 – 7 seconds produced white hair growth and hairless areas. Branding times ranging from 3.5 – 4.5 seconds produced brands with complete colouration and no areas with hair loss.

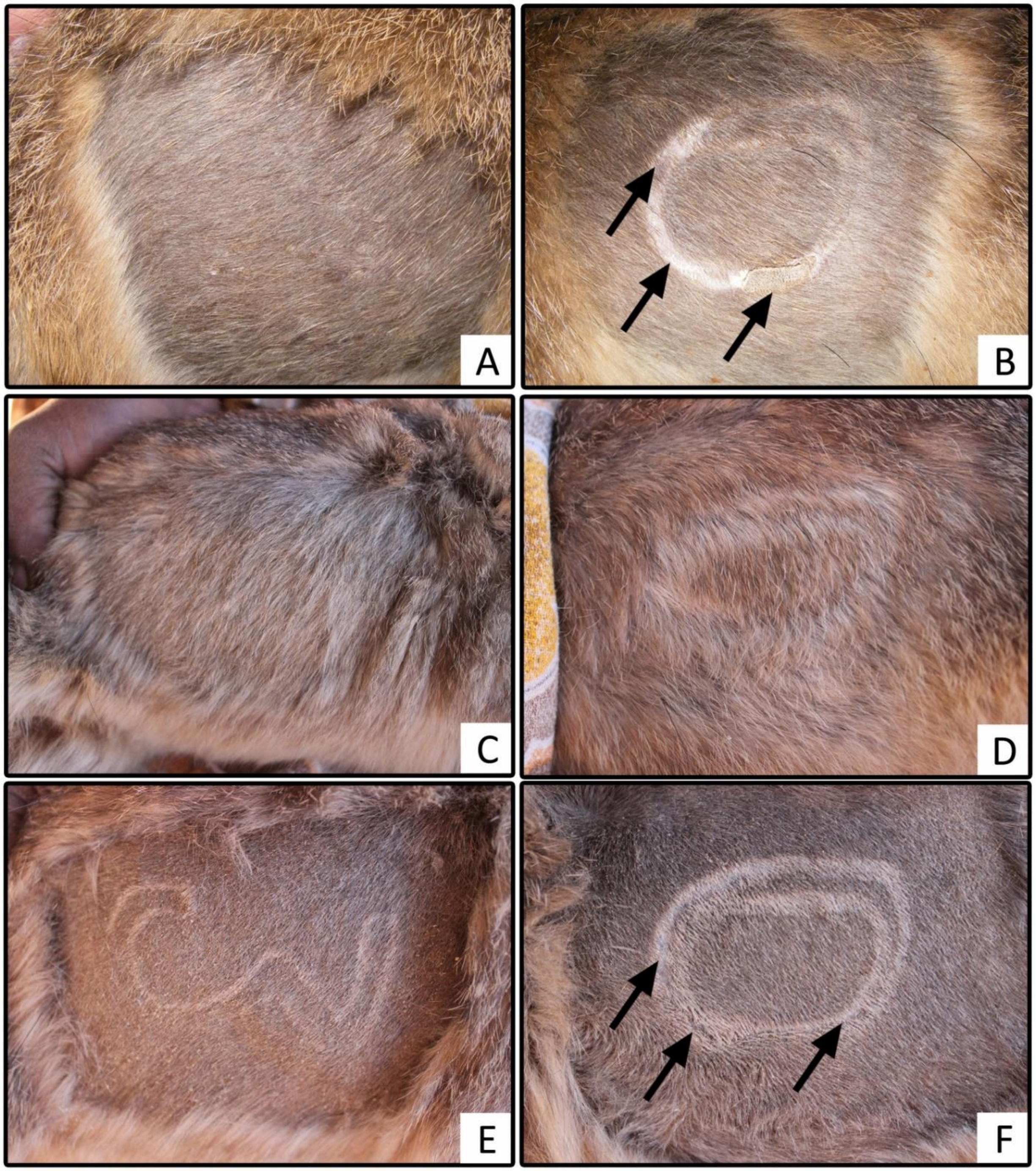

Figure 5.5 Branding iron applied for the correct amount of time or too short (left-side images) and for too long (right-side images). Brand appearance 4 weeks (A & B) and 8 weeks (C & D) after branding was done. Appearance of the clipped brands at 8 weeks (E & F) after branding was done.

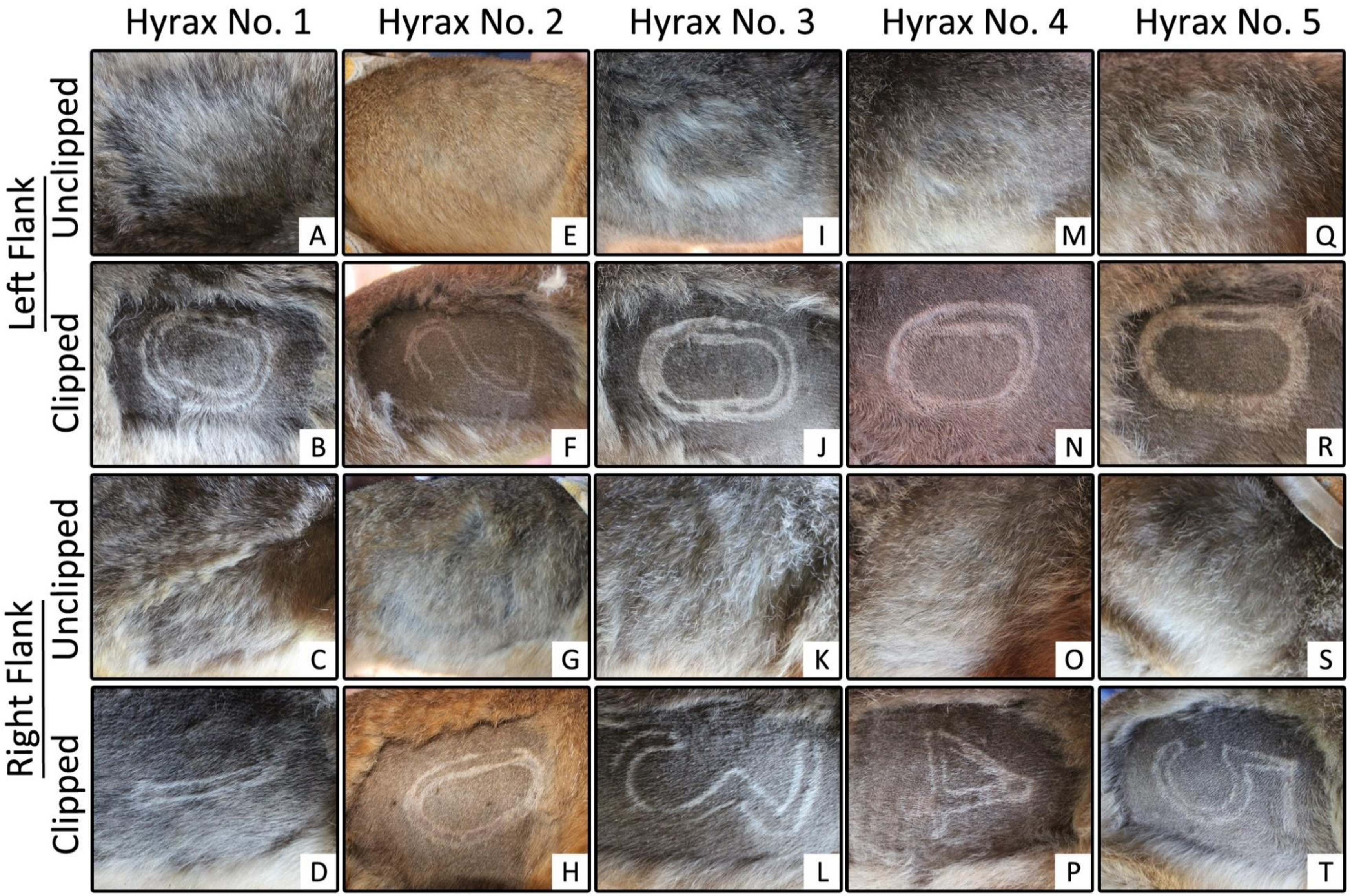

Figure 5.6 Summary on brand quality of the rock hyraxes branded during the freeze branding trials prior to the adjustments to the branding irons.

Table 5.1 Summary on brand quality of the rock hyraxes branded during the freeze branding trials (Best results highlighted)

Individual	No.	Position of Brand	Time of Brand (s)	Visibility of white regrowth (Unclipped Hair)	Visibility of white regrowth (Clipped Hair)	Description of white regrowth	Reference Pictures
Hyrax 1	0	Left flank	3.5	Partially visible, number discernible	Clearly visible, outline only	Total regrowth with no hairless areas	Appx. 6
Hyrax 1	1	Right flank	2.6	Partially visible, number not discernible	Partially visible, outline only	Partial regrowth, parts of brand unaffected	Appx. 7
Hyrax 2	2	Left Flank	4.6	Not visible	Partially visible, outline only	Partial regrowth, with hairless areas	Appx. 9
Hyrax 2	0	Right Flank	5.7	Partially visible, number not discernible	Clearly visible, outline only	Partial regrowth, with ± 50% hairless areas	Appx. 10
Hyrax 3	0	Left Flank	4.1	Visible, slight distortion	Clearly visible, ± 33% complete & rest outline only	Total regrowth with no hairless areas	Appx. 12
Hyrax 3	3	Right Flank	1.4	Not visible	Partially visible, outline only	Partial regrowth, parts of brand unaffected	Appx. 13
Hyrax 4	0	Left Flank	7.3	Partially visible, number discernible	Clearly visible, outline only	Partial regrowth, with ± 60% hairless areas	Appx. 15
Hyrax 4	4	Right Flank	2.3	Not visible	Partially visible, outline only	Partial regrowth, parts of brand unaffected	Appx. 16
Hyrax 5	0	Left Flank	6.2	Partially visible, number discernible	Clearly visible, outline only	Partial regrowth, with ± 50% hairless areas	Appx. 18
Hyrax 5	5	Right Flank	3.7	Partially visible, number not discernible	Clearly visible, ± 25% complete & rest outline only	Partial regrowth, parts of brand unaffected	Appx. 19

It was clear that due to a 2 mm deep groove in the branding irons (Fig. 5.7a), the skin only came into contact with about 50% of the surface area of the branding irons which resulted in a thinner, less clear, brand. In order to remove the 2mm deep groove and thus increase this surface area, the branding irons had to be sanded down. After sanding (Fig. 5.7b), the branding irons had a larger surface area which resulted in a thicker, clearer brand.

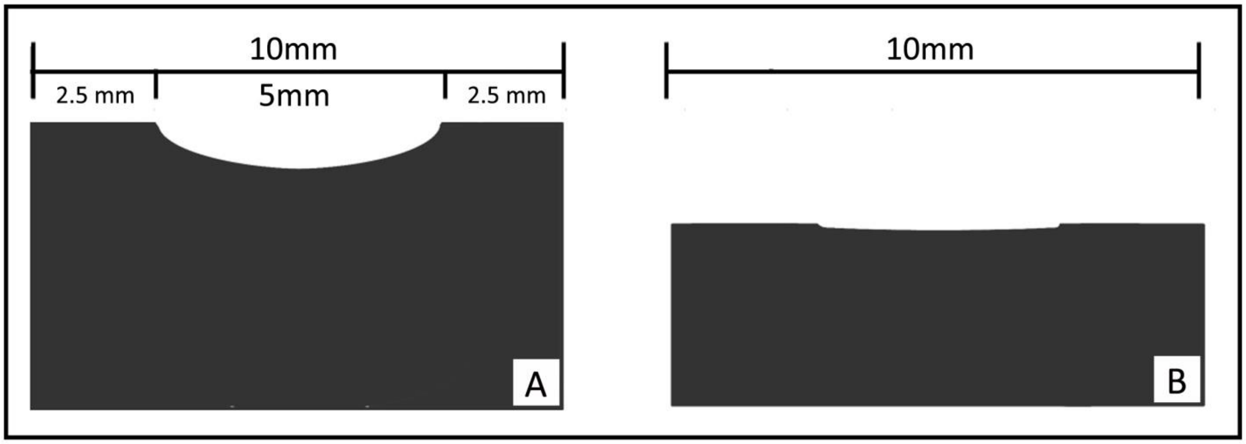

Figure 5.7 Illustration of groove in the branding irons (A) and the smoother, more level branding surface (B) after being sanded down.

5.2 Conclusion

For temporary marking of hyraxes, a number applied with a permanent marker lasted for approximately three weeks, while the shaved patch remained visible for at least eight weeks. The use of paint is not recommended due to the short lifespan of such markings.

Upon completion of the freeze branding trials it was evident that branding times ranging between 3.5 - 4.5 seconds seem to be the optimal freeze branding time for permanently marking rock hyraxes. Since the clearest brand was obtained using a branding time of 4 seconds, a branding time of 4 seconds was used to mark all hyraxes prior to translocation. Although the permanent marking of animals, using the freeze branding method seems to be cruel, the animals experienced no discomfort due the branding procedure per se. The only discomfort that was noted, was during the initial handling of the animal. This method of marking animals, especially when other marking techniques are inadequate, can therefore be considered as a useful marking technique. It is however recommended that the freeze branding procedure must be applied as swift as possible and preferably with assistance of helpers in order to reduce handling time of animals. It is further recommended that the head of the animals be covered by a cloth to further reduce stress to the animals. Although the application of disinfectant wound spray was only for precautionary measures, it is recommended that such disinfection be part of the procedure. Furthermore, follow-up inspections for at least four weeks after branding is compulsory to ensure that branding sites are not affecting the welfare of the animal.

Chapter 6

Population Dynamics

CHAPTER 6: POPULATION DYNAMICS

According to Estes (1991 & 1999), rock hyrax colonies in the wild may range from 30 to 40 individuals and usually consist of one adult territorial male with a harem of related females and their offspring. All sub-adult males are forced from the colony before they reach sexual maturity (Estes 1991). Populations in the wild tend to maintain a female to male ratio of approximately 2 : 1 but can range from 1.50 : 1 to 3 : 1 (Estes 1999). The average home range of hyraxes is approximately 4 250 m^2 for females and 4 800 m^2 for males (Hoeck *et al.* 1982). Once sub-adult males are forced from the group, they will search for their own home ranges or stay on the edge of the colony (known as peripheral males) waiting to take the place of the territorial male once he loses fitness (Hoeck *et al.* 1982). These peripheral males do not form bachelor groups and they do not become territorial until they find a territory of their own.

Sale (1969) suggested that rock hyraxes have a definite breeding season which corresponds to photoperiodic keying. However, Millar (1971) noted that within South Africa the breeding season for *Procavia* spp. occur later and last for a longer period as the latitude decrease, and also noted that births occur at times of increasing temperature and vegetation. However, Millar (1972) documented that mating is triggered by photoperiod and not by changes in rainfall or ambient temperature and is followed by a gestation period of 230 days. Van der Merwe and Skinner (1982) documented an increase in testes and epididymis size which was specifically keyed to the rate of change in photoperiod. While Estes (1991) noted that rock hyraxes are seasonal breeders with births occurring mainly during the wet season, Van der Merwe & Skinner (1982), specified that births peak when the summer rains begin which is in agreement with Fairall, Vermeulen & Van der Merwe (1986) who indicated a specific peak of births from October to December for South Africa.

It was clear from the published research that rock hyraxes have different mating and birth seasons in the different provinces of South Africa since these birth seasons usually occur during the wet season. The wet season in the Free State usually occur from mid-October to late-April (*vide* Fig. 2.5 and Fig. 2.6) and Skinner & Chimimba (2005) confirms that the births occur during November or December in this region (Table 6.1).

Table 6.1 Differences in mating and birth seasons of rock hyraxes from different provinces of South Africa (Modified from Skinner and Chimimba 2005).

Province	Mating Season	Time of parturition
Western Cape	February	September / October
Northern Cape (Karoo)	March	November
Northern Cape (Namaqualand)	September - November	June / July
Eastern Cape	March / April	October/ November
Free State	April	November / December
Limpopo	May	December / January

Due to the fact that births peak during October - December, population estimates for this study were largely done during the dry season of May to September for more accurate calculations. It was not always possible to capture hyraxes during this predetermined time, therefore some captures occurred earlier between the months of March and April. Both the Lincoln Index as well as the Robson-Whitlock Technique were used to determine population estimates.

According to Fourie (1983) it is crucial to accurately determine the age of individuals for studies on population dynamics and therefore require precise methods of age determination. Fourie & Perrin (1987a) and Wimberger *et al.* (2009) referred to three age groups of hyraxes namely, juveniles (younger than 12 months), sub-adults (13 to 24 months of age) and adults (older than 24 months). Fourie & Perrin (1987b) however mentioned that sub-adult males and females reach reproductive maturity at different ages where males are only reproductive after 28 months while females are sexually mature after 16 months. This large difference in reproductive age between males and females can cause disagreement over the allocation of young individuals into different age groups. Therefore, for this study, the classification of different age groups follows the description as suggested by Fourie & Perrin (1987a) as well as Wimberger *et al.* (2009).

6.1 Results and Discussion

Sex ratios are expressed as a calculated number of females per one individual male which are mentioned first followed by the calculated number of females.

6.1.1 Population size & composition

Two methods, the Lincoln Index (LI) and the Robson-Whitlock technique (RWT), were used to calculate population sizes during this study. Since the LI could not be used during the birth season or in the presence of a natural predator, while the RWT could be used at all colonies at any time, one would expect that only the RWT be used to determine population size. The LI, however, entails capturing individuals, which provide the necessary opportunity to gather specific information regarding sex, weight and body measurements. This information is required to determine the correct age of individuals, population composition and biomass of a population. Therefore all population sizes to follow, were calculated using the RWT while values of sex ratio, composition and biomass were determined using the LI.

Population estimates were calculated at both Rusplaas colonies during March - April 2012. According to population estimates, the population of the Kranskop colony was slightly smaller (23 individuals) compared to that of the Patroonkop colony (33 individuals) (Table 6.2). The overall sex ratio at the Kranskop colony was within the normal limits at 1 : 2.63 (Fig. 6.1). Two adult males were captured within this home range during the capture and recapture phases of LI, which at the time of capture was suspected to be the territorial male and possibly a peripheral male. This was confirmed after observations over a period of six days, where several threat displays by the territorial male were witnessed. These displays usually resulted in the territorial male chasing the intruder male when the latter tried to enter the home range of the territorial male.

This colony thus consisted of the territorial male, several adult females, sub-adults of both genders and a single juvenile male, conforming to the norm as described by Estes (1991). The sex ratio, of captured individuals which have already reached adulthood, was calculated at 1 : 17 (Fig. 6.2). When the age of individuals was taken into account, two-thirds (66%) of the individuals of this colony have already reached adulthood, while the remaining 34% immature individuals consisted mostly of sub-adults (31%) and only a single juvenile (Fig. 6.3).

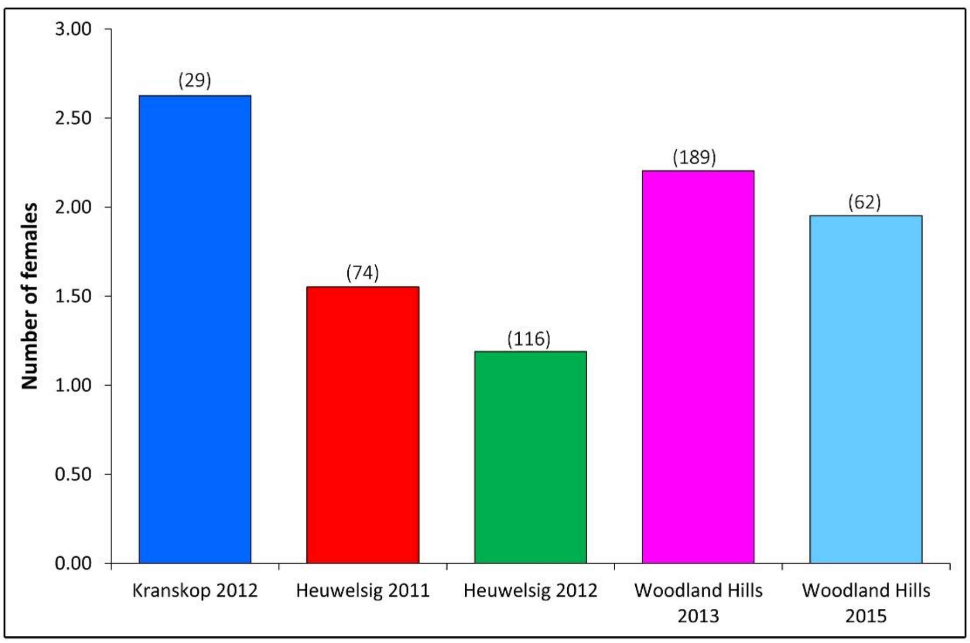

Figure 6.1 Number of females per male, including all ages, in hyrax populations at different study sites in the Free State. Number between brackets indicates the number of individuals in populations.

Table 6.2 Calculated population sizes of hyrax colonies in the Free State using two methods, Robson-Whitlock technique and Lincoln Index.

Robson-Whitlock Technique				
	Heuwelsig Site			
	June 2011	**June 2012**	**November 2013**	**December 2013**
Population size	**70**	**100**	**34**	**28**
Highest Count (n_{max})	61	88	31	26
2nd Highest Count (n_{max-1})	52	76	28	24
95% Upper confidence limit (N_u)	232	316	88	64
	Rusplaas Sites		**Woodland Hills Wildlife Estate**	
	Kranskop March 2012	**Patroonkop March 2012**	**March 2013**	**March 2015**
Population size	**23**	**33**	**102**	**58**
Highest Count (n_{max})	19	30	94	47
2nd Highest Count (n_{max-1})	15	27	86	36
95% Upper confidence limit (N_u)	95	87	246	256

Lincoln Index					
	Heuwelsig Site		**Kranskop**	**Woodland Hills Wildlife Estate**	
	June - July 2011	**June - July 2012**	**March - April 2012**	**March - April 2013**	**March - April 2015**
Population size	**74**	**116**	**29**	**189**	**62**
Standard Error (SE)	10	14	2	48	3
Limits	55 - 93	89 - 143	26 - 32	95 - 283	57-67

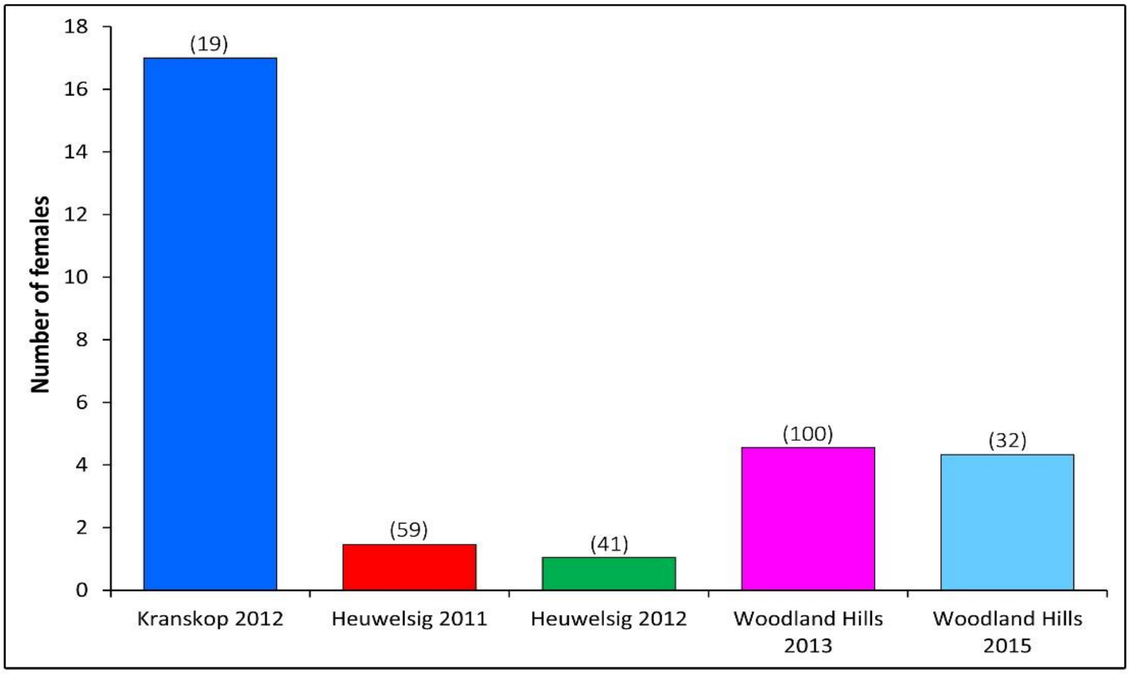

Figure 6.2 Number of females per male (only adults) in hyrax populations at different study sites in the Free State during different years. Number between brackets indicates number of individuals in populations.

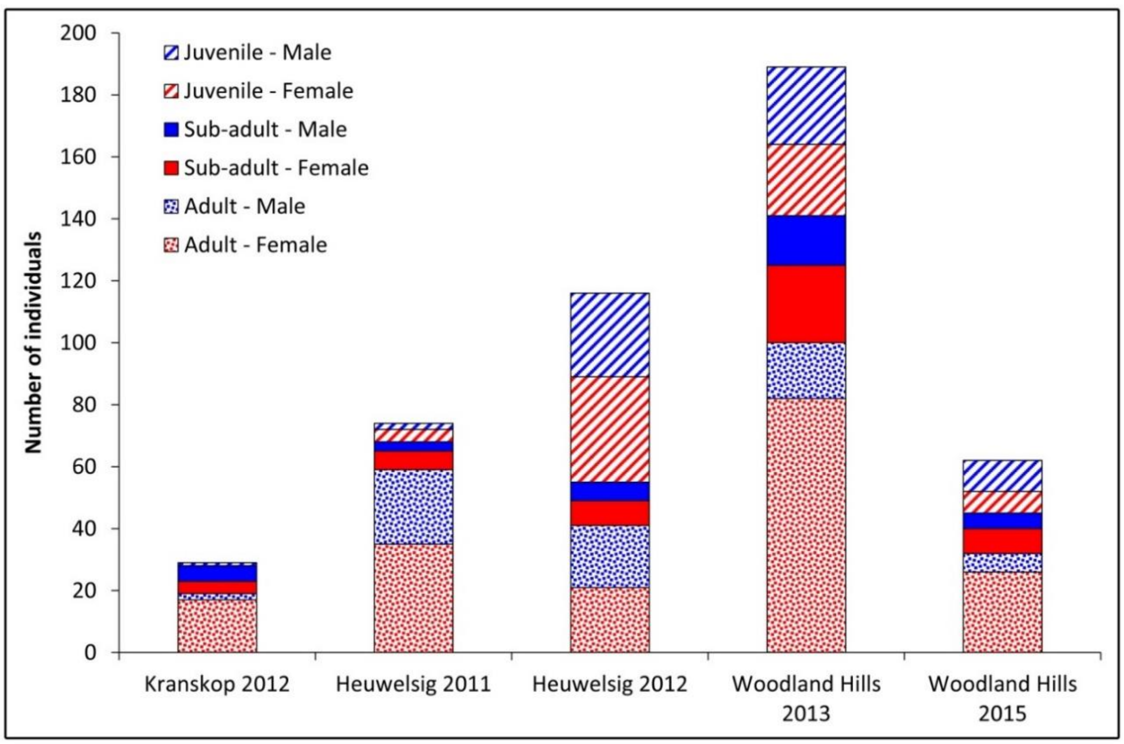

Figure 6.3 Size and composition of hyrax colonies at different study sites in the Free State during different years.

Population estimates at the Heuwelsig Site were calculated during winter months (June and July) of 2011 and 2012 and during two summer months (November and December) of 2013. The RWT was used to calculate population estimates on every occasion but the Lincoln Index could only be used in 2011 and 2012 but not in 2013 when a natural predator was present. The population size was calculated at around 70 individuals (Table 6.2) during 2011 and showed an increase to the next year when the number of individuals rose by more than 42% to 100 individuals (Table 6.2). The following year, with the presence of a predator, the population size dropped to only a third (34 individuals, November 2013; 28 individuals, December 2013) of what was calculated the previous year (Table 6.2).

During the winter census of 2011, the majority (80%) of the individuals within this population were adults while the immature individuals consisted of almost equal numbers of sub-adults (12%) and juveniles (8%) (*vide* Fig. 6.3). Inclusive of all age groups, calculations of the sex ratio resulted in 1 : 1.55 for this period (*vide* Fig. 6.1) while a slightly lower sex ratio was calculated for adult individuals alone (1 : 1.46, *vide* Fig. 6.2). During the capture and recapture phase, numerous adult males were captured within the core of the home range which is an unfamiliar observation for rock hyrax populations since a single territorial male usually protects his territory and will not allow other adult males in his territory (Estes 1991).

The increase in population size from 2011 to 2012, might be attributed to the above average rainfall that occurred during the 2010 and 2011 rain season when 870 mm and 839 mm of rain was measured respectively (*vide* Fig. 2.5). During the same time, however, the proportion of adult individuals declined to only 35% of the population while the number of immature individuals (12% sub-adults and 53% juveniles) increased to 65% of the total population (*vide* Fig. 6.3). This high number of offspring produced during 2012 also influenced the number of adult females relative to the number of males where the sex ratio dropped from 1 : 1.55 to only 1 : 1.19. (*vide* Fig. 6.1). As in the previous year, numerous adult males were present in this population. The number of adult female hyraxes, however, indicated a dramatic decline over the 12 month period from 2011 to 2012 as almost equal numbers of males and females (1 : 1.05) were calculated (*vide* Fig. 6.2). The drastic decrease in numbers at the Heuwelsig site, during 2012 to 2013, can be attributed to population management measures that were implemented at this site. This included the translocation of 60 individuals from February – May as well as the introduction of a single female caracal (*Caracal caracal*) into the Heuwelsig biosphere during March 2013.

Population estimates at Woodland Hills Wildlife Estate were calculated during March and April of both 2013 and 2015. These captures occurred earlier than the pre-determined time, May - September, and the availability of more natural food sources and consequent ignoring of bait in traps might be the reason for the lower trapping success during both these trapping times. The population was estimated at 102 and 58 individuals respectively during 2013 and 2015 (Table 6.2).

Although similar in size to the population at Heuwelsig (100 individuals), the sex ratio of 1 : 2.20 (*vide* Fig. 6.1) at the Woodland Hills Wildlife Estate indicated a slightly higher number of females. Adult hyraxes contributed more than half (53%) of the total number of individuals in this colony, while the immature individuals consisted of almost equal numbers of sub-adults (22%) and juveniles (25%) (*vide* Fig. 6.3). The number of adult males in the colony, just like the Heuwelsig colony, was higher than that of the Kranskop colony. Captured adult males were outnumbered (1 : 4.57) by the adult females (*vide* Fig. 6.2).

In March and April, 2015 population estimates showed a decline of 44 individuals (43%). This decline was due to the capture and translocation of a large portion of this population, from April 2013 to September 2014, in an attempt to control this population. The decline also affected the overall sex ratio which decreased to 1 : 1.95 (*vide* Fig. 6.1). The sex ratio of adults decreased to 1 : 4.33 (*vide* Fig. 6.2) since several adult males were captured during translocation. The percentage adult individuals in this population decreased by 1% whereas the percentage immature individuals increased by the same percentage. The immature individuals still consisted of slightly more juveniles than sub-adults (21% sub-adults, 27%

juveniles) (*vide* Fig. 6.3). The adult sex ratio of populations as well as the total sex ratio, including sub-adults and juveniles, of populations, were inversely proportional to population sizes and showed a negative correlation (R = -0.81; R^2 = 0.66) and (R = -0.63; R^2 = 0.40) respectively, calculated using Pearson's Correlation. Pearson's Correlation was also used to calculate the correlation between total sex ratio (including sub-adults and juveniles) and the adult sex ratio of the same populations, showing a relatively strong positive correlation of (R = 0.86; R^2 = 0.74).

6.1.2 Reproduction and Mating Systems

Populations at Rusplaas were observed during the entire period whilst population estimates were determined. The Kranskop Colony had a single juvenile male; roughly two to four months of age, present during this time. This suggests a birth season which conforms to the normal birth season, November or December, as described by Skinner & Chimimba (2005). The territorial male was witnessed copulating with several females during this time. The peripheral male was also seen approaching sub-adult females on several occasions, which one can only expect was done with the intention of copulating. This behaviour was always witnessed on the edge of the home range since the territorial male chased the peripheral male away when he tried to move towards the central parts of the home range. These successful and unsuccessful mating attempts by both males suggest that this colony conforms to the normal mating season as suggested by Skinner & Chimimba (2005).

At the Heuwelsig site, several adult males were present within the colony. According to literature, this is not a common sight since colonies usually consist of a single territorial male with a harem of females. In this colony, however, different males were observed copulating with adult females within this home range. Some of these males were close to the edge of the home range, suggesting that they might be peripheral males. Yet still, numerous adult males were observed copulating with adult females at the central parts of the home range. No aggressive behaviour, territorial behaviour, displays or even fighting was witnessed between these males during this time. Mating behaviour was witnessed during the months of February to April which suggested a birth season from October – December; this still conforms to the normal mating and birth season parameters as discussed by Skinner & Chimimba (2005).

During 1982, Hoeck reported two birth seasons in the Serengeti, the first from May to July and the second from December to January. Hoeck *et al.* (1982) also stated that births in any one colony occurred only during one of these periods. According to Estes (1991), births within the same colony are synchronised. During the population estimates at the Heuwelsig Site, June - July 2011 and 2012, several juveniles were captured. The ages of these juveniles, however, ranged from 2 - 3 months as well as 7 - 8 months, which suggest two different birth seasons within the same colony, one occurring from late February to April and the other from November to January (Fig. 6.4). One can only assume that the abundance in food sources, due to the above average rainfall during 2010 and 2011 (vide Fig. 2.6), and abundance in refuges within residential areas might have instigated this unlikely behaviour.

Mating behaviour at this colony was only witnessed from February – April. Again different males were seen mating with adult females. This time, however, these males were more aggressive towards other males but not as aggressive as would be the case in natural populations. Males were seen chasing other males on several occasions. Aggressive displays, which included raising the hair around the dorsal gland, were also seen more frequently. It, however, was difficult to single out a specific territorial male for this area as it seems like each male maintained his own, smaller than normal, home range. The birth season of this colony seems to coincide with the normal birth season as reported by Skinner & Chimimba (2005) since juveniles captured in March were round about 2 - 4 months of age.

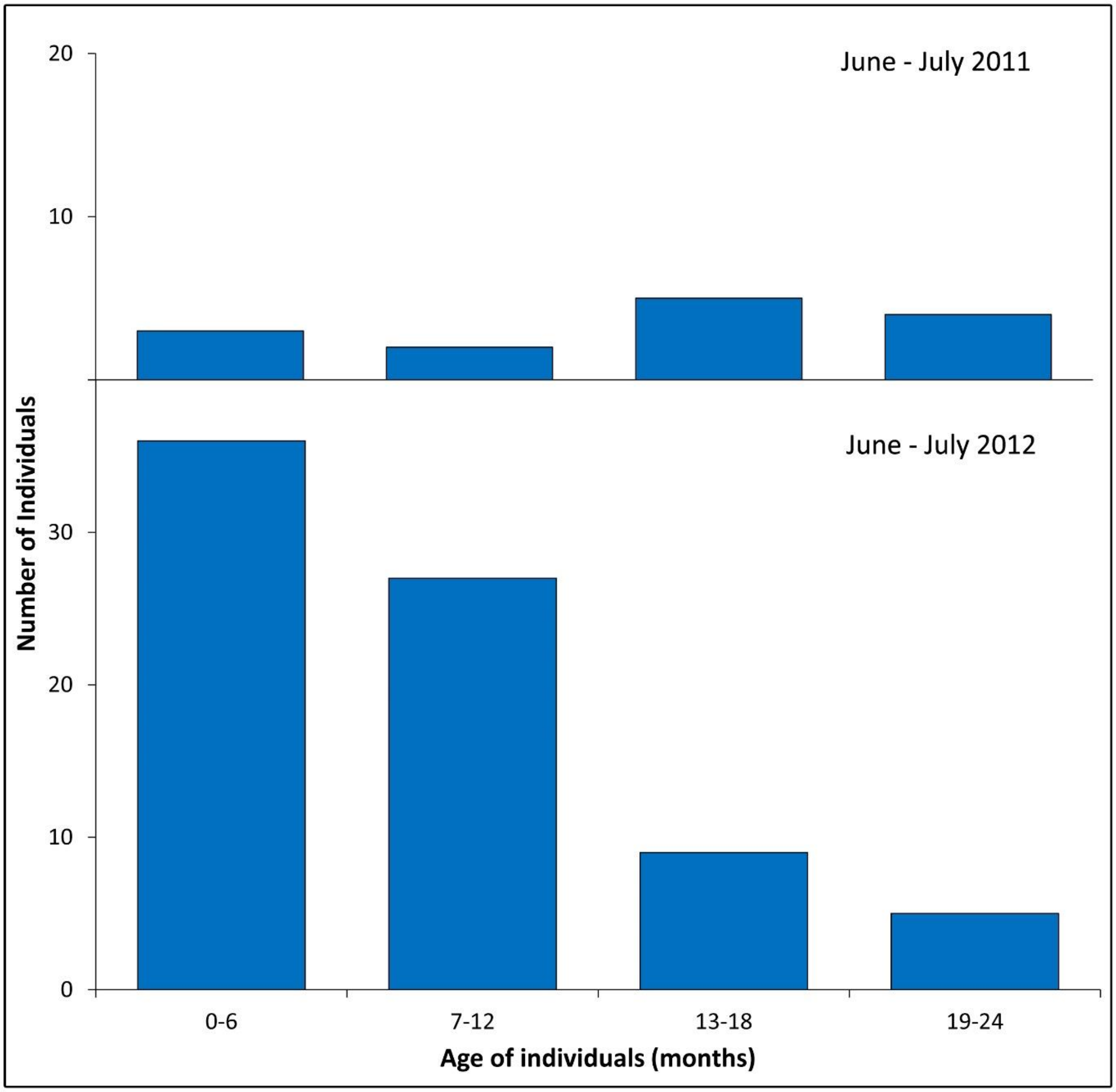

Figure 6.4 Number of immature individuals per age group (6 month intervals) during two consecutive years, 2011 and 2012, at the Heuwelsig site.

6.1.3 Body Measurements, Mass and Condition Index

Rock hyraxes were weighed and measured once captured; these measurements included body length, girth and head length of individuals. The mean of measurements of the different categories, for the different populations, were compared to determine if there is any difference between populations. According to Skinner & Chimimba (2005), the average body mass of populations from different locations will vary (Table 6.3).

Table 6.3 Body mass (kg) of adult rock hyraxes from different regions within the Southern African Subregion (Modified from Skinner & Chimimba 2005)

	Males			**Females**		
Region	$\bar{x}$	***n***	**Range**	$\bar{x}$	***n***	**Range**
Zimbabwe	3.52	10	3.21 – 4.65	3.09	10	2.47 – 3.46
the former Transvaal	2.8	10	1.5 – 4.3	3.26	12	1.80 – 4.30
Free State	3.76	15	3.16 – 4.34	3.56	13	3.01 – 4.15

Comparison of the average body mass indicates a significant difference ($P < 0.05$) [ANOVA; d.f. = 4; $F = 26.65$; $p = 0.0006$] between different populations (Fig. 6.5). However, a comparison of the average length (Fig. 6.6), average girth (Fig. 6.7) and average head length (Fig. 6.8) between different populations did not show any difference ($p > 0.05$). This difference in body mass, while the other body measurements remained similar, led to the investigation if the body condition index of the different populations. The mean body condition index (CI), as defined by Barry & Mundy (1998), were calculated for the entire population (Fig. 6.9) as well as the different sexes and age groups (Fig. 6.10). The difference between the mean CI of these populations was highly significant ($p < 0.01$) [ANOVA; d.f. = 4; $F = 25.58$; $p = 0.0009$). The mean CI of the Kranskop, Heuwelsig 2011 and Woodland Hills 2015 colonies (0.053 ± 0.003, 0.057 ± 0.003 and 0.054 ± 0.003, respectively) were very similar when compared to the mean CI (0.058 ± 0.003) of rock hyraxes from wild populations in Zimbabwe (Barry & Mundy 1998).

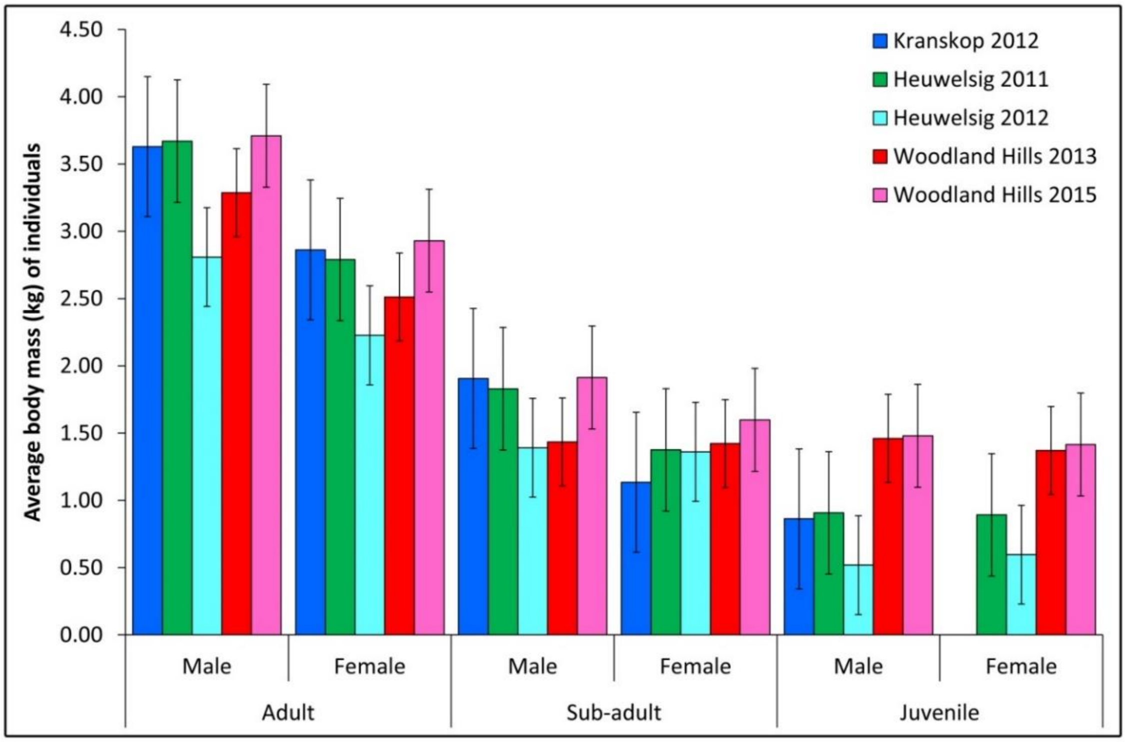

Figure 6.5 Average body mass of different age groups of three hyrax populations in the Free State.

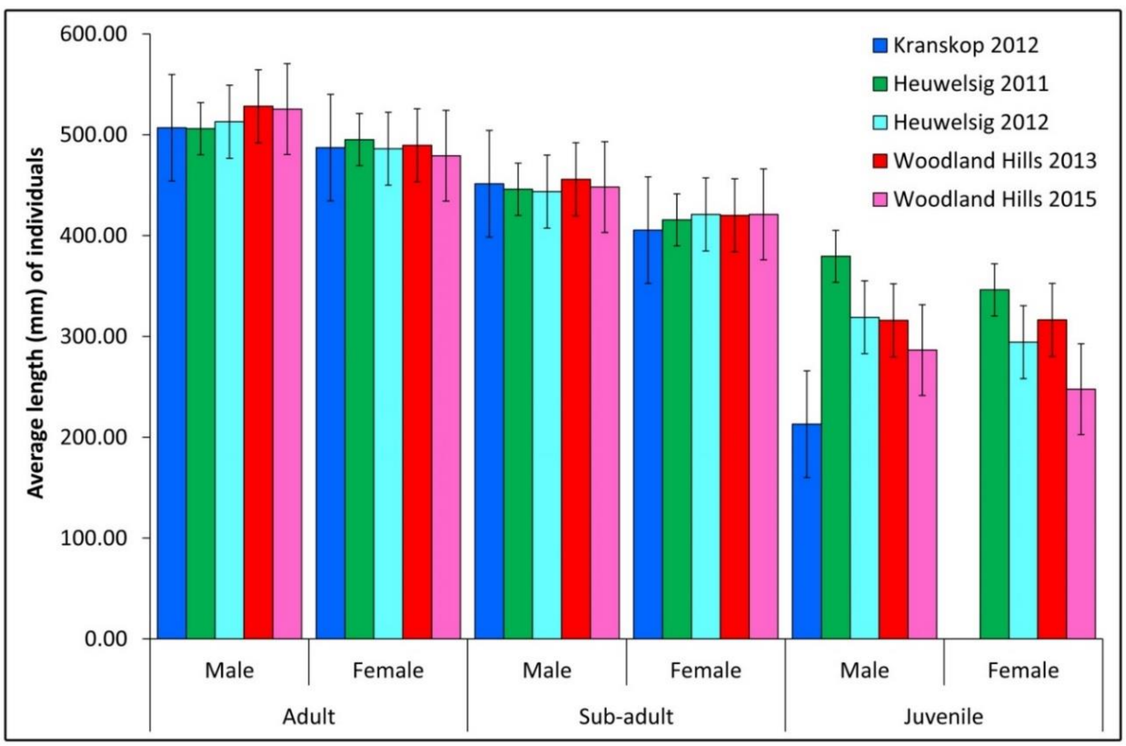

Figure 6.6 Average length of different age groups of three hyrax populations in the Free State.

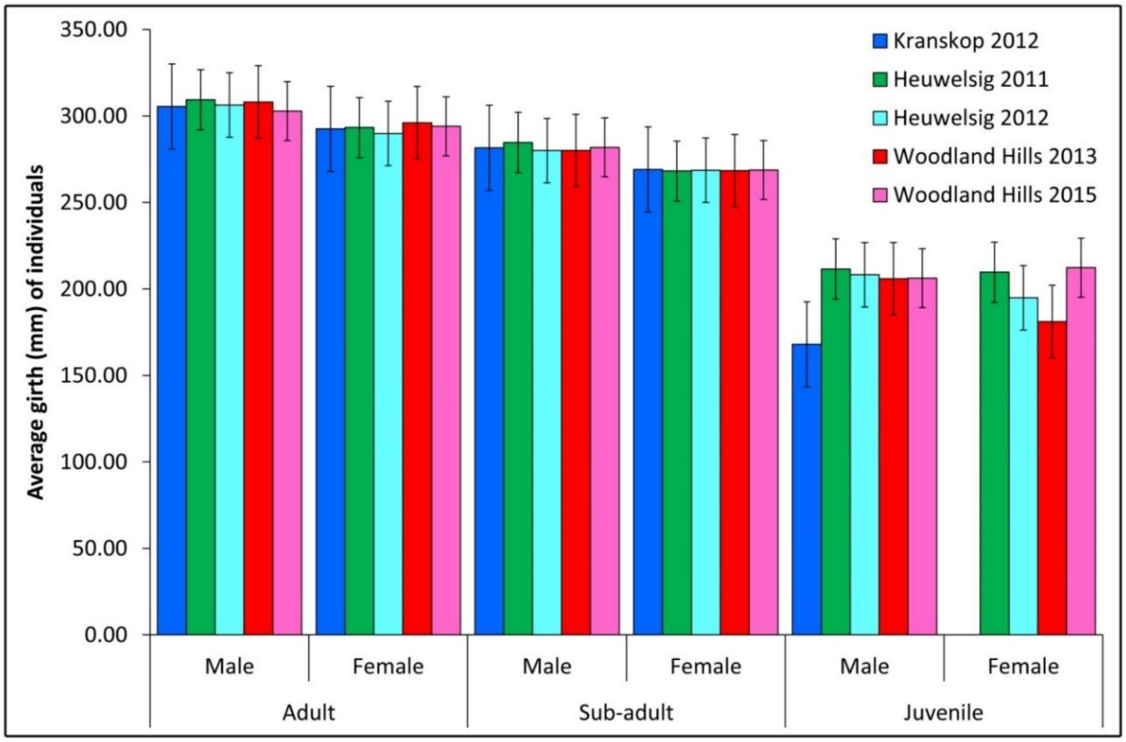

Figure 6.7 Average girth of different age groups of three hyrax populations in the Free State.

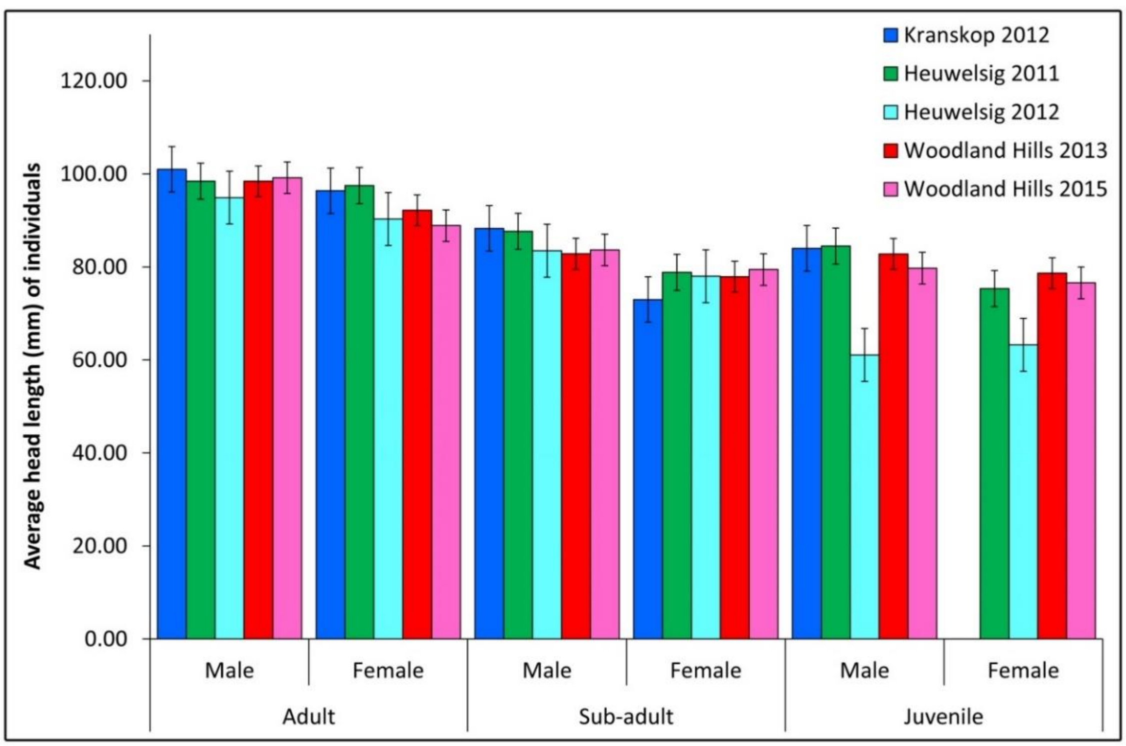

Figure 6.8 Average head length of different age groups of three hyrax populations in the Free State.

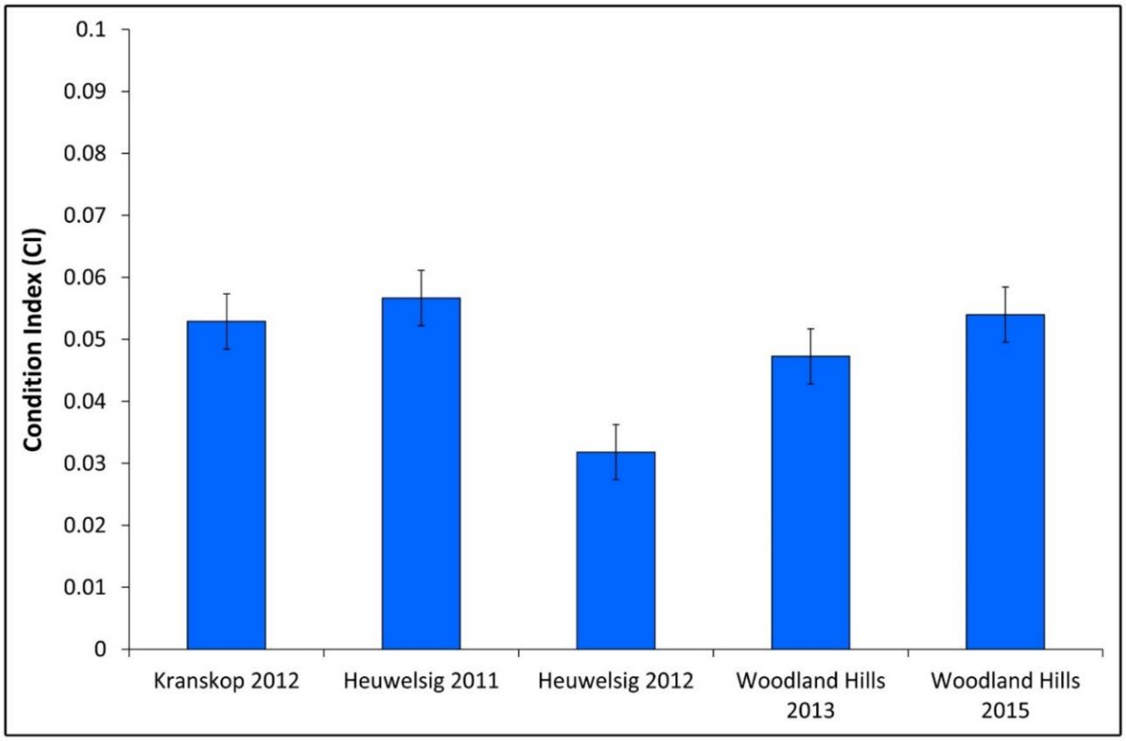

Figure 6.9 Average body condition index of individuals from different hyrax populations in the Free State.

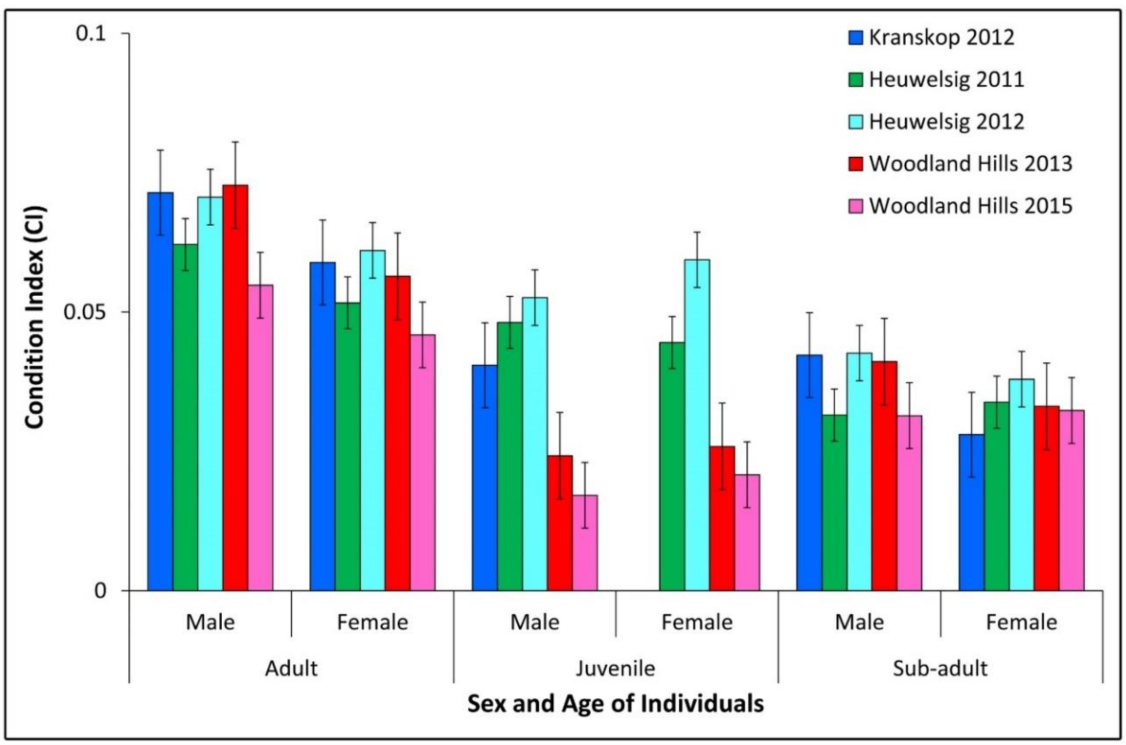

Figure 6.10 Average head length of individuals from different age groups of three hyrax populations in the Free State.

Since the Heuwelsig 2011 and Woodland Hills 2015 colonies were larger, 175% and 145% respectively, than the Kranskop colony the fact they have similar CI values might seem unusual. However, the additional food available for hyraxes in residential areas makes it possible for these colonies to maintain a CI similar to populations in the wild. One also need to take into account that the Heuwelsig 2011 CI were calculated during winter months while the other were a couple of months after the rain season, showing that the CI in residential areas can be easily maintained even when food sources are scarce.

The Heuwelsig 2012 and Woodland Hills 2013 showed a much lower CI, 0.032 ± 0.002 and 0.047 ± 0.002 respectively, than the other populations. If one take into account that these populations were 250% and 255% larger at the time of calculation than the Kranskop colony it is understandable that due to competition these populations will have lower CI values.

6.1.4 Population Density and Biomass

Population densities of rock hyraxes in wild populations vary greatly from those found in residential areas. Davies (1994) calculated the hyrax density of the Karoo National Park (KNP), South Africa to be 35.2 individuals/km^2 (0.352 individuals/ha). Barry & Mundy (1998) reported a hyrax density of 73 to 94 individuals/km^2 (0.73 – 0.94 individuals/ha) during 1992 - 1996 at the Matobo National Park (MNP), Zimbabwe. Chiweshe (2007) reported a wider density range from 47 to 174 individuals/km^2 (0.47 - 1.74 individuals/ha) from 1998 - 2004 at the MNP. The respective density of different populations during this study ranged from 17.47 to 84.00 individuals/ha (Table 6.4), which was clearly much higher than any of the densities reported by Davies (1994); Barry & Mundy (1998) and Chiweshe (2007).

One can only assume that the presence of natural predators in an area will restrict population growth and therefore also regulate the density of prey animals. According to Erlinge *et al.* (1984), prey populations are indeed regulated by natural predators. The top predators of rock hyraxes include the Verreaux's eagle (black eagle) and the caracal (Estes 1991). These top predators can occur at diverse densities within their home ranges.

Brown (1988) reported a density of 8 pairs/520km^2 (1 pair/65.00 km^2) for Verreaux's eagles in the Giant's Castle area of the KwaZulu - Natal Drakensberg, South Africa. Davies (1994) and Chiweshe (2007) however reported 18 pairs/435 km^2 (1 pair/24.16 km^2) and 59 pairs/424 km^2 (1 pair/7.20 km^2) respectively for Verreaux's eagles at KNP and MNP.

The density for caracal at KNP was calculated at 0.26 caracal/km^2 and included a total of 85 caracals in the 330 km^2 area (Davies 1994). Palmer & Fairall (1988) calculated a density of 0.23 caracal/km^2 during their study at KNP. According to Avenant & Nel (1997; 1998 & 2002), the density of caracal at the Postberg Conservancy, Western Cape was estimated to be at 0.23 - 0.47 caracal/km^2. The densities reported by Smith (2012) for the Winterberg district in the Eastern Cape, was slightly lower at 0.20 caracal/km^2. Therefore a caracal density within the range of 0.20 – 0.47 caracal/km^2 will be accepted as conforming to the norm.

With regards to the feeding behaviour of these top predators, several differences have been found in previous studies. Davies (1994) reported that at KNP a single, non-breeding pair of Verreaux's eagles can catch approximately 155 hyraxes per year at a capture rate of 0.42 hyraxes/day. This calculates to a biomass of 1 090 g/day (398 kg/year). For a single, breeding pair Davies (1994) calculated an approximate total of 185 hyrax captures per year at a rate of 0.57 hyraxes/day. This number calculates to a total biomass of 1 465 g/day (473 kg/year). However, Gargett (1990) reported nearly double these values, 292 – 365 hyraxes per year at Matobo Hills in Zimbabwe.

According to Grobler (1981), a tame but free-ranging caracal male with an age of eight months and weighing 11.2kg was monitored in order to determine how much meat it consumes per day. A value of 796 g per day was determined. Grobler (1981) calculated, according to the consumption rate of this tame caracal, that juveniles and adults will consume approximately 500 - 1 000g of meat per day. Using this value he calculated that the 25 caracals (15 adults and 10 juveniles) in Mountain Zebra National Park can consume up to 7300 kg of meat per annum. With a 53.3% occurrence of hyrax in caracal scats, this calculates to roughly 2993 hyraxes per year (119 hyraxes, $\bar{x}$ weight = 1.3kg, per caracal per year).

Table 6.4 Population composition (%), density and biomass of different populations in the Free State. (Adult = A, Sub-adult = S, Juvenile = J, Male = ♂, Female = ♀)

		Kranskop	Heuwelsig		Woodland Hills	
		2012	2011	2012	2013	2015
Number of individuals	A ♂	2	24	20	18	6
	S ♂	5	3	6	16	5
	J ♂	1	2	27	25	10
	A ♀	17	35	21	82	26
	S ♀	4	6	8	25	8
	J ♀	0	4	34	23	7
Total		**29**	**74**	**116**	**189**	**62**
% of total population	A ♂	0.07	0.32	0.17	0.10	0.10
	S ♂	0.17	0.04	0.05	0.09	0.08
	J ♂	0.03	0.03	0.23	0.13	0.16
	A ♀	0.59	0.48	0.18	0.43	0.42
	S ♀	0.14	0.08	0.07	0.13	0.13
	J ♀	0.00	0.05	0.30	0.12	0.11
Avg. weight (kg) / age group	A ♂	3.63	3.67	2.81	3.29	3.71
	S ♂	1.91	1.83	1.39	1.43	1.91
	J ♂	0.86	0.91	0.52	1.46	1.48
	A ♀	2.86	2.79	2.23	2.51	2.93
	S ♀	1.13	1.38	1.36	1.42	1.60
	J ♀		0.89	0.60	1.37	1.42
Population Density						
Individuals / ha		17.47	35.07	54.98	84.00	27.56
Calculated biomass according to the method of Davies (1994), Barry & Mundy (1998) and the derived method used for this study.						
Davies	(kg/ha)	45.80	99.15	78.28	169.79	62.65
	(kg/km^2)	4580.09	9914.78	7828.13	16979.47	6265.22
Barry & Mundy	(kg/ha)	57.80	129.00	108.79	291.61	103.31
	(kg/km^2)	5780.18	12899.68	10879.40	29160.97	10331.12
This study	(kg/ha)	42.66	97.09	74.13	174.06	64.67
	(kg/km^2)	4266.25	9709.28	7413.19	17406.01	6466.59

Palmer & Fairall (1988) used the estimate proposed by Grobler (1981) to calculate that the 28 caracals at KNP could consume 10 000kg of meat per annum, which according to the 12% hyrax occurrence in scat calculates to 461 hyraxes per annum (16 hyraxes, $\bar{x}$ weight = 2.6 kg, per caracal per annum). Pohl (2015) reported a consumption rate of 22 – 55 hyraxs per year (1.83 – 4.58 per month) by a single caracal.

Although not a ranking predator, the black-back jackal is a known predator of hyraxes. These animals are considered true opportunists and have been recorded to not only feed on meat but on fruits, berries and carrion (Stuart & Stuart 2007). Jackals occur at densities ranging from 0.34 – 0.4 jackals / km^2 (Rowe-Rowe 1982), 4 – 7 jackals / km^2 (McKenzie 1990) to 22 jackals / km^2 (Hiscooks & Perrin 1988). Pohl (2015) have found, by scat analysis that approximately 2.2% of the diet of black-back jackal consist of hyraxes.

Looking at the natural densities of Verreaux's eagles, caracal and jackal as described in literature and considering the number of hyraxes they consume within one year, one can only assume how the absence of natural predators can affect population densities. The Kranskop colony, although a wild population, are also influenced by lower predator numbers. According to Pohl (2015), an average of 6 – 13 animals per species (caracal and jackal) are either caught or hunted every year, decreasing the number of predators on this livestock farm considerably. Bearing in mind that a single caracal can take 22 – 55 hyraxes each year according to Pohl (2015). By rough calculation using the lowest possible number of hyraxes taken by caracal, killing 6 – 13 caracals can lead to an increase of 132 – 286 hyraxes per year.

When comparing the rock hyrax densities from all the study sites to the densities found in literature, the difference is very clear. At the Kranskop colony, where natural predators are constantly controlled by catching and/or shooting, the population density were almost 10 times that of the highest density recorded for populations in the wild. Hyrax densities recorded at the other residential sites were approximately 1.6 - 4.8 times larger than the density at Kranskop (*vide* Table 6.4) which is approximately 16 - 48 times larger than the highest density recorded for populations in the wild.

6.2 Conclusion

Populations found in residential areas; were 175 - 255% larger when compared to populations found in the wild (30 - 40 individuals). The structure and composition of these residential populations were also different from those of populations in the wild. Larger numbers of sexually matured males were present in residential populations, while wild populations seem to have only one sexually matured male. It appeared the lack of predators in residential areas had an influence on the survival rate of juveniles and sub-adults since the majority of residential populations had a higher percentage of young individuals. Except for the Heuwelsig site which only had a higher percentage once the population increased in size from 2011 - 2012.

Abundant resources in residential areas enabled populations to maintain an average body mass similar to that of the Kranskop colony, these averages were supported by calculations of the CI. However, the moment these residential populations reached sizes of more than double that of the Kranskop colony, the resources available simply was not enough to support these colonies, therefore, this significant decrease ($p < 0.05$) were witnessed. This difference in CI and average body mass can be attributed to an increase in competition. Body mass seems to be the only variable affected by larger populations since other body measurements (length, girth and head length) remained unaffected.

Residential sites, where these larger than normal populations were found, were larger in size compared to the normal home ranges of rock hyraxes in the wild. Initially, these large populations were thought to be caused by several colonies living together in these residential areas. Therefore it was expected that several territorial males would be present all defending different home ranges within these residential areas. Males, however, were not as territorial as would be the case with populations in the wild since they were found in the same core areas, lacking the typical territorial behaviour described by Estes (1991). This lack of territorial behaviour was confirmed by the fact that different males copulated with numerous females within the same home range, which according to the literature should not happen.

The lack of territorial fighting, however, suggests that this is indeed one large population with several males and females coexisting in one home range. Once again this was confirmed when the sex ratios of adult individuals in residential areas were compared. At the Kranskop colony, an adult male to female ratio of 1 : 17 were recorded. The highest ratio recorded for residential areas was 1 : 4.56. The adult sex ratio of populations as well as the total sex ratio, including sub-adults and juveniles, of populations, were showed a negative correlation when compared to population sizes.

It was clear that the abundance of food and refuges together with the shortage of natural predators not only caused an increase in number of individuals but also caused these populations to change their composition and structure in order to take full advantage of these abundant resources.

Chapter 7

Invasion Prevention and Population Management

CHAPTER 7: INVASION PREVENTION AND POPULATION MANAGEMENT

A number of methods - whereby invasions to properties as well as the control of hyrax numbers in a population - were identified, assessed and tested during this study. Methods to prevent invasion of properties were only tested at the homes which were situated directly adjacent or across the street from the Heuwelsig site since the most frequent reports of rock hyrax invasions came from the owners of these properties. Methods to control densities of hyraxes in a population were tested at both the Heuwelsig site and Woodland Hills Wildlife Estate. Information gathered using questionnaires (Chapter 4) made it possible to identify the effectiveness level (EL) of current invasion preventive methods at properties. Methods to prevent the invasion of properties had to adequately decrease the number of rock hyrax sightings in residential areas while methods of population control had to rapidly reduce rock hyrax numbers and then keep populations within its natural limits in order to be regarded effective or successful.

In the past, several methods have been implemented in order to control rock hyrax populations. These methods included chemical control by means of poisoning (Moran *et al.* 1987), culling (Barlow *et al.* 1987), trapping and euthanasia (Panzacchi *et al.* 2007), reintroduction of natural predators (Hayward *et al.* 2007; Hayward & Somers 2009), fertility control by means of contraceptives (Caughley *et al.* 1992; Hinds *et al.* 2003; Hone 2004; Jacob *et al.* 2008) and the translocation of individuals from overpopulated areas (Crawford & Fairall 1984; Griffith *et al.* 1989; Griffith *et al.* 1990; Griffith *et al.* 1993; Bright & Morris 1994; *Wolf et al.* 1998; Teixeira *et al.* 2007; Wimberger *et al.* 2009).

According to Barlow *et al.* (1987) rock hyrax numbers can be controlled by culling large portions of populations in a matter of days. However, this method is not preferred since the problem areas are situated within residential areas and thus, according to the environmental officer from the Mangaung local municipality (Mr Jaco Lamprecht, pers. comm. 2012[12]),

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require special permission and numerous safety measures, as it is a criminal offence in South Africa to discharge a firearm in a residential area (Firearm Control Act 60 of 2000).

The reintroduction of natural predators has been used with success in the past (Hayward *et al.* 2007; Hayward & Somers 2009) and was therefore considered as a possible control method for hyraxes in the Bloemfontein area. Since these predators will be reintroduced into residential areas, the chosen predator/species had to pose no threat whatsoever to humans or pet animals in the vicinity. Reintroduction of natural predators was not viable at Woodland Hills, as there were no fences separating houses from wildlife. The Heuwelsig site however, encompassed the Heuwelsig conservancy which had adequate fencing to retain natural predators, making reintroduction of natural predators at this site possible.

Fertility control had been used with success by several researchers (Caughley *et al.* 1992; Hinds *et al.* 2003; Hone 2004; Jacob *et al.* 2008). This method , if used properly, can however be expensive and will take some time to achieve the wanted results since contraceptives – which have been used on other species - might not be as effective for hyrax, if effective at all, which means different contraceptives will then need to be tested (Dr Giovanna Massei pers. comm. 2013[13]). The population control method required for this study had to ensure a rapid decrease in hyrax numbers in order to address the problem and therefore fertility control was not considered.

Translocation as a possible control method was considered for the Bloemfontein hyrax colonies as this method had been used in previous studies with various levels of success (Stenseth 1981; Hoeck 1982; Crawford & Fairall 1984; Hoeck 1989; Wimberger *et al.* 2009; Banks *et al.* 2002). Culling would be used to control rock hyrax populations only in the event of all other methods failing. One should however keep in mind that once the abundance of a

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pest population is reduced, the population may respond by increasing the fertility and/or decreasing the rate of mortality of the remaining individuals (Sinclair 1997).

7.1 Results and Discussion

7.1.1 Invasion prevention

Information regarding current invasion preventive measures were collected from homeowners by means of a questionnaire. In order to determine and compare the effectiveness of these different methods, a standardised unit of evaluation was required. Since information regarding sightings were already collected, the number of rock hyrax sightings (average days per week) were used to create an Effectiveness Level score (EL score). The EL score, represents how effective an invasion preventive measure is in lowering the number of hyrax sightings; therefore the EL score is inversely proportional to the effectiveness level, meaning a low EL score represents a highly effective deterrent method (Table 7.1).

Table 7.1 An Effectiveness Level (EL) scale used as indicator of the efficiency of deterrent methods of hyraxes at private properties in Heuwelsig residential suburb.

Effectiveness Level (EL) Scale		
Hyrax Sightings (Days per week)	**Effectiveness**	**EL Score**
0	Highest	0
1 or 2	Higher than average	1.5
3 or 4	Average	3.5
5 or 6	Lower than average	5.5
7	Lowest	7

Due to different preventive measures present at each property, one would expect that these measures would have an influence on the effectiveness of others. For this reason an average EL score for each preventive measure had to be calculated; once calculated this average score would then be compared to the score of other measures to determine which is most effective. As soon as the average score for each measure were known, the combined EL score for different combinations of preventive measures were calculated. Due to the limited number of properties included in the survey, the EL score for several combinations of measures could not be determined and therefore, in these instances, no EL score will be presented in the results. An EL score of zero is an indication of a highly effective method for the prevention of properties invasions.

7.1.1.1 Barriers

Barriers were divided into two distinct categories namely open (those with openings or gaps) and solid barriers. These two categories were further divided into four types of barriers; wire fences and devils fork fences which fall within the first category of open barriers, as wells as brick walls and precast concrete walls which fall in the solid barrier group. The average EL score of these barrier types, with their variations, is summarized in Table 7.2.

Of the four types of barriers, properties with wire fences were most effective and therefore had the least number of hyrax sightings (days per week) (Table 7.2). The properties surrounded by brick walls, had the second lowest EL score. In theory this value could have been lower, if the brick walls were plastered, since plastered brick walls were more effective against hyrax intrusions than non-plastered brick walls. (Table 7.2).

Devils fork fences and precast concrete walls were regarded ineffective due to the high average EL score found at properties enclosed by these barriers. It is further evident that the effectiveness of barriers clearly increased as the barriers increased in height (Table 7.2). Barriers with an overhang at the top considerably lowered the number of hyrax sightings at properties, therefore barriers with an overhang are more effective than those without. (Table 7.2).

Table 7.2 Effectiveness of different barrier types against hyrax invasions at properties in Bloemfontein.

Barrier Type and Variable	n	$\bar{x}$ EL Score	± SE
Wire Fences	13	2.21	± 0.44
Diamond mesh aperture < 50mm	2	1.17	± 0.61
Diamond mesh aperture > 50mm	9	2.50	± 1.17
Diamond mesh, top aperture > 50mm and bottom aperture < 50mm	1	1.50	± 0.00
Welded mesh aperture > 50mm	1	3.50	± 0.00
Devils Fork Fences	3	5.38	± 0.72
Brick Walls	5	3.50	± 0.65
Plastered	2	2.50	± 0.58
Not plastered	3	4.50	± 1.00
Precast Concrete Walls	2	7.00	± 0.00
Overhang			
Present	3	0.60	± 0.37
Absent	20	3.68	± 0.41
Electric Fence			
Present	7	3.50	± 0.73
Absent	16	3.15	± 0.48
Height of Barrier (All inclusive, fences & walls)			
0 m – 1.2 m	1	7.00	± 0.00
1.2 m – 1.5 m	7	4.25	± 0.58
1.5 m – 1.8 m	9	3.81	± 0.60
> 1.8 m	6	1.00	± 0.34

Surprisingly, electric fences proved inadequate in keeping hyraxes from entering properties since more hyrax sightings were reported at properties with electric fences than at those without (Table 7.2). Despite the fact that less damages were documented at properties with electric fences (Chapter 4) than at those without, properties with electric fences were less effective in keeping hyraxes out than those without electric fences. When different barrier related variables were combined, it was clear that the effectiveness of a specific barrier type - irrespective of the height - and specific barrier height - irrespective of the type - in the presence of an electric fence (Fig. 7.1 & 7.2) or an overhang (Fig. 7.3 & 7.4) were more effective than when those variables were not present.

Only wire fences proved to be more effective (lower EL score) when combined with an electric fence while the other barrier types were less effective (Fig. 7.1). The only barrier height that had an improved EL score, when combined with an electric fence, were barriers of 1.5 m - 1.8 m high (Fig. 7.2), other barriers were more effective without an electric fence. All barrier types were more effective when combined with an overhang (Fig. 7.3); similar results were found for the combination of barrier of different heights and an overhang (Fig. 7.4).

When three variables (barrier type, barrier height and electric fence) (Fig. 7.5) were combined the only change in effectiveness were noted for wire fences; it is evident that electric fences had no influence on the effectiveness, since the only variable that changed was the height of barriers. Earlier results -height of fence, *vide* Table 7.3 & barrier height in combination with electric fence, Fig. 7.2- support that the increase in the barrier height is what caused the increase in effectiveness. Although data is limited for barriers with an overhang, it is still easy to see that barriers with an overhang were more effective than those without (Fig. 7.6).

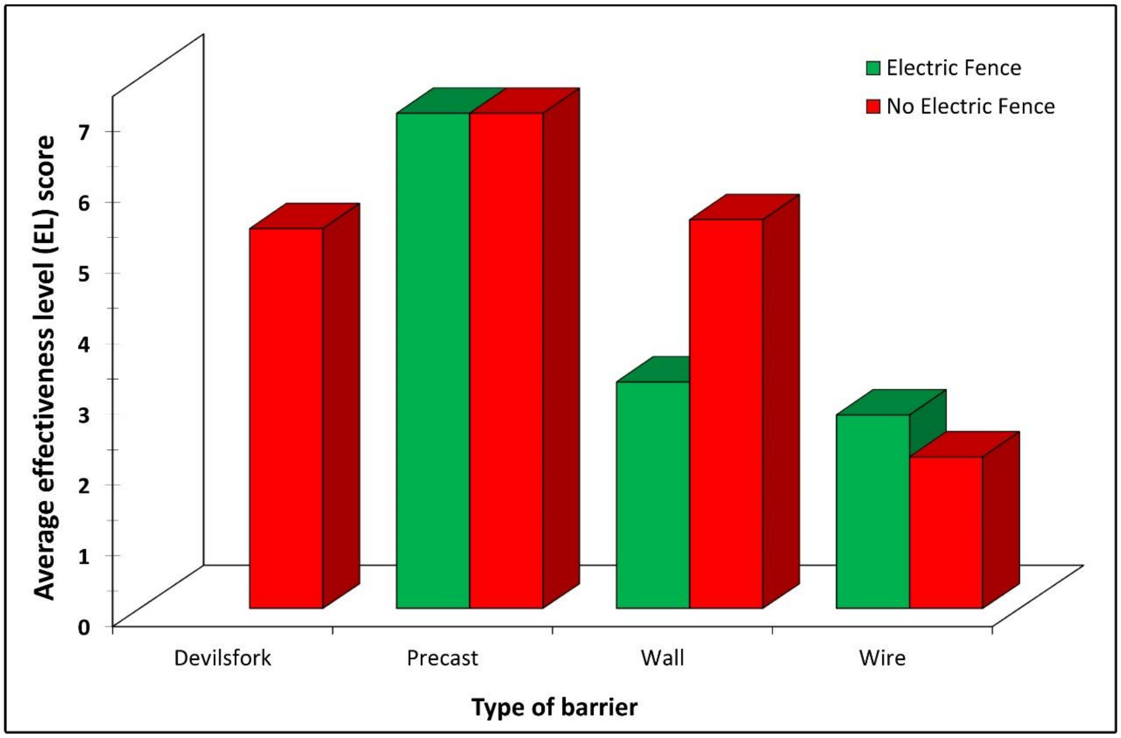


Figure 7.1 The effectiveness level of a specific type of barrier in the presence and absence of an electric fence.

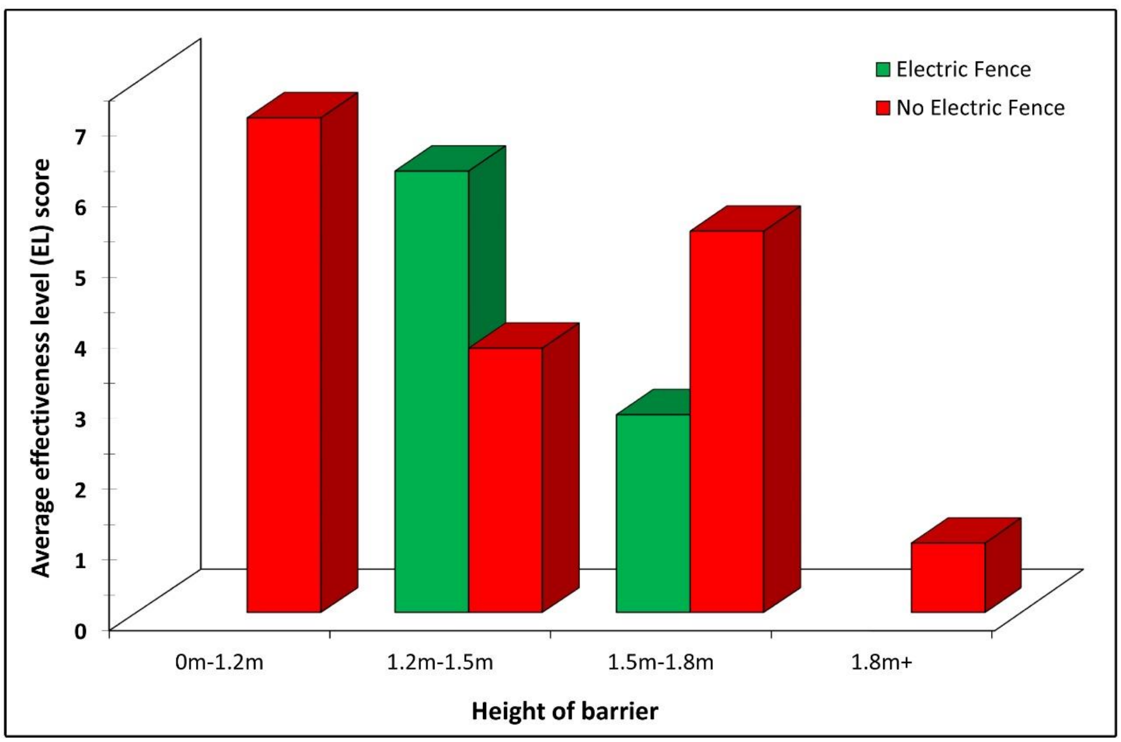


Figure 7.2 The effectiveness level of a specific height of barrier in the presence and absence of an electric fence.

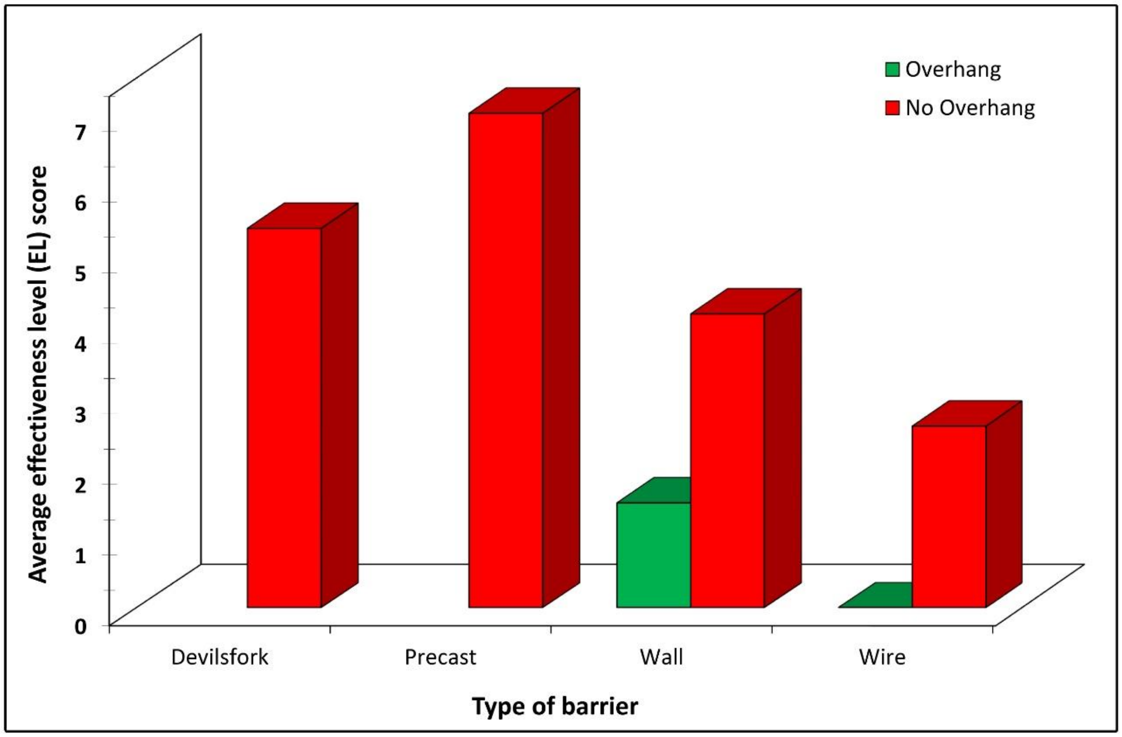


Figure 7.3 The effectiveness level of a specific type of barrier in the presence and absence of an overhang.

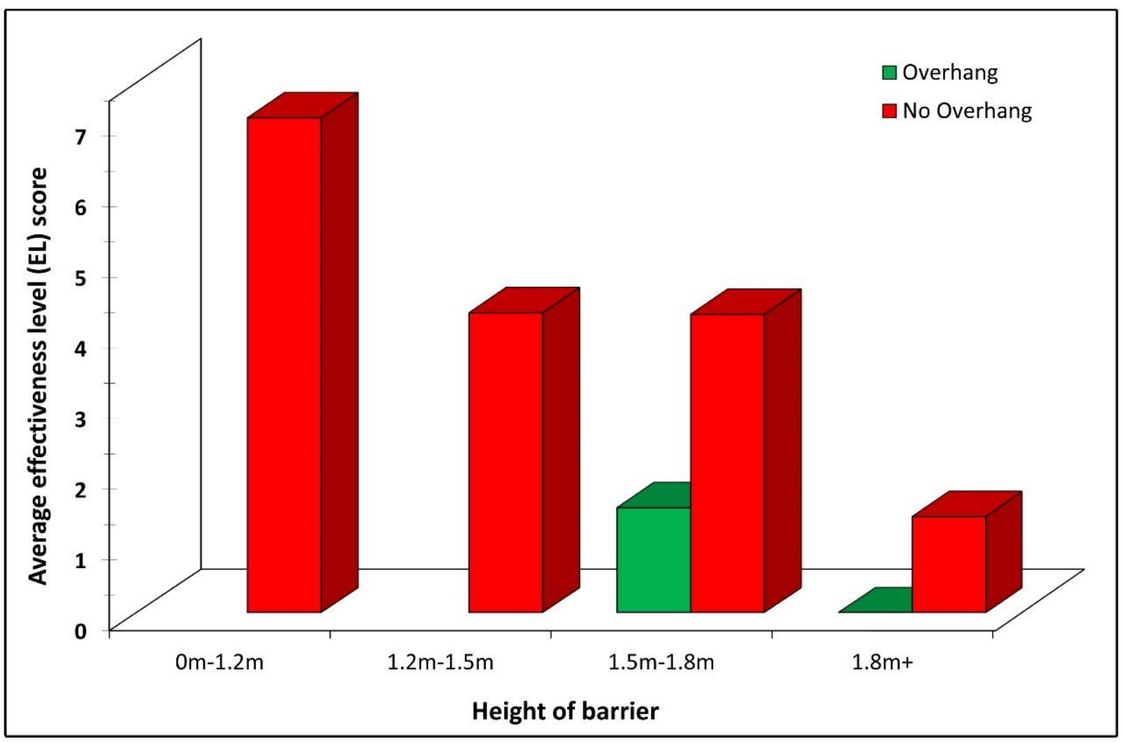


Figure 7.4 The effectiveness level of a specific height of barrier in the presence and absence of an overhang.

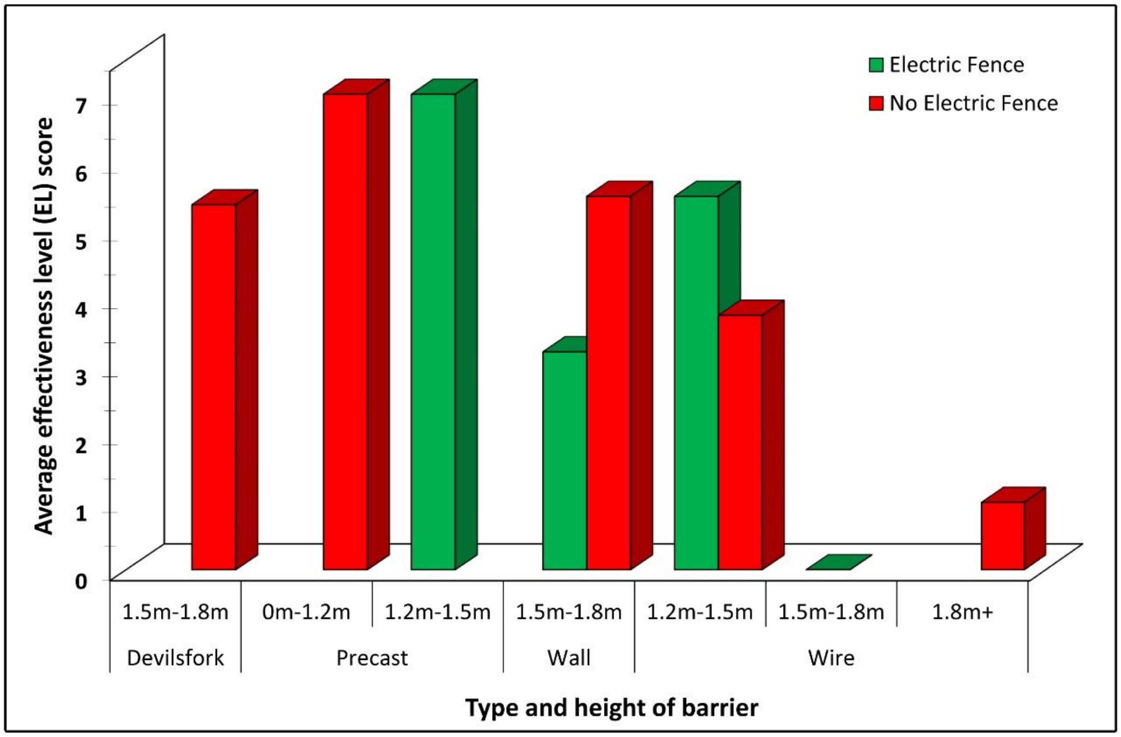


Figure 7.5 The effectiveness level of a combination of type and height of barrier in the presence and absence of an electric fence.

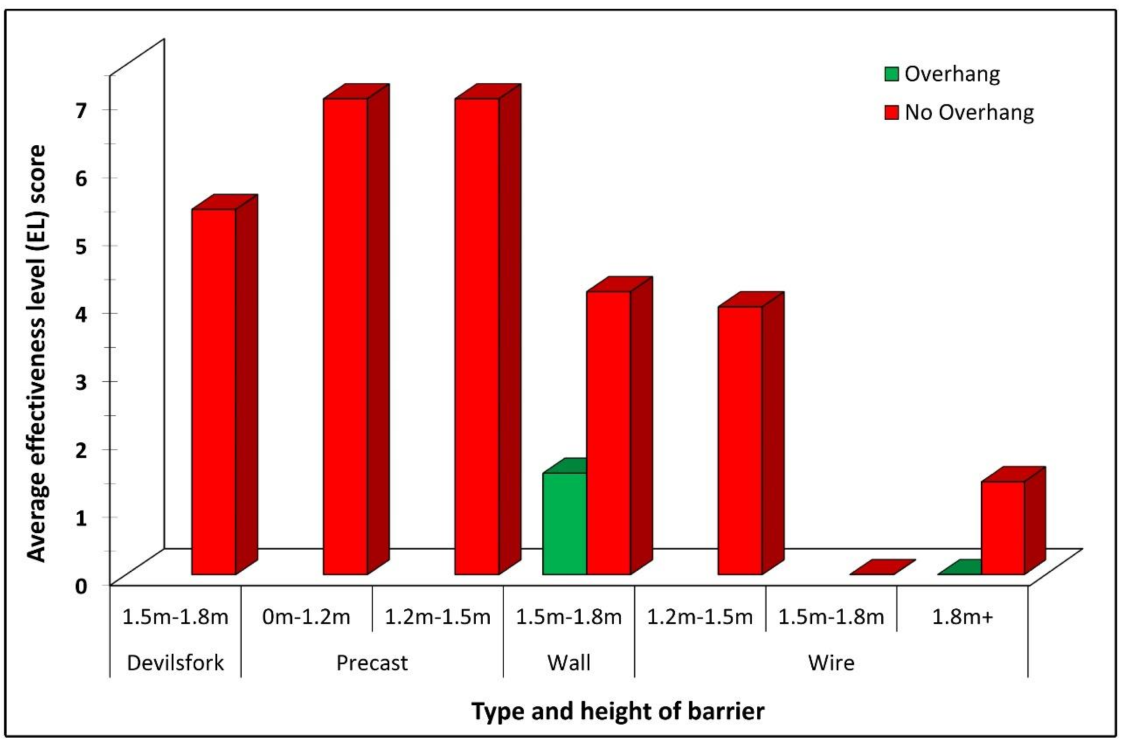


Figure 7.6 The effectiveness level of a combination of type and height of barrier in the presence and absence of an overhang.

7.1.1.2 Dogs

Due to the mere number of dog breeds that exist today, dogs were grouped according to seven groups as described by the American Kennel Club (Anonymous 2011) as well as the Westminster Dog Show (Anonymous 2014). The EL score of different variables such as number of dogs, breed of dogs and access or movement of dogs on the property were examined. At the time of gathering information the age of dogs were not taken into consideration, this however might also play a role in the effectiveness of a specific dog breed/group and might be the explanation why some dog groups were not as effective as one would expect them to be.

It was clear that properties where dogs were present had a lower EL score than those with no dogs present (Table 7.3). The number of dogs per property seemed to have little effect on the invasion prevention since the effectiveness did not increase when the number of dogs increased (Table 7.3). Dogs which were free to move about the properties at night, were more effective in keeping hyraxes away than when dogs were kept indoors (Table 7.3). Dogs belonging to the hound group were most effective as hyrax deterrent since this group had the lowest EL score -not considering the influence of other variables. The terrier group were second most effective while dogs from the herding, working and non-sporting groups were least effective. Although non-sporting groups had the highest EL score (3.67) of all dog groups this score was still lower than the EL score when no dogs were present at the property, confirming that it is indeed better to have a dog present at a property.

Table 7.3 Effectiveness of different dog groups and dog related variables against hyrax intrusions at properties in Bloemfontein.

Variable	n	$\bar{x}$ EL Score	± SE
Presence of dogs			
Dogs present	5	3.19	± 0.56
No dogs present	18	4.30	± 1.21
Number of dogs			
1 dog	3	4.17	± 0.67
2 dogs	11	2.68	± 0.64
3 dogs	3	5.17	± 1.83
4 dogs	1	0.00	± 0.00
Dog movement around property			
Indoors only	6	4.08	± 0.93
Outdoors only	6	2.58	± 1.09
Both indoors and outdoors	6	2.92	± 0.93
Dog Groups			
Herding Group	3	3.50	± 1.15
Hound Group	1	1.50	± 0.00
Non-Sporting Group	3	3.67	± 1.83
Sporting Group	3	3.00	± 1.61
Terrier Group	7	2.64	± 0.97
Toy Group	11	3.14	± 0.76
Working Group	3	3.50	± 1.15

In order to determine if the average costs towards repair of damages (*vide* Fig. 4.8 & Fig. 4.9) and the effectiveness of each dog group was in any way related, a comparison of these values were done. According to results there was no correlation between average costs of each dog group and the EL score (R = 0.16, R^2 = 0.02). The reason for this could be because a property with little hyrax sightings might have had a single damage causing event, which resulted in these high costs. The effect of variables could also play a critical role in these differences.

An example, of this occurrence is observed with the accumulation of costs in the presence of the terrier group. Terriers have the second lowest low EL score (2.64) (Table 7.3), but had the second highest cost towards repairs associated with this group (*vide* Table 4.8). A total of seven properties had dogs from the terrier group. At four of these properties dogs were kept indoors, at one property dogs were allowed both indoors and outdoors and at two properties dogs were only kept outdoors. The respective average damage per property according to the movement of dogs was R5 547.00 where dogs were kept indoors, R500.00 where allowed to move both indoors and outdoors and only R100.00 where dogs were only kept outdoors and therefore could guard the outside of the property on a constant basis. This show that when the dogs are allowed to move about freely or kept outdoors at properties they were more efficient at keeping hyraxes at bay than at properties were they were only kept indoors. This also confirms why there is no correlation between average cost towards repairs and the EL scores of different variables.

A combination of dog groups and electric fences revealed that dogs from the terrier and working groups were the only groups to be more effective in the presence of an electric fence (Fig. 7.7). One would expect that if this decrease was in fact a result of the effectiveness of the electric fences, that this improvement would be visible for all dog groups, which clearly was not the case. All dog groups were more effective in the presence of an overhang (Fig. 7.8) which means the overhang must have played a role in lowering the EL score and could thus be deemed effective as an invasion preventive method.

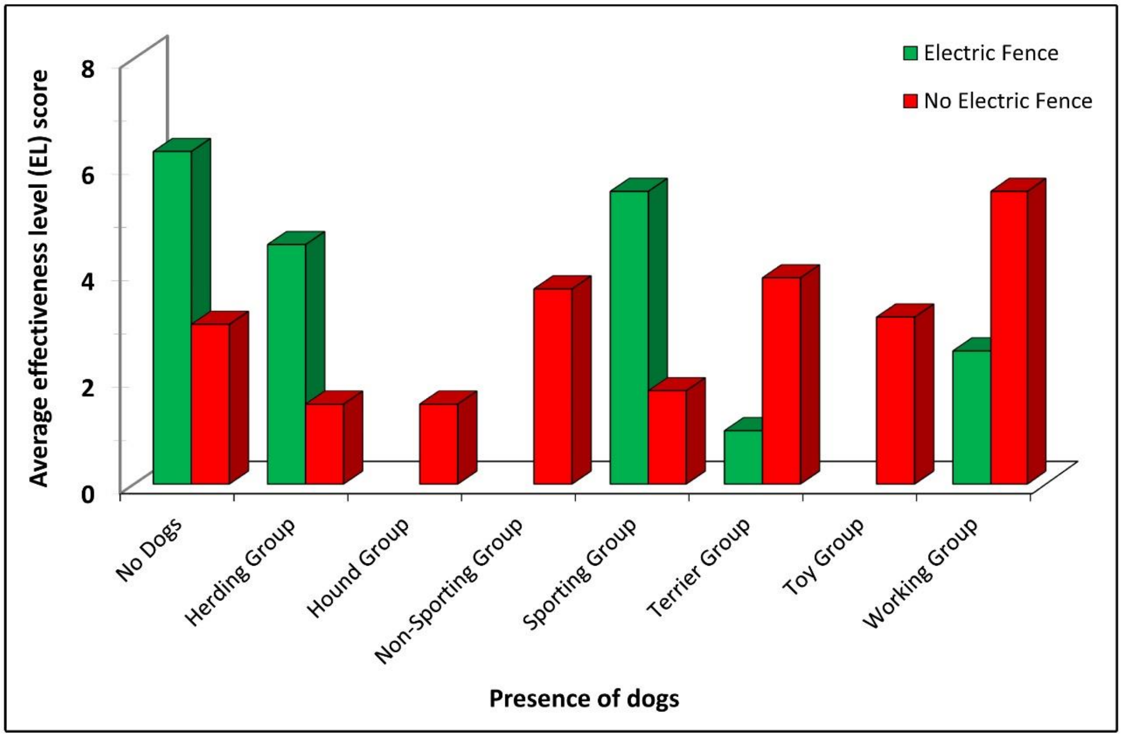


Figure 7.7 The effectiveness level of different dog groups in combination with an electric fence.

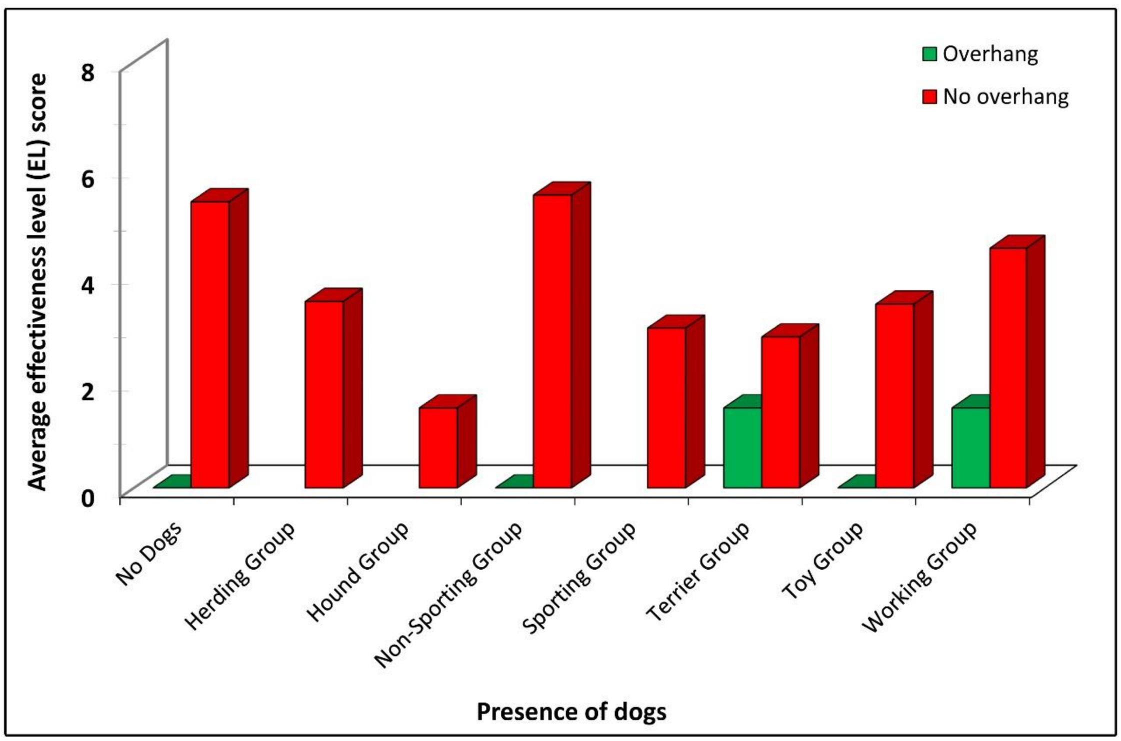


Figure 7.8 The effectiveness level of different dog groups in combination with an overhang.

7.1.1.3 Combinations of barriers and dogs

EL scores of dog groups - when the influence of other variables were not considered - were consecutively compared to the EL scores of dog groups in the presence of a wire fence as well as barriers higher than 1.8 m (Table 7.4) using ANOVA and Kruskal-Wallis tests. The EL scores of dog groups in the presence of both these variables were significantly lower ($p < 0.05$) [ANOVA; d.f. = 2; $F = 14.25$; $p = 0.0001$] [KRUSKAL-WALLIS; d.f. = 2; $H = 11.651$; $p = 0.003$] than that of dog groups - when the influence of other variables were not considered. The scale to which the effectiveness level will be affected by combining different variables had to be further assessed.

The majority dog groups, when combined with a wire fence or brick walls (Fig. 7.9), were more effective than when combined with devils fork fences or precast concrete walls. This proves that - in the presence of dogs - wire fences and brick walls are more effective than precast concrete walls or devils fork fences. When dog groups and barrier height were combined (Fig. 7.10), the effectiveness of the majority of dog groups increased as the height of barriers increased. One can therefore, without any doubt, say that the height of barriers are directly proportional to the effectiveness.

Table 7.4 Effectiveness of the combination of different dog groups and other variables against hyrax intrusions at properties in Bloemfontein.

Dog Groups	No other variable			Wire Fence			Barriers 1.8 m and higher		
	n	$\bar{x}$ EL Score	± SE	n	$\bar{x}$ EL Score	± SE	n	$\bar{x}$ EL Score	± SE
No Dogs	5	4.30	± 1.83	3	3.67	± 1.83	1	0.00	± 0.0
Herding Group	3	3.50	± 1.50	1	1.50	± 0.00	1	1.50	± 0.00
Hound Group	1	1.50	± 0.00	1	1.50	± 0.00	0	No data	No data
Non-Sporting Group	3	3.67	± 2.75	2	2.75	± 2.75	1	0.00	± 0.00
Sporting Group	3	3.00	± 1.75	2	1.75	± 1.75	1	0.00	± 0.00
Terrier Group	7	2.64	± 0.50	3	1.00	± 0.50	1	1.50	± 0.00
Toy Group	11	3.14	± 0.61	9	2.28	± 0.61	6	1.29	± 0.53
Working Group	3	3.50	± 1.15	0	No data	No data	0	No data	No data

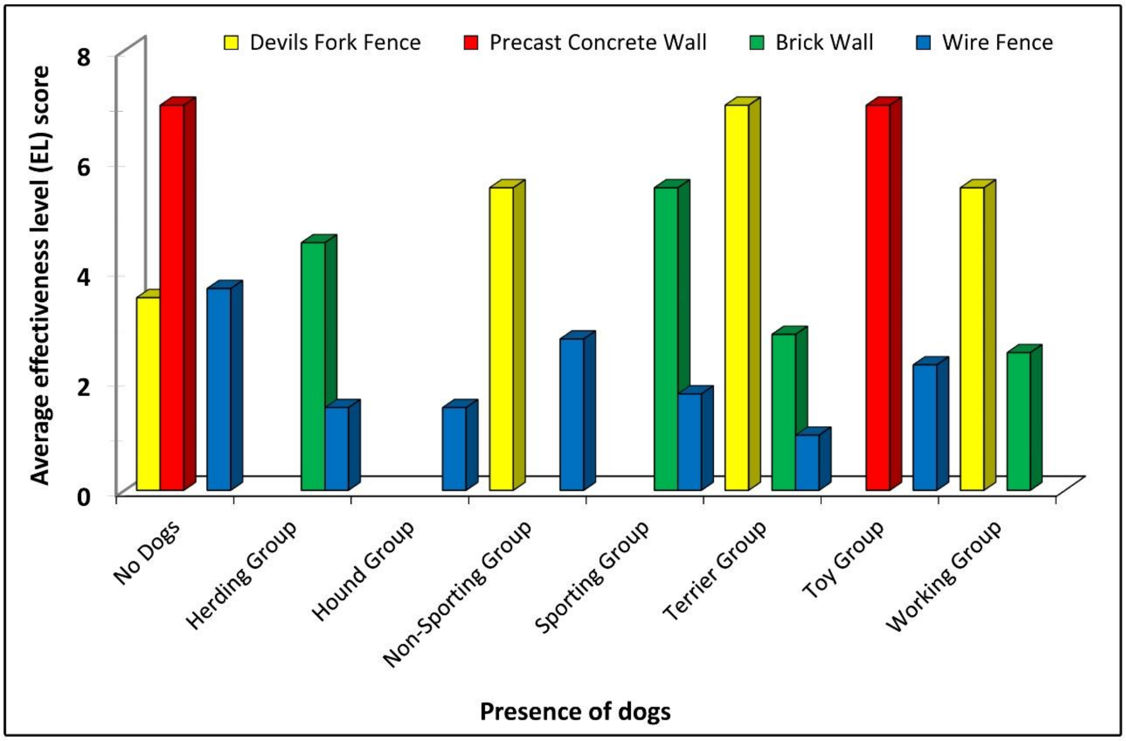


Figure 7.9 The effectiveness level of different dog groups in combination with a barrier of a specific type.

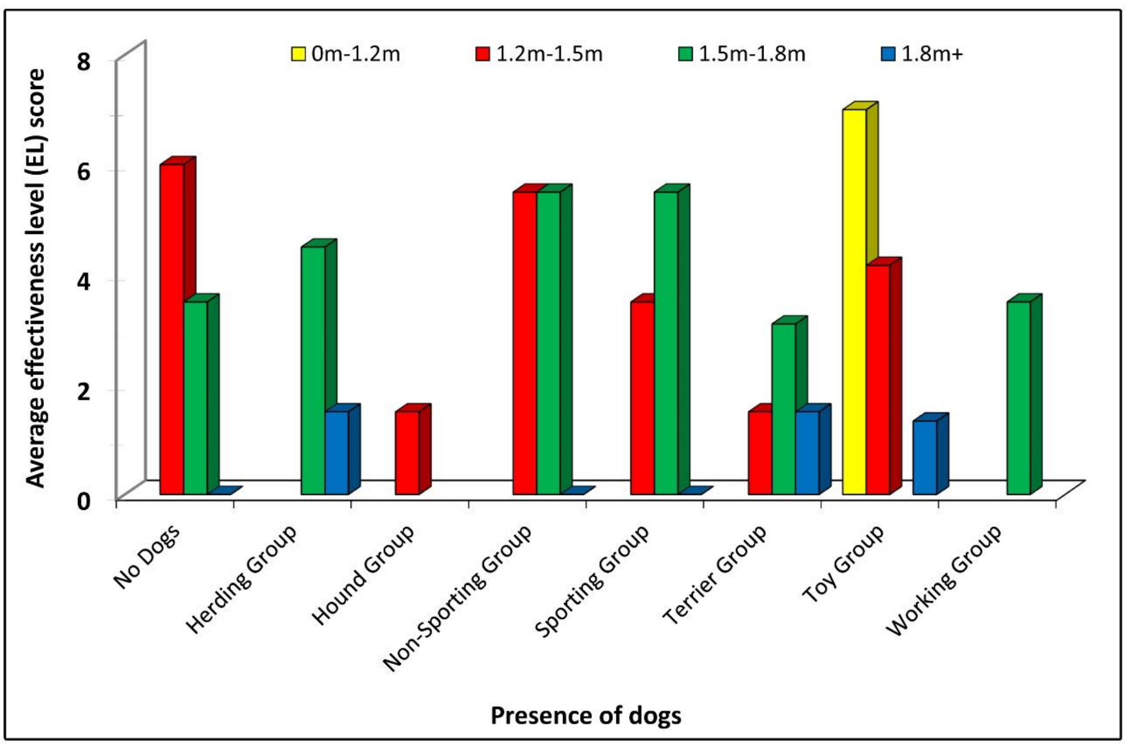
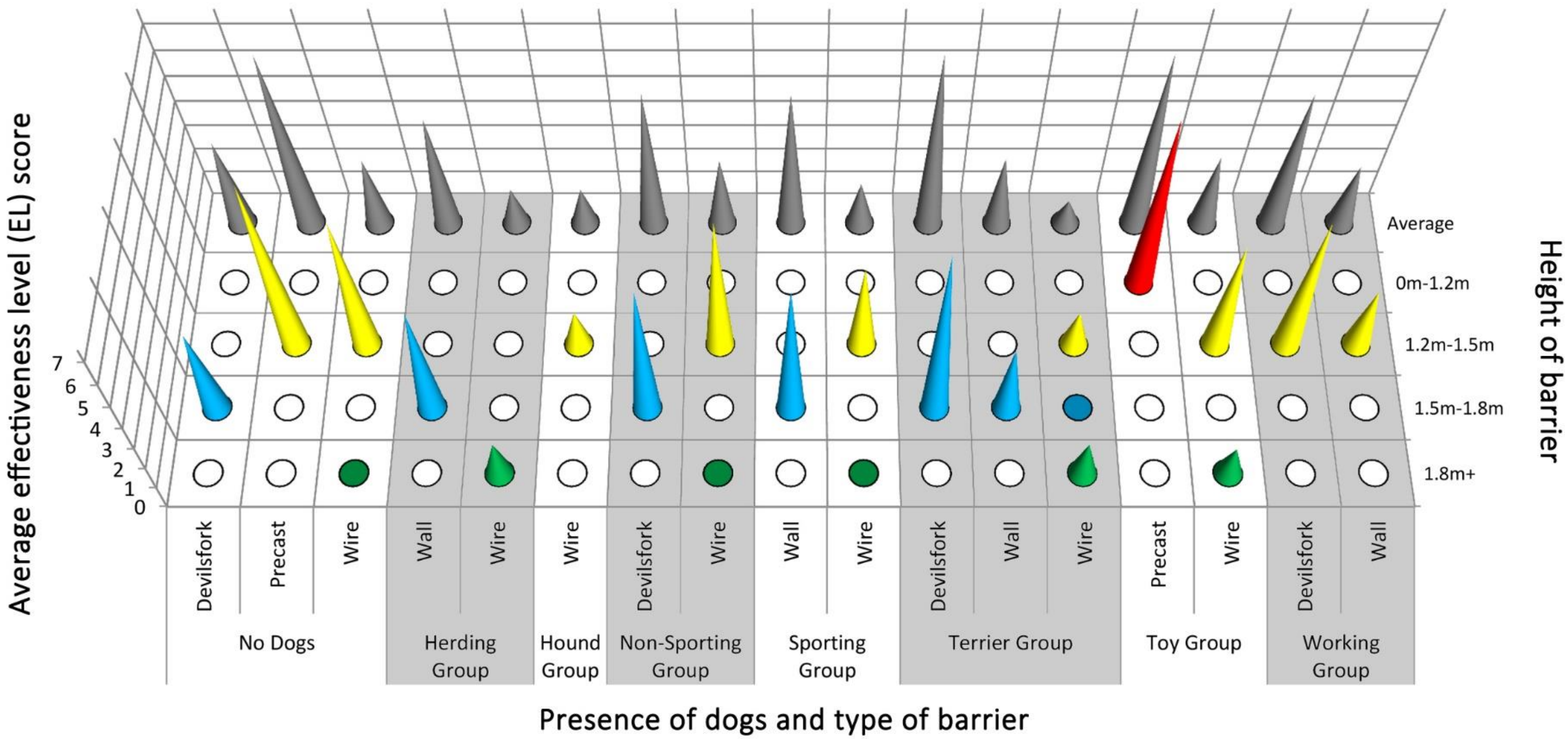


Figure 7.10 The effectiveness level of different dog groups in combination with a barrier of a specific height.

Wire fences and brick walls seem to be more effective than precast concrete walls or devils fork fences when combined with the other variables. In order to determine which barrier, wire fence or brick wall, were most effective the combination of dog groups, barrier types and barrier heights were tested (Fig. 7.11). This triple combination once again confirms that the effectiveness increased as the barrier height increased. When comparing dog groups and barrier types at a specific height - dog groups when combined with wire fences were more effective than the dog group and brick wall combination - proving wire fences are more effective than brick walls, and consequently the most effective barrier type. Dogs from the hound group were most effective in preventing or limiting hyrax invasions, followed by dogs from the terrier and sporting groups.

Although wire fences were proven most effective, it still had to be determined what size of aperture, of these wire fences, when combined with dog groups would be the most effective. The EL scores of wire fences with an aperture smaller than 50 mm were not significantly different ($p > 0.05$) [ANOVA; d.f. = 1; F = 0.051; p = 0.83] [KRUSKAL-WALLIS; d.f. = 1; H = 0.141; p = 0.71] from wire fences with an aperture larger than 50 mm, the effectiveness however, increased as wire fences increased in height. This suggests that the aperture of wire fences did not have a noticeable influence on the effectiveness.



	No Dogs			Herding Group		Hound Group	Non-Sporting Group		Sporting Group		Terrier Group			Toy Group		Working Group	
	Devilsfork	Precast	Wire	Wall	Wire	Wire	Devilsfork	Wire	Wall	Wire	Devilsfork	Wall	Wire	Precast	Wire	Devilsfork	Wall
1.8m+			0.00		1.50			0.00		0.00			1.50		1.25		
1.5m-1.8m	3.50			4.50			5.50		5.50		7.00	2.83	0.00				
1.2m-1.5m		7.00	5.50			1.50		5.50		3.50			1.50		4.50	5.50	2.50
0m-1.2m														7.00			
Average	3.50	7.00	2.75	4.50	1.50	1.50	5.50	2.75	5.50	1.75	7.00	2.83	1.00	7.00	2.88	5.50	2.50

Figure 7.11 The effectiveness level of different dog groups in combination with several barrier types and heights.

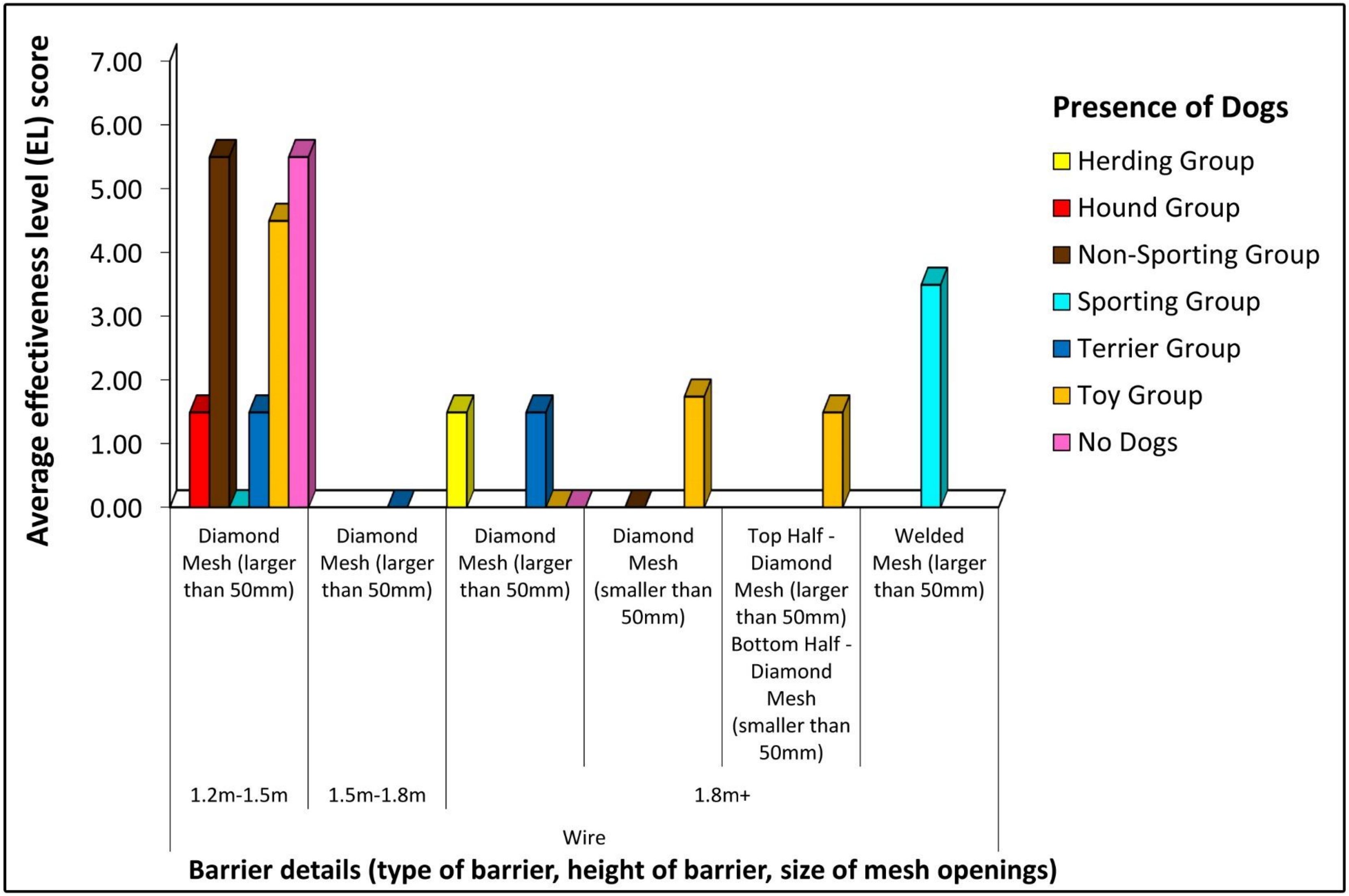


Figure 7.12 The effectiveness of different dog groups in combination with wire fences, taking different heights and mesh openings of different sizes into account.

7.1.1.4 Modifications to fences by property owners

During 2011, after sharing the questionnaire results with the homeowners, five homeowners made modifications to their barriers according to these results. A summary of these modifications and the effect they had on the number of hyrax sightings can be seen in Table 7.5 & Table 7.6.

After modifications, the barriers of three homeowners fell in the category of open barriers, containing openings or gaps (Table 7.5). Homeowner A replaced the 1.2 m – 1.5 m wire fence with a wire fence higher than 1.8 m. The aperture size was also decreased to less than 50 mm. An additional overhang was added to the fence. These modifications lowered the EL score at this property with 79%. Homeowner B replaced the precast concrete wall enclosing the property with a wire fence that was a little over 2 m in height with an aperture smaller than 50 mm. This change decreased the EL score at this property with 50%. Homeowner C took down the 1.2 m – 1.5 m wire fence with an aperture larger than 50 mm, which enclosed his property, erected a wire fence higher than 1.8 m. The bottom half had an aperture smaller than 50 mm, and the top half an aperture larger than 50mm. This change reduced the EL score at this property by 28%.

After modifications, the barriers of two homeowners fell in the category of solid barriers (Table 7.6). Homeowner D replaced the precast concrete walls surrounding the property with a 1.5 – 1.8 m brick wall, not plastered, with an overhang at the top and also acquired two Jack Russel terriers. These changes decreased the EL score of this property by 78%. The only adjustment made by homeowner E was the addition of an overhang on top of the 1.5 m – 1.8 m plastered brick wall. This change reduced the EL score at this property by 28%.

After modifications were made in 2011, the population size was estimated again during 2012. Rock hyraxes at the Heuwelsig site decreased in body mass (*vide* Fig. 6.4) since 2011. Individuals at the Heuwelsig site, prior to modifications during 2011, and at Woodland Hills Wildlife Estate site in 2013, where no preventive measures were implemented, had an average body mass similar to that of the population at Kranskop (*vide* Fig. 6.4). The decrease in body mass could have been attributed to these modifications preventing hyraxes to enter properties to feed, but the increase in population size from 2011 to 2012 could also have played a part in decreasing the body mass. The decrease in EL score demonstrates that these preventive measures were indeed effective.

Table 7.5: Summary of the responses by the owners living on a property surrounded by a barrier which contains openings or gaps.

	Homeowner A		Homeowner B		Homeowner C	
	Before	After	Before	After	Before	After
Fence (Yes or No)	Yes	Yes	Yes	Yes	Yes	Yes
Type of fence	Wire Fence	Wire Fence	Precast Wall	Wire Fence	Wire Fence	Wire Fence
Height of fence	1.2m - 1.5m	> 1.8m	1.2m - 1.5m	> 1.8m	1.2m - 1.5m	> 1.8m
Type of wire fence	Diamond Mesh (larger than 50mm)	Diamond Mesh (smaller than 50mm)	n/a	Diamond Mesh (smaller than 50mm)	Diamond Mesh (larger than 50mm)	Top Half - Diamond Mesh (larger than 50mm) Bottom Half - Diamond Mesh (smaller than 50mm)
Overhang at top of fence (Yes or No)	No	Yes	No	No	No	No
Electric Fence in addition to regular fence (Yes or No)	No	No	No	No	No	No
Dogs Present (Yes or No)	Yes	Yes	Yes	Yes	Yes	Yes
Breed of the dog/s	English Bulldog & Miniature Pincher	English Bulldog & Miniature Pincher	Yorkshire Terrier & Chihuahua	Yorkshire Terrier & Chihuahua	Pug & Miniature Pincher	Pekingese, Pug & Miniature Pincher
Days per week of hyraxes sightings per property	**5 or 6**	**0**	**7**	**3 or 4**	**3 or 4**	**1 or 2**
EL Score	**5.5**	**0**	**7**	**3.5**	**3.5**	**1.5**
% change	**79%**	**0%**	**100%**	**50%**	**50%**	**22%**

Table 7.6: Summary of the responses by the owners living on a property surrounded by a solid barrier.

	Homeowner D		Homeowner E	
	Before	After	Before	After
Fence (Yes or No)	Yes	Yes	Yes	Yes
Type of fence	Precast Wall	Wall	Wall	Wall
Height of fence	1m-1.2m	1.5m - 1.8m	1.5m - 1.8m	1.5m - 1.8m
Wall plastered (Yes or No)	n/a	No	Yes	Yes
Overhang at top of fence (Yes or No)	No	Yes	No	Yes
Electric Fence in addition to regular fence (Yes or No)	Yes	Yes	Yes	Yes
Dogs Present (Yes or No)	No	Yes	Yes	Yes
Breed of the dog/s	no dogs	Jack Russel Terrier	Rottweiler	Rottweiler
Days per week of hyraxes sightings per property	**7**	**1 or 2**	**3 or 4**	**1 or 2**
EL Score	**7**	**1.5**	**3.5**	**1.5**
% change	**100%**	**22%**	**50%**	**22%**

7.1.1.5 Supplementary Feeding

Daily counts of rock hyraxes at the 23 properties, of the homeowners who completed the survey, were done for a period of one week prior to the provision of supplementary feed, which consisted of chopped vegetables, chopped fruits and rabbit pellets, as well as two consecutive weeks during the time supplementary food was provided. From this data an average number of rock hyraxes per property per day were calculated for both periods. The average number of individuals counted at properties prior to the feeding experiment ($\bar{x}$ 4.1 ± 0.7 SE) was not significantly different ($p > 0.05$) [ANOVA; d.f. = 1; F = 0.60; p = 0.448] [KRUSKAL-WALLIS; d.f. = 1; H = 0.736; p = 0.391] to the average number of individuals counted at properties during the feeding experiment ($\bar{x}$ 3.8 ± 0.7 SE) (Fig. 7.13). The average number of individuals counted, on the days when feed were presented, were slightly lower ($\bar{x}$ 3.7 ± 0.7 SE) than the number counted during non-feeding days ($\bar{x}$ 3.9 ± 0.7 SE) (Fig. 7.13). Supplementary feeding was thus ineffective in keeping hyraxes from entering properties.

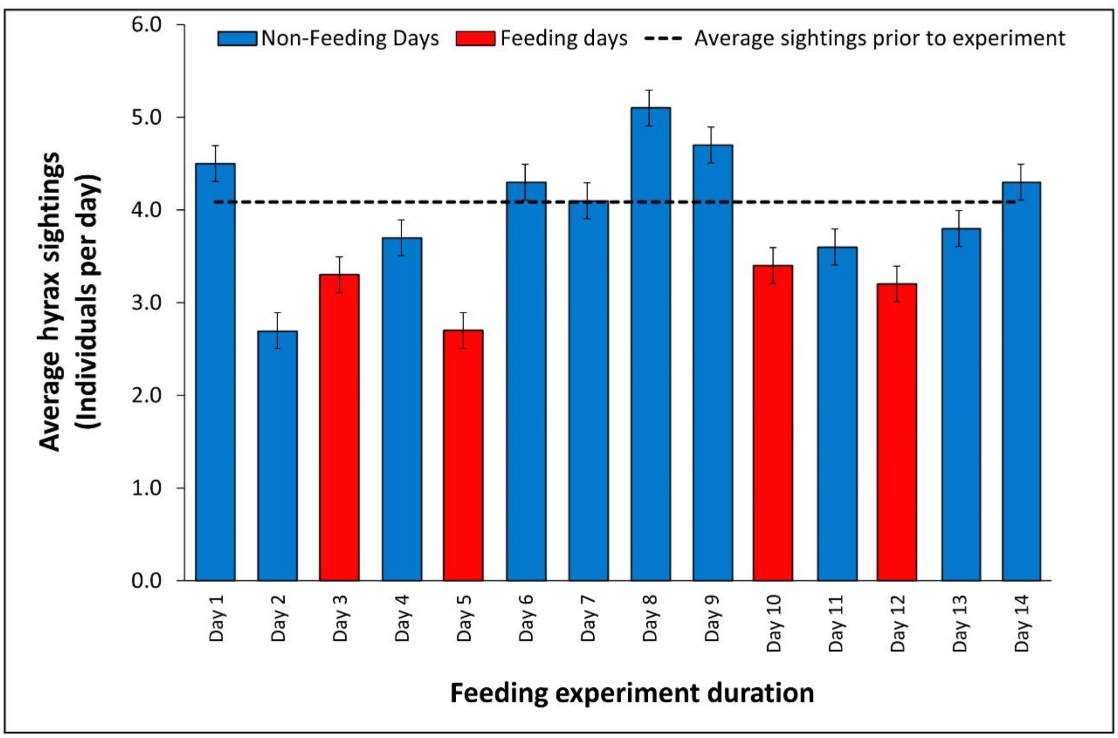


Fig 7.13 Number of hyrax sightings within properties during the two week feeding experiment. Red bars indicate the days on which feed was presented at the feeding stations and blue bars indicate the non-feeding days.

7.1.2 Population Management

7.1.2.1 Introduction of natural predators

The hyrax population at the Heuwelsig Conservancy was estimated at 100 individuals during June 2012 (*vide* Table 6.2). During February 2013, 30 rock hyraxes were translocated from this site to the release site (see 7.1.2.2). During the following month, March 2013, a female caracal was captured on a livestock farm by Free State Nature Conservation and released at the Heuwelsig Conservancy. An additional 30 rock hyraxes were translocated to the release site at Kwaggafontein during May 2013. Therefore translocation accounts for a population decrease of 60 individuals.

After translocations and the introduction of a natural predator the hyrax population was estimated at 34 individuals [95% upper CL (Nu) = 88] in November 2013, and at 28 individuals [95% upper CL (Nu) = 64] in December 2013 (Table 6.2). Using these population estimates as basis, the introduction of a natural predator appeared to be successful since a decrease was seen in the population of at least 6 – 12 hyraxes from March 2013 to December 2013, as a result of predation and/or natural deaths. Considering the number of hyraxes translocated during February and May 2013, it is still difficult to make a reliable estimation of losses due to predation since additional births at this site could have occurred from November 2012 to April 2013.

Caracals normally capture around 15 or 16 rock hyraxes per year (Palmer & Fairall 1988). This number is suspected to be larger for the present study owing to the lack of other prey species normally utilised by caracals. The number of urban bird species and smaller mammals, which could be preyed upon is also unknown. In earlier literature it was stated that caracals do not return to previous catches and do not feed on carrion (Pringle & Pringle 1979). In another study, however, it was observed that a caracal would return to its kill (Grobler 1981). The same observation was made during the present study when a caracal left a rock hyrax kill just to return a day later and feed on the carcass again. This behaviour might be evidence of the caracal at the Heuwelsig site, fully utilising the animals it prey upon due to the lack of other prey species.

Assuming that the rate of decrease in the hyrax numbers will continue as current; the population at the Heuwelsig site will have to be regularly monitored in order to determine if the prey animals available will be sufficient to maintain the need of the predator. Therefore the introduction of predators in order to maintain populations will have to be monitored on a regular basis.

7.1.2.2 Translocation

Translocation of several species had been completed in previous studies with various levels of success (Stenseth 1981; Hoeck 1982; Crawford & Fairall 1984; Hoeck 1989; Banks *et al.* 2002; Wimberger *et al.* 2009). Attempts to translocate rock hyraxes were mostly unsuccessful, however, Hoeck (1982) reported successful translocations over the long term.

Many factors can influence the success of translocation. According to Adams *et al.* (2004) researchers have to complete all processes as fast as possible, although this could increase the amount of exposure to stressing factors it also decreases the duration an individual is exposed to these factors. Various researchers reported that animals may find it difficult to find food after translocation (Heinrichs & Richard 1999; Richard *et al.* 2002; Crespi & Denver 2005; Gouirand & Matuszewich 2005). Respective studies by Banks *et al.* (2002) and Gusset *et al.* (2006) mentioned that group disintegration may result in increased predation of these released individuals. Wimberger *et al.* (2009) attributes this lack of group cohesion to incorrect group compositions, possible stress factors during capture and captivity of individuals and the type of release. Bright & Morris (1994) suggested that hard release may result in individuals dispersing from the release site in order to find food, it is thus important to provide food at the release site on the day of the release.

During the post-release period hyraxes are extremely vulnerable to predation when dispersing (Hoeck 1982) or when trying to find suitable refuges (Biggens *et al.* 1999; Truett et al 2001). The vulnerability of these individuals could have increased due to small group sizes and group disintegration upon release (Hoeck 1975) or when rock hyraxes is required to move away from refuges in order to feed (Druce *et al.* 2006). Translocated individuals might be disoriented at the new release site and start to move away from cover and protected areas, thus exposing these animals to predation even more (Carrie *et al.* 1999; Mosillo *et al.* 1999; Moehrenschlager & Macdonald 2003; Adams *et al.* 2004). Due to the new, unknown location, hyraxes might not have sufficient knowledge of were to find refuges, making it difficult to escape from predators (Mesa *et al.* 1998; Pérez-Tris *et al.* 2004; Sundell *et al.* 2004). According to Jordan (2002), during soft release, individuals will have a chance to get to know a specific area at the release site, which will allow these individuals to have a improved chance of escaping predators. However, Banks *et al.* (2002) suggest that soft release might actually attract more predators since there will be an increase in activity and scent of prey individuals in the temporary holding cage to be placed at the release site.

In order to improve the success of introductions Wimberger *et al.* (2009) suggested that a thorough estimation of predators in the area be conducted, that hyraxes only be captured during the dry season in order to improve capture success and that a soft release should be considered.

During this study a total of 226 rock hyraxes where translocated from residential areas to the release site. A total of 60 hyraxes were captured at the Heuwelsig site, while a further 166 individuals were captured at the Woodland Hills Wildlife Estate. Captured hyraxes were transported to temporary holding pens where they were kept until a predetermined amount was accumulated, only then were individuals translocated to the release site, Kwaggafontein. Rock hyraxes were translocated in groups, with a composition similar to wild populations, with the largest group consisting of 47 individuals (Table 7.7).

Since Wimberger *et al.* (2009) used both types of release methods, soft and hard, with little difference in the final outcome it seemed that the type of release did not affect the success of translocation. In this study hard release was used. To assist hyraxes in finding food, cabbages and rabbit pellets were left in two to three areas at the release site during the first week. All translocations occurred early morning, thus allowing hyraxes the entire day to find shelter.

The release procedure for the first four groups entailed transport crates being opened one-by-one and releasing individuals at the foot of the outcrop. This type of release might have led to an increase of dispersal of hyraxes. Therefore during the release of the 5th group the release procedure were slightly modified. The new procedure entailed multiple people, standing along the foot of the outcrop, with transport crates positioned in a semi-circle facing towards the outcrop. All transport crates were opened simultaneously, with the hope that this would encourage hyraxes to move as a group. Upon release the rock hyraxes dispersed in multiple directions, probably due to being startled by the persons opening the transport crates, some individuals ran into the veld in the opposite direction than the outcrop, hiding under nearby bushes and between the long grasses.

Upon release of the 6th translocation group hyraxes were carried approximately 15 m uphill, in an attempt to prevent hyraxes from running into the veld, before being released. Transport crates were placed in line and this time all helpers retreated the moment the crates were opened. This time all hyraxes ran uphill. Hyrax continued running uphill or until they found sufficient cover to hide under. All individuals were out of site in a matter of minutes after release.

Table 7.7: Rock hyrax groups translocated during 2013 and 2014 from the Heuwelsig site (HS) and Woodland Hills Wildlife Estate (WHWE). Adult (A), subadults (S), juvenile (j), total (Tot)

Group	Translocation Date	Capture Site	Release Site	Number of Individuals	Males				Females				Male to Female Ratio
					A	S	J	Tot	A	S	J	Tot	
1	2013/02/26	HS	Renosterkop	30	1	1	6	**8**	9	7	6	**22**	1 : 2.75
2	2013/05/16	HS	Bomakop	30	1	6	3	**10**	8	4	8	**20**	1 : 2.00
3	2013/10/04	WHWE	Brandkop Plateau	45	10	8	0	**18**	14	13	0	**27**	1 : 1.50
4	2013/10/18	WHWE	Brandkop Plateau	39	6	7	0	**13**	7	15	4	**26**	1 : 2.00
5	2013/11/21	WHWE	Brandkop Peak	35	7	4	1	**12**	7	10	6	**23**	1 : 1.92
6	2014/09/23	WHWE	Brandkop Peak	47	5	14	0	**19**	9	19	0	**28**	1 : 1.47

The first four groups of rock hyraxes could not be monitored post-translocation. Proper monitoring could only be done for the 5th and 6th translocation groups. Prior to the release of the second, third and fourth groups a brief search was done at the former release sites. The only hyraxes seen during these brief searches was four individuals which were seen at the first release site, Renosterkop, three months after translocation. No rock hyraxes were seen at Bomakop or Brandkop (Plateau) on the next visits.

Prior to the release of the 5th group another brief search was done and 11 rock hyraxes were counted at the peak of Brandkop but none at the plateau. Freeze-branding marks were visible on all 11 individuals therefor it was evident that the individuals released at the plateau of Brandkop have moved and settled at the peak, which provided more crevices and refuges. Hyraxes from the 5th and 6th translocation group, were therefore released near the foot of Brandkop peak.

Results of post-translocation monitoring indicated a decline in rock hyrax numbers from the day of release. The number of individuals fluctuated daily for the first week. After which counts for both groups showed a steady decline in numbers for each of the subsequent monitoring days (Fig. 7.14). Seven individuals, from the 5th group, were seen during the monitoring. It was not possible to determine how many individuals survived until a year after release since the 6th group was released at the same site prior to the 52 week count of the 5th group. The decline in numbers, from the day of release, can be attributed to dispersal of individuals and to predation. Verreaux's eagles were seen at the release, 2 months after the release of the 5th group. Hyraxes were still seen 12 months after releasing the 6th group, proving that translocation was at least successful over the short term. However the constant decline in number of individuals counted from the release day suggests that reintroduction of hyrax at Kwaggafontein was not successful.

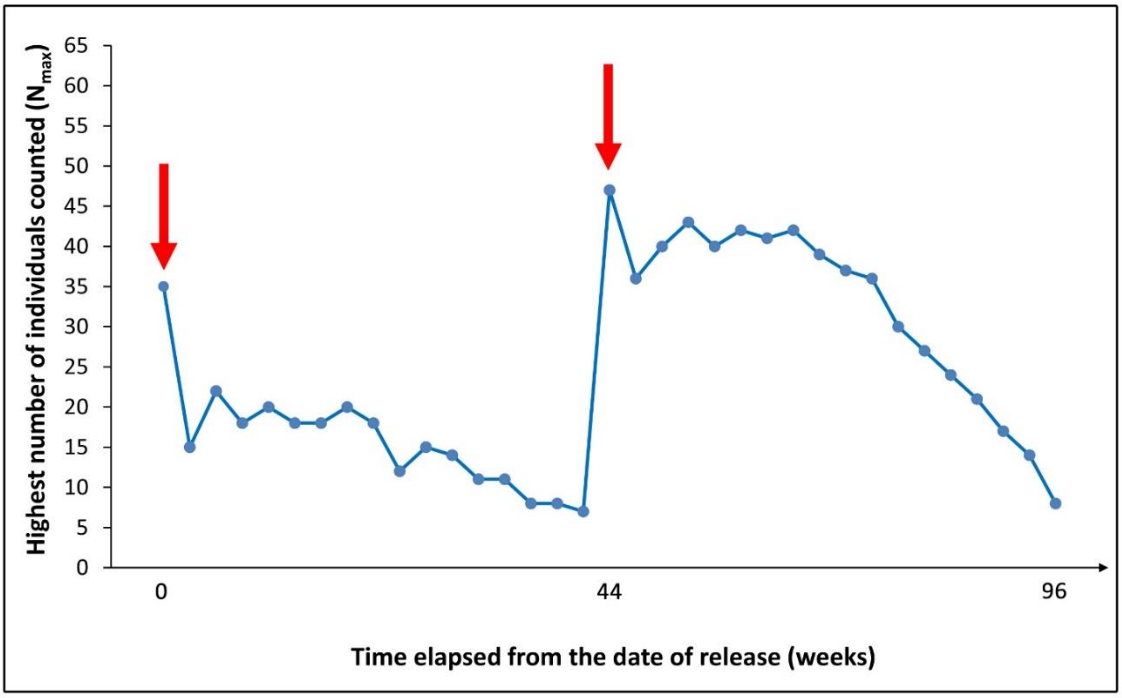


Fig 7.14 Highest number of hyrax counted (N_{max}) on each observation day, over a period of 96 weeks, of post-translocation monitoring and the time of release (red arrows) of 5th and 6th translocated groups.

7.2 Conclusion

Wire fences were the most effective, followed by brick walls. The aperture size of wire fences did not have an effect on the EL scores, however, plastered brick walls were more effective than walls that were not plastered. Effectiveness of barriers increased as the height of barriers increased. Of the two fence variables which can be added to the fence, overhangs improved the effectiveness but electric fences had no influence.

Although the presence of dogs lowered the EL score at properties, the number of dogs did not have any influence in the effectiveness. The movement of dogs also influenced the EL score; since dogs that were allowed to move around outside at night were more effective than those kept indoors. Dogs from the hound, terrier and sporting group, were more effective in keeping hyraxes at bay than others.

To further emphasise the influence movement of dogs have on effectiveness one should only have to look at the amount of damage recorded at certain properties. Some properties had dogs from these effective dog groups present, but the owners predominantly kept these dogs inside the house. Which still resulted in high amounts of damages at these properties since the dogs were not able to patrol and thus prevent hyraxes from entering and causing damage at these properties.

From the results it seems that the best combination of preventive methods to have, would be a combination of a wire fence higher than 1.8m, with an overhang at the top, with dogs from either the hound, terrier group or sporting group which are allowed to freely roam the property at night. Supplementary feeding however was unsuccessful as a preventive method.

The assessment of different control methods led to the following conclusions: introduction of a natural predator was successful to control hyrax populations, capturing and translocating rock hyraxes in order to rapidly decrease the number of hyraxes in residential areas was successful, however the translocation and release of these captured individuals were considered unsuccessful since the number of individuals continued to decline over a period of 12 months.

SUMMARY

Frequent reports of rock hyrax (*Procavia capensis*) invasions in residential areas across South Africa prompted an investigation in order to identify and assess invasion prevention and population management methods. Two study sites with the most frequent reports of hyrax invasions, situated in residential areas in Bloemfontein, were selected for this study. For comparison, an additional site, representing hyrax populations from the wild, were included in the study. To gather information regarding the frequency of hyrax intrusions, details on invasion preventive methods, as well as damages and costs of repairs at each of the respective properties, homeowners completed a questionnaire. According to 23 respondents of the questionnaires, wire fences higher than 1.8 m and with apertures smaller than 50 mm were most effective as barriers against hyrax invasions. By adding an overhang to fences, also increased the effectiveness of these barriers. Electric fences did not seem to increase the expected effectiveness of fences. The keeping of dogs as deterrents seem to assist in the prevention of hyrax intrusions although the type of breed had differing results. Dogs from the working groups were more effective than others but those that slept indoors were less effective than those allowed to move around freely during the night. An increase in the number of dogs at properties did not lead to fewer hyrax invasions of premises. The average hyrax sightings of more than four hyraxes per property per day at Heuwelsig resulted in a combined cost, as a direct result of hyrax invasions, of R76 861.00. Although costs towards injuries (R15 650.00) did occur, the cost towards damages of structures (R39 491.00) and gardens (R21 720.00) was the highest. The Robson-Whitlock technique and the Lincoln Index were used in order to establish population densities. In order to identify individual hyraxes during capture and recapture phases, animals were temporary marked, by shaving an area on the rump where after a number was scripted with a permanent marker. Population densities in residential areas were calculated between 175 - 225 % larger than populations in the wild. Uncommon for rock hyraxes, populations in suburban areas also had two distinct birth seasons in one year. This resulted in higher population densities and consequently higher biomass compared to hyrax populations in the wild. The difference in composition within suburban colonies is further demonstrated with a higher percentage of immature individuals present. Unlike typical populations, which have a single territorial male present, residential hyrax populations had multiple adult males within the same home range. Subsequently, typical populations have one male for every two to three females while residential populations have fewer females (one to two) per adult male. Contributing to the higher biomass of suburban hyrax populations is the significantly higher body mass ($p<0.05$) as well as a higher average body condition index of such populations. As part of population control methods, hyraxes that were translocated were freeze branded with liquid nitrogen. Translocation as a population management method was successful since it drastically lowered hyrax numbers in a short time. It is recommended that the compilation of hyraxes be translocated, be representative of a natural population. This method, however, require trapping cages and the constant monitoring of these traps. In addition, trapped hyraxes have to be housed until enough individuals of different genders and ages are caught for translocation. The introduction of natural predators into areas where hyraxes pose to be invasive, seemed to be successful in decreasing population numbers. Constant monitoring of such a predator is however recommended.

OPSOMMING

Gereelde berigte van dassies (*Procavia capensis*) wat woonbuurte reg oor Suid Afrika binnedring, het tot ʼn studie oor die identifisering en evalusie van metodes vir die voorkoming van indringing asook bevolkingsbeheer gelei. Twee studieareas, geleë in woonbuurte van Bloemfontein waar die meeste berigte oor dassie indringing voorgekom het, is as studiegebiede gekies. Vir vergelykende doeleindes is ʼn bykomende gebied, wat verteenwoordigend is van natuurlike dassiebevolkings, in die studie ingesluit. Ten einde inligting rakende die voorkomsfrekwensie, besonderhede rakende beheermaatreëls teen indringing asook skade en kostes verbonde aan die herstel daarvan in te samel, het inwoners ʼn vraelys voltooi. Volgens 23 respondente is draadheinings hoër as 1.8 m, met maasgrootte kleiner as 50 mm mees effektief as versperring teen die indringing van dassies. Die byvoeging van ʼn oorhang aan die bokant van heinings verhoog die effektiwiteit van diesulke versperrings. Dit blyk dat geëlektrifiseerde heinings nie, soos verwag, die effektiwiteit van heinings verhoog nie. Alhoewel die onderskeie rasse verskillende resultate toon, blyk die algehele resultate ondersteunend te wees van die feit dat honde as afskrikmiddel in die voorkoming van dassie besettings kan dien. Meer as vier dassie waarnemings is op ʼn daaglikse basis by elke eiendom in Heuwelsig aangeteken. Skade aan eiendomme as direkte gevolg van dassie besettings het gelei tot gesamentlike herstelkostes van sowat R76 861.00. Alhoewel kostes ten opsigte van die behandeling van beserings (R15 650.00) wel voorgekom het, was die koste ten opsigte van die beskadiging van strukture (R39 491,00) en tuine (R21 720,00) die hoogste. Die Robson-Whitlock tegniek en die Lincoln Indeks is gebruik om bevolkingsdigthede te bepaal. Ten einde identifikasie van individuele dassies tydens die vang en hervangs fases moontlik te maak, is tydelike merke op die kruis van die dassies geskeer waarna ʼn getal met ʼn permanente merkpen aangebring is. Bevolkingsdigthede in woonbuurte is tussen 175 - 225% groter as bevolkings in die natuur bereken. Alhoewel ongewoon vir dassies, het bevolkings in hierdie woonbuurte twee afsonderlike geboorte seisoene in een jaar gehad. Dit het tot groter bevolkingsdigthede asook hoër biomassas, vergeleke met bevolkings in die natuur, gelei.

Verskille in die samestelling van kolonies in woongebiede is deur hoër persentasies onvolwasse individue beklemtoon. In teenstelling met tipiese bevolkings, waar ʼn enkele territoriale mannetjie teenwoordig is, het dassie bevolkings in woonbuurte verskeie volwasse mannetjies in dieselfde tuisgebied. Vervolgens het tipiese bevolkings een manlike individu vir elke twee tot drie vroulike individue waar populasies in woonbuurte minder vroulike individue (een tot twee) vir elke mannetjie het. Wat bygedra het tot die hoër biomassa van dassie bevolkings in woonbuurte is die aansienlike hoër liggaamsmassa ($p<0.05$), asook ʼn hoër gemiddelde liggaamskondisie indeks van sulke bevolkings. As deel van die bevolkingsbeheer, is dassies hervestig. Dassies is deur middel van vriesbrand met vloeibare stikstof, vir identifikasie doeleindes gemerk voor hervestiging. Hervestiging was suksesvol as 'n bevolkingbeheer metode, aangesien hierdie metode dassie getalle drasties, in ʼn kort tyd, verlaag het. Dit word aanbeveel dat die samestelling van dassie groepe wat hervestig word, verteenwoordigend van 'n natuurlike bevolking is. Hierdie metode vereis egter die gebruik van vanghokke wat op ʼn gereëlde basis gemoniteer moet word. Dassies moet verder vir ʼn tydperk aangehou totdat die voorafbepaalde aantal individue, van verskillende geslagte en ouderdomme, gevang is. Die vrylating van natuurlike roofdiere in woongebiede waar dassie besettings moontlik plaasvind, blyk suksesvol te wees in die vermindering van bevolkingsgetalle. Konstante monitering van hierdie roofdiere word egter aanbeveel.

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Appendices

Appendix 1: Invasion Assessment Survey Questionnaire presented to the 23 homeowners from the Heuwelsig Residential Area who live adjacent or across the street from the Heuwelsig Site.

UFS Hyrax Project Questionnaire / UV Dassie Projek Vraelys

This questionnaire was compiled by members of the Department of Zoology and Entomology, University of the Free State, to obtain specific information and must be answered as completely and honestly as possible.

Hierdie vraelys is opgestel deur lede van die Departement Dierkunde en Entomologie, Universiteit van die Vrystaat, om spesifieke inligting in te win en moet so volledig en eerlik as moontlik beantwoord word.

Name & Surname / Naam & Van

Address / Adres

Telephone Number / Telefoon Nommer

Cellphone Number / Selfoon Nommer

E-mail / E-pos

This study is done in collaboration with the following organisations:
Hierdie studie word gedoen in samewerking met die volgende organisasies:

1. How many DAYS OF THE WEEK do you see hyraxes in your yard? (Pick only one)
1. Hoeveel DAE VAN DIE WEEK sien u dassies in u erf ? (Kies slegs een)

1 of 2 ☐ 3 of 4 ☐ 5 of 6 ☐ daily / elke dag ☐ never / nooit ☐

2. How many TIMES PER WEEK do you see hyraxes? (Pick only one)
2. Hoeveel KEER PER WEEK sien u dassies in u erf? (Kies slegs een)

1-5 ☐ 6-10 ☐ 11-15 ☐ > 15 ☐ never / nooit ☐

3. How many TIMES PER DAY do you see hyraxes? (Pick only one)
3. Hoeveel KEER PER DAG sien u dassies in u erf? (Kies slegs een)

1 ☐ 2-3 ☐ 4-5 ☐ > 5 ☐ never / nooit ☐

4. What is the AVERAGE NUMBER of hyraxes that you see in your property per day? (Pick only one)
4. Wat is die GEMIDDELDE GETAL dassies wat u daagliks in u erf sien? (Kies slegs een)

None / Geen ☐ 1-3 ☐ 4-6 ☐ 7-9 ☐ 10-20 ☐ > 20 ☐

5. During what part of the day do you see hyraxes in your yard? (Can pick more than one)
5. Watter tye van die dag is die dassies in u erf? (Indien meer as een van toepassing verduidelik hoe)

morning	**afternoon**	**evening**	**early morning**	
6h-12h ☐	12h-18h ☐	18h-24h ☐	24h-6h ☐	never / nooit ☐
oggend	**middag**	**aand**	**vroeg oggend**	

6. Do you have any dogs? (Pick only one)
6. Het u enige honde? (Kies slegs een)

Yes / Ja ☐ No / Nee ☐

7. If Yes, provide details of the dogs (number and breed/s)
7. Indien Ja, verskaf besonderhede van die honde (hoeveelheid en ras/se)

7.1) Number of dogs / Hoeveelheid honde		7.2) Number of Breed(s) / Aantal Ras(se)	

Appendix 1: continued

8. Are the dogs free to move around at night or do they sleep in the house / in a cage?
8. Slaap u honde snags in die huis of is hulle vry om rond te beweeg soos hul wil?

In house or cages / huis of hokke — In ☐ Can move around freely / Kan vrylik rond beweeg ☐ Both / Beide ☐

9. Is there a fence around your property? (Pick only one)
9. Is u erf omhein? (Kies slegs een)

Yes / Ja ☐ No / Nee ☐

9.1. If yes, what type of fence? (If more than one applicable explains how)
9.1 Indien ja, hoe is u erf omhein? (Indien meer as een van toepassing verduidelik hoe)

Wire Fence / Draad heining ☐ Wall / Muur ☐ Prefab ☐ Devilsfork ☐

10. If you selected the wall option in 9.1 is this wall plastered or not
10. Indien u die muur opsie gekies het in 9.1 is hierdie muur gepleister of nie

Yes / Ja ☐ No / Nee ☐

11. What is the height of your fence? (If more than one applicable explains how)
11. Wat is die hoogte van die omheining? (Indien meer as een van toepassing verduidelik hoe)

< 1m ☐ 1m - 1.2m ☐ 1.2m - 1.5m ☐ 1.5m - 1.8m ☐ > 1.8m ☐

12. If it is a wire fence, what type of wire fence is it? (If more than one applicable explains how)
12. Indien die erf met 'n draad heining omhein is, merk die gepaste blok: (Indien meer as een van toepassing verduidelik hoe)

Diamond mesh smaller than 50 mm
Jakkalsproef (diamond mesh) kleiner as 50mm ☐

Diamond mesh larger than 50 mm
Jakkalsproef (diamond mesh) groter as 50mm ☐

Wired Mesh smaller than 50 mm
Wired Mesh kleiner as 50mm ☐

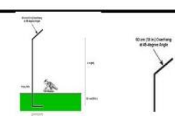
Wired Mesh larger than 50 mm
Wired Mesh groter as 50mm ☐

Boundary Fence (No Diamond Mesh)
Grensomheining (Geen jakkalsproef) ☐ ______

13. Does the fence have an overhang?
13. Het die heining 'n oorhang aan die bokant?

Yes / Ja ☐ No / Nee ☐

See pictures for reference / Sien prentes vir verwysing



14. Electric wires on or next to fence?
14. Het die heining elektriese drade aan of bo-op die heining?

Yes / Ja ☐ No / Nee ☐

15. What are the hyraxes doing when you see them? (More than one can be marked)
15. Wat is die aktiwiteit van die dassies wanneer u hul sien? (Meer as een kan gemerk word)

Feeding on plants within the garden / Vreet aan plante in die tuin ☐

Sunbathing on walls or on the roof / Lê op die dak of op 'n muur en bak in die son ☐

Chasing each other or playing / Jaag mekaar rondof speel ☐

16. What is the size of the hyraxes you see? (More than one option can be marked)
16. Hoe groot is die dassies wat u in u tuine sien? (Meer as een opsie kan gemerk word)

Immature / Onvolwasse < 30cm ☐ Adult / Volwasse > 30 cm ☐ Not sure / Onseker ☐

Appendix 1: continued

17. Select the category of damages caused by hyraxes at your property. (More than one option can be marked) Give a short description of the damages.
17. Kies die kategorie van skade aangerig, deur dassies, by u eiendom. (Meer as een opsie kan gemerk word) Gee 'n kort beskrywing van die skade.

17.1 House structure (paint, leaking roofs, damaged ceilings, etc.)
17.1 Huis se struktuur (verf, dakke wat lek, beskadigde plafonne, ens.) ☐

17.2 Garden (eaten plants, trampled and those that had to be replaced, etc.)
17.2 Tuin (plante gevreet, vertrap en wat vervang moet word, ens.) ☐

17.3 People/Pets (any medical costs due to injuries caused by hyraxes)
17.3 Mense/Troeteldiere (enige mediese kostes a.g.v. beserings veroorsaak deur dassies) ☐

17.1

17.2

17.3

18. What were the cost towards repairs of these damages during the past 12 months? (If not sure, please do not leave unanswered, rather provide an estimated value)
18. Wat was die koste van herstelwerk van skade aangerig gedurende die afgelope 12 maande? (Indien nie seker gee eerder 'n geskatte waarde as om oop te los)

17.1 House structure (paint, leaking roofs, damaged ceilings, etc.)
17.1 Huis se struktuur (verf, dakke wat lek, beskadigde plafonne, ens.) R ____

17.2 Garden (eaten plants, trampled and those that had to be replaced, etc.)
17.2 Tuin (plante gevreet, vertrap en wat vervang moet word, ens.) R ____

17.3 People/Pets (any medical costs due to injuries caused by hyraxes)
17.3 Mense/Troeteldiere (enige mediese kostes a.g.v. beserings veroorsaak deur dassies) R ____

18. If you have noticed anything unusual or interesting, feel free to mention it here...
18. Indien u enigeiets ongewoon of interessant opgemerk het, voel vry om dit hier te noem...

____

____

____

____

____

Thank you for taking the time to complete this survey. We truly value the information you have provided! Dankie vir die tyd wat u geneem het om hierdie vraelys te voltooi. Ons opregte waardering vir die inligting wat u verskaf het!

Appendix 2: A summary of all properties, with barriers which contains openings or gaps, indicating the effectiveness of these barriers in combination with different preventive methods.

Type of fence	Wire Fence [43%]									Devilsfork [26%]		
Height of fence	1.2m-1.5m [60%]					1.5m-1.8m [10%]	1.8m+ [30%]			1.5m-1.8m [100%]		
Type of wire fence	Diamond Mesh (larger than 50mm) [83%]				Welded Mesh (smaller than 50mm) [17%]	Diamond Mesh (larger than 50mm) [100%]	Diamond Mesh (smaller than 50mm) [33%]	Diamond Mesh (larger than 50mm) [67%]		n/a		
Overhang at top of fence (Yes or No)	No [100%]				No [100%]	No [100%]	No [100%]	**Yes** [50%]	No [50%]	No [100%]		
Electric Fence in addition to regular	**Yes** [20%]	No [80%]			**Yes** [100%]	**Yes** [100%]	No [100%]	No [100%]	No [100%]	No [100%]		
Dogs Present (Yes or No)	No [100%]	**Yes** [75%]		No [25%]	**Yes** [100%]	**Yes** [100%]	**Yes** [100%]	No [100%]	**Yes** [100%]	**Yes** [67%]		No [33%]
Breed of the dog/s	no dogs	Greyhound & Fox Terrier	English Bulldog & Miniature Pincher	no dogs	Labrador Retriever	Jack Russel Terrier	Labrador Retriever & Pekingese	no dogs	Border Collie & Jack Russel Terrier	Saint Bernard & Dalmation	Scottish Terriers	no dogs
Dogs predominantly kept in yard or in house	n/a	Yard	House	n/a	Yard	Yard	Yard	n/a	Yard	Yard	Yard	n/a
Days per week that hyraxes were sighted on the property	**5 or 6**	**1 or 2**	**5 or 6**	**5 or 6**	**3 or 4**	**0**	**0**	**0**	**1 or 2**	**5 or 6**	**7**	**3 or 4**

Appendix 3: A summary of all properties, with solid barriers, indicating the effectiveness of these barriers in combination with different preventive methods.

Type of fence	Brick Wall [22%]					Precast Wall [9%]	
Height of fence	1.5m-1.8m [100%]					0m-1.2m [50%]	1.2m-1.5m [50%]
Wall plastered (Yes or No)	**Yes** [60%]			No [40%]		n/a	n/a
Overhang at top of fence (Yes or No)	No [100%]			No [100%]		No [100%]	No [100%]
Electric Fence in addition to regular	**Yes** [60%]		No [40%]	**Yes** [50%]	No [50%]	No [100%]	**Yes** [100%]
Dogs Present (Yes or No)	**Yes** [100%]		**Yes** [100%]	**Yes** [100%]	**Yes** [100%]	**Yes** [100%]	No [100%]
Breed of the dog/s	Bull Terrier	Rottweiler	German Sheperd	Border Collie & Labrador Retriever	Jack Russel Terriers	Yorkshire Terrier & Chihuahua	no dogs
Dogs predominantly kept in yard or in house	Yard	Yard	Yard	House	House	House	n/a
Days per week that hyraxes were sighted on the property	**1 or 2**	**3 or 4**	**3 or 4**	**5 or 6**	**5 or 6**	**7**	**7**

Appendix 4: Research Article – Population management of rock hyraxes (*Procavia capensis*) in residential areas.

Research Article

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Population management of rock hyraxes (*Procavia capensis*) in residential areas†

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Abstract

BACKGROUND: Frequent reports of rock hyrax (*Procavia capensis*) invasions in residential areas prompted an investigation of this problem in order to identify possible solutions. From these reports, problem areas in South Africa were identified, and sites within the Free State Province were selected for this study. At these sites, rock hyrax populations demonstrate an unusual annual increase. This increase has led to a food and habitat shortage, forcing individuals into residential areas in search of additional refuges and food sources. In order to manage populations, several preventive as well as control methods have been assessed and implemented. Population densities were determined using the Lincoln index and the Robson–Whitlock technique. Wild populations were included in the study for comparison purposes.

RESULTS: Additional resources within residential areas have facilitated populations to grow much larger, in some instances exceeding the natural limits (30–40 individuals) by 470%. This influx contributes to human–wildlife conflict. With the use of relocation, populations were reduced within 3 months.

DISCUSSION: Preventive methods have shown various levels of success. Specific combinations of these methods have proved to be more effective than others. The strategy of capture and relocation of individuals for rapid reduction in the population has been successful. Preliminary results show that the establishment of relocated populations is not successful owing to high predation rates. The reintroduction of natural predators for rock hyrax population control appears to have positive results, but this will have to be monitored on a regular basis.

Keywords: *Procavia capensis*; rock hyrax; Lincoln index; Robson–Whitlock technique; population management; relocation

1 INTRODUCTION

People are constantly altering the world and the different habitats within it. These changes result in the destruction and/or alteration of habitats and ecosystems, which can lead to reduced biodiversity.[1] In this process of change and destruction, humans are, however, creating new ecosystems.[2] The increase in human structures and residential areas has several effects on animal life. Some species (avoider species) will relocate to escape these changes, while other species (exploiter species) will move into the new human habitat, exploiting the additional resources available to them.[3] These exploiter species cause an increased opportunity for human–wildlife interactions, which in turn may lead to human–wildlife conflicts.[3] In South Africa, an increase in residential development next to rocky outcrops is causing a decline in the natural habitat of rock hyraxes (Goosen L, private communication, 2010).

This decrease in natural habitat has led to a decline in natural predators, which have either left the area (avoider species) or been removed by humans, which in turn results in less control of rock hyrax populations. The absence of natural predators seems to have contributed to the increase in rock hyrax populations over the last couple of years (Van Zyl J, private communication, 2010).

Rock hyraxes have many predators,[4,5] including snakes, various raptors, jackals and several cat species, and even mongooses have been recorded to prey upon rock hyrax offspring.[4,5] The top-ranking predators of rock hyraxes are, however, Verreaux's eagles (*Aquila verreauxii*) and martial eagles (*Polemaetus bellicosus*), cobras (*Naja* spp.), caracals (*Caracal caracal*) and leopards (*Panthera pardus*).[4,5] Hyraxes form 89–99% of Verreaux's eagle prey in the southern Africa and south-east Africa regions.[6–8]

The presence of parasites and diseases can play a very important role in the regulation of wild mammal populations.[9,10] Ectoparasites recovered from 77 rock hyraxes included ten tick species, four species of biting lice (Ischnocera), two species of sucking lice (Anoplura) and fleas.[11] Endoparasites included Cestodes and *Inermicapsifer* species.[11] In natural environments, rock hyrax populations tend to decrease during periods of drought[12] when food resources are limited, and as a result of this the natural and acquired resistance to parasites may deteriorate because of protein deficiency.[12]

It was expected that the rock hyrax populations in areas adjacent to residential areas would only increase until the habitat could support no further growth, and the lack of resources would lead to a decrease. This, however, was not the case, as rock hyraxes

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expanded their habitat into residential areas. An abundance of food sources in gardens led to a further increase in rock hyrax numbers. The present study on rock hyraxes was conducted at the request of residents and Free State Nature Conservation.

Several methods have been implemented in the past in order to control rock hyrax populations. These methods have included chemical control[13] and culling.[14] Rock hyrax numbers can be controlled by culling large portions of populations in a matter of days. However, this method is not preferred because the problem areas are situated within residential areas and thus require special permission and numerous safety measures (Lamprecht J, private communication, 2012), as it is a criminal offence in South Africa (Firearm Control Act 60 of 2000) to discharge a firearm in a residential area. The reintroduction of natural predators to residential areas might be the solution to the problem and was considered as a possible control method.

Fertility control has also been used with success by several researchers.[15–18] Fertility control, if done properly, can be expensive and will take some time to show results. The method required for this study had to ensure a rapid decrease in rock hyrax numbers in order to address the problem, and therefore fertility control was not considered. Relocation of individuals had been used in previous studies with various levels of success.[8,19–23] Therefore, relocation was also considered as a possible control method. It was decided that culling would be used to control rock hyrax populations only in the event of all other methods failing.

The present study was initiated to provide insight into different methods of control for hyrax populations in residential areas. The aims of this study were to identify methods that might rapidly reduce rock hyrax populations, such as the fencing-off of properties, the removal of rock hyraxes and elevation of predation in order to reduce the possibility of human–wildlife conflict. It was predicted that higher fences and/or walls would be more effective in preventing hyraxes from entering properties, and that homeowners with dogs present at their properties would have fewer invasions. It was also expected that the introduction of natural predators would not be possible at all the sites, and that all sites to be used would have to be inspected prior to the release of natural predators to ensure that these sites would be able to contain predators.

2 MATERIALS AND METHODS

2.1 Study sites

This study focused on suburban residential areas and residential wildlife estates. Two sites, one to represent each of these categories, were selected in the Bloemfontein area. Two sites from natural areas were included for comparison purposes. A release site, to be used for relocation of rock hyraxes as part of the population management process, was identified for the study.

The Heuwelsig Nature Reserve (29° 5′ 20.14″ S, 26° 11′ 55.25″ E) (suburban residential area) encompassed a small nature reserve and a recreational park with a combined area of 15 800 m^2. Situated on the edge of a rocky outcrop within the residential area in the north-western parts of Bloemfontein, the nature reserve was approximately 12 000 m^2. Rock hyraxes were the only mammals (larger than 1 kg) remaining within this nature reserve, as the other wildlife had been removed from this reserve over the last 10 years. An area of approximately 4000 m^2, consisting of large boulders and rocks, was colonised by rock hyraxes.

The Woodland Hills Wildlife Estate (29° 2′ 48.29″ S, 26° 11′ 43.46″ E) (residential wildlife estate) was situated 8.5 km north-west of Bloemfontein, within a wildlife estate of 7 100 000 m^2. Although this wildlife estate had several antelope and other game species, no large terrestrial predator species were present. A large gorge, with several rocky areas in the walls, was situated between the houses and presented several crevices in which rock hyraxes could take refuge.

Rusplaas, a livestock farm 130 km south-west of Bloemfontein (30° 17′ 32.82″ S, 25° 56′ 3.69″ E) (natural area) was approximately 15 100 000 m^2 and had several cliffs and rocky outcrops. The Kranskop colony (30° 18′ 38.30″ S, 25° 55′ 21.20″ E) was situated on the eastern side of a rocky outcrop that had a cliff with several clefts used as refuges by the rock hyraxes. The second colony, the Patroonkop colony (30° 18′ 52.21″ S, 25° 56′ 0.85″ E), was situated on the south-eastern side of a rocky outcrop and only had trees and large boulders as shelter for the rock hyraxes. These rocky outcrops were separated by a valley running between them.

Kwaggafontein Game Farm (29° 6′ 8.25″ S, 26° 6′ 55.98″ E) (release site) offered several rocky outcrops providing suitable habitats for rock hyraxes, but no rock hyraxes had been seen on the farm since 2012 (Barnes D, private communication). This site was situated 7.4 km west of Bloemfontein and covered an area of more than 10 000 000 m^2.

2.2 Capture, population size, population composition and age determination

Ten cages (30 × 30 × 75 cm), with wire mesh sides and a single trap door which was operated by a treadle, were built to the requirements of Free State Nature Conservation to capture rock hyraxes, as previous studies[24–26] had used cages to capture hyraxes with great success. Cages were baited with oranges in the morning and monitored every hour. Cages were placed in areas that had sufficient shade cover during the day, as ambient temperature affects the body temperature of the rock hyrax.[27,28] Trapped rock hyraxes were removed from the cages with a restraining noose. In an attempt to limit the stress of the animals while being handled, a blanket was used to cover each rock hyrax the moment it was removed from the cage, and further handling of individuals, when being marked, was done as quickly as possible.[29] A permit (Permit Number 01/12568) to catch, collect and transport the rock hyrax was obtained from the Free State Department of Economic Development, Tourism and Environmental Affairs (DETEA).

In order to determine the age of rock hyraxes correctly, individuals were measured and weighed when captured. The body mass of individuals and the skull length and skull width were used to determine the age of an individual.[11,30] It was important to determine the age of individuals in order to know the exact composition of populations.

Population estimates were made at the different sites during 2011, 2012 and 2013. Estimates at the suburban residential site were made during June–July 2011, June–July 2012, November 2013 and December 2013, at the natural sites during March–April 2012 and at the residential wildlife estate site during March–April 2013. The Lincoln index[31–33] and the Robson–Whitlock Technique[34,35] were used for these population estimates. The Lincoln index was used to determine population sizes at the suburban residential site, the residential wildlife estate site and the Kranskop site. The Patroonkop site, however, did not allow the use of cages to capture rock hyraxes, and for this site the Robson–Whitlock technique was used. This technique was also used to determine population sizes at the suburban residential site, the residential wildlife estate site and the Kranskop site during the time the Lincoln index was used. This was done in order to

Appendix 4: continued

calibrate methods. Results obtained when both methods were used showed a positive correlation of $R = 0.88$, calculated with Pearson's correlation coefficient.[36–38] The Lincoln index could not be used during the breeding season or when natural predators were present, as one of the assumptions of this method is that the population is closed, i.e. N must be constant, and thus there should be no births or deaths. Therefore, the population size at the suburban residential site was calculated by the Robson–Whitlock Technique after a natural predator was introduced.

This technique is based on recurring counts and the probability that individuals may be seen at any one counting occurrence, with n_{max} representing the highest number and n_{max-1} the second highest number of individuals counted at one occurrence. An approximate upper confidence limit (N_u)[34,39] was also calculated at the 95% [$100(1-\alpha)$] level.

Rock hyraxes were captured and marked during the first phase of the Lincoln index. The marks had to last until the second phase have been completed, which was usually no longer than 1 month. A round patch of 50 mm diameter was shaved on the lower back with the use of electric clippers. A number was written on the shaved patch with a permanent marker to distinguish individuals.

In addition, individuals were freeze branded with a supercooled branding iron made from a copper alloy metal with a branding surface of 10 cm which was cooled with liquid nitrogen and applied for 3–4.5 s to the skin. The mark produced was visible from a distance. This technique had been used with success on small mammals[40] and rock hyraxes before.[8,11,41]

2.3 Population management methods

Several preventive and control methods were observed and tested during this study. This was done at the suburban residential site, as this was one of the areas with the most frequent reports of rock hyrax invasions. Preventive methods had to reduce the number of rock hyrax sightings in residential areas adequately. Control methods had to reduce rock hyrax numbers rapidly and then keep the population within natural limits in order to be regarded as effective or successful.

2.3.1 Preventive methods and questionnaires

Information was gathered from 23 homeowners with the use of a questionnaire in July 2011. Their homes were situated directly adjacent to or across the street from the nature reserve. This questionnaire was created to obtain information (1) regarding the type of fence surrounding the property as well as other structures that might aid in keeping rock hyraxes out, (2) regarding rock hyrax sightings (e.g. times per day, times per week, days per week) and (3) regarding damage caused at properties and the total cost of repairs.

All the properties had fences that could be divided into four distinct categories: wire fences, brick walls, precast walls and devil's fork fences. The effectiveness of these fences was determined by the number of rock hyraxes sighted in each property. In addition to the fences, six properties had electric fences. Observations were done for 1 week at each property to see how rock hyraxes reacted to these electric wires and whether they were harmed in any way. The number of dogs, the breed of dogs and whether the dogs were predominantly kept in the yard or in the house were recorded. The ability of each dog breed to keep rock hyraxes from entering properties was judged on the number of rock hyraxes sighted in each property. Five homeowners made adjustments to their fences according to the results from the questionnaire.

A population estimate, using the Lincoln index, was carried out at the Heuwelsig Nature Reserve during June–July 2011 before any adjustments had been made. Another estimation of population size was done during June–July 2012 after adjustments to the fences were made. The average body mass of rock hyraxes before and after implementation of preventive measures was compared within the suburban residential site and also with the average body mass of individuals from the Kranskop site.

2.3.2 Feeding

Rock hyraxes were fed within the suburban residential site in order to establish whether additional feeding would prevent rock hyraxes from entering residential areas in search of food. Feeding took place twice a week at two feeding locations, roughly 30 m apart and at a central location in relation to the homes. Feed consisted of chopped vegetables, chopped fruits and rabbit pellets (Epol, Johannesburg). Three plastic containers (30 × 15 × 60 cm) with a volume of 27 L each were filled with the chopped vegetables and fruit and divided between the two locations. A 50 kg bag of rabbit pellets was also divided between the feeding locations. A total volume of 40.5 L of chopped fruit and vegetable mix and 25 kg of rabbit pellets was thus placed at every feeding location on a feeding day.

Daily counts of rock hyraxes were done for a week prior to feeding and for two feeding weeks. From these data, the average daily number of rock hyraxes per property was calculated per period.

2.3.3 Control methods

Control methods included the introduction of natural predators and the relocation of hyraxes. In March 2013 a female caracal (*Caracal caracal*) was captured on a livestock farm and introduced at the suburban residential site. A female caracal was used because females have smaller home ranges than males.[42]

In order to capture rock hyraxes for relocation, the methods described in Section 2.2 were used. Once a rock hyrax had been removed from a cage, that individual was immediately placed in a wooden transport crate.

Rock hyraxes were held in captivity at the holding site until a minimum of 30 rock hyraxes were captured. Rock hyraxes were relocated to a site further than 5 km from the release site, as rock hyraxes have been reported to return to their former home ranges.[21]

3 RESULTS

3.1 Capture, population size, population composition and age determination

Populations in residential areas tended to be larger than populations in natural areas (Table 1). The suburban residential site showed a 57% increase in the rock hyrax population, from the time the survey was done in 2011 until the next survey during 2012. Populations in the wild tended to maintain a male-to-female ratio of approximately 1:2. All populations within residential areas had a male-to-female ratio that was lower than the ratio of wild populations (Table 1). Residential populations had numerous adult males present within the same colony (Table 1).

3.2 Population management methods

3.2.1 Preventive methods and questionnaires

The effectiveness of fences was determined by the number of rock hyraxes sighted in each property every day of the week [type of fence, average days per week with hyrax sightings ± SE:

Appendix 4: continued

Table 1. Population estimates of Procavia capensis, calculated using the Lincoln Index and the Robson–Whitlock Technique. Limits are calculated 95% confidence limits. The number of individuals captured during the Lincoln Index, for each sex and age group, are also included

		Lincoln index		Robson–Whitlock				Males			Females		
	Date surveyed	Estimate ± SE	Limits	Estimate	n_{max}	n_{max-1}	N_u	Adults	Subadults	Juveniles	Adults	Subadults	Juveniles
Suburban residential (Heuwelsig)	June 2011	74 ± 10	55–93	70	61	52	232	24	3	2	35	6	3
	June 2012	116 ± 14	89–143	100	88	76	316	20	6	27	21	8	34
	November 2013	–	–	34	31	28	88	–	–	–	–	–	–
	December 2013	–	–	28	26	24	64	–	–	–	–	–	–
Residential wildlife estate (woodland hills)	March 2013	189 ± 48	95–283	102	94	86	246	18	15	26	82	26	23
Natural (Kranskop)	March 2012	29 ± 2	26–32	23	19	15	95	2	7	1	17	3	0
Natural (Patroonkop)	March 2012	–	–	30	30	27	87	–	–	–	–	–	–

devil's fork, 5.38 ± 0.72; precast walls, 7.00 ± 0; walls (plastered), 2.50 ± 0.58; walls (not plastered), 4.50 ± 1.00; wire fence (1.2–1.5 m), 3.94 ± 0.56; wire fence (1.5–1.8 m), 0.00 ± 0.00; wire fence (1.8 m+), 1.00 ± 0.34]. It was clear that the level of effectiveness increased as fences increased in height (height of fence, average days per week with hyrax sightings ± SE: 0–1.2 m, 7.00 ± 0.00; 1.2–1.5 m, 4.25 ± 0.58; 1.5–1.8 m, 3.81 ± 0.60; 1.8 m+, 1.00 ± 0.34) (Appendix 1). Fences that had an additional overhang at the top also proved to be more effective than those without an overhang [overhang (yes or no), average days per week with hyrax sightings ± SE: overhang (no), 3.68 ± 0.37; overhang (yes), 0.60 ± 0.41] (Appendix 1), while additional electric fences had no influence on the effectiveness of fences [electric fence (yes or no), average days per week with hyrax sightings ± SE: electric fence (no), 3.15 ± 0.48; electric fence (yes), 3.50 ± 0.73] (Appendix 1). Results showed a distinct decline in the number of rock hyrax sightings per day at each of the five properties where adjustments to fences were made (Appendix 2).

Fences might have had a slight influence on the results, but when properties had similar fences it could still be seen that some dog breeds/dog groups were more effective in preventing rock hyraxes from entering properties (dog group, average days per week with hyrax sightings ± SE: terrier group, 1.00 ± 0.97; herding group, 1.5 ± 1.15; hound group, 1.5 ± 0; sporting group, 1.75 ± 1.61; toy group, 2.28 ± 0.76; non-sporting group, 2.75 ± 0.54; no dogs, 3.67 ± 1.21). Results further showed that a combination of certain preventive methods was more effective than others (Appendices 1 and 2). The best combination of preventive methods seemed to be wire fences (diamond mesh smaller than 50 mm) higher than 1.8 m or walls (plastered) higher than 1.8 m with an overhang at the top and with dogs from the terrier group, herding group, hound group or sporting group.

In the period from 2011 to 2012, rock hyraxes in the suburban residential site decreased in body mass (Fig. 1). Individuals at the residential wildlife estate site in 2013, where no preventive measures were implemented, had an average body mass similar to that of populations in the wild in 2012 (Fig. 1).

The number of rock hyraxes seen within properties on non-feeding days (average number of hyraxes ± SE: 4.1 ± 0.7) and feeding days (3.8 ± 0.7) was similar to the average number prior to the feeding experiment (Fig. 2).

The damage per household to property structures (maximum value, average value ± SE: $US 1793, $US 165 ± 79) was almost twice as high as damage to gardens ($US 433, $US 91 ± 22) and about 2.5 times higher than monetary losses associated with treatment of injuries ($US 240, $US 65 ± 15).

3.3 Control methods

Prior to the release of the caracal female, the rock hyrax population was 116 individuals, of which a total number of 60 rock hyraxes were captured and relocated. The population was estimated at 34 individuals [95% upper CL (N_u) = 88] in November 2013, and at 28 individuals [95% upper CL (N_u) = 64] in December 2013 (Table 1). These results suggest a decrease in population of at least 22–28 individuals from July 2012 to December 2013, probably as a result of predation and/or natural deaths.

A total of 142 rock hyraxes were relocated from the residential wildlife estate site to the release site. Thus, a total of 202 rock hyraxes were relocated during the study. Rock hyraxes were relocated in groups with a composition similar to wild populations, with the largest group consisting of 42 individuals. Preliminary

Appendix 4: continued

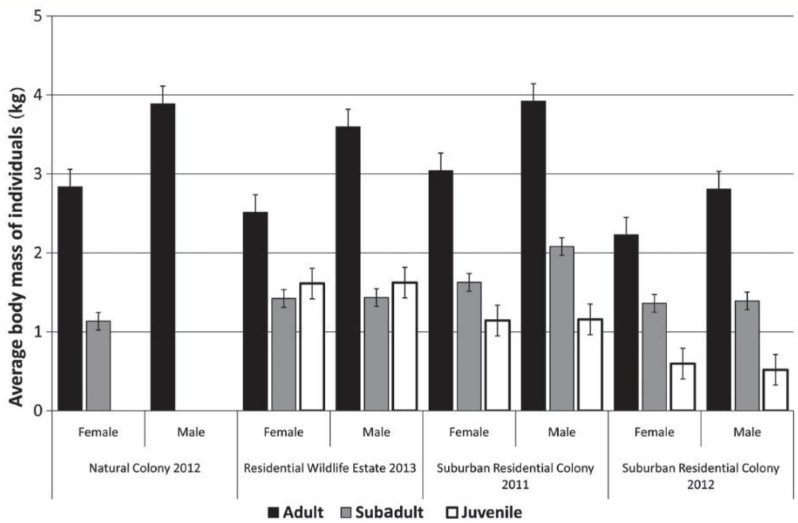

Figure 1. The average body mass (in kilograms) of males and females, for every age group, of different rock hyrax colonies.

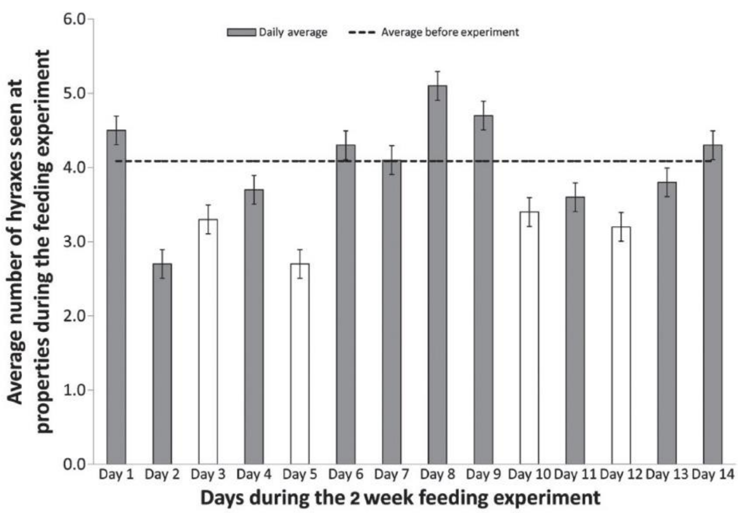

Figure 2. Average number of hyrax sightings within properties during the two week feeding experiment. White bars indicate the days on which feed was placed at the feeding stations.

results showed that large numbers of rock hyraxes fell prey to predators. Although rock hyrax numbers tended to decrease over time, rock hyraxes were observed at the release site 3 months after relocation.

4 DISCUSSION

Residential populations were more than double the size of populations in the wild (30–40 individuals).

It appeared that the lack of predators at residential areas had an influence on the survival[11] of juveniles and subadults, as residential populations had a larger percentage of young individuals than populations in the wild. This percentage increased at the suburban residential site as the population increased in size. The birth season of rock hyraxes usually occurs just prior to or during the main rainy season of a specific region.[25,43,44] The main rainy season of Free State Province occurs during the summer, September–December, but births in August and January have been noted before.[25,43,44]

Appendix 4: continued

The abundance of food at these residential sites seemed to have had an influence on the reproductive season of this colony, as the presence of juveniles (1–2 months of age) was recorded during May, June and July. This suggested that young had to be born during March–April, indicating two birth seasons. The first season was from February to April and the second from September to December. The structure and composition of residential populations were also different to those of populations in the wild. Larger numbers of sexually matured males were present in residential populations, while wild populations seemed to have only one sexually matured male.

These residential sites were either similar in size or smaller than the normal home range of a territorial male. When taken into account that the normal home range of territorial males is about 4800 m^2, then these males either had smaller home ranges that overlapped in certain areas or they were coexisting within the same home range. The general thought was that these large populations had to be several colonies living within the same home range, and that a specific territory in this home range would be defended by each of the territorial males. Males, however, were not as territorial as would be the case with populations in the wild. This was confirmed by observations that different males copulated with several females within the same home range, which according to the literature should not happen because a colony usually consists of a territorial male with his harem of females, and the male would fight off challengers.[4] The lack of territorial fighting, however, suggested that this is indeed one large population with several males and females coexisting in one home range. An abundance of food sources and refuges and a shortage of natural predators might have caused this unusual behaviour.

Different combinations of preventive measures had different levels of success in keeping rock hyraxes from entering properties (Appendix 1). From the questionnaires it appears that wire fences with a height of 1.8 m or more are most effective in keeping out rock hyraxes, as it is difficult for rock hyraxes to climb so high. Wire fences with mesh openings smaller than 50 mm were also more effective than those with mesh openings larger than 50 mm, as smaller openings made it more difficult for smaller rock hyraxes to climb through. Walls (not plastered) also proved less effective in keeping rock hyraxes out. Electric fences, precast walls and devil's fork fences were ineffective in keeping rock hyraxes from entering properties. Fences that had an overhang at the top proved to be more effective than those without an overhang, as it was more difficult to climb over. Results show a decline in the average body mass of individuals at the Heuwelsig colony from 2011 to 2012. During this time, adjustments were made to fences and preventive methods were implemented in some of the residential areas (Appendix 2). It could be argued that food sources available to each individual might have decreased as the colony increased in size.

The presence of dogs had some degree of success in keeping out rock hyraxes. It seems that the number of dogs, the breed and where the dogs slept at night all played a role in their effectiveness. Dogs from the terrier group (especially Jack Russell terriers), herding group, hound group and sporting group seemed to be successful in keeping rock hyraxes at bay.

Results obtained from observations on non-feeding days and feeding days showed no change in the number of rock hyraxes sighted in properties from the average obtained prior to feeding. Therefore, the feeding of rock hyraxes in order to keep them from going into gardens was not successful.

For control and rapid reduction in rock hyrax populations, the removal of a portion of the individuals from the population and the introduction of a natural predator seemed to be successful in the preliminary trials. The introduction of a caracal at the suburban residential site appeared to be successful. Results suggest a decrease in the population of at least 22–28 individuals from July 2012 to December 2013 as a result of predation and/or natural deaths. However, it is difficult to make a reliable estimation of losses due to predation. Caracals normally capture about 15 or 16 rock hyraxes per year.[45] This number is suspected to be larger for the present study owing to the lack of other prey species normally utilised by caracals.[45] In earlier literature it was stated that caracals do not return to previous catches and do not feed on carrion.[46] In another study, however, it was observed that a caracal would return to its kill.[47] The same observation was made during the present study when a caracal left a rock hyrax kill just to return a day later and feed on the carcass again.

The results of preliminary trials to establish whether rock hyraxes could be successfully relocated showed a decrease in the number of individuals at the relocation site. This might have been due to predation and dispersion, but further monitoring. Although rock hyraxes are still being monitored at the release site, preliminary results show that rock hyrax populations disintegrated from the time of release. Single rock hyraxes have been observed at the release site for up to 3 months after release. Further monitoring and research are still required to determine whether this approach is indeed successful.

In conclusion, the population management of rock hyraxes within residential areas only seemed to be successful when the correct preventive methods and control methods were used. The strategy of capture and relocation appears to be most successful in rapidly reducing a population. The preliminary results will need to be validated in large-scale replicated trials, and may require refinement.

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Appendix 4: continued

APPENDIX 1. A summary of all information collected with the use of a questionnaire from 23 homeowners that live adjacent or across the street from the Heuwelsig Nature Reserve (Suburban Residential Site), indicating the effectiveness of different preventative methods. Information represents data for the month of July 2011

Fence (yes or no)	Yes (100%)																		
Type of fence (wire fence, wall, etc.)	Wire fence (43%)									Brick wall (22%)					Precast wall (9%)		Devil's fork (26%)		
Height of fence	1.2–1.5 m (60%)				1.5–1.8 m (10%)			1.8 m + (30%)		1.5–1.8 m (100%)					0–1.2 m (50%)	1.2–1.5 m (50%)	1.5–1.8 m (100%)		
Type of wire fence (diamond mesh, welded mesh, etc.) and size of mesh openings	Diamond mesh (larger than 50 mm) (83%)				Welded mesh (smaller than 50 mm) (17%)	Diamond mesh (larger than 50 mm) (100%)	Diamond mesh (smaller than 50 mm) (33%)	Diamond mesh (larger than 50 mm) (67%)		n/a					n/a		n/a		
Wall plastered (yes or no)	n/a				n/a	n/a	n/a	n/a		Yes (60%)			No (40%)		n/a	n/a	n/a		
Overhang at top of fence (yes or no)	No (100%)				No (100%)	No (100%)	No (100%)	Yes (100%)	No (100%)	No (100%)			No (100%)		No (100%)	No (100%)	No (100%)		
Electric fence in addition to regular fence (yes or no)	Yes (20%)	No (80%)			Yes (100%)	Yes (100%)	No (100%)	No (100%)	No (100%)	Yes (60%)		No (40%)	Yes (50%)	No (50%)	No (100%)	Yes (100%)	No (100%)		
Dogs present (yes or no)	No (100%)	Yes (75%)		No (25%)	Yes (100%)	Yes (100%)	Yes (100%)	No (100%	Yes (100%)	Yes (100%)		Yes (100%)	Yes (100%)	Yes (100%)	Yes (100%)	No (100%)	Yes (67%)		No (33%)
Breed of dog(s)	No dogs	Greyhound and Fox Terrier	English Bulldog and Minia-ture Pincher	No dogs	Labrador Retriever	Jack Russell Terrier	Labrador Retriever and Pekingese	No dogs	Border Collie and Jack Russell Terrier	Bull Terrier	Rottweiler	German Shep-herd	Border Collie and Labrador Retriever	Jack Russell	Yorkshire Terrier and Chi-huahua	No dogs	Saint Bernard and Dal-mation	Scottish Terrier	No dogs
Dogs predominantly kept in yard or in house	n/a	Yard	House	n/a	Yard	Yard	Yard	n/a	Yard	Yard	Yard	Yard	House	House	House	n/a	Yard	Yard	n/a
Days per week that hyraxes were sighted on property	5 or 6	1 or 2	5 or 6	5 or 6	3 or 4	0	0	0	1 or 2	1 or 2	3 or 4	3 or 4	5 or 6	5 or 6	7	7	5 or 6	7	3 or 4

Appendix 4: continued

APPENDIX 2. A summary of the adjustments made by five homeowners to their fences, according to results obtained from questionnaires, indicating the effect these changes had on keeping hyraxes from entering these residential areas

	Homeowner A		Homeowner B		Homeowner C		Homeowner D		Homeowner E	
	Before	After	Before	After	Before	After	Before	After	Before	After
Fence (yes or no)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type of fence (wire fence, wall, etc.)	Wire fence	Wire fence	Precast wall	Wall	Precast wall	Wire fence	Wall	Wall	Wire fence	Wire fence
Height of fence	1.2–1.5 m	1.8 m+	1–1.2 m	1.5–1.8 m	0–1.2 m	1.8 m+	1.5–1.8 m	1.5–1.8 m	1.2–1.5 m	1.8 m+
Type of wire fence (diamond mesh, welded mesh, etc.) and size of mesh openings	Diamond mesh (larger than 50 mm)	Diamond mesh (smaller than 50 mm)	n/a	n/a	n/a	Diamond mesh (smaller than 50 mm)	n/a	n/a	Diamond mesh (larger than 50 mm)	Top half – diamond mesh (larger than 50 mm), bottom half – diamond mesh (smaller than 50 mm)
Wall plastered (yes or no)	n/a	n/a	n/a	No	n/a	n/a	Yes	Yes	n/a	n/a
Overhang at top of fence (yes or no)	No	Yes	No	Yes	No	No	No	Yes	No	No
Electric fence in addition to regular fence (yes or no)	No	No	Yes	Yes	No	No	Yes	Yes	No	No
Dogs present (yes or no)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Breed of dog(s)	English Bulldog and Miniature Pincher	English Bulldog and Miniature Pincher	No dogs	Jack Russell Terrier	Yorkshire Terrier and Chihuahua	Yorkshire Terrier and Chihuahua	Rottweiler	Rottweiler	Pug and Miniature Pincher	Pekingese, Pug and Miniature Pincher
Days per week that hyraxes were on property	5 or 6	1 or 2	7	1 or 2	7	3 or 4	3 or 4	1 or 2	3 or 4	1 or 2
Average percentage of days per week that hyraxes were on property	79	22	100	22	100	50	50	22	50	22

Appendix 4: continued

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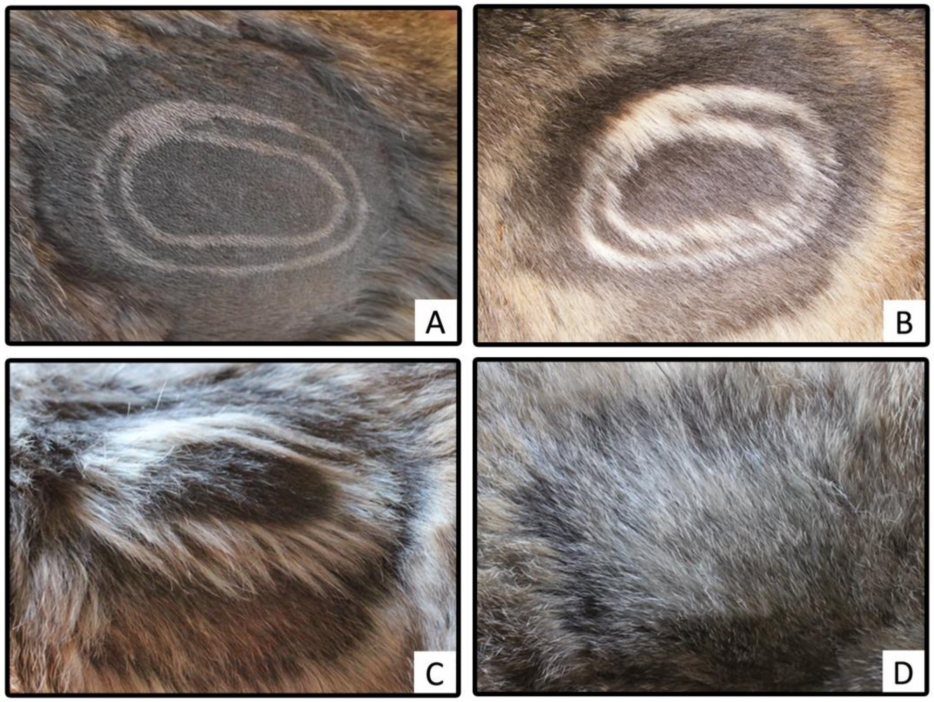
Appendix 5: Description of the marks branded on the left (duration of 3.5 seconds) and right (duration of 2.6 seconds) flanks of the first rock hyrax.

<table>
<tr><th>Side and number branded</th><th>Time elapsed after branding and description (Brands described separately except where appearance are similar)</th><th>Pictures reference(s)</th></tr>
<tr><td colspan="3">4 weeks after branding</td></tr>
<tr><td>Left flank (0)</td><td rowspan="2">Coat regrowth was approximately 33% of the normal length. Hairless areas, as a result of peeling skin, and/or scabs were visible at the site of application but no white regrowth was visible at this stage.</td><td rowspan="2">Fig. 5.5a & b</td></tr>
<tr><td>Right flank (1)</td></tr>
<tr><td colspan="3">8 weeks after branding</td></tr>
<tr><td>Left flank (0)</td><td rowspan="2">Coat regrowth was approximately 75% of the normal length. No white regrowth was visible until the brand area was clipped, after which the brand number was clearly visible. .</td><td>Fig. 5.5c & d (unclipped), Appx. 6a (clipped)</td></tr>
<tr><td>Right flank (1)</td><td>Fig. 5.5c & d (unclipped), Appx. 7a (clipped)</td></tr>
<tr><td colspan="3">12 weeks after branding</td></tr>
<tr><td>Left flank (0)</td><td>Coat regrowth was approximately 33%, of the normal length, after re-clipping at 8 weeks. White regrowth in the shape of the brand number was clearly visible. The brand number displayed clearer in areas due to denser white regrowth.</td><td>Appx. 6b</td></tr>
<tr><td>Right flank (1)</td><td>Coat regrowth appeared visually similar to the left. White regrowth was not as clear as on the left flank as part of the number did not show any white regrowth.</td><td>Appx. 7b</td></tr>
</table>

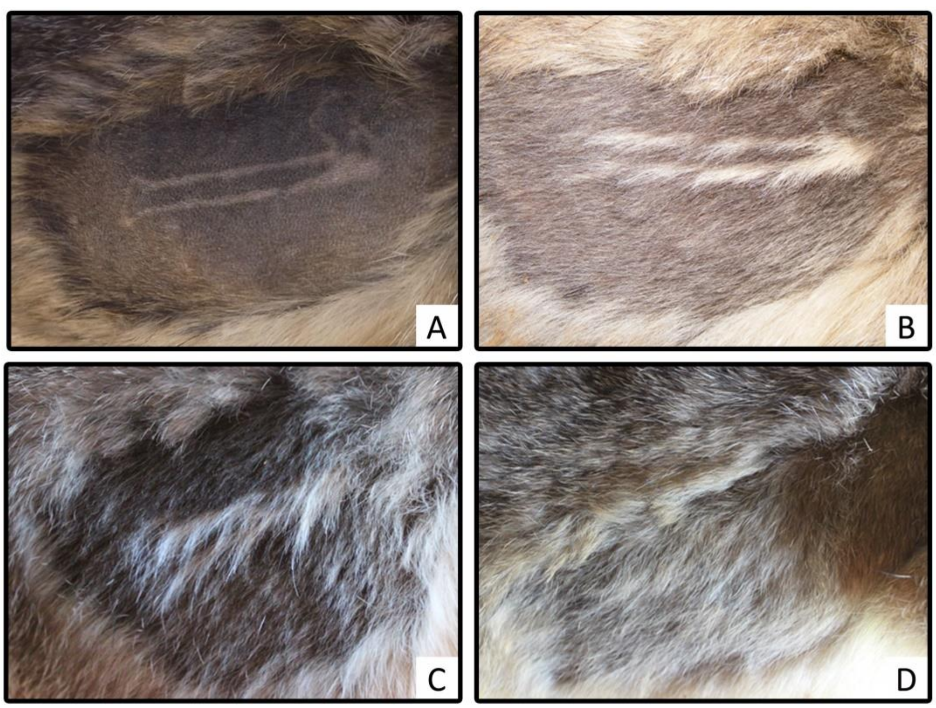
Appendix 5: continued

Side and number branded	Time elapsed after branding and description (Brands described separately except where appearance are similar)	Pictures reference(s)
	18 weeks after branding	
Left flank (0)	Coat regrowth was approximately 80% of the normal length. Even with the longer coat the white regrowth, in the shape of the brand, was clearly visible. The shorter coat appeared slightly darker in colour than the rest of the coat at normal length. Brand area was clipped for further inspection and all areas that appeared to be hairless during the previous inspection, was now covered.	Appx. 6c
Right flank (1)	Coat regrowth appeared visually similar to the left. White regrowth was not as clear as with the brand on the left flank, as part of the number did not show any white regrowth.	Appx. 7c
	31 weeks after branding	
Left flank (0)	Coat has regrown to normal length. White regrowth in the shape of the brand number was not clearly discernible. Due to the long brown-grey coloured coat the white hair got distorted. The brand number could be recognised in areas where white regrowth was denser. After clipping the branding area the brand was clearly visible and displayed similar to Fig. 5.6a.	Appx. 6d
Right flank (1)	Coat regrowth appeared visually similar to the left. After clipping the branding area the brand was visible and similar to Fig. 5.7a.	Appx. 7d

Appendix 6: Appearances of freeze brand of rock hyrax No. 1 (left flank), 8 weeks (A), 12 weeks (B), 18 weeks (C) and 31 weeks (D) after branding.



Appendix 7: Appearances of freeze brand of rock hyrax No. 1 (right flank), 8 weeks (A), 12 weeks (B), 18 weeks (C) and 31 weeks (D) after branding.



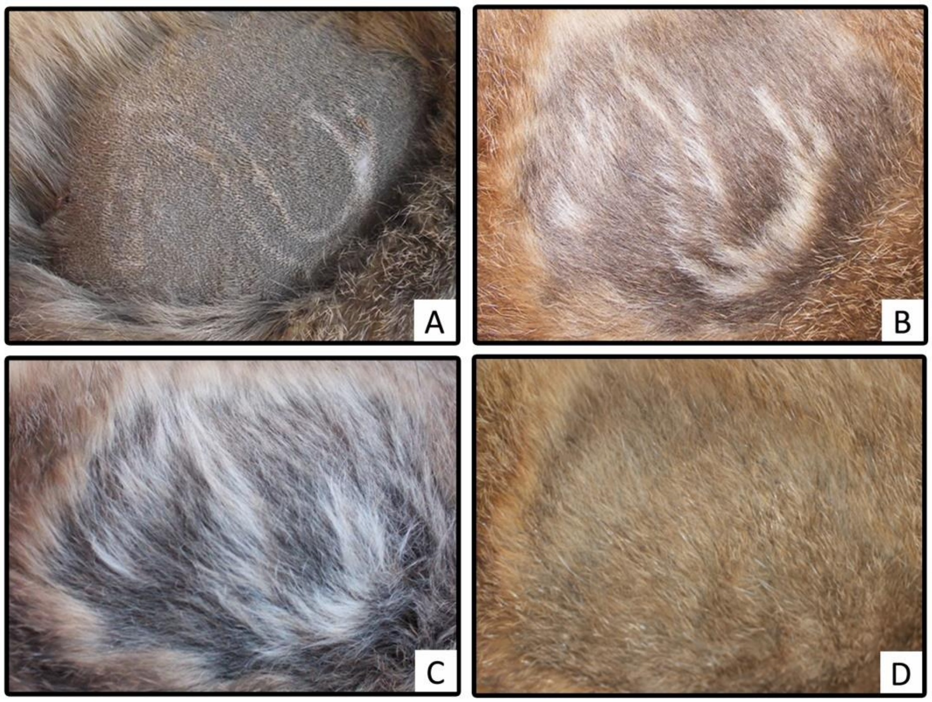
Appendix 8: Description of the marks branded on the left (duration of 5.7 seconds) and right (duration of 4.6 seconds) flanks of the second rock hyrax.

<table>
<tr><th>Side and number branded</th><th>Time elapsed after branding and description
(Brands described separately except where appearance are similar)</th><th>Pictures reference(s)</th></tr>
<tr><td colspan="3">4 weeks after branding</td></tr>
<tr><td>Left flank (2)</td><td rowspan="2">Coat regrowth was approximately 33% of the normal length. Hairless areas, as a result of peeling skin, and/or scabs were visible at the site of application but no white regrowth was visible at this stage.</td><td>Fig. 5.5a & b</td></tr>
<tr><td>Right flank (0)</td><td>Fig. 5.5a & b</td></tr>
<tr><td colspan="3">8 weeks after branding</td></tr>
<tr><td>Left flank (2)</td><td rowspan="2">Coat regrowth was approximately 75% of the normal length. No white regrowth was visible until the brand area was clipped, after which the brand number was clearly visible. Large hairless areas were still visible within the brand number.</td><td>Fig. 5.5c & d (unclipped); Appx. 9a (clipped)</td></tr>
<tr><td>Right flank (0)</td><td>Fig. 5.5c & d (unclipped); Appx. 10a (clipped)</td></tr>
<tr><td colspan="3">12 weeks after branding</td></tr>
<tr><td>Left flank (2)</td><td>Coat regrowth was approximately 33% of the normal length after re-clipping at 8 weeks. White regrowth in the shape of the brand was clearly visible and displayed clearer in areas due to denser white regrowth. A clear outline of the number was visible with normal coloured hair in the centre of the number.</td><td>Appx. 9b</td></tr>
<tr><td>Right flank (0)</td><td>Coat regrowth appeared similar to the left. One half of the brand showed a denser, clearer white regrowth.</td><td>Appx. 10b</td></tr>
</table>

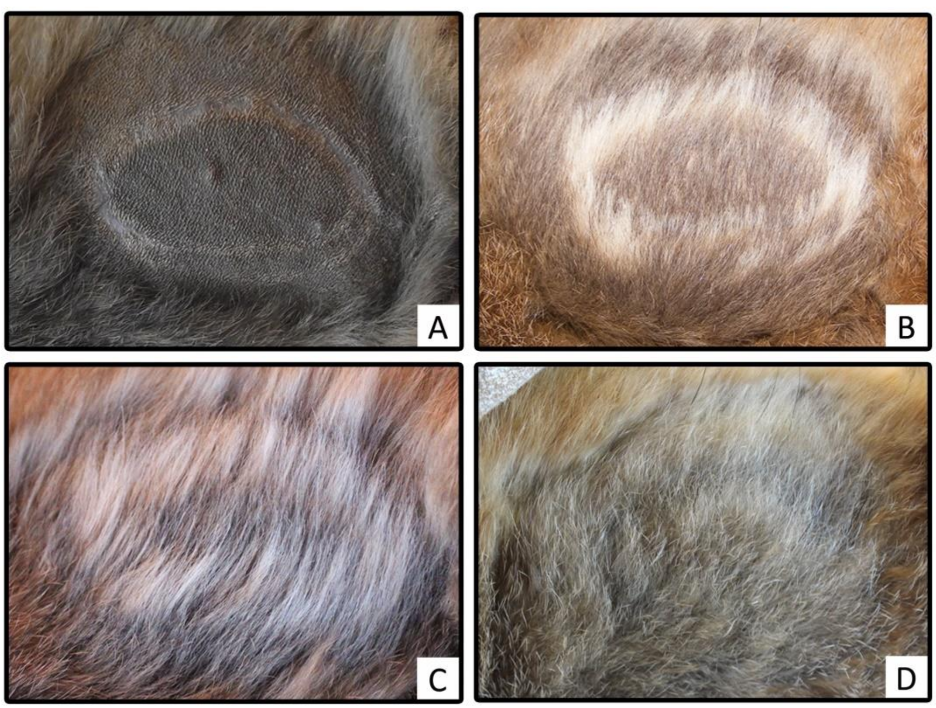
Appendix 8: continued

Side and number branded	**Time elapsed after branding and description** (Brands described separately except where appearance are similar)	**Pictures reference(s)**
18 weeks after branding		
Left flank (2)	Coat regrowth was approximately 80% of the normal length. Even with the longer coat the white regrowth, in the shape of the brand, was clearly visible. The shorter coat appeared slightly darker than the rest of the coat at normal length. Brand area was clipped in order to determine if previously visible hairless areas remained uncovered. A small hairless area at the top of the number was still visible.	Appx. 9c
Right flank (0)	Coat regrowth appeared similar to that of the left flank. One half of the number had a slightly denser white regrowth than the other. After clipping and inspecting the brand site it was clear that one half of the number still had several hairless areas causing the white regrowth to display less prominent.	Appx. 10c
31 weeks after branding		
Left flank (2)	Hair has regrown to normal length. White hair regrowth in the shape of the brand number was not discernible. Due to the long brown-grey coloured coat the white hair, which was in the minority, got distorted. After re-clipping the branding area the brand number was clearly visible and displayed similar to Fig. 5.8a. The hairless area at the top of the number was still visible, but has decreased in size.	Appx. 9d
Right flank (0)	Similar observations as on the left flank prior to re-clipping. Brand was again clearly visible after the branding area was clipped. Hairless patches similar in size as in Fig. 5.9a was still visible.	Appx. 10d

Appendix 9: Appearances of freeze brand of rock hyrax No. 2 (left flank), 8 weeks (A), 12 weeks (B), 18 weeks (C) and 31 weeks (D) after branding.



Appendix 10: Appearances of freeze brand of rock hyrax No. 2 (right flank), 8 weeks (A), 12 weeks (B), 18 weeks (C) and 31 weeks (D) after branding.



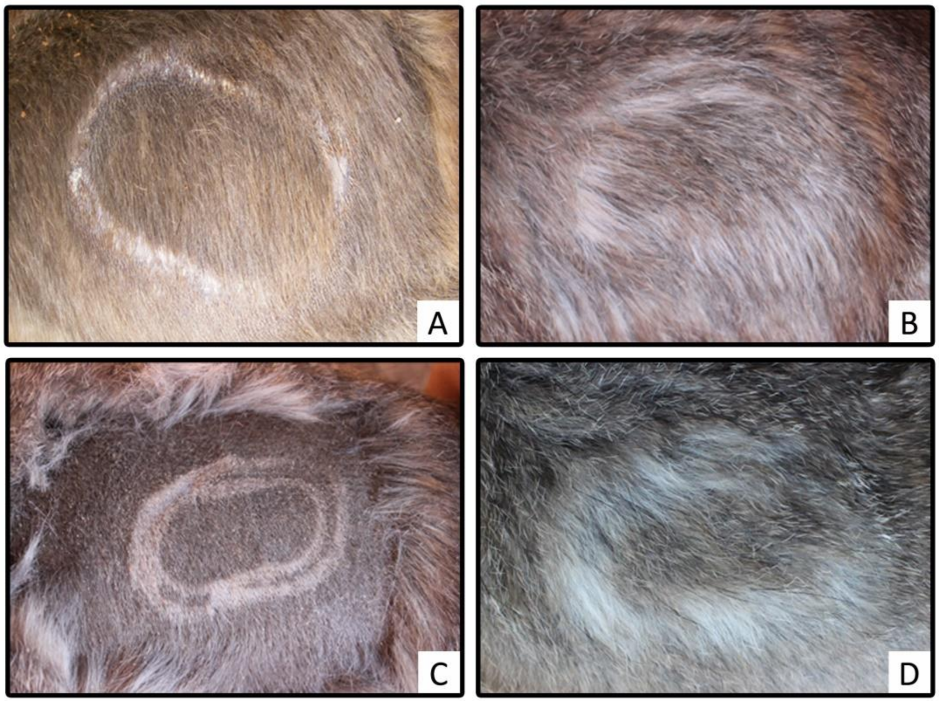
Appendix 11: Description of the marks branded on the left (duration of 4.1 seconds) and right (duration of 1.4 seconds) flanks of the third rock hyrax.

Side and number branded	**Time elapsed after branding and description** (Brands described separately except where appearance are similar)	**Pictures reference(s)**
4 weeks after branding		
Left flank (0)	Coat regrowth was approximately 33% of the normal length. Hairless areas, as a result of peeling skin, and/or scabs were visible at the site of application but no white regrowth was visible at this stage.	Appx. 12a
Right flank (3)	Coat regrowth similar as to that of the left flank. Small, less prominent scabs were visible at the site of application but no white regrowth was visible at this stage.	Appx. 13a
10 weeks after branding (unclipped)		
Left flank (0)	Coat regrowth was approximately 80% of the normal length. White hair growth was visible, although somewhat distorted, the number could still be read with ease.	Appx. 12b
Right flank (3)	Coat regrowth similar as to that of the left flank. White hair growth was not visible, thus no number could be discerned.	Appx. 13b
10 weeks after branding (clipped)		
Left flank (0)	Once clipped the number was clearly visible. Complete colouration of hair in the shape of the branding iron was visible in approximately 33% of the number while the rest showed only the outline of the number. A small area was without hair.	Appx. 12c
Right flank (3)	Once clipped a partial outline of the number was visible but not as prominent as with the brand on the left. No hairless areas were visible on the skin.	Appx. 13c

Appendix 11: continued

Side and number branded	**Time elapsed after branding and description** (Brands described separately except where appearance are similar)	**Pictures reference(s)**
23 weeks after branding		
Left flank (0)	Hair has regrown to normal length. White hair regrowth in the shape of the brand number was visible with a slight of the brand number. Although the brown-grey coloured coat did distort the white hair somewhat, those areas which showed complete colouration were less distorted than the others. Hairless areas visible after 10 weeks (Fig. 5.10c) was also completely covered by white regrowth.	Appx. 12d
Right flank (3)	Hair has regrown to normal length. No white hair regrowth was visible. The long brown-grey coloured coat completely distorted the brand. Once clipped brand appeared similar to Fig. 5.11c.	Appx. 13d

Appendix 12: Appearances of freeze brand of rock hyrax No. 3 (left flank), 4 weeks (A), 10 weeks, unclipped (B) and clipped (C) and 23 weeks (D) after branding.



Appendix 13: Appearances of freeze brand of rock hyrax No. 3 (right flank), 4 weeks (A), 10 weeks, unclipped (B) clipped (C) and 23 weeks (D) after branding.

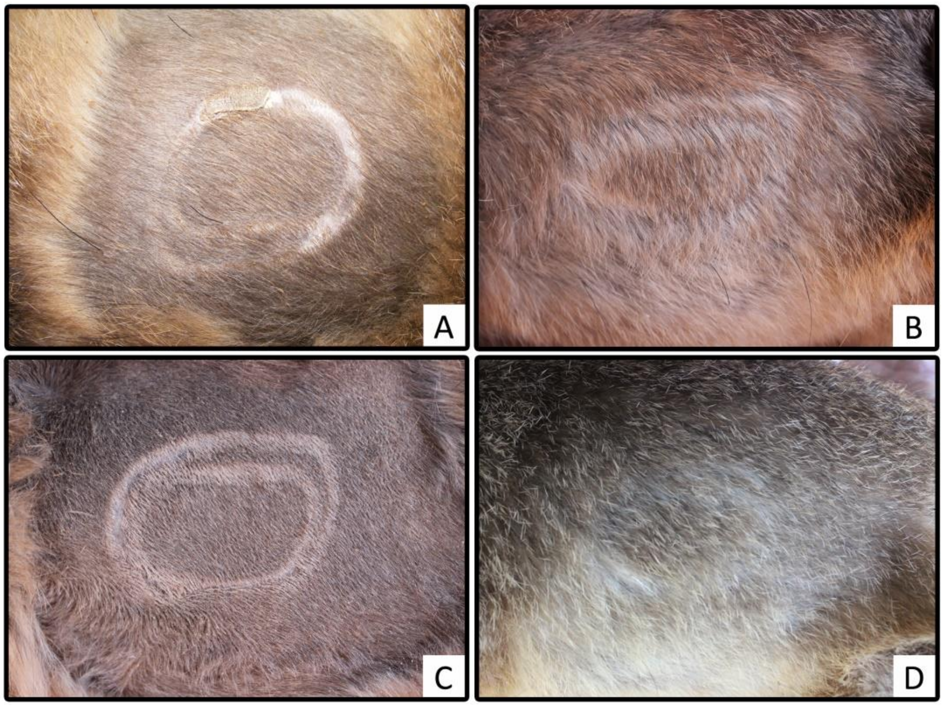
Appendix 14: Description of the marks branded on the left (duration of 7.3 seconds) and right (duration of 2.3 seconds) flanks of the fourth rock hyrax.

Side and number branded	**Time elapsed after branding and description** (Brands described separately except where appearance are similar)	**Pictures reference(s)**
4 weeks after branding		
Left flank (0)	Coat regrowth was approximately 33% of the normal length. Large hairless areas and scabs were visible at the site of application but no white regrowth was visible at this stage.	Appx. 15a
Right flank (4)	Coat regrowth was at approximately 33% of the normal length. Hairless areas, as a result of peeling skin, and scabs were visible at the site of application but no white regrowth was visible at this stage.	Appx. 16a
10 weeks after branding (unclipped)		
Left flank (0)	Coat regrowth was approximately 80% of the normal length. White regrowth was visible, the brand number was distorted but the number shape could still be recognised.	Appx. 15b
Right flank (4)	Coat regrowth was approximately 80% of the normal length. Slight white regrowth was visible, but no brand number could be discerned.	Appx. 16b
10 weeks after branding (clipped)		
Left flank (0)	Once clipped the number was clearly visible. White regrowth could be seen along the outline of the number. No scabs were present but a fairly large area was without hair.	Appx. 15c
Right flank (4)	Once clipped a partial outline of the number was visible but not as prominent as with the brand on the left. A small strip of the skin was without hair.	Appx. 16c

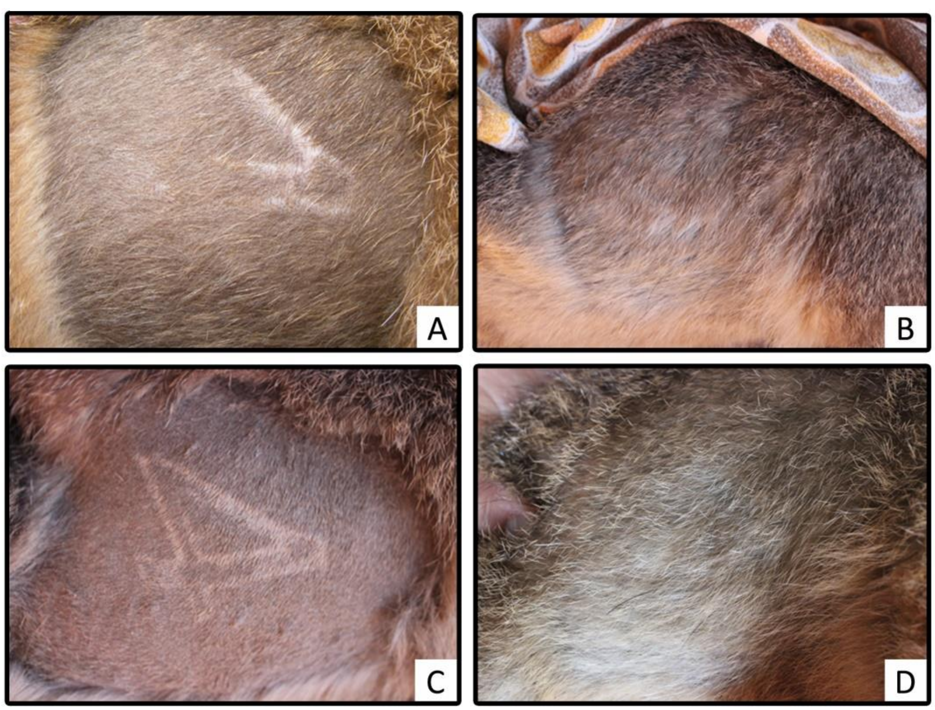
Appendix 14: continued

Side and number branded	**Time elapsed after branding and description** (Brands described separately except where appearance are similar)	**Pictures reference(s)**
23 weeks after branding		
Left flank (0)	Coat has regrown to normal length. Although white regrowth in the shape of the brand number was visible, it was not clearly discernible. Due to the long brown-grey coloured coat the white hair got distorted. Blotches of white hair displayed clearer in areas where the iron produced a thicker brand resulting in a denser regrowth. After clipping, it was noted that the hairless areas visible at 10 weeks, Fig. 5.12b, were still present.	Appx. 15d
Right flank (4)	Coat has regrown to normal length. White regrowth was not clearly visible. The long brown-grey coloured coat completely distorted the brand number. Once clipped the brand appeared similar to Fig. 5.13c but no hairless areas were visible anymore.	Appx. 16d

Appendix 15: Appearances of freeze brand of rock hyrax No. 4 (left flank), four weeks (A), 10 weeks, unclipped (B) and clipped (C) and 23 weeks (D) after branding.



Appendix 16: Appearances of freeze brand of rock hyrax No. 4 (right flank), four weeks (A), 10 weeks, unclipped (B) clipped (C) and 23 weeks (D) after branding.

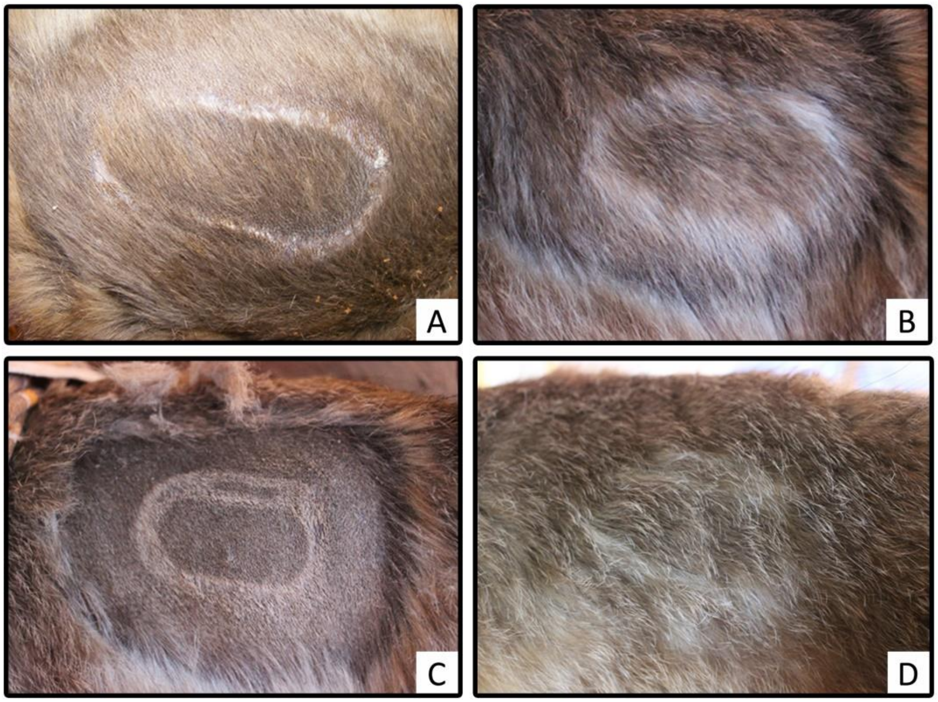


Appendix 17: Description of the marks branded on the left (duration of 6.2 seconds) and right (duration of 3.7 seconds) flanks of the fifth rock hyrax.

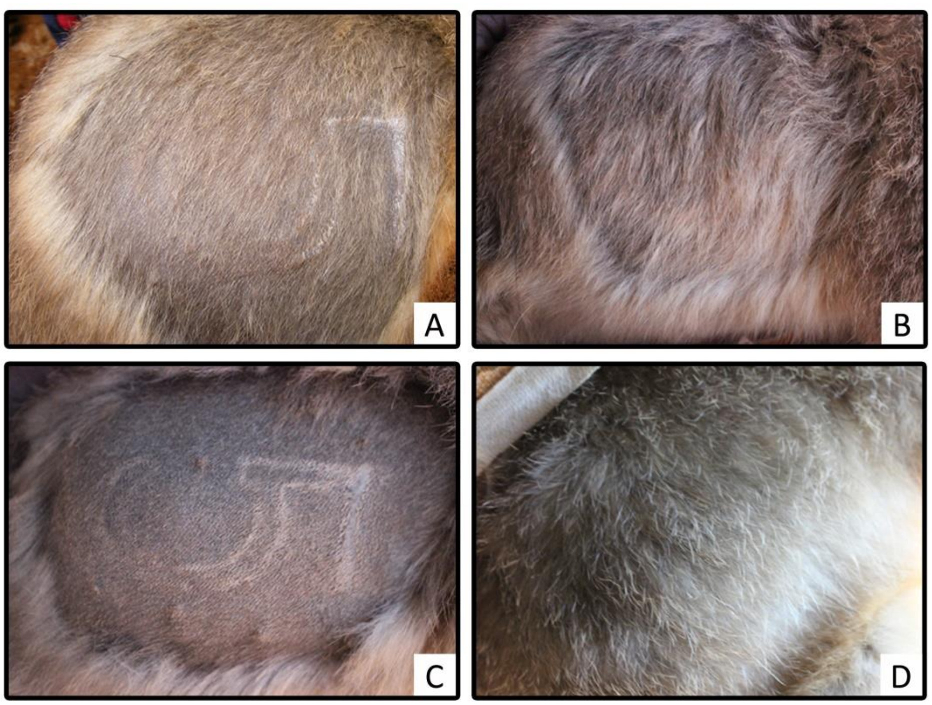
Side and number branded	**Time elapsed after branding and description** (Brands described separately except where appearance are similar)	**Pictures reference(s)**
	4 weeks after branding	
Left flank (0)	Coat regrowth was approximately 33% of the normal length. Hairless areas and scabs were visible at the site of application but no white regrowth was visible at this stage.	Appx. 18a
Right flank (4)	Coat regrowth was approximately 33% of the normal length. Hairless areas and scabs were visible at the site of application, although not as prominent as on the left, but no white regrowth was visible at this stage.	Appx. 19a
	10 weeks after branding (unclipped)	
Left flank (0)	Coat regrowth was approximately 80% of the normal length. White regrowth was visible, although somewhat distorted the number could still be read with ease.	Appx. 18b
Right flank (4)	Coat regrowth was approximately 80% of the normal length. White regrowth was visible but not clear, the number could hardly be discerned.	Appx. 19b
	10 weeks after branding (clipped)	
Left flank (0)	Once clipped the prominent white regrowth clearly displayed the number. Brand was clearer in the areas where white regrowth were denser. No scabs were present but some areas were still without hair.	Appx. 18c
Right flank (4)	Once clipped a partial outline of the number was visible but not as prominent as with the brand on the left. The bottom half of the number was less clear. A hairless strip was visible at the top of the brand.	Appx. 19c

Appendix 17: continued

Side and number branded	**Time elapsed after branding and description** (Brands described separately except where appearance are similar)	**Pictures reference(s)**
23 weeks after branding		
Left flank (0)	Coat has regrown to normal length. White regrowth in the shape of the brand number was not clearly discernible. Due to the long brown-grey coloured coat the white hair got distorted. Blotches of white hair displayed clearer in areas where the iron produced a thicker brand resulting in a denser regrowth. After clipping, it was noted, that the hairless areas visible at 10 weeks, Fig. 5.14c, were still present.	Appx. 18d
Right flank (4)	Coat has regrown to normal length. White regrowth was not clearly visible. The long brown-grey coloured coat completely distorted the brand number. Once clipped brand appeared clearer compared to what it looked like in Fig. 5.15c. Hairless areas at the top number was still visible but was smaller.	Appx. 19d



Appendix 18: Appearances of freeze brand of rock hyrax No. 5 (left flank), four weeks (A), 10 weeks, unclipped (B) and clipped (C) and 23 weeks (D) after branding .



Appendix 19: Appearances of freeze brand of rock hyrax No. 5 (right flank), four weeks (A), 10 weeks, unclipped (B) clipped (C) and 23 weeks (D) after branding.